ANL/EVS/R-09/3

Comparative Analysis of Discharges to Lake Michigan Phase II – The Entire Lake

Environmental Science Division

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Comparative Analysis of Discharges to Lake Michigan Phase II – The Entire Lake

prepared for
Purdue University

prepared by
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Acronyms and Abbreviations

AGNPS	Agricultural Nonpoint Source Pollution
AnnGNPS	Annualized Agricultural Nonpoint Source Pollution
AOC	area of concern
Argonne	Argonne National Laboratory
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BAT	best available technology
BOD	biochemical oxygen demand)
BP	BP Products North America Inc.
CAFO	concentrated animal feeding operations
$CBOD_5$	five-day carbonaceous biochemical oxygen demand
CFR	*Code of Federal Regulations*
COD	chemical oxygen demand
DL	detection level
<DL	less than detection level
DMR	discharge monitoring report
DNR	Department of Natural Resources
ECHO	Enforcement and Compliance History Online
ELG	effluent limitations guideline
EMC	event mean concentration
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
GIS	geographical information system
GLWQA	Great Lakes Water Quality Agreement
GWLF	Generalized Watershed Loading Functions
Hg	mercury
Hg_T	total mercury
HSPF	Hydrological Simulation Program—FORTRAN
IADN	Integrated Atmospheric Deposition Network
IDEM	Indiana Department of Environmental Management
IEPA	Illinois Environmental Protection Agency
IL	Illinois
IN	Indiana
IND	industrial
LaMP	Lakewide Management Plan
LMMBP	Lake Michigan Mass Balance Project
MDEQ	Michigan Department of Environmental Quality
MI	Michigan
MeHg	methylmercury
MUN	municipal
NADP	National Atmospheric Deposition Program
NAICS	North American Industry Classification System
NH_3	ammonia

NH_4^+	ammonium
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NSP	nonpoint source pollution
PCS	Permit Compliance System
Purdue	Purdue University–Calumet Water Institute
RAP	Remedial Action Plan
RELMAP	Regional Lagrangian Model of Air Pollution
REMSAD	Regulatory Modeling System for Aerosols and Disposition
Se	selenium
SPARROW	Spatially Referenced Regression On Watershed Attributes
STEPL	Spreadsheet Tool for Estimating Pollutant Load
SWAT	Soil and Water Assessment Tool
SWMM	Storm Water Management Model
TMDL	Total Maximum Daily Load
TRI	Toxics Release Inventory
TSS	total suspended solids
USDA	U.S. Department of Agriculture
USDA-ARS	U.S. Department of Agriculture-Agricultural Research Service
USGS	U.S. Geological Survey
V	vanadium
WDNR	Wisconsin Department of Natural Resources
WI	Wisconsin

Units of Measure

µm	micrometer(s)
µg	microgram(s)
°C	degree(s) Celsius
cm	centimeter(s)
d	day(s)
ft	foot (feet)
g	gram(s)
gal	gallon(s)
ha	hectare(s)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
m	meter(s)
mg	milligram(s)
MG	million gallons
MGD	million gallons per day
mi	mile(s)

ng	nanogram(s)
ppm	part(s) per million
s	second(s)
yr	year(s)

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Executive Summary

BP Products North America Inc. (BP) owns and operates a petroleum refinery located on approximately 1,700 acres in Whiting, East Chicago, and Hammond, Indiana, near the southern end of Lake Michigan. BP provided funding to Purdue University–Calumet Water Institute (Purdue) and Argonne National Laboratory (Argonne) to conduct studies related to wastewater treatment and discharges. Purdue and Argonne are working jointly to identify and characterize technologies that BP could use to meet the current discharge permit limits for total suspended solids (TSS) and ammonia after refinery modernization, and for the treatment of heavy metals such as mercury and vanadium, which will be regulated in 2012. In addition to the technology characterization work, the project includes a separate task involving quantifying levels of pollutant discharges to Lake Michigan; that is the subject of this report. The primary purpose of this study is to develop an inventory of the significant sources of five target pollutants entering Lake Michigan. The target pollutants included TSS, ammonia, mercury, selenium, and vanadium.

Recent (for the year 2007) levels of discharge to Lake Michigan from significant point and nonpoint sources were evaluated. This task was carried out in two phases. In Phase I (Veil et al. 2008), the current levels of discharge to southern Lake Michigan from significant point and nonpoint sources in Illinois, Indiana, and portions of Michigan were estimated. In Phase II of the study (this report), the Phase I analysis was expanded to cover the entire Lake Michigan drainage basin. Results presented here represent the combined analysis of both phases of the study. For consistency, actual discharge data from the year 2007 were used in both phases.

ES.1 Point Sources

Point sources are discharges that enter water bodies through pipes, ditches, and other discrete conduits. Examples include industrial discharges, municipal wastewater treatment plant discharges, and some stormwater runoff. Point sources are regulated by state agencies under the National Pollutant Discharge Elimination System (NPDES) program. Many NPDES permits contain numeric limits for various pollutants. For those permits that require monitoring and reporting of effluent quality for the target pollutants, discharges were quantified using information from the NPDES system.

The agencies with NPDES responsibility in each of the four states encompassing the study area were contacted. Each agency provided lists of facilities with NPDES permits. More than 2,300 facilities were subsequently evaluated. Facilities on the lists that did not have significant discharges of the target pollutants were excluded from further study. After review and analysis of the discharges, 381 facilities (108 industrial facilities and 273 municipal facilities) were found to make significant discharges to Lake Michigan.

Three different types of data can be obtained through NPDES permit program records. Each of these provides different types of discharge quality information. Each type is likely to be found in the permit files to varying degrees:

- Data included on permit application forms often provide one-time analytical data on a wider range of pollutants than those normally limited in the permit.

- Issued permits include numeric limits for different pollutants. The limits represent the highest allowable concentration of load for each pollutant that the facility may discharge.

- Compliance monitoring data are collected at specified frequencies and reported monthly to the state agencies as discharge monitoring reports (DMRs). Two of the target pollutants (TSS and ammonia) were monitored frequently, providing many data points to calculate averages. On the other hand, mercury was monitored less frequently (sometimes quarterly or annually). Relatively few data points were available for calculating the average mercury values for the entire year. Very few of the permits required monitoring for selenium and vanadium. The few facilities that did monitor for those metals typically did so infrequently.

In addition to the NPDES data, the U.S. Environmental Protection Agency's (EPA's) Toxics Release Inventory (TRI) program was investigated to get additional information on discharges of TRI chemicals to surface waters.

ES.2 Nonpoint Sources

Nonpoint source pollution (NSP) discharges enter water bodies in ways other than through discrete conduits. Nonpoint source pollution generally results from stormwater runoff (agricultural, urban, suburban), atmospheric contributions through rainfall and dry fall, drainage, seepage, groundwater exfiltration, or hydrologic modification. Nonpoint sources are not formally regulated by federal or state environmental programs. It is very difficult to quantify the amounts of pollutants that can be attributed to nonpoint sources. Information on NSP was collected through analysis of literature data and limited use of models that were extrapolated to correspond to the size and location of the study area. Very rough estimates of the annual nonpoint source loads of the target key pollutants to the lake were developed.

ES.3 Results and Discussion

The point source data for the study area from the full DMR data set and the nonpoint source data are summarized in Table ES-1. Because the DMR data set reflects actual monitoring of the discharges during 2007, it is probably the best source of data for estimating point source loadings. The second and third columns in the table show the composite total of the average daily load and maximum daily load (respectively) of all facilities in the data set. Data from the permit limits data set and the application data set (in Tables 4-7 and 4-8 of the report) showed mixed agreement with the DMR data set.

Table ES-1 Comparison of Point and Nonpoint Source Data

Pollutant	Composite Total of Facility Average Loads (lb/day)	Composite Total of Facility Maximum Loads (lb/day)	Average Nonpoint Source Estimate – Lower End of Range (lb/day)	Ratio of Nonpoint Source Estimate to Point Source Estimate
TSS	120,520	559,284	9,205,479	76 to 1
Ammonia	16,755	63,562	89,041	5.3 to 1
Mercury	0.049	0.115	5.5	112 to 1
Selenium	3.6	8.2	199.7	55 to 1
Vanadium	10.1	37.7	265.2	26 to 1 (7.5 to 1[a])

[a] The vanadium value in parentheses is taken from the TRI data set rather than from the DMR data set.

Point source data collected from the TRI system had limited relevance because only industrial facilities are required to report releases as part of TRI, and only a small percentage of the industrial facilities reported releases of the target pollutants. In all, only 31 release entries covering four chemicals were found. However, in the absence of much DMR data for vanadium, the TRI data reported for vanadium compounds was a useful addition to the DMR data.

Nonpoint source data were collected for the five target pollutants. The estimated loads were reported as a range, indicating estimates derived from different analytical models. The lower end of the nonpoint source estimated average loads are shown in Table ES-1 in comparison with the average point source loads. For all five target pollutants, the nonpoint source load is larger than the point source load. The TSS, mercury, selenium, and vanadium loads from nonpoint sources are at least one order of magnitude higher than the point source loads.

Although some other sources of pollutants that remain unquantified or poorly quantified (e.g., groundwater exfiltration into surface water bodies, excrement from birds and fish) have the potential to make substantial contributions of the target pollutants, they were not included in the loading estimates.

Chapter 1 Introduction

1.1 Background and Purpose of Study

In 2007, BP Products North America Inc. (BP) provided funding to Purdue University–Calumet Water Institute (Purdue) and Argonne National Laboratory (Argonne) to conduct studies related to wastewater treatment and discharges. Purdue and Argonne are working jointly to identify and characterize technologies that BP could use to meet discharge permit limits for total suspended solids (TSS) and ammonia after refinery modernization, and for the treatment of heavy metals such as mercury.

As part of that overall research program, Argonne developed an inventory of the significant sources of five target pollutants (TSS, ammonia, mercury, selenium, and vanadium) entering Lake Michigan. This report describes the inventory. The inventory includes not only the discharges entering the lake directly, but also discharges to tributary streams and rivers flowing into Lake Michigan. The purpose of the inventory is to examine point and nonpoint sources of pollution entering Lake Michigan in a lake-wide context.

Recent (for the year 2007) levels of discharge to Lake Michigan from significant point and nonpoint sources were evaluated. This task was carried out in two phases. In Phase I (Veil et al. 2008), the current levels of discharge to southern Lake Michigan from significant point and nonpoint sources in Illinois, Indiana, and portions of Michigan were estimated. In Phase II of the study (this report), the Phase I analysis was expanded to cover the entire Lake Michigan drainage basin. Results presented here represent the combined analysis of both phases of the study.

1.2 Content of Report

This chapter provides background information on the issue being addressed by the study and reviews the focus and purpose of the study. Chapter 2 describes the design and scope of the study and provides information relating to the target pollutants on which the study focuses.

Chapter 3 describes the types of point source data that were evaluated and how the data were collected, screened, and analyzed. Chapter 4 presents the point source data results in summary form. Chapter 5 describes the nonpoint source contributions to the study area. The sources of data are explained, and nonpoint source loads are estimated.

Chapter 6 provides discussion of the data. It compares point sources and nonpoint sources of the target pollutants. It also includes discussion on the completeness and uncertainty of the data sets that were collected for the study. Chapter 7 provides a review of the report's findings and makes several conclusions.

Chapter 2 Study Design

2.1 Phased Approach

The study was designed to identify and estimate the quantity of the point and nonpoint discharges of target pollutants entering Lake Michigan and its tributaries. Figure 2-1 shows the entire Lake Michigan watershed. In order to provide some regional information within a short period of time, the study was divided into two phases. During Phase I, discharges to southern Lake Michigan were evaluated. The results were presented in a June 2008 report (Veil et al. 2008). The upper geographic boundary of the Phase I study area was the Wisconsin/Illinois border on the west and South Haven, Michigan on the east. This area included all of the Illinois and Indiana discharges and a portion of the Michigan discharges that enter Lake Michigan and its tributaries. Phase II of the study evaluated the Wisconsin and remaining Michigan discharges entering Lake Michigan and its tributaries. This report includes the combined results of both phases.

Figure 2-1 Lake Michigan Watershed
Source: EPA 2006b

2.2 Types of Discharges

The study tries to quantify all types of discharges, including point sources and nonpoint sources. These types of discharges are described below.

2.2.1 Point Sources

Point source discharges are discharges that enter water bodies through pipes, ditches, and other discrete conduits. Examples include industrial discharges, municipal wastewater treatment plant discharges, and some stormwater runoff. Point sources are regulated by state agencies under the National Pollutant Discharge Elimination System (NPDES) program. Many NPDES permits contain numeric limits for various pollutants. For those permits that require monitoring and reporting of effluent quality for the target pollutants, the discharges were quantified. Chapter 3 describes the types of data available from the state NPDES offices and discusses how the data were evaluated.

In addition to the NPDES data, the U.S. Environmental Protection Agency's (EPA's) Toxics Release Inventory (TRI) program requires companies that meet certain manufacturing, production, or use thresholds to submit data on annual releases of more than 600 toxic pollutants to different environmental media (e.g., air emissions, underground injection, discharges to surface waters).

2.2.2 Nonpoint Sources

Nonpoint source discharges enter water bodies in ways other than through discrete pipes or conduits. Nonpoint source pollution generally results from stormwater runoff (agricultural, urban, suburban), atmospheric contributions through rainfall and dry fall, drainage, seepage, groundwater exfiltration, or hydrologic modification. Nonpoint sources are not formally regulated by federal or state environmental programs. Consequently, those sources are infrequently monitored. Chapter 5 describes the data and methods used to compile estimates of nonpoint source contributions to the study area. Estimates of nonpoint source pollution included in the report are based on data from the limited number of related studies available in the scientific literature and include a significant amount of uncertainty.

2.2.3 Other Sources

Some types of discharges straddle the line between point and nonpoint sources. An important example of this is urban stormwater runoff. Some cities operate separate sewer systems:
(1) a sanitary sewer that conveys sewage to the municipal wastewater treatment plant, and
(2) a storm sewer that conveys stormwater directly to water bodies without treatment. Although municipalities must obtain NPDES permits for stormwater runoff, often those permits do not establish numeric limits. Instead they require best management practices that reduce the amount of contaminants that are released to water bodies. Therefore, data on the quantity of pollutants contained in stormwater runoff is minimal. Because of the volume and intensity of storms varies considerably, the pollutant releases are quite variable and sporadic.

Other cities have only a single set of sewer infrastructure, known as combined sewer systems. In these cities, stormwater enters sewer pipes that convey the stormwater to the municipal wastewater treatment plant along with sewage. When rainfall is low, the sewers can accommodate the additional flow. However, when rainfall is heavy or intense over a short period, the stormwater runoff into the combined sewers exceeds the sewer capacity. Under those

circumstances, these sewers typically have separate discharge points that allow release of the untreated mixture of sewage and stormwater runoff. These discharges are known as combined sewer overflows. While they are often identified in the NPDES permits, they are not necessarily limited or monitored on any regular basis.

Both types of sewer systems can contribute significant loads of pollutants to water bodies, but in the absence of robust data to characterize the volume and pollutant concentrations of the discharges, they have not been included in the point source loading estimates for this study.

2.3 Target Pollutants

The list of target pollutants for the Phase I study included TSS, ammonia, total chromium, hexavalent chromium, mercury, selenium, and vanadium. For the Phase II study, total chromium and hexavalent chromium were dropped because only limited data values were found in the state agency files during Phase I. The Phase II final list included TSS, ammonia, mercury, selenium, and vanadium. Each of these pollutants is described below. The summaries for ammonia and the metals are based on toxicological profiles prepared by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR). These can be downloaded from the agency's Web site.[1]

2.3.1 TSS

Unlike the other target pollutants, TSS is not a specific chemical. Instead, it represents a composite of all small particulates that are captured by a filter during a specific analytical test. The test measures the presence of solids but does not indicate the chemical nature of those solids. The solids could be sand, rust, dirt, metals, or other materials. The approved analytical method for TSS is to filter a water sample through a glass-fiber filter with pore size of 2 µm or less. The residue on the filter is heated in a furnace to a temperature of 103 to 105°C. The weight of the dried filter is compared to the weight of the new filter at the start of the test.

Suspended solids are present in municipal sanitary wastewater and many types of industrial wastewater. There are also nonpoint sources of suspended solids, such as soil erosion from agricultural areas and construction sites. As levels of suspended solids increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels.

Suspended solids settle to the bottom and can eventually blanket the river bed, damaging aquatic habitat. Suspended solids can smother the eggs of fish and aquatic insects and can suffocate newly hatched insect larvae. Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in a diminished food sources and increased difficulties in finding food.

[1] The URL is http://www.atsdr.cdc.gov/toxpro2.html#bookmark05, accessed April 8, 2008.

2.3.2 Ammonia

Ammonia is a chemical that is made both by humans and by nature. Ammonia is a colorless gas with a very sharp odor. Ammonia in this form is also known as ammonia gas or anhydrous ammonia. Ammonia gas can also be compressed and becomes a liquid under pressure. The odor of ammonia is familiar to most people because it is used in smelling salts, household cleaners, and window cleaning products. Ammonia easily dissolves in water. In this form, it is known as liquid ammonia, aqueous ammonia, or ammonia solution. In water, most of the ammonia (NH_3) changes to the ionic form of ammonia, known as ammonium ions, represented by the formula NH_4^+. Ammonium ions are not gaseous and have no odor. Ammonia and ammonium ions can change back and forth in water. In wells, rivers, lakes, and wet soils, the ammonium form is the most common. Ammonia can also be combined with other substances to form ammonium compounds, including salts such as ammonium chloride, ammonium sulfate, ammonium nitrate, and others.

Ammonia is found in water, soil, and air, and it is a source of much needed nitrogen for plants and animals. In high concentrations, ammonia can be toxic or harmful to aquatic life. Most states have established water quality standards for ammonia. However, at lower concentrations in water bodies, ammonia becomes a readily biodegradable chemical and a food source for phytoplankton and aquatic plants. Under certain circumstances, ammonia can contribute to algal blooms and related conditions that can degrade water quality and negatively impact biota.

Ammonia does not last very long in the environment. The nitrogen portion of ammonia gets converted into some other type of nitrogen chemical or product (e.g., nitrate, nitrite, nitrogen gas). Ammonia does not build up in the food chain, but serves as a nutrient for plants and bacteria. Most of the ammonia in the environment comes from the natural breakdown of manure and dead plants and animals. Eighty percent of all manufactured ammonia is used as fertilizer. A third of this is applied directly to soil as pure ammonia. The rest is used to make other fertilizers that contain ammonium compounds, usually ammonium salts.

2.3.3 Mercury

Mercury occurs naturally in the environment and exists in several forms. These forms can be organized under three headings: elemental mercury, inorganic mercury, and organic mercury. Elemental mercury is a shiny, silver-white metal that is liquid at room temperature. Elemental mercury is the familiar liquid metal used in thermometers and some electrical switches. At room temperature, some of the metallic mercury will evaporate and form mercury vapors. Mercury vapors are colorless and odorless.

Inorganic mercury compounds occur when mercury combines with elements such as chlorine, sulfur, or oxygen. Most inorganic mercury compounds are white powders or crystals, except for mercuric sulfide (also known as cinnabar), which is red and turns black after exposure to light. When mercury combines with carbon, the compounds formed are called organic mercury compounds. The most common organic mercury compound in the environment is methylmercury.

Several forms of mercury occur naturally in the environment. The most common are elemental mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury. Some microorganisms (bacteria and fungi) and natural processes can change the mercury in the environment from one form to another. Methylmercury is of particular concern because it is highly toxic and can build up in certain edible freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water (a process called biomagnification).

Mercury enters the environment as the result of the normal breakdown of minerals in rocks and soil from exposure to wind and water, from volcanic activity, and from anthropogenic sources such as the combustion of fossil fuels. Human activities since the start of the industrial age have resulted in the additional release of mercury to the environment. Estimates of the total annual mercury releases that result from human activities range from one-third to two-thirds of the total mercury releases. The levels of mercury in the atmosphere are very low and do not pose an acute health risk; however, the steady release of mercury has resulted in current levels that are three to six times higher than the estimated levels in the pre-industrial era atmosphere. Approximately 80% of the mercury released from human activities is elemental mercury released to the air, primarily from fossil fuel combustion, mining, smelting, and solid waste incineration.

According to EPA's mercury Web site,[2] after mercury falls from the atmosphere, it can end up in streams, lakes, or estuaries, where it can be transformed to methylmercury through microbial activity. Methylmercury accumulates in fish at levels that may harm the fish and the other animals that eat them. Birds and mammals that eat fish are more exposed to methylmercury than any other animals in water ecosystems. Similarly, predators that eat fish-eating animals are at risk. Effects of methylmercury exposure on wildlife can include reduced fertility, slower growth and development, abnormal behavior that affects survival, and mortality, depending on the level of exposure. In addition, research indicates that the endocrine system of fish, which plays an important role in fish development and reproduction, may be altered by the levels of methylmercury found in the environment.

Mercury is given special attention by the EPA as a "bioaccumulative chemical of concern" under EPA's Great Lakes water quality guidance. EPA established stricter mercury water quality criteria for the Great Lakes and their tributaries than the criteria that apply to other U.S. waters. Each state with waters that drain to the Great Lakes was required to adopt state water quality standards that reflect the strict mercury criteria.

2.3.4 Selenium

Selenium is a naturally occurring substance found in rocks and soil and in the earth's crust. In its pure form of metallic gray to black crystals, selenium is referred to as elemental selenium. Elemental selenium is commercially produced, primarily as a by-product of copper refining. Selenium is not often found in the environment in its elemental form, but is usually combined with other substances. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals. Selenium and its compounds are used in some

[2] The URL is http://www.epa.gov/earlink1/mercury/index.htm, accessed on April 28, 2008.

photographic devices, gun bluing, plastics, paints, antidandruff shampoos, vitamin and mineral supplements, fungicides, and certain types of glass.

Weathering of rocks and soils may release low levels of selenium to water, which then may be taken up by plants. Weathering also releases selenium into the air on fine dust-like particles. Volcanic eruptions may release selenium in air. Selenium commonly enters the air from burning coal or oil. Selenium that may be present in fossil fuels combines with oxygen when burned, which may then react with water to form soluble selenium compounds. Airborne particles of selenium, such as in ash, can settle on soil or surface water.

In humans and animals, selenium is an essential nutrient that plays a role in protecting tissues from oxidative damage. Nonetheless, exposure to high levels of selenium via inhalation or ingestion may cause adverse health effects. Selenium accumulates in many organ systems in the body; in general, the highest concentrations are found in the liver and kidneys. Upon contact with human skin, industrial selenium compounds have been reported to cause rashes, redness, heat, swelling, and pain. Brief, acute exposure of the eyes to selenium dioxide as a dust or fume in workplace air may result in burning, irritation, and tearing. However, only people who work in industries that process or use selenium or selenium compounds are likely to come into contact with levels high enough to cause eye irritation.

Selenium can be toxic to aquatic life (such as fish and invertebrates) where concentrations are excessive. It is also toxic to other biota, such as cormorants and other birds that consume aquatic organisms containing excessive levels of selenium. Selenium is sometimes referred to as a bioaccumulative pollutant, but it is not a “bioaccumulative chemical of concern” under EPA’s Great Lakes water quality guidance[3]. Aquatic life and birds are exposed to selenium primarily through diet. Risks stem from aquatic life eating food that is contaminated with selenium, rather than from direct exposure to selenium in the water. Although selenium bioaccumulates in tissues of biota, it is not significantly biomagnified.

2.3.5 Vanadium

Vanadium is a white to gray metal, often found as crystals. It has no particular odor. Vanadium occurs naturally in fuel oils and coal. In the environment it is usually combined with other elements such as oxygen, sodium, sulfur, or chloride. One manmade form, vanadium oxide, is most often used by industry, primarily in steelmaking. Much smaller amounts are used in making rubber, plastics, ceramics, and other chemicals. Vanadium oxide can be a yellow-orange powder, dark-grey flakes, or yellow crystals. The most likely way for the chemical to get into the air is when fuel oil is burned. When rocks and soil containing vanadium are broken down into dust by wind and rain, vanadium can get into the air, groundwater, surface water, or soil. It does not dissolve well in water, but it can be carried by the water, much as particles of sand might be carried. Vanadium is naturally found in soil and rocks at about 150 parts of vanadium per million parts of soil (150 ppm) in the earth’s crust.

The EPA has not published any water quality criteria for vanadium. Vanadium is not commonly found in industrial discharges and is not generally limited by discharge permits. However, the

[3] The URL is http://www.epa.gov/waterscience/standards/gli/, accessed on November 30, 2009.

Indiana Department of Environmental Management (IDEM) did calculate aquatic life protection values for vanadium using data from the literature. These values were used as the basis for establishing numeric limits for vanadium in NPDES permits.

In humans, the major adverse health effect from vanadium has been seen in workers exposed to large amounts of vanadium pentoxide dusts. Affected workers have coughs, chest pains, sore throats, and irritated eyes, but the symptoms disappear soon after exposure ceases. The response is similar to that of an upper respiratory tract infection. No other significant health effects of vanadium have been found. The gastrointestinal absorption of vanadium is so low that the health implications for people drinking the water are not readily apparent. There are no reports of death in humans following inhalation or oral or dermal exposure to vanadium. Humans are unlikely to be in contact with large enough amounts of vanadium to cause death.

Chapter 3 Point Source Data Collection

The primary sources of point source data used in this study were state agency records from Illinois, Indiana, Michigan, and Wisconsin. The environmental agencies in each of those states were contacted as a starting point for data collection. In addition, water program personnel at EPA's Region V office in Chicago were consulted to assess what types of regional information could supplement the state information.

Each state provided information in a different format. Although all data were in spreadsheets, the categories of information differed among the agencies. In each case, the initial lists contained a large number of facilities, many of which were not relevant to formulation of target pollutant loads because of either the volume or chemical characteristics of the discharges at those facilities. The following sections describe, for each state, the nature of the initial information, the types of screening that were used to remove facilities from the list, and the ways in which relevant data were extracted from files and online resources.

A brief review of the NPDES permit process is provided before the state-specific sections. Section 3.1 describes NPDES permits and the types of information that can be derived from three separate aspects of the NPDES program—permit applications, issued permits, and monitoring reports. Each of these offers different types of data and is likely to be found in the permit files to varying degrees:

- Application data typically represent actual discharge data, but are normally collected only once. Often included are data on a wider range of pollutants than are normally assigned limits in the permit. For some of the less-common target pollutants, such as vanadium and selenium, this may be the only place where effluent data are available.

- Issued permits include numeric limits for different pollutants. The limits represent the highest allowable concentration and/or load for each pollutant that the facility may discharge. In composite form, the permitted or calculated loads represent the total permitted load to the Lake Michigan drainage.

- Compliance monitoring data are collected at specified frequencies and reported monthly to the state agencies as discharge monitoring reports (DMRs). For those pollutants limited by the permits, ongoing monitoring data should be available, thereby allowing the most accurate accounting of a facility's discharges over time. These data allow averaging of the monthly results over a year or more.

3.1 The NPDES Program

The NPDES permit program is a federal program assigned to the EPA under the Clean Water Act. NPDES permits are required for all point source discharges to surface water bodies. EPA can delegate the authority for administering the NPDES program to states that demonstrate the willingness and ability to manage the program. All four of the states bordering Lake Michigan have received authorization to administer the NPDES program.

3.1.1 Data from Permit Applications

Dischargers must submit NPDES permit applications before starting new discharges and within 180 days of the expiration of existing permits. Although each state may use a somewhat different application form for different groups of permits, large industrial dischargers must provide some analytical data describing their discharges on Application Form 2C. Form 2C lists nine pages of pollutants. Depending on the nature of the specific discharge, analyses must be provided for some or all of the pollutants through each point of discharge (referred to as an outfall).

In Form 2C, pages V-1 and V-3 contain the target pollutants. Copies of those pages from an actual industrial application made to IDEM are shown in Figures 3-1 and 3-2.[4] The pages contain a great deal of information. This application is for the main outfall 001 at a facility that has multiple outfalls. Effluent data are provided for up to three sets of columns (maximum daily value, maximum 30-day value, and long-term average). Data are often reported separately in concentration and mass (loading). Where data were available, the reported long-term average loading value was used as the average load in the database for this study. The maximum daily loading value was used as the maximum load in the database.

Data for TSS and ammonia can be seen in Figure 3-1. TSS data are found on Part A, line d. Ammonia data are found in the next line. Data for total mercury and total selenium are found in Figure 3-2 on lines 8M and 10M, respectively. Application Form 2C does not require testing for vanadium, thus no application data are available for that parameter. Figure 3-2 shows three columns under the heading A. The first column, “Testing Required,” refers to a list of toxic pollutants that must be measured on an industry-by-industry basis, as specified in the Form 2C instructions. The next two columns allow the applicant to indicate if each pollutant is believed to be present or absent. In the example shown in Figure 3-2, the applicant believed that chromium and mercury would be present but that selenium would be absent. The monitoring data confirmed that assessment.

The sensitivity of the analytical method used in monitoring for permit applications can affect conclusions. For example, mercury was typically not quantifiable below 200 parts per trillion until Analytical Method 1631 became approved for use in 1999. Method 1631 can detect mercury at the 0.5-part-per-trillion level. Some of the larger permit applications reviewed as part of this study were submitted to the agencies in the 1990s. Mercury would have most likely been measured using an older analytical method. Unless the more sensitive method is used, mercury may be reported as “below detection” and, therefore, erroneously confirm a conclusion that it is not present.

[4] The images come from a second-hand scanned copy of the application and are not available at high resolution. They are included here to show an example of how actual data are filled in on the form. A blank copy of Form 2C can be viewed on EPA’s Web site at: http://www.epa.gov/npdes/pubs/3510-2C.pdf.

V. INTAKE AND EFFLUENT CHARACTERISTICS *(continued from page 3 of Form 2-C)*

OUTFALL NO. 001

PART A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.

1. POLLUTANT	2. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	3. UNITS (specify if blank) a. CONCEN-TRATION	b. MASS	4. INTAKES (optional) a. LONG TERM AVG. VALUE (1) CONCEN-TRATION	(2) MASS	b. NO. OF ANALYSES
a. Biochemical Oxygen Demand (BOD)	22.0	852			7.5	268	14	mg/L	lb/day			
b. Chemical Oxygen Demand (COD)	24.8	860					1	mg/L	lb/day			
c. Total Organic Carbon (TOC)	12.8	444					1	mg/L	lb/day			
d. Total Suspended Solids (TSS)	19.0	804	6.1	230	3.5	122	126	mg/L	lb/day			
e. Ammonia (as N)	0.160	5.55			J 0.051	J 1.80	14	mg/L	lb/day			
f. Flow	VALUE 5.074		VALUE 4.450		VALUE 4.159		146	MGD		VALUE		
g. Temperature (winter)	VALUE 74.8		VALUE 70.6		VALUE 57.1		79	°F		VALUE		
h. Temperature (summer)	VALUE 82.0		VALUE 79.0		VALUE 76.8		27	°F		VALUE		
i. pH	MINIMUM 6.7	MAXIMUM 8.6	MINIMUM 7.4	MAXIMUM 8.2			106	STANDARD UNITS				

PART B - Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2a for any pollutant which is limited either directly, or indirectly but expressly, in an effluent limitation guideline you must provide the results of at least one analysis for that pollutant. For other pollutants for which you mark column 2a, you must provide quantitative data or an explanation of their presence in your discharge. Complete one table for each outfall. See the instructions for additional details and requirements.

1. POLLUTANT AND CAS NO. (if available)	2. MARK "X" a. BELIEVED PRESENT	b. BELIEVED ABSENT	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG VALUED (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	4. UNITS a. CONCEN-TRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVG. VALUE (1) CONCEN-TRATION	(2) MASS	b. NO. OF ANALYSES
a. Bromide (24959-67-9)		X	< 0.5	< 15					1	mg/L	lb/day			
b. Chlorine, Total Residual	X		< 0.01		< 0.01		< 0.01		122	mg/L	lb/day			
c. Color		X	< 5						1	Pt-Co				
d. Fecal Coliform		X	< 2						1	#/100 mL				
e. Fluoride (16984-48-8)	X		0.81	28.5			J 0.73	J 25.5	8	mg/L	lb/day			
f. Nitrate-Nitrite (as N)	X		1.50	52.7			0.47	16.6	14	mg/L	lb/day			

Figure 3-1 Page V-1 from NPDES Permit Application Form 2C

PART C - If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark colpn 2-a (secondary industries, nonprocess wastewater outfalls, and nonrequired GC/MS fractions), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe is absent. If you mark column 2a for any pollutant, you must provide the results of at least one analysis for that pollutant. If you mark column 2b for any pollutant, you must provide the results of at least one analysis for that pollutant if you know or have reason to believe it will be discharged in concentrations of 10 ppb or greater. If you mark column 2b for acrolein, acrylonitrile, 2,4 dinitrophenol, or 2-methyl-4, 6 dinitrophenol, you must provide the results of at least one analysis for each of these pollutants which you know or have reason to believe that you discharge in concentrations of 100 ppb or greater. Otherwise, for pollutants for which you mark in column 2b, you must either submit at least one analysis or briefly describe the reasons the pollutant is expected to be discharged. Note that there are 7 pages to this part; please review each carefully. Complete one table (all 7 pages) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBERS (if available)	2. MARK "X"			3. EFFLUENT							4. UNITS		5. INTAKE (optional)		
	a. TESTING REQUIRED	b. BELIEVED PRESENT	c. BELIEVED ABSENT	a. MAXIMUM DAILY VALUE (1) CONCENTRATION	a. MAXIMUM DAILY VALUE (2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	b. MAXIMUM 30 DAY VALUE (if available) (2) MASS	c. LONG TERM VALUE (if available) (1) CONCENTRATION	c. LONG TERM VALUE (if available) (2) MASS	d. NO. OF ANALYSES	a. CONCENTRATION	b. MASS	a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	a. LONG TERM AVERAGE VALUE (2) MASS	c. NO. OF ANALYSES
METALS, CYANIDE, AND TOTAL PHENOLS															
1M. Antimony, Total (7440-36-0)	X		X	< 0.05	< 1.502					1	mg/L	lb/day			
2M. Arsenic, Total (7440-38-2)	X	X		0.002	0.070			J 0.001	J 0.043	8	mg/L	lb/day			
3M. Beryllium, Total (7440-41-7)	X		X	< 0.001	< 0.036			< 0.001	< 0.035	6	mg/L	lb/day			
4M. Cadmium, Total (7440-43-9)	X		X	< 0.0010	< 0.036			< 0.0008	< 0.028	8	mg/L	lb/day			
5M. Chromium, Total (7440-47-3)	X	X		0.0004	0.014			J 0.0038	J 0.135	8	mg/L	lb/day			
6M. Copper, Total (7440-50-8)	X	X		0.0074	0.260			J 0.0047	J 0.165	8	mg/L	lb/day			
7M. Lead, Total (7439-92-1)	X	X		0.0138	0.474	0.0083	0.286	0.0022	0.078	125	mg/L	lb/day			
8M. Mercury, Total (7439-97-6)	X	X		1.21	0.000042			0.64	0.000022	3	µg/L	lb/day			
9M. Nickel, Total (7440-02-0)	X	X		0.0024	0.084			J 0.0043	J 0.150	8	mg/L	lb/day			
10M. Selenium, Total (7782-49-2)	X		X	< 0.005	< 0.178			< 0.004	< 0.148	8	mg/L	lb/day			
11M. Silver, Total (7440-22-4)	X		X	< 0.01	< 0.300					1	mg/L	lb/day			
12M. Thallium, Total (7440-28-0)	X		X	< 0.02	< 0.601					1	mg/L	lb/day			
13M. Zinc, Total (7440-66-6)	X	X		0.186	7.871	0.039	1.457	0.020	0.693	125	mg/L	lb/day			
14M. Cyanide, Total (57-12-5)	X		X	< 0.005	< 0.176					2	mg/L	lb/day			
15M. Phenols, Total	X		X	< 0.005	< 0.176					2	mg/L	lb/day			
DIOXIN															
2,3,7,8-Tetrachlorodibenzo-P-Dioxin (1764-01-6)			X	DESCRIBE RESULTS											

CONTINUED ON PAGE V-4

Figure 3-2 Page V-3 from NPDES Permit Application Form 2C

3.1.2 Permit Limits

NPDES permits contain numeric discharge limits for various pollutants. They may also contain other operational and management requirements as well as general administrative and compliance requirements. Permit writers must calculate limits using two separate approaches (*technology-based limits* and *water quality-based limits*) and then apply the limits that are found to be more stringent.

The first approach calculates "technology-based limits." The Clean Water Act specifies that industrial discharges must meet best available technology economically achievable (BAT). It is important to understand that EPA must select as the basis for BAT a technology that is already in use in a particular industry (or sometimes in a related industry) with a proven long-term record of performance under the conditions associated with the type of discharge in question. Furthermore, the technology has to be affordable.

EPA has published effluent limitations guidelines (ELGs) for most large industrial categories. Where ELGs are available, permit writers use them to calculate technology-based limits. For example, a permit for a refinery would evaluate the ELGs from the petroleum refining industry; these are found at 40 CFR 419. These particular ELGs are based on the amount of feedstock processed by different units within the refinery. Production-based BAT limits are established for biochemical oxygen demand (BOD), chemical oxygen demand (COD), TSS, oil and grease, phenolic compounds, ammonia, sulfide, total chromium, and hexavalent chromium.

For municipal wastewater treatment plants, many of which are located in the study area, the national minimum technology-based discharge standard for municipal wastewater is referred to as "secondary treatment." This term is defined at 40 CFR 133.102 (see below). The secondary treatment regulation uses the terms SS (same as TSS) and $CBOD_5$ (five-day carbonaceous biochemical oxygen demand).

> *Sec. 133.102 Secondary treatment. The following paragraphs describe the minimum level of effluent quality attainable by secondary treatment in terms of the parameters—BOD_5, SS and pH. All requirements for each parameter shall be achieved except as provided for in Sec. 133.103 and 133.105.* [Note that these two sections refer to alternate ways of meeting secondary standards.]
>
> *(a) BOD_5.*
>
> *(1) The 30-day average shall not exceed 30 mg/l.*
>
> *(2) The 7-day average shall not exceed 45 mg/l.*
>
> *(3) The 30-day average percent removal shall not be less than 85 percent.*
>
> *(4) At the option of the NPDES permitting authority, in lieu of the parameter BOD_5 and the levels of the effluent quality specified in paragraphs (a)(1), (a)(2) and (a)(3), the parameter $CBOD_5$ may be substituted with the following levels of the $CBOD_5$ effluent quality provided:*
>
> *(i) The 30-day average shall not exceed 25 mg/l.*
>
> *(ii) The 7-day average shall not exceed 40 mg/l.*
>
> *(iii) The 30-day average percent removal shall not be less than 85 percent.*

(b) SS.

(1) The 30-day average shall not exceed 30 mg/l.

(2) The 7-day average shall not exceed 45 mg/l.

(3) The 30-day average percent removal shall not be less than 85 percent.

(c) pH.

The effluent values for pH shall be maintained within the limits of 6.0 to 9.0 unless the publicly owned treatment works demonstrates that:

(1) Inorganic chemicals are not added to the waste stream as part of the treatment process; and

(2) contributions from industrial sources do not cause the pH of the effluent to be less than 6.0 or greater than 9.0.

The second approach for calculating limits is known as "water quality-based limits." Permit writers calculate the concentration of discharged pollutants at the edge of a mixing zone after any allowable dilution. These concentrations are compared to the state's water quality standards for each pollutant. If any calculated concentrations exceed the water quality standards, stricter limits are developed for those pollutants. Many permits, particularly those for large facilities, contain numeric limits derived from both technology-based and water quality-based limits.

3.1.3 Data from Issued Permits

NPDES permits may place limits on the concentration of a pollutant (milligrams of pollutant per liter of discharger [mg/L]), on the mass loading of a pollutant (pounds per day [lb/day]), or on both. The permits may contain average limits, maximum limits, or both. In some cases, the permit does not establish limits but requires monitoring for various parameters. The permits also indicate the type and frequency of sampling that must be done. The results of the monitoring must be submitted to the permitting agency monthly or at some other specified frequency.

Figure 3-3 shows a final limitations page from an actual NPDES permit issued in 2007. The final outfall, after the process modifications and installation of a diffuser structure on the discharge pipe, is numbered 005. The first column indicates the parameters with restrictions for this outfall. The next three columns show the mass loading limits (most with units of lb/day). The next set of three columns indicates limits or monitoring requirements in concentration units (mg/L, except for mercury, which is in ng/L). The last two columns indicate the required frequency of sampling and the type of sample that the discharger must collect.

For each discharger that underwent a file review as part of the data collection efforts for this study, the average and maximum loading limits and concentration limits from the permit were entered into the database. This reflects the legal allowances for that discharger. Most facilities discharged quantities well below their permit limits most of the time.

Some permits had different limits for different months of the year. This was particularly common for ammonia limits at municipal wastewater treatment plants that used biological treatment systems. The water bodies to which the plants discharge have different assimilative capacities depending on the water temperature and the dissolved oxygen in the water column. In those cases, the highest monthly or seasonal limits were used in the study database.

Other permits established more than one set of limits as the facilities modified their operations or changed their wastewater treatment systems. Typically, the permit would have a more lenient set of interim limits and a stricter set of final limits. In those cases, the final limits were used in the study database.

DISCHARGE LIMITATIONS OUTFALL 005 [1][3]

	Quantity or Loading			Quality or Concentration			Monitoring	Requirements
Parameter	Monthly Average	Daily Maximum	Units	Monthly Average	Daily Maximum	Units	Measurement Frequency	Sample Type
Flow	Report	Report	MGD	----	----	----	Daily	24-Hr. Total
BOD5	4,161	8,164	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
TSS	4,925	7,723	lbs/day	Report	Report	mg/l	2 x Weekly	24 Hr. Comp.
COD	30,323	58,427	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Oil and Grease	1,368	2,600	lbs/day	Report	Report	mg/l	1 x Weekly	Grab
Phenolics (4AAP)	20.33	73.01	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Phosphorus	Report	Report	lbs/day	Report	1.0	mg/l	1 x Weekly	24 Hr. Comp.
Ammonia as N	1,584	3,572	lbs/day	Report	Report	mg/l	5 x Weekly	24 Hr. Comp.
Sulfide	23.1	51.4	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Total Chromium [4]	23.9	68.53	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Hex. Chromium [5]	2.01	4.48	lbs/day	Report	Report	mg/l	1 x Weekly	Grab
Total Vanadium [7]								
Interim	Report	Report	lbs/day	Report	Report	mg/l	1 x Monthly	24-Hr. Comp.
Final	50	100	lbs/day	0.28	0.56	mg/l	1 x Monthly	24-Hr. Comp.
Total Mercury [7]								
Interim	Report	Report	lbs/day	Report	Report	ng/l	2 x Yearly	Grab
Final [6]	0.00023	0.00057	lbs/day	1.3	3.2	ng/l	6 x Yearly	Grab
Whole Effluent Toxicity [8]								
Chronic	-	-	-	Report	-		TUc	2 x Yearly
pH [2]					Report	s.u.	3 x Weekly	Grab

Figure 3-3 Effluent Limits Page from an NPDES Permit

3.1.4 Data from Discharge Monitoring Reports

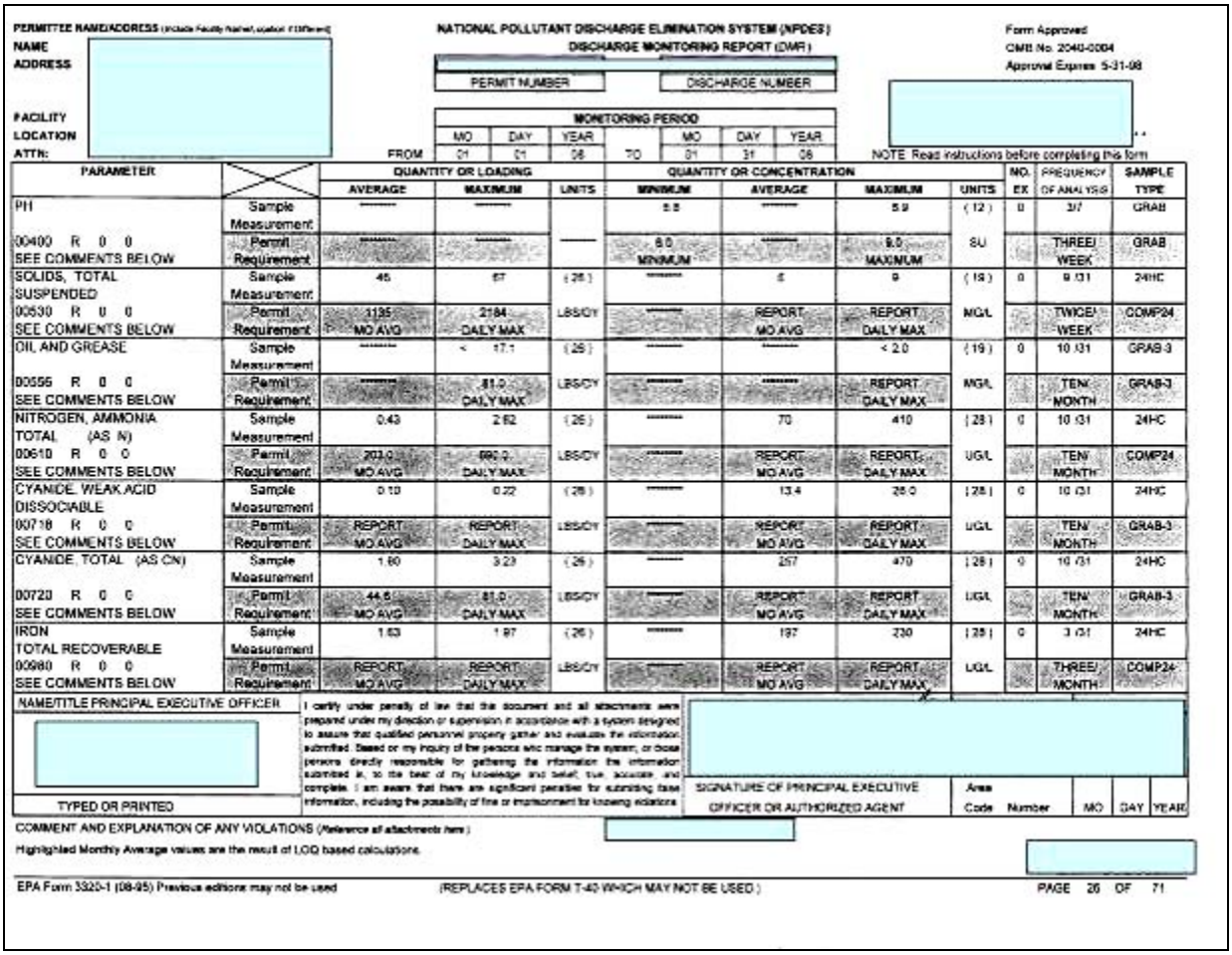
Under the NPDES program, all monitoring is conducted by the discharger for the parameters indicated in the permit and at the frequency specified in the permit. Figure 3-3 shows the types of monitoring that the discharger will be expected to conduct when the new outfall with a diffuser structure is in place. Dischargers are required to submit monthly DMRs to the permitting agency. The DMRs show the parameters limited in the permit and the facilities' actual performance.

A sample page from the January 2008 DMR submitted by an industrial facility is shown in Figure 3-4.[5] The identity of the company and facility has been masked. For each parameter, the shaded row shows the permit requirement, and the row with a white background shows the

[5] The image comes from a second-hand scanned copy of the DMR and is not available at high resolution. It is included here to show an example of how actual data are filled in on the form. A blank DMR form on EPA's Web site can be viewed at: http://www.epa.gov/npdes/pubs/dmr.pdf.

sample result for that month. In this example, the TSS and ammonia values reported on the DMR were well below the permitted limits.

With limited exceptions, electronic reporting for DMRs is not currently in practice. This means that each month the agencies receive hundreds of printed DMRs that must be reviewed and filed. Programs are in place to manually enter the data from each DMR into online databases set up by EPA.


PERMITTEE NAME/ADDRESS (Include Facility Name/Location if Different)
NAME
ADDRESS
FACILITY
LOCATION
ATTN:

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
DISCHARGE MONITORING REPORT (DMR)

Form Approved
OMB No. 2040-0004
Approval Expires 5-31-98

PERMIT NUMBER | DISCHARGE NUMBER

MONITORING PERIOD	MO	DAY	YEAR		MO	DAY	YEAR
FROM	01	01	08	TO	01	31	08

NOTE Read instructions before completing this form

PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
PH	Sample Measurement	------	------		5.8	------	5.9	(12)	0	3/7	GRAB
00400 R 0 0 SEE COMMENTS BELOW	Permit Requirement	------	------	------	6.0 MINIMUM	------	9.0 MAXIMUM	SU		THREE/ WEEK	GRAB
SOLIDS, TOTAL SUSPENDED	Sample Measurement	45	67	(26)	------	6	9	(19)	0	9 /31	24HC
00530 R 0 0 SEE COMMENTS BELOW	Permit Requirement	1135 MO AVG	2184 DAILY MAX	LBS/DY	------	REPORT MO AVG	REPORT DAILY MAX	MG/L		TWICE/ WEEK	COMP24
OIL AND GREASE	Sample Measurement	------	< 17.1	(26)	------	------	< 2.0	(19)	0	10 /31	GRAB-3
00556 R 0 0 SEE COMMENTS BELOW	Permit Requirement	------	81.0 DAILY MAX	LBS/DY	------	------	REPORT DAILY MAX	MG/L		TEN/ MONTH	GRAB-3
NITROGEN, AMMONIA TOTAL (AS N)	Sample Measurement	0.43	2.62	(26)	------	70	410	(28)	0	10 /31	24HC
00610 R 0 0 SEE COMMENTS BELOW	Permit Requirement	203.0 MO AVG	692.0 DAILY MAX	LBS/DY	------	REPORT MO AVG	REPORT DAILY MAX	UG/L		TEN/ MONTH	COMP24
CYANIDE, WEAK ACID DISSOCIABLE	Sample Measurement	0.10	0.22	(26)	------	13.4	26.0	(28)	0	10 /31	24HC
00718 R 0 0 SEE COMMENTS BELOW	Permit Requirement	REPORT MO AVG	REPORT DAILY MAX	LBS/DY	------	REPORT MO AVG	REPORT DAILY MAX	UG/L		TEN/ MONTH	GRAB-3
CYANIDE, TOTAL (AS CN)	Sample Measurement	1.60	3.23	(26)	------	257	470	(28)	0	10 /31	24HC
00720 R 0 0 SEE COMMENTS BELOW	Permit Requirement	44.6 MO AVG	81.0 DAILY MAX	LBS/DY	------	REPORT MO AVG	REPORT DAILY MAX	UG/L		TEN/ MONTH	GRAB-3
IRON TOTAL RECOVERABLE	Sample Measurement	1.63	1.97	(26)	------	197	230	(28)	0	3 /31	24HC
00980 R 0 0 SEE COMMENTS BELOW	Permit Requirement	REPORT MO AVG	REPORT DAILY MAX	LBS/DY	------	REPORT MO AVG	REPORT DAILY MAX	UG/L		THREE/ MONTH	COMP24

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER

TYPED OR PRINTED

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT | Area Code | Number | MO | DAY | YEAR

COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here.)

Highlighted Monthly Average values are the result of LOQ based calculations.

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Figure 3-4 Page from an Actual DMR

3.1.4.1 Permit Compliance System

EPA has operated the online Permit Compliance System (PCS) database of NPDES information for many years.[6] Much of the DMR information is entered in PCS, where it can be retrieved. However, due to output limitations, PCS is generally of limited use for compiling summary statistics. The states of Illinois, Michigan, and Wisconsin use PCS. As part of reviewing (for this

[6] The URL for PCS is http://www.epa.gov/enviro/html/pcs/pcs_query_java.html, accessed on April 10, 2008.

study) the large number of Michigan facilities in Phase II, an alternate way of accessing the DMR data stored in PCS was discovered that allowed more efficient data compilation and summarization.

3.1.4.2 Enforcement and Compliance History Online

Some states (including Indiana) have moved their NPDES data onto a newer online data system called Enforcement and Compliance History Online (ECHO).[7] During 2005, Indiana stopped entering data into PCS and began entering data into ECHO. ECHO provides more features and allows users to display and export monitoring data much more easily than does PCS. All DMR data for Indiana used in the study database were extracted from ECHO. Where sufficient monthly samples were available, all 2007 data were used. In most cases, 12 monthly sample values could be found in ECHO. For other parameters that were reported at a frequency of less than monthly, as many data values as possible were used to calculate an average and to identify a maximum value.

The emphasis of the study is to identify the quantity of target pollutants discharged by individual dischargers. Therefore, where mass loading data were available from ECHO, only those data were entered into the database. Where mass loading data were not available, concentration data and flow data were entered into the database. Mass loading was calculated by multiplying concentration by flow by a conversion factor.

3.2 Data from State Agencies

During Phase I of the study, letters were sent to representatives of the NPDES programs at the Illinois Environmental Protection Agency (IEPA), Indiana Department of Environmental Management (IDEM), and Michigan Department of Environmental Quality (MDEQ). Information was requested about those facilities holding NPDES permits that discharge to Lake Michigan or within the Lake Michigan drainage area. Within that subset of permits, information was requested on those facilities that might discharge more than small amounts of the following pollutants:

- TSS,
- Ammonia,
- Total nitrogen,
- Total chromium,
- Hexavalent chromium,
- Mercury,
- Vanadium, and
- Selenium.

Initially data on total nitrogen were sought even though it is not on the target pollutant list. Study researchers had anticipated that such data might be available for facilities that did not have any ammonia data. They felt that it might be possible to discern a relationship between ammonia

[7] The URL for ECHO is http://www.epa-echo.gov/echo/compliance_report_water_icp.html, accessed on April 10, 2008.

concentration and total nitrogen concentration, and thereby extrapolate ammonia concentrations for facilities without that data. However, after examining numerous applications, permits, and DMRs, it became apparent that very minimal total nitrogen data were available. As a result, total nitrogen data were not included in the final database for point source discharges, nor was total nitrogen included in the Phase II data collection effort.

Wisconsin was not part of the Phase I study. When the Phase II data collection began, representatives of the NPDES program in the Wisconsin Department of Natural Resources (WDNR) were contacted. The initial request for data was sent on February 24, 2009. As noted previously, the list of target pollutants for Phase II was reduced to include TSS, ammonia, mercury, vanadium, and selenium.

3.2.1 Evaluation of State Data

Each state replied with different levels and types of information. Each state provided a master list containing the names of all facilities that discharge to the Lake Michigan drainage. However, the specific data elements on those master lists differed among states, necessitating slightly different approaches to evaluating the master lists. Different screening mechanisms were used to remove those facilities that were unlikely to discharge levels of the target pollutants that would make "significant" contributions to the database. Examples of the types of facilities excluded from additional consideration by the screening process include facilities with very low flow and facilities that do not have permit limits or reporting requirements for any of the target pollutants.

Other facilities that provided quantifiable data but were considered not to be "significant" in comparison to the larger dischargers were also screened and excluded from further consideration. The threshold for "significant" quantities was loosely defined as 25 lb/day for TSS, 1 lb/day for ammonia, and any detectable amount for the metals. The types of information received from each state, the screening approaches used to develop final lists of facilities and the methods used to obtain specific data are described in the following sections.

3.2.2 Illinois

3.2.2.1 Sources of Information

The Division of Water Pollution Control, IEPA, provided a list of 12 facilities that discharge into the Lake Michigan drainage area. Illinois has only a short stretch of frontage on Lake Michigan. Around the year 1900, the Chicago Sanitary and Ship Canal was constructed to connect the south branch of the Chicago River to the Des Plaines River. This redirected the drainage from much of the greater Chicago region away from Lake Michigan so that it now flows into the Mississippi River watershed, except under extreme rainfall events. As a result of these two factors, very few Illinois discharges currently flow into or toward the lake. The 12 facilities are, for the most part, either industrial facilities with minimal current operations, or discharges that are not likely to contain any significant quantities of the pollutants listed above.

3.2.2.2 First Screen—Elimination of Closed and Insignificant Discharges by Individual PCS Evaluation

Six of the 12 facilities were found to be either closed or to have discharges that did not contribute significant quantities of the target pollutants. Those facilities were eliminated from further study.

3.2.2.3 Final List and Visit to IEPA

An Argonne representative visited the IEPA office in Springfield, Illinois, on December 11, 2007, to examine the agency's NPDES files for the remaining six facilities. Other than a significant TSS load at one facility, the other facilities had minimal discharges of the target pollutants and were not considered in the Illinois database.

3.2.3 Indiana

3.2.3.1 Sources of Information

The Permitting Branch of IDEM's Office of Water Quality provided a list of NPDES permitted facilities discharging into Lake Michigan or its tributaries. That list contained 187 permitted facilities and served as the starting point. Of these, 32 facilities are ranked by EPA as major facilities. Although screening methods excluded some facilities from detailed evaluation, all of the major facilities were individually evaluated by file review.

Indiana has only a relatively short stretch of frontage on Lake Michigan. Most of the facilities in northwestern Indiana discharge directly into the lake or into tributaries that enter the Indiana portion of Lake Michigan. Some of the facilities near the Illinois border discharge into water bodies that flow west to the Chicago Sanitary and Ship Canal, which in turn flows into the Mississippi River watershed. However, in other portions of northern Indiana, most facilities discharge into water bodies that flow northward into the St. Joseph River system. The St. Joseph River continues into Michigan, where it enters Lake Michigan within the Phase I boundaries.

3.2.3.2 First Screen—Permit Type

The full list contains 45 Indiana facilities that are covered by NPDES general permits. To be covered under a general permit, facilities submit a rather brief Notice of Intent (NOI) form rather than a detailed permit application. The NOIs rarely contain detailed analytical information about pollutants in the effluent.

Fifteen of the facilities are covered by a general permit for groundwater petroleum remediation systems (generally these are groundwater cleanup efforts at gas stations). The permits have limits only on benzene and pH. Nine other facilities operate under a general permit for noncontact cooling water. That permit requires monitoring only for oil and grease, temperature, and pH. The permit files are unlikely to contain any information on the target pollutants. One facility operates under a general permit for hydrostatic pressure testing. Hydrostatic testing is typically a one-time or infrequent event at any given location. There is no ongoing discharge at the location. Therefore, these 25 facilities were dropped from further study.

Three other facilities discharge under the provisions of a general permit for sand and gravel operations. This permit requires monitoring for TSS. An additional 17 facilities discharge under the provisions of a general permit for discharges associated with petroleum products terminals. That general permit establishes limits on three pollutants and includes monitoring requirements for six other pollutants, including TSS and ammonia. Because these permits include monitoring for one or more of the target pollutants, these facilities remained on the list for further study.

3.2.3.3 Second Screen—Discharge Flow Volume

After the first screening, 162 facilities remained on the list for Indiana. A facility's discharge volume has a direct relationship to the loading of the target pollutants from that facility. The relationship between concentration and loading can be described as:

$$\textit{Concentration (mg/L)} \times \textit{Flow (MGD)} \times 8.32 = \textit{Loading (pounds/day)}$$

As an example, if a discharge of 0.1 million gallons per day (MGD) has a TSS concentration of 30 mg/L (a common permit effluent limit for TSS), the resulting load of TSS is about 25 lb/day. Compared to larger industrial and municipal facilities that discharge hundreds of pounds of TSS per day, discharges of this magnitude are small and can reasonably be excluded from the analysis. Although this example uses TSS as the pollutant, the same principle applies for the other four target pollutants. After reviewing hundreds of NPDES permit files, it became apparent to the researchers that facilities with small volumes of discharge rarely, if ever, monitored for the metals. The facilities with any likelihood of having monitoring for the metals were major facilities; these were not automatically removed by the low-volume screening approach, but rather were individually evaluated.

The information provided by IDEM includes flow data for some of the facilities. Where flow data values are available, all nonmajor permits that had flow of 0.1 MGD or less were eliminated from further study. Fifty-six facilities were removed from the list by the application of this flow volume screen.

3.2.3.4 Third Screen—Individual Evaluation Using ECHO

Following the second screening, 106 facilities remained on the list. Each was then individually evaluated to determine the pollutants limited by the permit and to review some recent DMR data by using the ECHO online database for environmental data. A total of 41 facilities were removed from the third screen list. Twenty-one facilities were removed because of some combination of low discharges of TSS and ammonia. Another 18 facilities were dropped because they had reported no recent discharges, had discharge volumes much lower than had been considered during the second screening, or were discharging wastewater streams that did not have any effluent limits for the target pollutants. Two facilities on the list do not discharge into the Lake Michigan drainage area but rather into the Lake Erie drainage area and were, therefore, removed from further study.

3.2.3.5 Final List, Visit to IDEM, and Revised Final List

An Argonne representative visited the IDEM offices in Indianapolis on March 24 and 25, 2008. He reviewed IDEM files for the 65 facilities on the final list. After reviewing the actual DMR and flow data, he determined that 18 of the facilities did not contribute significant quantities of the target pollutants (based on the threshold values described in Section 3.2.1). These facilities were eliminated, leaving a revised final list of 47 facilities.

For the remaining facilities, permit limits were obtained, as applicable, for the target pollutants. Where NPDES permit applications were available that included effluent concentrations or loadings for the target pollutants, that information was entered into an Indiana database. The DMR concentration and loading data for all facilities were obtained from ECHO.

3.2.4 Michigan

Veil et al. (2008) describe the data collection and screening approaches used to develop the Phase I subset of the Michigan point source loads. This section describes the Phase II efforts to update and expand the Michigan data set to encompass the entire Lake Michigan drainage.

3.2.4.1 Sources of Information

During the Phase I evaluation, the MDEQ's Water Bureau provided data on all of the permitted facilities that discharge into the Lake Michigan drainage area (1,744 municipal, industrial, stormwater, and other discharges). Because the loading analysis is based on the year 2007, this same list of permitted facilities was used as the basis for the Phase II study. This is justified because any new facilities that began discharging during 2008 and 2009 would not be quantified in the loading analysis. MDEQ also provided separate pollutant-specific lists of permits that had limits or monitoring requirements for any of the target pollutants and a table showing all the 2007 discharge volumes from facilities in the Phase II region.

3.2.4.2 First Screen—Facility and Permit Type

The facilities on the initial list can be categorized as follows:

Individual NPDES permits
- industrial or commercial facilities (152 facilities),
- sanitary wastewater facilities (113 facilities).

General NPDES permits with monitoring for at least one target pollutant
- industrial stormwater (38 facilities),
- wastewater contaminated by gasoline or other petroleum (41 facilities),
- small sanitary facilities and stabilization lagoons (92 facilities),
- sand and gravel mining wastewater (11 facilities),
- wastewater from Superfund sites (6 facilities),

General NPDES permits without monitoring for the target pollutants

- municipal separate storm sewers (92 facilities),
- industrial stormwater (1,030 facilities),
- noncontact cooling water (116 facilities),
- hydrostatic pressure test water (9 facilities),
- swimming pool wastewater (4 facilities),
- concentrated animal feeding operations (23 facilities),
- wastewater from drinking water treatment plants[8] (17 facilities).

The MDEQ has issued various NPDES general permits for 1,479 of the permitted facilities. More than 85% of these general permits do not require monitoring for any of the target pollutants. In the absence of application or permit data, no useful data for the inventory can be derived from these permits. Therefore, the general permits shown in the third group were dropped from further study. The 453 facilities in the first and second groups remained on the list for additional screening and investigation.

3.2.4.3 Second Screen—Likelihood of Presence of Target Pollutants

After the first screening, 453 facilities remained on the list. The pollutant-specific spreadsheets provided by the MDEQ were then examined to see which of the 453 facilities were listed. If a facility appeared on any of the spreadsheets, it was retained on the working list for additional evaluation.

This screening scheme eliminated from further evaluation 155 facilities that were not listed on any of the pollutant-specific lists. After the second screening, 298 facilities remained on the active list. In order of frequency of listing: 283 facilities were on the TSS list, 218 were on the ammonia list, 87 were on the mercury list, 13 were on the selenium list, and 4 were on the vanadium list.

Seventy-six of the facilities are categorized by EPA as major facilities. All but two of the major facilities[9] on the second-screen list were permitted to discharge at least one of the target pollutants. Those two facilities were dropped from the list after individual examination confirmed that their permits did not contain any limits for any of the target pollutants.

3.2.4.4 Third Screen—Discharge Flow Volume

The third screening approach removed facilities that, by virtue of low flow volume, would not contribute more than very small loadings of pollutants. As described in Section 3.2.3.3, discharges of less than 0.1 MGD are unlikely to contribute significant quantities of target pollutants.

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[8] Although MDEQ requires monitoring for TSS in this general permit, the results of the monitoring do not need to be submitted. The records are retained by the permit holder and must be made available upon request.

[9] EPA defines major municipal dischargers as facilities with design flows of greater than 1 MGD and facilities with EPA/State approved industrial pretreatment programs. Major industrial facilities are determined based on specific ratings criteria developed by EPA/State.

Flow data were provided by MDEQ. Seventy-nine facilities with reported average flows lower than 0.1 MGD were removed from further consideration—44 facilities reported average flows of less than 0.1 MGD and 35 did not report any discharge data.

3.2.4.5 Fourth Screen-Individual Evaluation Using PCS

All 219 facilities on the third-screen list were individually reviewed by evaluating the online NPDES data maintained by the MDEQ and EPA's PCS resources. Eight facilities were dropped following this review because they had TSS loads lower than 25 lb/day and/or ammonia loads lower than 1 lb/day. For all of the remaining 211 facilities, loads were calculated for the target pollutants when data were available in the electronic records. In some cases, the loads were reported directly. In other cases, loads were calculated using the reported concentrations and the average annual flow.

3.2.4.6 Final List and Visit to MDEQ

An Argonne representative visited the MDEQ offices in Lansing on October 13-14, 2009, to review permit files for the facilities on the final Phase II Michigan list. He extracted application data for each facility and entered it into the Michigan database.

3.2.5 Wisconsin

3.2.5.1 Sources of Information

The Permits Section of the WDNR provided a list of permitted facilities discharging into Lake Michigan or its tributaries. The full list contained 398 permitted facilities and served as the starting point. Fifty-six of these facilities are ranked by EPA as major facilities. Although screening methods excluded some facilities from detailed evaluation, all of the major facilities were individually evaluated by file review. The WDNR also sent a second list including those permits that had limits for any of the target pollutants.

3.2.5.2 First Screen—Permit Type

The first list of permitted facilities included all types of discharge permits issued by the WDNR. In addition to regular NPDES permits, the list included many state groundwater discharge permits and other permits issued for concentrated animal feeding operations (CAFOs). Neither the groundwater discharge permits nor the CAFO permits authorize regular discharges to surface waters. Thus, no surface water discharge data would be available from the WDNR records for those 121 facilities, and they were removed from the list.

3.2.5.3 Second Screen—Likelihood of Presence of Target Pollutants

After the first screening, 277 facilities remained. All facilities shown on the WDNR list of permits with limits for any of the target pollutants were included on the working list for additional evaluation.

By use of this screening scheme, 61 facilities were removed, leaving 216 facilities remaining on the second-screen list. In order of frequency of listing, 212 Wisconsin facilities had limits for TSS, 89 for ammonia, 11 for mercury, and 2 for selenium. No facilities on the list had vanadium limits. All of the major facilities were included for further study.[10]

3.2.5.4 Third Screen—Discharge Flow Volume

The third screening approach removed facilities that, by virtue of low flow volume, would not contribute more than very small loadings of pollutants. As described in Section 3.2.3.3, discharges of less than 0.1 MGD are unlikely to contribute significant quantities of target pollutants.

Flow data were provided by WDNR. In a first step, WDNR provided a list of all permitted municipal facilities that showed the design flow for each wastewater treatment facility. Those facilities with design flow lower than 0.1 MGD were removed from further consideration.

Additional information was requested to evaluate and characterize the remaining facilities on the second screen list (industrial facilities plus municipal facilities with flow greater than 0.1 MGD). The WDNR provided individual files containing all the 2007 DMR data for 172 facilities. These DMR data summary files were reviewed to determine the actual reported flow volume in 2007. Seventy-nine facilities reporting an average flow of less than 0.1 MGD were removed from the list.

3.2.5.5 Fourth Screen—Individual Evaluation Using DMR Data from WDNR

Following the third screening, 137 facilities remained on the list. Each of these facilities was individually evaluated to determine the pollutants limited by the permit and to review some recent DMR data. This facility-by-facility review was conducted using the 2007 DMR data summaries provided by WDNR as described in the previous subsection. Unlike some of the other states, the Wisconsin PCS and ECHO online databases for environmental data were not fully populated and therefore were not useful for this task. Wisconsin did enter DMR data into ECHO for major facilities, so all the major facilities were double-checked for mercury data using ECHO.

Fifteen facilities had TSS loadings below the 25-pound threshold for significant discharges. Most of these did not report ammonia data, but the three facilities that did report ammonia had loadings lower than the 1-pound threshold. All of these facilities were dropped from the final list.

For the remaining 122 facilities, all had TSS data, 86 facilities had ammonia data, but only 48 facilities had mercury data. None of the facilities reported selenium or vanadium data. These data were all converted to loadings and tabulated in a spreadsheet.

[10] Note that some facilities had limits for more than one of the pollutants, thus the sum of individual limits are greater than the total number of facilities.

3.2.5.6 Final List, Visit to WDNR, and Revised Final List

The NPDES permits for each of the 122 remaining facilities were evaluated to determine the numerical limits for the target pollutants in each permit. In addition, the permit applications were individually reviewed to determine if they contained additional data on the target pollutants. A few of the applications were provided electronically by the WDNR. To view the other applications, an Argonne representative visited the WDNR offices and reviewed the paper files maintained by the WDNR.

3.3 Data Analysis and Interpretation Issues

3.3.1 Number of Data Points

The NPDES permits specify the frequency at which each pollutant must be monitored. All data points collected during a month are reported to the state agencies in the DMRs. The frequency of monitoring directly affects the number of data points that will be available during the study year (2007).

Two of the target pollutants (TSS and ammonia) were monitored frequently at most large facilities, providing many data points for use in calculating averages. Often these parameters are monitored daily or weekly. In addition to providing 12 monthly averages and maxima for 2007, each of the averages is based on multiple individual analyses.

On the other hand, mercury was monitored less frequently (sometimes quarterly or annually). Relatively few data points were available for calculating the average values for the entire year. Historically, most permits did not require monitoring for mercury. However, many of the NPDES permits issued since 2005 do contain mercury monitoring requirements. Depending on when the latest NPDES permit for a facility was issued, that facility may have conducted monitoring for all of 2007, a part of 2007, or no monitoring at all (if the permit was issued in 2008 or later). Several of the larger dischargers examined in this study have less than a full year's worth of mercury data because their permits were not issued until part way through 2007 or later.

Very few of the permits required monitoring for selenium and vanadium. The few facilities that did monitor for those metals typically did so infrequently. The values listed as annual averages and maxima are likely to be based on one or just a few data points.

3.3.2 Data Values below Detection Level

Most of the data values reported for TSS and ammonia were well above the detection level of the approved analytical tests. On the other hand, many of the results for the metals analyses were reported as less than the detection level (<DL) of the method used. Values reported as <DL can be treated in several ways:

- Set the value equal to the full value of the DL, accepting that this is an overestimate;
- Set the value at zero, accepting that this may be an underestimate; or
- Set the value at half of the DL, as a compromise.

While examining data from applications and DMRs, the researchers handled data reported as <DL in the following way: when a single data value was shown as <DL, such as on an application form, it was considered to be zero and was not included in the database. When all of the 2007 monthly entries were <DL, as was found in some of the DMR results, they were treated as zero, and not included n the database. When a set of monthly data values for 2007 DMRs included some data points with discrete values above the DL but others were reported as <DL, the values listed as <DL were set equal to the DL for the purposes of calculating an average. No statistics were calculated on how many facilities reported values <DL. However, empirical observations suggest that virtually no TSS or ammonia values were reported as <DL, while a large percentage of the metals values, particularly for selenium and vanadium, were reported as <DL.

3.3.3 Confusion about Units

Although metric concentration units (mg/L, µg/L, and ng/L) are readily interchangeable, errors in transcription or retyping may occur. The concentrations of TSS and ammonia are typically reported in units of mg/L. Selenium and vanadium can be reported in either mg/L or µg/L. Mercury can be reported in either µg/L or ng/L.

During the review of permit files and DMRs, some data points appeared to the researchers to be mistaken-unit values. Values that were orders of magnitude out of line with other comparable data points were carefully scrutinized by the researchers and generally were not included in the calculations.

3.4 Toxics Release Inventory

Although the NPDES program provides the most detailed information about discharges to Lake Michigan and its tributaries, information was reviewed under a completely separate national program known as the Toxics Release Inventory (TRI). Begun in 1988 through the Emergency Planning and Community Right-to-Know Act (EPCRA), the TRI contains information on releases of nearly 650 chemicals and chemical categories from industries, including manufacturing, metal and coal mining, electric utilities, and commercial hazardous waste treatment, among others. Facilities must report release and other waste management information if they:

- Have 10 or more full-time employees or the equivalent;
- Are in a covered North American Industry Classification System (NAICS) code; and
- Exceed any one threshold for manufacturing (including importing), processing, or otherwise using a toxic chemical listed in 40 CFR Section 372.65. (Additional information can be found in 40 CFR Section 372.22.)

Each year, industries within the scope of the TRI must report releases of the listed chemicals to different environmental media, such as air, surface water, groundwater via underground

injection, land via land treatment, impoundments, or other mechanisms. EPA makes the TRI data readily available through its TRI Explorer tool.[11] Users can extract data from different geographic regions, for subsets of the chemicals, or for different industry sectors.

3.4.1 Limitations of TRI Data

TRI has several limitations that restrict the amount of information that could be collected for this study. First, TRI is limited to toxic chemicals; therefore, TSS data cannot be derived from TRI. Second, TRI does not contain releases of the target pollutants from all facilities—just those from facilities that exceed a specific threshold. Third, TRI does not provide information on releases from municipal wastewater treatment plants. Only industrial facilities are required to report releases as part of TRI, and only a small percentage of the industrial facilities reported releases of the target pollutants.

3.4.2 TRI Data Collection

In spite of its limitations, TRI can serve as a secondary check for large dischargers of the target pollutants. If the reported TRI loadings are considerably higher than the NPDES loadings for the same pollutants, additional evaluation can resolve the discrepancy.

For the purposes of this study, data were extracted from TRI on all chemical releases to surface water reported for each of the 85 counties in Illinois, Indiana, Michigan, and Wisconsin that contribute discharges to the Lake Michigan drainage area.

The data are reported as total pounds released per year. The TRI chemicals that are relevant to the study's target pollutant list are:

- Ammonia,
- Mercury compounds,
- Selenium compounds, and
- Vanadium compounds.

The results from the individual county outputs were combined into a single list. They are discussed in Section 4.4.

[11] The URL is http://www.epa.gov/triexplorer/facility.htm, visited October 22, 2009.

Chapter 4 Point Source Results

For the purposes of this analysis, dischargers are identified as either industrial or municipal and are assigned a number (e.g., IND-ST-01 or MUN-ST-13 [where "IND" stands for industrial, "MUN" for municipal, and ST for the two letter state code – IL for Illinois, IN for Indiana, MI for Michigan, and WI for Wisconsin]). The results of the loadings can be compiled by state, by municipal sector vs. industrial sector, and for the entire Lake Michigan drainage area.

Table 4-1 shows the numbers of facilities included in the final Phase II study database. Michigan has about 55% of the facilities, Wisconsin about 32%, Indiana 12%, and Illinois less than 1%. Almost three-quarters of the facilities overall are municipal dischargers.

Table 4-1 Distribution of Facilities in the Final Database

State	No. Industrial Dischargers	No. Municipal Dischargers	Total
Illinois	1	0	1
Indiana	15	32	47
Michigan	51	160	211
Wisconsin	41	81	122
Total	108	273	381

The most complete and current set of data comes from the DMRs. The loadings determined by evaluating the DMRs are presented first. These are followed by a review of the permit limits and the application data. In the final section, the TRI data are presented.

4.1 DMR Data

Table 4-2 shows the average and daily maximum loadings for the facilities in the database. For each of the target pollutants, different numbers of facilities reported DMR data as shown below:

- TSS—375 facilities,
- Ammonia (NH_3)—290 facilities,
- Mercury (Hg)—146 facilities,
- Selenium (Se) —9 facilities, and
- Vanadium (V)—5 facilities.

However, as noted in Section 3.3.1, the number of actual analyses taken during the year 2007 varies greatly among the five pollutants. For example, even though 146 facilities provided mercury data, many of those facilities sampled only once or a few times during 2007.

The loadings for each facility listed in Table 4-2 were developed using DMR data that were available for each month. If a facility reported loadings directly in its DMRs, the monthly values were averaged to make the annual average loading, and the highest single monthly maximum was used as the annual maximum. If a facility reported only concentration values rather than

loadings, the annual average and maximum concentrations were calculated as described in the previous sentence and then were converted to loadings by multiplying by the annual average flow value reported for that facility.

Table 4-2 Summary of DMR Data

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
IND-IL-001	53	143								
IND-IN-001	1,259	4,438	12.0	86.0						
IND-IN-002	1,522	4,684	143.0	404.0						
IND-IN-003	963	9,474	35.0	530.0	0.000300	0.000500	2.000	2.540	9.900	36.300
IND-IN-004	52	100			0.000860	0.003800				
IND-IN-005	609	1,597			0.004400	0.008600				
IND-IN-006	23,935[a]	137,071[a]	533.0	1,647.0						
IND-IN-007	4,065	18,151	35.0	166.0						
IND-IN-008	365	930			0.008000	0.017000				
IND-IN-009	1,745	8,677	131.0	446.0			0.760	2.660		
IND-IN-010	146	1,001								
IND-IN-011	1,523	6,018								
IND-IN-012	8	17	0.3	2.3						
IND-IN-013	13	27	1.0	11.0						
IND-IN-014	38									
IND-IN-015	25	90	17.0	63.0	0.000010	0.000020	0.003	0.010		0.117
IND-MI-001	4,505	20,370			0.000500					
IND-MI-002	69	141								
IND-MI-003	408	1,227				0.000016	0.564			
IND-MI-004	22	71		73.0						
IND-MI-005	10	19			0.000023	0.000064				
IND-MI-006	14	76								
IND-MI-007	77	464								
IND-MI-008			8.7	20.6	0.000016	0.000025				
IND-MI-009	2,303	10,170								
IND-MI-010	74	74								
IND-MI-011	154	481								
IND-MI-012	166	382			0.000001	0.000003				
IND-MI-013	3	39	1.1	1.5						
IND-MI-014	142	948			0.000000	0.000005				
IND-MI-015	0	4			0.000019	0.000023				
IND-MI-016			6.0	13.5	0.000612	0.001211				
IND-MI-017	785	2,909	243	333						
IND-MI-018	235	298	12.8	15.2						
IND-MI-019	245	1,463	245.0	1,463.0						
IND-MI-020	1,634	3,102			0.000031	0.000046				
IND-MI-021	2,837	28,508			0.000262	0.000423				
IND-MI-022	25	947	4.7	17.4						
IND-MI-023	10	59								

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
IND-MI-024	129	563								
IND-MI-025	52	299								
IND-MI-026	201	426								
IND-MI-027		3								
IND-MI-028	15	39	0.2	3.2						
IND-MI-029	61	233								
IND-MI-030	205	1,961								
IND-MI-031	30	107								
IND-MI-032	90	285								
IND-MI-033	8	24								
IND-MI-034	122	361								
IND-MI-035	20	29								
IND-MI-036	45	140	0.9	15.5						
IND-MI-037	538	992						2.396		0.839
IND-MI-038	67	136								
IND-MI-039	5	15			0.000030	0.000070	0.110	0.140		
IND-MI-040	872	5,094	89.0	137.0	0.000900	0.001200				
IND-MI-041	421	1,101								
IND-MI-042	20	180	0.2	27.0						
IND-MI-043	24	168								
IND-MI-044	36	136								
IND-MI-045	38	272	17.0	235.0						
IND-MI-046	21	64								
IND-MI-047	511	2,417			0.000090	0.000100				
IND-MI-048						0.000732				
IND-MI-049	10	35	1.2	25.0						
IND-MI-050	112	235	230.0	415.0						
IND-MI-051					0.000004	0.000009			0.019	0.024
IND-WI-001	16	40								
IND-WI-002	787	8,146	116.0	491.0	0.000058	0.000077				
IND-WI-003	143	1,752			0.000179	0.000504				
IND-WI-004	5	25	0.1	0.5	0.000437	0.002096				
IND-WI-005	7	36	1.9	13.2						
IND-WI-006	7	21	5.5	18.4	0.000007	0.000015				
IND-WI-007	522	3,305			0.000586	0.000659				
IND-WI-008	338	1,179			0.000324	0.000396				
IND-WI-009	236	738			0.000078	0.000131				
IND-WI-010	10.1	49.4	0.9	16.9						
IND-WI-011	166	1,197			0.000023	0.000048				
IND-WI-012	45	110								
IND-WI-013	144	1,011			0.000017	0.000023				
IND-WI-014	20	111	2.5	44.9						
IND-WI-015	28	477	2.6	75.8						
IND-WI-016	128	1,066	5.9	19.0	0.000005	0.000009				
IND-WI-017	262	1,598			0.000356	0.000789				

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
IND-WI-018	1,469	6,446			0.000156	0.000422				
IND-WI-019	13	109								
IND-WI-020	5	18	1.6	50.3						
IND-WI-021	12	128								
IND-WI-022	10	29	5.2	9.5						
IND-WI-023	73	631	2.7	62.6						
IND-WI-024	400	2,292			0.000206	0.000251				
IND-WI-025	2	22	0.7	11.0						
IND-WI-026	12	29			0.000005	0.000013				
IND-WI-027	1,238	13,330			0.000079	0.000148				
IND-WI-028	627	12,639			0.000516	0.000913				
IND-WI-029	2,737	9,837			0.000199	0.000277				
IND-WI-030	5	39								
IND-WI-031	22	134	13.8	23.9						
IND-WI-032	25	160			0.000005	0.000018				
IND-WI-033	89	239			0.000471	0.001292				
IND-WI-034	16	226								
IND-WI-035	159	1,031			0.004008	0.007109				
IND-WI-036	9	44	1.6	3.3						
IND-WI-037	98	366								
IND-WI-038	262	775								
IND-WI-039	18	34	2.6	5.7						
IND-WI-040	495	1,194			0.000075	0.000102				
IND-WI-041	114	702			0.000000	0.003053				
Subtotal of All Industrial	**64,469**	**350,801**	**1,930.7**	**6,996.2**	**0.023851**	**0.052192**	**3.437**	**7.746**	**9.919**	**37.279**
MUN-IN-001	23	87	0.3	1.2						
MUN-IN-002	116	320	15.0	146.0	0.002000	0.002000				
MUN-IN-003	35	92	0.8	14.0	0.000006	0.000011				
MUN-IN-004	18	55	2.3	20.5						
MUN-IN-005	61	139	2.6	6.7	0.000158	0.000375				
MUN-IN-006	62	153	5.3	35.0	0.000024	0.000042				
MUN-IN-007	5	9	1.7	3.5						
MUN-IN-008	6	14	0.6	8.1						
MUN-IN-009	97	156	26.9	48.4						
MUN-IN-010	12	109	2.0	20.0						
MUN-IN-011	127	289	6.0	41.0	0.000059	0.000091				
MUN-IN-012	311	691	3.8	104.0	0.000190	0.000310				
MUN-IN-013	3	20	0.7	4.4						
MUN-IN-014	2,702	8,395	332.0	2,169.0	0.003275	0.006310				
MUN-IN-015	338	14,482	109.0	1,049.0	0.000800	0.002000				
MUN-IN-016	41	71	44.0	95.0	0.000015	0.000020				
MUN-IN-017	185	368	9.0	40.0	0.000094	0.000247				

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
MUN-IN-018	17	56	2.0	13.0	0.000496	0.003802				
MUN-IN-019	129	657	5.0	30.0						
MUN-IN-020	1,816	3,422	95.0	988.0						
MUN-IN-021	209	1,349	8.0	109.0	0.000090	0.000875				
MUN-IN-022	229	468	6.8	14.2						
MUN-IN-023	437	1,197	156.0	521.0						
MUN-IN-024	649	1,573	19.0	50.0	0.000500	0.000985				
MUN-IN-025	329	983	35.0	260.0	0.000214	0.000314				
MUN-IN-026	46	141	13.0	25.0	0.000072	0.000178				
MUN-IN-027	40	381	4.0	49.0	0.000026	0.000060				
MUN-IN-028	14	32	2.0	25.0						
MUN-IN-029	16	31	0.2	2.0						
MUN-IN-030	10	98	1.2	28.0						
MUN-IN-031	12	30	0.8	5.0						
MUN-IN-032	8	42	4.5	0.3						
MUN-MI-001	108	375	12.1	25.6	0.000010	0.000019				
MUN-MI-002	15	18	0.1	0.1						
MUN-MI-003	6	9	0.9	20.7						
MUN-MI-004	116	396	30.3	256.3	0.000095	0.000120				
MUN-MI-005	140	346	159.7	239.6						
MUN-MI-006	21	47	7.9	19.6	0.000019	0.000068				
MUN-MI-007	113	245	11.5	40.8	0.000025	0.000044				
MUN-MI-008	54	147	7.6	37.9	0.000023	0.000037				
MUN-MI-009	113	399	34.0	50.0	0.000050	0.000100				
MUN-MI-010	49	375	35.0	138.0	0.000013	0.000065				
MUN-MI-011	120	290	50.0	80.0	0.000049	0.000068				
MUN-MI-012	26	131	7.6	26.0	0.000007	0.000011				
MUN-MI-013	42	68	13.0	40.0	0.000019	0.000023				
MUN-MI-014	66	121	39.9	83.9	0.000006	0.000009				
MUN-MI-015	54	108	7.7	19.4	0.000013	0.000018				
MUN-MI-016	84	424	9.2	32.2	0.000050	0.000100				
MUN-MI-017	41	117	1.1	1.5	0.000012	0.000014				
MUN-MI-018	22	52	0.2	0.9						
MUN-MI-019	6	15	0.7	2.3						
MUN-MI-020	6	11	2.8	7.9	0.000170	0.000290				
MUN-MI-021	11	25	1.3	2.4						
MUN-MI-022	40	143	40.3	86.0	0.000017	0.000040				
MUN-MI-023	147	581	151.4	194.7	0.000001	0.000001				
MUN-MI-024	113	304	66.2	188.4	0.000010	0.000010				
MUN-MI-025	84	140	1.7	12.9	0.000010	0.000020			0.183	0.458
MUN-MI-026	269	460	85.0	139.0	0.000056	0.000056				
MUN-MI-027	164	500	598.0	598.0	0.000040	0.000060				
MUN-MI-028	260	400	151.8	327.2	0.000009	0.000009		0.111		
MUN-MI-029	42	143	16.0	34.0	0.000036	0.000150				
MUN-MI-030	9	40	42.4	124.5	0.000060	0.000150				

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
MUN-MI-031	15	33	0.8	1.5	0.000010	0.000040				
MUN-MI-032	71	207	3.4	8.3	0.000010	0.000030				
MUN-MI-033	34	71	1.2	4.4	0.000014	0.000031				
MUN-MI-034	95	235	99.0	188.0	0.000020	0.000030				
MUN-MI-035	1,157	2,412	90.0	212.0	0.000230	0.000300		0.158		
MUN-MI-036	410	952			0.000300	0.000320				
MUN-MI-037	142	361	249.6	379.4	0.000022	0.000025				
MUN-MI-038	74	163	86.5	4,239.9	0.000014	0.000040				
MUN-MI-039	46	164	34.0	92.0	0.000010	0.000013				
MUN-MI-040	41	108	2.3	4.0	0.000040	0.000070				
MUN-MI-041	426	775	41.0	53.0	0.000110	0.000160				
MUN-MI-042	57	149	3.8	7.4	0.000017	0.000047				
MUN-MI-043	783	8,020	126.0	626.0	0.000110	0.000200	0.129	0.150		
MUN-MI-044	79	264	6.1	26.0						
MUN-MI-045	287	519	351.0	453.0	0.000100	0.000100				
MUN-MI-046	22	41			0.000016	0.000016				
MUN-MI-047	745	1,782	1,797.1	2,246.4	0.000112	0.000127				
MUN-MI-048	186	581	159.7	319.5	0.000064	0.000121				
MUN-MI-049	571	2,050	11.0	51.0	0.000100	0.000150				
MUN-MI-050	523	1,347	55.0	77.0	0.000100	0.000200				
MUN-MI-051	96	225	8.7	25.0						
MUN-MI-052	64	176	6.4	94.0	0.000100	0.000300				
MUN-MI-053	58	338	6.0	15.0	0.000020	0.000030				
MUN-MI-054	56	130	83.6	195.9						
MUN-MI-055	145	301			0.000030	0.000070				
MUN-MI-056	34	68	21.0	116.0						
MUN-MI-057	60	102	5.3	7.1	0.000320	0.002900				
MUN-MI-058	74	122	2.3	4.7	0.000007	0.000007				
MUN-MI-059	102	187	3.8	5.9						
MUN-MI-060	35	52	0.4	0.9						
MUN-MI-061	1,140	5,915	843.0	2,231.0	0.000281	0.000300				
MUN-MI-062	460	900	99.0	108.0						
MUN-MI-063	120	415	257.9	381.7	0.000020	0.000020				
MUN-MI-064	135	769	11.2	141.0	0.000004	0.000007				
MUN-MI-065	2,545	6,994	1,652.0	4,581.0	0.001100	0.002000				
MUN-MI-066	71	246	1.6	6.4	0.000020	0.000060				
MUN-MI-067	1,409	8,859	20.1	2,214.8	0.003000	0.005800				
MUN-MI-068	28	145	1.1	1.3	0.000032	0.000060				
MUN-MI-069	25	348	27.0	101.0	0.000009	0.000038				
MUN-MI-070	636	1,747								
MUN-MI-071	2.1	3.9	0.4	0.6	0.000002	0.000004	0.002	0.006		
MUN-MI-072	134	564	0.9	199.0	0.000014	0.000014				
MUN-MI-073	73	105	6.9	12.8	0.000025	0.000047				
MUN-MI-074	62	197	4.7	6.0						
MUN-MI-075	13	29								

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
MUN-MI-076	124	375	2.6	10.4						
MUN-MI-077	28	80								
MUN-MI-078	2	7	1.1	3.1						
MUN-MI-079	20	45	20.0	34.9						
MUN-MI-080	6	23	0.1	0.1						
MUN-MI-081	2	21	0.5	25.0						
MUN-MI-082	40	51								
MUN-MI-083	133	293	5.3	8.0						
MUN-MI-084	49	67			0.000013	0.000026				
MUN-MI-085	4	8	16.0	40.0						
MUN-MI-086	42	85	14.3	20.8	0.000024	0.000026				
MUN-MI-087	54	130	66.9	233.6	0.000009	0.000013				
MUN-MI-088	25	80	49.5	116.5	0.000023	0.000105				
MUN-MI-089	10	13								
MUN-MI-090	33	63								
MUN-MI-091	16	33								
MUN-MI-092	25	31								
MUN-MI-093	29	59	8.1	12.2						
MUN-MI-094	187	200	7.6	8.9						
MUN-MI-095	247	339	2.0	2.3						
MUN-MI-096	25	57	0.4	0.7						
MUN-MI-097	442	599	15.6	15.6						
MUN-MI-098	15	26	1.5	2.8						
MUN-MI-099	88	146	5.1	9.7						
MUN-MI-100	33	72	0.7	1.2						
MUN-MI-101	105	130	0.6	0.6						
MUN-MI-102	110	586	1.0	1.3						
MUN-MI-103	97	108	6.0	6.6						
MUN-MI-104	38	77	22.7	29.5						
MUN-MI-105	197	346	11.0	24.0						
MUN-MI-106	120	198	7.0	15.0						
MUN-MI-107	245	641	5.2	7.4						
MUN-MI-108	17	26	0.1	0.3						
MUN-MI-109	101	618	1.4	2.7						
MUN-MI-110	184	255	1.0	1.8						
MUN-MI-111	329	329	2.3	2.3						
MUN-MI-112	179	599	2.0	3.8						
MUN-MI-113	458	499	4.3	8.3						
MUN-MI-114	166	283	1.8	1.8						
MUN-MI-115	89	89	12.0	12.0						
MUN-MI-116	68		13.0	21.0						
MUN-MI-117	177	240	0.9	0.9						
MUN-MI-118			0.2	0.2						
MUN-MI-119	135	135	3.9	3.9						
MUN-MI-120	81	139	5.0	7.2						

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
MUN-MI-121	266	586	5.5	10.0						
MUN-MI-122	100	170	4.0	4.3						
MUN-MI-123	3	3	1.6	1.6						
MUN-MI-124	240	699	3.8	6.0						
MUN-MI-125	50	119	1.7							
MUN-MI-126	89	193	4.4	6.7						
MUN-MI-127	231	666	2.5	3.6						
MUN-MI-128	252	660	6.7	12.6						
MUN-MI-129	57	162	2.3	4.1						
MUN-MI-130	32	67	12.5	16.8						
MUN-MI-131	15	18	0.1	0.1						
MUN-MI-132	54	57	14.9	14.9						
MUN-MI-133	172	306	2.5	6.1						
MUN-MI-134	101	183	5.3	5.9						
MUN-MI-135	4	4	0.4	0.4						
MUN-MI-136	186	759	1.0	1.5						
MUN-MI-137	82	99	3.5	7.0						
MUN-MI-138	179	318	0.8	1.0						
MUN-MI-139	90	221	1.1	3.1						
MUN-MI-140	42	50	1.5	2.3						
MUN-MI-141	65	70	1.3	0.3						
MUN-MI-142	917	1,138	7.4	23.0						
MUN-MI-143	100	130	7.3	9.7						
MUN-MI-144	58	85	7.8	11.3						
MUN-MI-145	134	134	0.9	0.9						
MUN-MI-146	489	759	2.2	4.1						
MUN-MI-147	517	517	4.4	4.4						
MUN-MI-148	41	245	1.8	5.0						
MUN-MI-149	2,390	2,390	0.1	0.1						
MUN-MI-150	27	33	2.7	4.5						
MUN-MI-151	215	434	0.3	0.3						
MUN-MI-152	11	11	3.0	4.3						
MUN-MI-153	109	169	6.5	6.5						
MUN-MI-154	4	6	0.1	0.1						
MUN-MI-155	253	285	2.0	2.0						
MUN-MI-156	35	52	5.4	7.5						
MUN-MI-157	119	162	0.1	0.2						
MUN-MI-158	103	103	0.8	0.8						
MUN-MI-159	42	49	2.3	2.3						
MUN-IN-160	32	111	0.3	0.7						
MUN-WI-001	3	11	0.7	7.8						
MUN-WI-002	431	1,797	116.0	491.0	0.000487	0.001117				
MUN-WI-003	21	91	1.7	82.8						
MUN-WI-004	17	48								
MUN-WI-005	26	97	1.2	17.1						

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
MUN-WI-006	7	30	1.4	15.0						
MUN-WI-007	3	33	4.2	24.7						
MUN-WI-008	43	195	0.4	8.3	0.000023	0.000027				
MUN-WI-009	34	235	4.2	54.6						
MUN-WI-010	10	39								
MUN-WI-011	15	30	6.3	31.5						
MUN-WI-012	9	23	1.3	7.1						
MUN-WI-013	50	182	0.9	13.8						
MUN-WI-014	13	84	1.0	30.2						
MUN-WI-015	628	4,420	676.2	1,970.2	0.000556	0.004846				
MUN-WI-016	10	35	11.9	44.5						
MUN-WI-017	17	290	0.4	7.3						
MUN-WI-018	162	1,064	64.9	616.5	0.000116	0.000266				
MUN-WI-019	15	49	15.6	21.2						
MUN-WI-020	54	179		1.3						
MUN-WI-021	580	2,724	895.0	1,363.0	0.000080	0.000193				
MUN-WI-022	873	1,656	33.6	172.3	0.000795	0.004118				
MUN-WI-023	33	75	3.5	11.5						
MUN-WI-024	16	49	1.9	17.9						
MUN-WI-025	513	3,634	516.0	1,918.0	0.000973	0.003295				
MUN-WI-026	7	85	0.2	2.4						
MUN-WI-027	29	123								
MUN-WI-028	24	59								
MUN-WI-029	1	7	0.2	3.4						
MUN-WI-030	41	175	7.4	88.8	0.000014	0.000015				
MUN-WI-031	1,610	9,360	273.3	2,658.2	0.000537	0.001067				
MUN-WI-032	19	156	0.2	0.6						
MUN-WI-033	12	27	8.2	33.0						
MUN-WI-034	16	321	1.6	17.0						
MUN-WI-035	19	77	11.2	11.6						
MUN-WI-036	23	63	5.6	27.2						
MUN-WI-037	7	16								
MUN-WI-038	519	3,479	423.0	1,091.6	0.000138	0.000199				
MUN-WI-039	60	343			0.000132	0.000195				
MUN-WI-040	8	26	0.2	5.3						
MUN-WI-041	10	32	0.2	0.6						
MUN-WI-042	10,057	42,607	753.0	7,985.0	0.004027	0.011048				
MUN-WI-043	403	6,584	60.0	1,120.0						
MUN-WI-044	19	36	1.5	3.1						
MUN-WI-045	65	160	45.9	62.9	0.000023	0.000051				
MUN-WI-046	7	29	6.4	19.4						
MUN-WI-047	13	24								
MUN-WI-048	28	97	0.9	9.1						

Facility ID	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
MUN-WI-049	37	100	51.9	65.7						
MUN-WI-050	16	46	60.9	107.5	0.000010	0.000020				
MUN-WI-051	19	45								
MUN-WI-052	11	38	0.2	0.4						
MUN-WI-053	403	1,405	60.0	1,216.9	0.000157	0.000300				
MUN-WI-054	83	229	3.8	12.1	0.000110	0.000241				
MUN-WI-055	9	94	1.3	114.0						
MUN-WI-056	99	1,952	55.2	678.9						
MUN-WI-057	22	56	3.3	8.9						
MUN-WI-058	1,322	5,855	1,095.4	2,587.4	0.000601	0.001020				
MUN-WI-059	16	30	0.6	2.5						
MUN-WI-060	5	19	1.4	20.7						
MUN-WI-061	28	92	3.4	248.2	0.000005	0.000008				
MUN-WI-062	9	70	0.0	1.1						
MUN-WI-063	32	77	1.1	16.2						
MUN-WI-064	7	31	0.5	19.3						
MUN-WI-065	368	686	282.8	1,276.9	0.000206	0.000540				
MUN-WI-066	7	28	3.8	31.9						
MUN-WI-067	17	52	4.2	48.3						
MUN-WI-068	5	18	0.2	2.1						
MUN-WI-069	186	894	11.4	89.4	0.000057	0.000094				
MUN-WI-070	98	693	17.0	165.5	0.000051	0.000072				
MUN-WI-071	151	755	8.7	166.9	0.000120	0.000174				
MUN-WI-072	38	283	10.1	109.8	0.000265	0.000666				
MUN-WI-073	33	99	27.6	121.1	0.000027	0.000059				
MUN-WI-074	28	221	0.6	26.6	0.000035	0.000079				
MUN-WI-075	10	40	4.1	123.1						
MUN-WI-076	23	1,233								
MUN-WI-077	23	185	16.9	86.0						
MUN-WI-078	7	22	0.2	1.4						
MUN-WI-079	80	156			0.000061	0.000105				
MUN-WI-080	9	38	8.3	62.9						
MUN-WI-081	13	49	0.3	1.7						
Subtotal of All Municipal	**56,050**	**208,483**	**14,824.8**	**56,565.6**	**0.024876**	**0.062761**	**0.131**	**0.425**	**0.183**	**0.458**
Subtotal of All Industrial	**64,469**	**350,801**	**1,930.7**	**6,996.2**	**0.023851**	**0.052192**	**3.437**	**7.746**	**9.919**	**37.279**
Total	**120,520**	**559,284**	**16,755.4**	**63,561.8**	**0.048727**	**0.114953**	**3.567**	**8.171**	**10.102**	**37.737**

[a] The TSS values for this facility were extremely high for one month. That month was examined in relation to a 3-year window surrounding the month. Revised values are reported here and are discussed in the report immediately following this table.

4.1.1 TSS Results

The TSS results for 2007 for individual dischargers range from less than 5 lb/day to more than 580,000 lb/day (at IND-IN-006). That latter value is many times higher than the next highest value and, therefore, it strongly influences the overall average and maximum TSS loads.

The DMRs for IND-IN-006 from July 2006 to June 2009[12] were reviewed to see what the long-term TSS discharge loads actually were. The very high value was reported for October 2007 at outfall 002. The average TSS value for that month was 175,807 lb/day, and the maximum TSS value was 534,971 lb/day.

Table 4-3 shows the outfall 002 loads by year. Excluding the single high month in 2007, the average for each of the years ranges from 7,462 to 12,932 lb/day. Even when the very high month is left in, the overall average is 14,876 lb/day. This value was chosen as a conservative estimate of the average at 002 for this facility.

For the maximum, the very high month has a value more than six times higher than the second highest value. Curiously, that second highest month occurred only two months after the highest month. The next highest month for the entire three-year period had a load of just 58,807 lb/day. The second-highest monthly value (86,366 lb/day) was chosen to reflect the maximum discharge at this facility.

Table 4-3 Summary of TSS Loads at Facility IND-IN-006 by Year

Year	Average TSS Load (lb/day)	Maximum TSS Load (lb/day)
2006 (last 6 months)	9,765	58,807
2007 (all 12 months)	25,238	534,971
2007 (the high month is dropped)	11,550	86,366
2008	12,932	46,580
2009 (first 6 months)	7,462	26,107
The whole period (these values are used to characterize outfall 002 contributions for facility IND-IN-006)	14,876	86,366 (this is the second-highest reported monthly maximum)

Note that facility IND-IN-006 has multiple outfalls, and some of those other than 002 also discharge TSS; therefore, the total TSS loading for the whole facility as presented in Table 4-3 represents the sum of the loadings for each outfall.

Table 4-4 shows the distribution of TSS loads by sector. For the average loads, the sizes of industrial and municipal contributions are similar. However, for the maximum loads, the industrial facilities made up 63% of the total load. About one quarter of the total load was

[12] These months cover the full range of data available through the ECHO database as of September 30, 2009.

contributed by facility IND-IN-006. Fourteen of the industrial facilities and 10 of the municipal facilities discharge an average of more than 1,000 lb/day of TSS. Thirty-five of the industrial facilities and 31 of the municipal facilities discharge a maximum of more than 1,000 lb/day of TSS.

Table 4-4 Distribution of TSS Loads

Parameter	Total TSS from Industrial Dischargers	Total TSS from Municipal Dischargers	Total TSS
Average (lb/day)	64,469	56,050	120,520[a]
Maximum (lb/day)	350,801	208,483	559,284[b]

[a] The total slightly exceeds the sum of the two subtotals due to rounding of numbers.
[b] The total of the maximum values is an overestimate because the maximum values from different facilities did not occur during the same month.

Figure 4-1 is a bar graph of the average TSS discharge loads from each facility. Figure 4-2 shows the maximum TSS loads. The very high value at IND-IN-006 is readily apparent in both figures (it is so large that it restricts the readability of the relative sizes of the remaining bars). The second highest bar in both graphs is a large municipal discharge (MUN-WI-042).

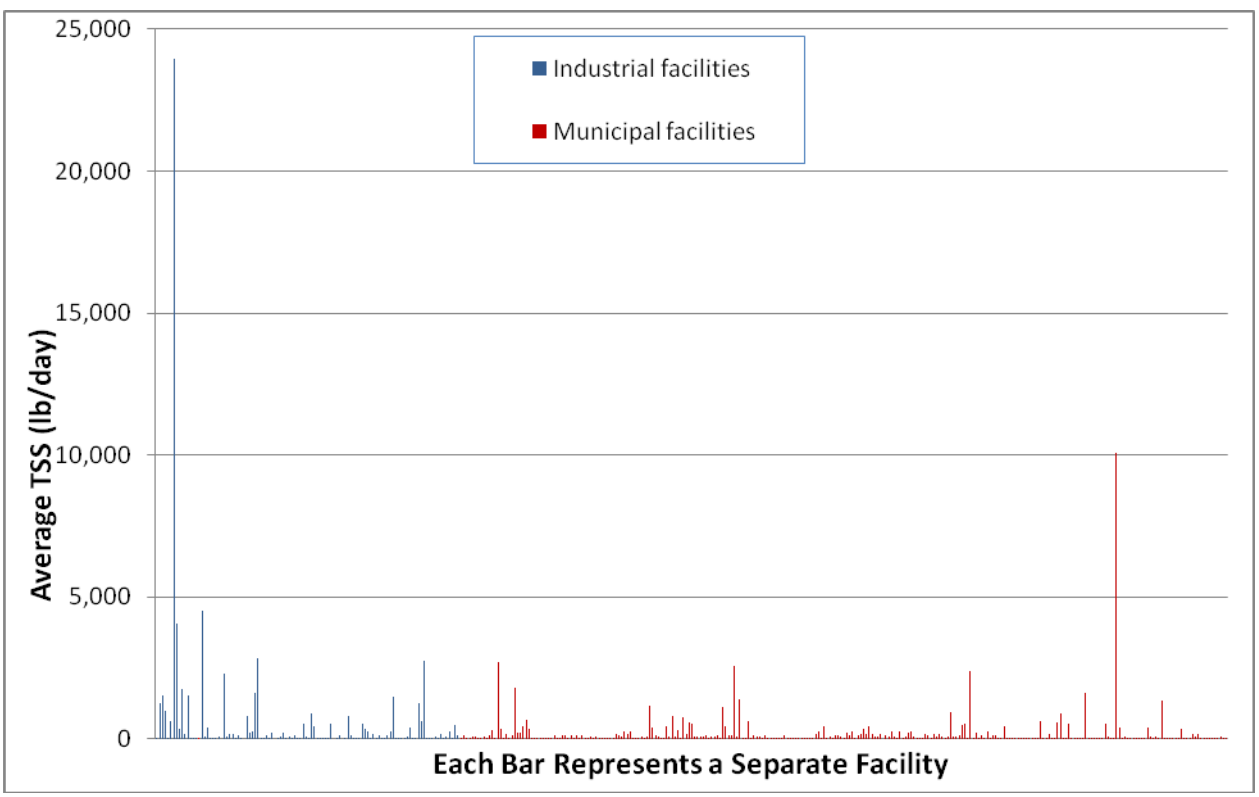

Figure 4-1 Average TSS Loadings for Facilities in the Database

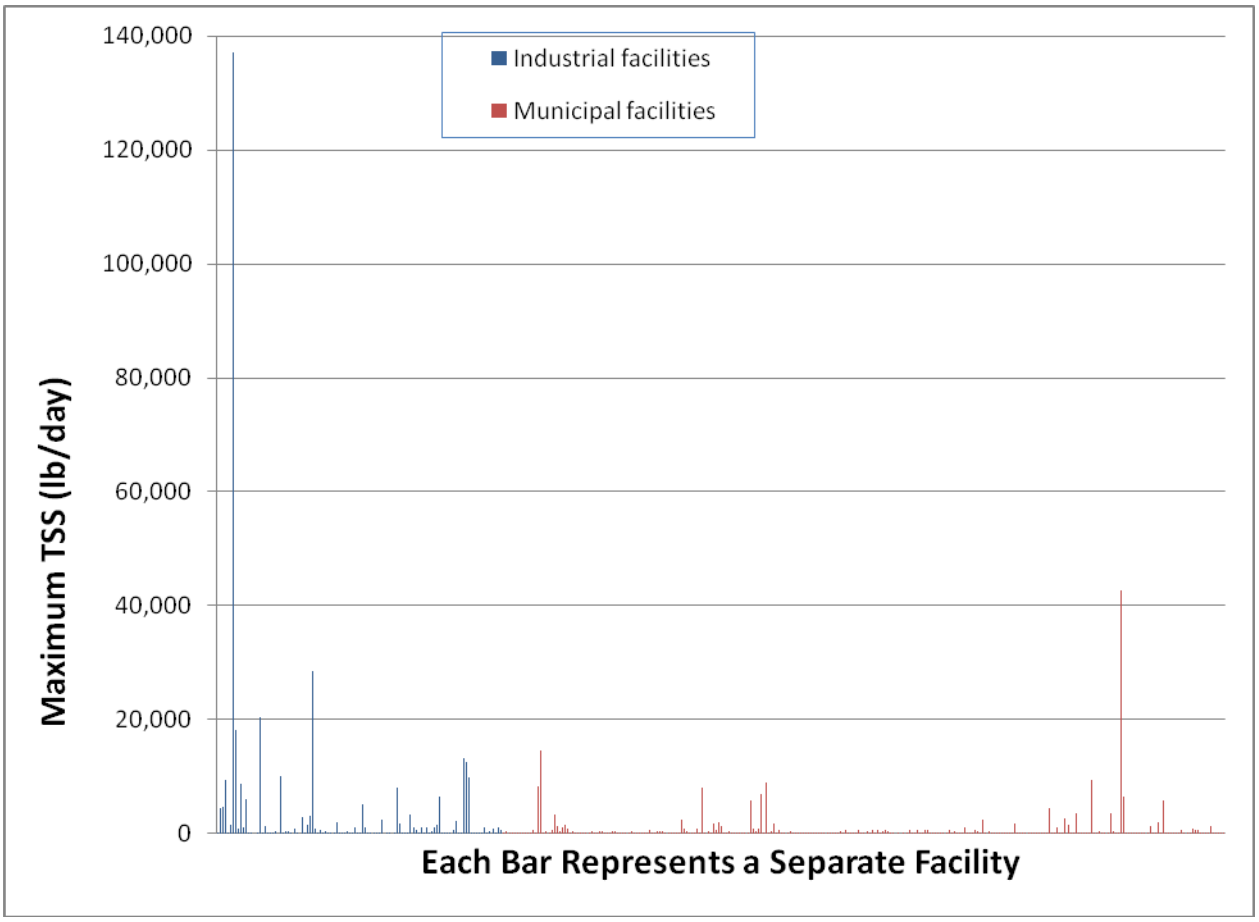

Figure 4-2 Maximum TSS Loadings for Facilities in the Database

4.1.2 Ammonia Results

The ammonia results for individual dischargers range from less than 1 lb/day to a maximum of 7,985 lb/day (at MUN-WI-042). Table 4-5 shows the distribution of ammonia loads. In contrast to the TSS loadings, both the total average and total maximum ammonia loadings (derived similar to the total TSS loads) are higher in the municipal sector. One of the industrial facilities and nine of the municipal facilities discharge an average rate of more than 500 lb/day of ammonia. Three of the industrial facilities and 23 of the municipal facilities discharge a maximum of more than 500 lb/day of ammonia. Note that the facility with very high TSS loads is not among the high dischargers for ammonia.

Figure 4-3 is a bar graph of the average ammonia discharge loads from each facility. Figure 4-4 shows the maximum ammonia loads. Each graph shows several facilities with large loadings but also many facilities with lower and intermediate loadings.

Table 4-5 Distribution of Ammonia Loads

Parameter	Total Ammonia from Industrial Dischargers	Total Ammonia from Municipal Dischargers	Total Ammonia
Average (lb/day)	1,931	14,825	16,755[a]
Maximum (lb/day)	6,996	56,566	63,562[b]

[a] The total slightly exceeds the sum of the two subtotals due to rounding of numbers.
[b] The total of the maximum values is an overestimate because the maximum values from different facilities did not occur during the same month.

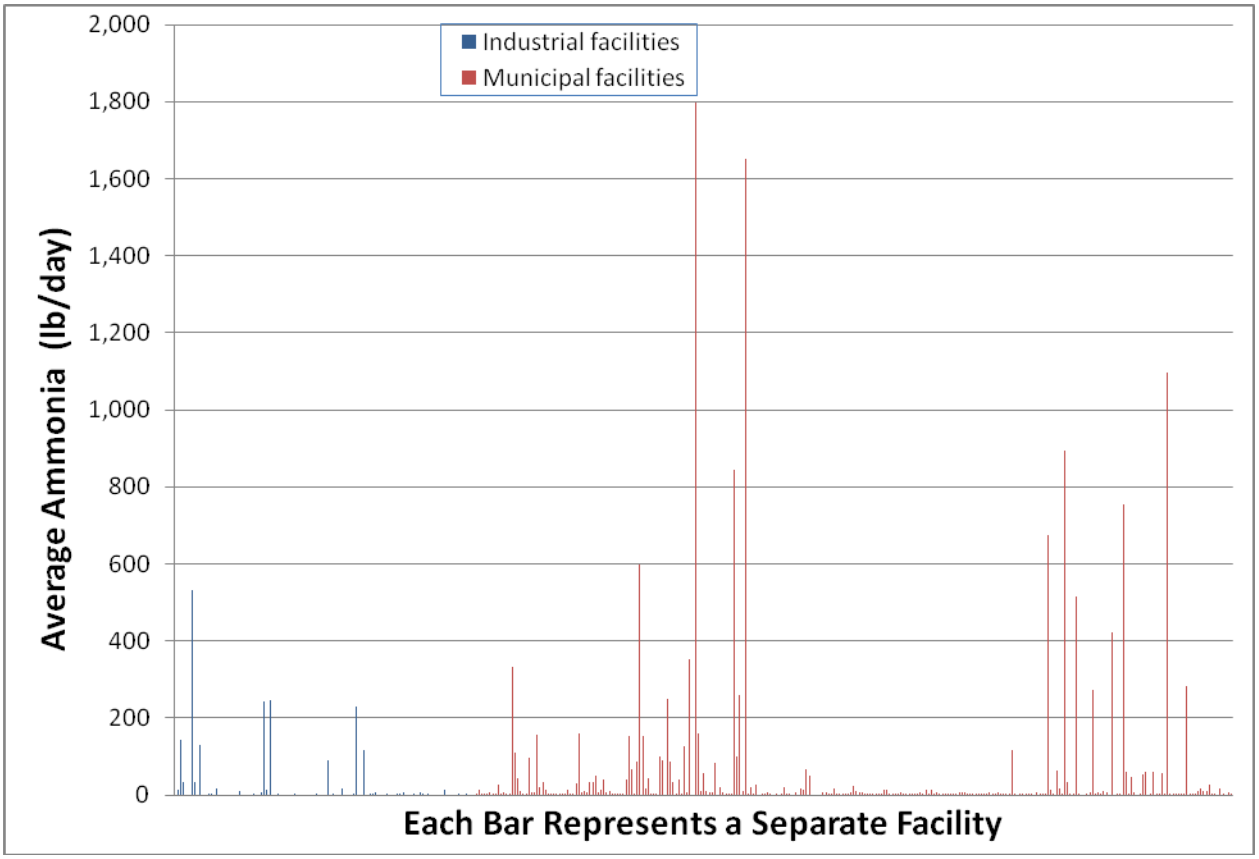

Figure 4-3 Average Ammonia Loadings for Facilities in the Database

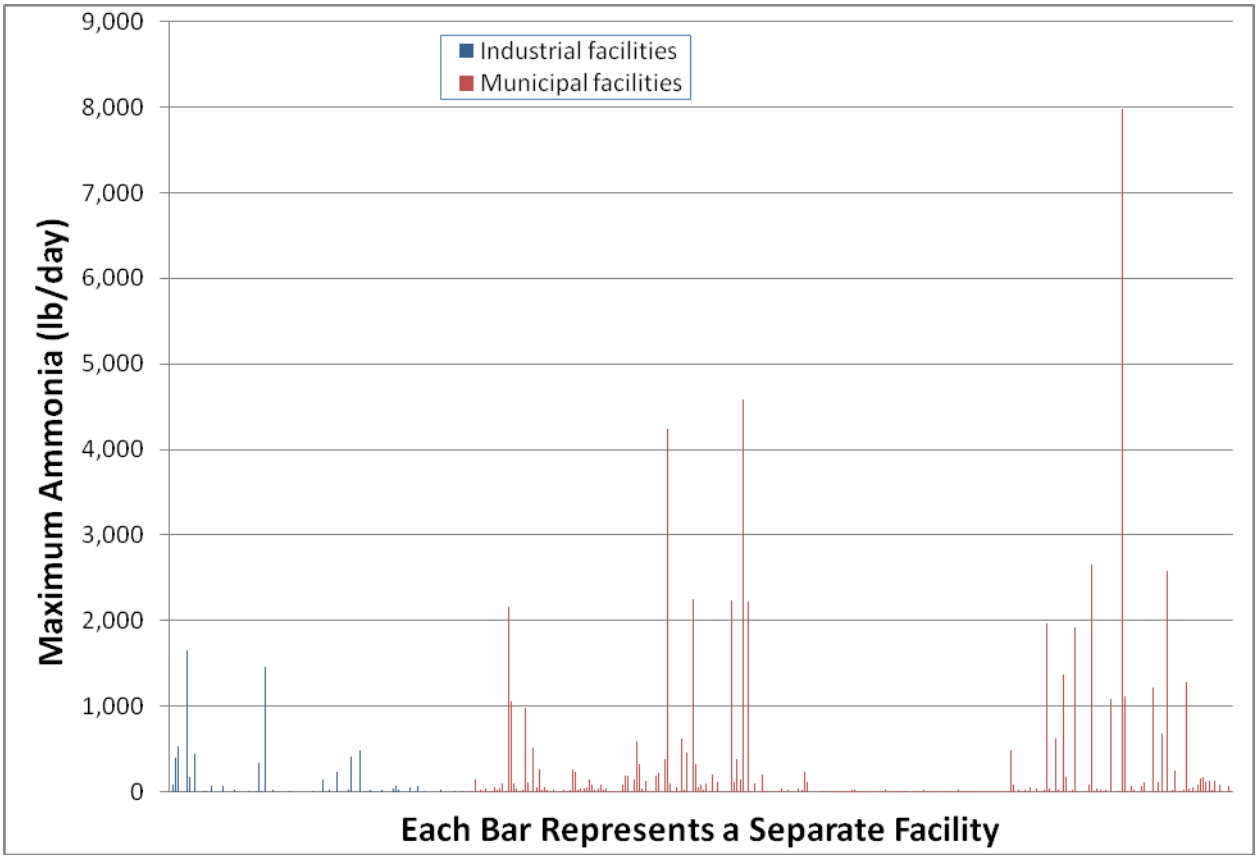

Figure 4-4 Maximum Ammonia Loadings for Facilities in the Database

4.1.3 Mercury Results

Many of the mercury values in the DMRs were reported as <DL. These were treated as equal to zero (see Section 3.3.2). Thus, many facilities had no mercury results entered into the loading database. Mercury results at or above the detection level were reported for 146 facilities (about 38% of the total number of facilities). Some of the results were directly available as loads (lb/day), but many others were shown only as concentrations (µg/L) and had to be converted to loads. Presumably, all mercury analyses made during 2007 utilized the more precise Analytical Method 1631.

The values for individual dischargers ranged from 0.000001 lb/day to a maximum of 0.011048 lb/day. Three of the industrial facilities and five of the municipal facilities discharge an average of more than 0.001 lb/day of mercury. Nine of the industrial facilities and 14 of the municipal facilities discharge a maximum of more than 0.001 lb/day of mercury.

Table 4-6 shows the distribution of mercury loads. The average mercury loadings are similar for the industrial and municipal sectors. The maximum mercury loadings for the municipal dischargers constitute more than 60% of the total loadings.

Table 4-6 Distribution of Mercury Loads

Parameter	Mercury from Industrial Dischargers	Mercury from Municipal Dischargers	Total Mercury
Average (lb/day)	0.023851	0.024876	0.048727
Maximum (lb/day)	0.052192	0.062761	0.114953[a]

[a] The total of the maximum values is an overestimate because the maximum values from different facilities did not occur during the same month.

Permits have not required mercury monitoring until recently. Now (and for the most part in 2007) mercury is typically measured at ng/L levels. As noted in Section 3.3.2, data from a few facilities in ECHO appeared to show mercury concentrations a thousand times larger than concentrations at comparable facilities. Although there is no way to confirm that these data were entered incorrectly, it is possible that at some point units expressed as µg/L and ng/L were interchanged while copying data from laboratory results sheets to ECHO data entry screens.

Figure 4-5 is a bar graph of the average mercury discharge loads from each facility. Figure 4-6 shows the maximum mercury loads. Both graphs show a wide range of loadings. The facilities showing the highest loads for mercury are different from those showing high loads for TSS or ammonia.

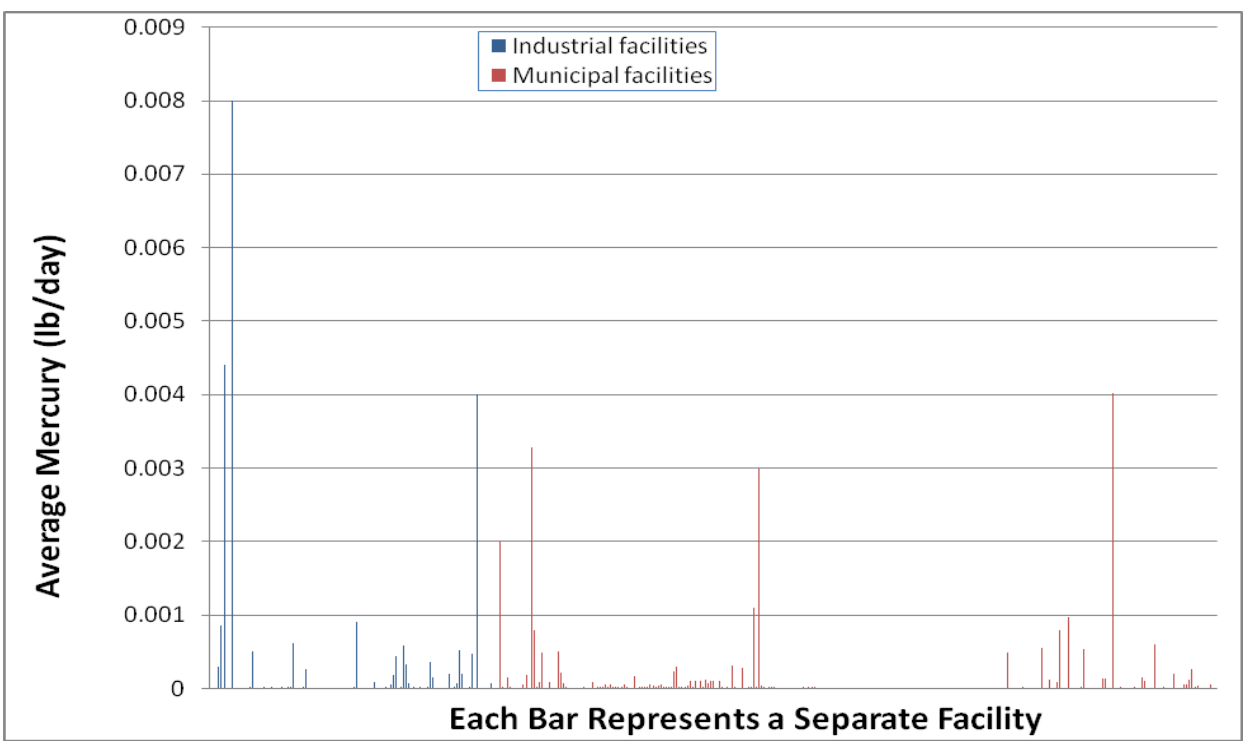

Figure 4-5 Average Mercury Loadings for Facilities in the Database

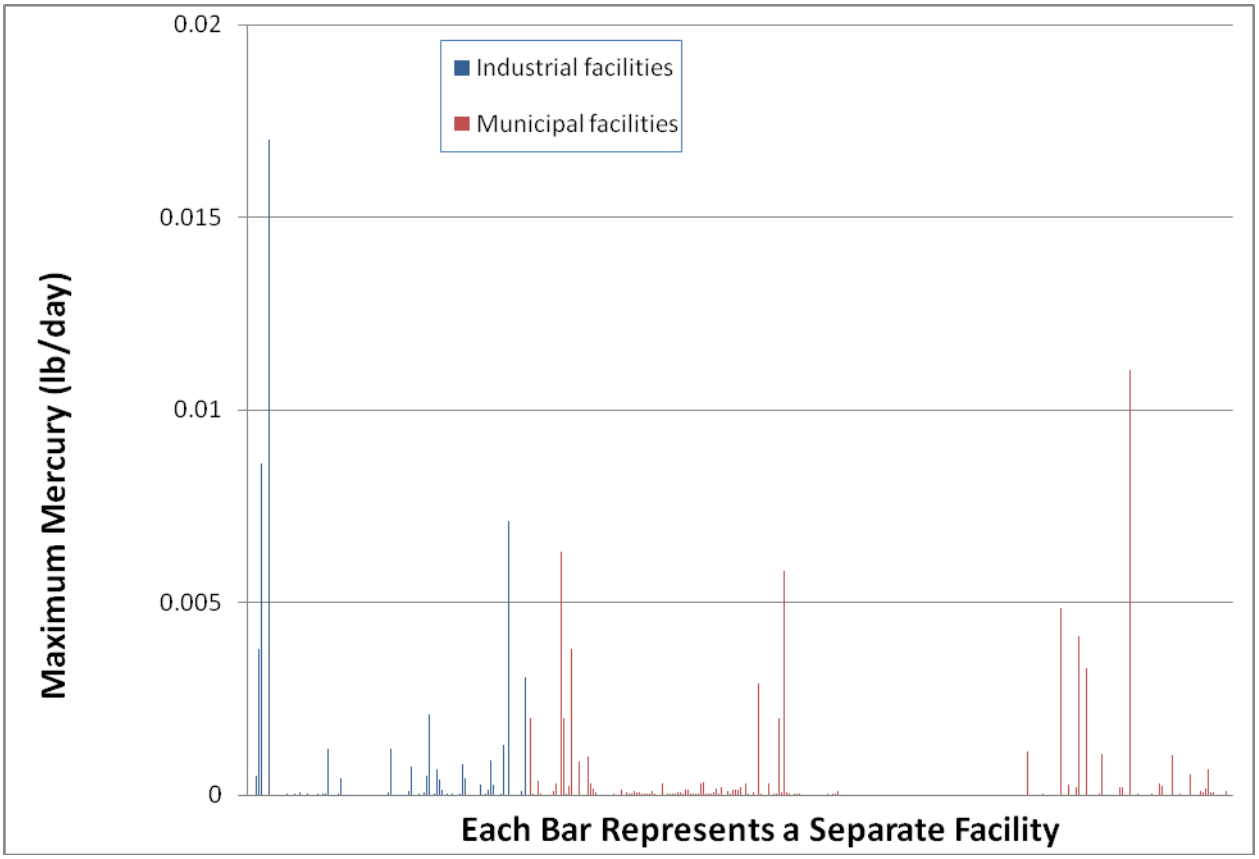

Figure 4-6 Maximum Mercury Loadings for Facilities in the Database

4.1.3.1 Mercury Concentration Data

Mercury receives more scrutiny than the other target pollutants, particularly in the Great Lakes region, where it is considered a bioaccumulative chemical of concern. Many NPDES permits in the Great Lakes region have placed very low concentration limits on mercury. Although this report focuses primarily on loadings, there is interest in examining the range of mercury concentrations reported in the DMRs.

Most, but not all of the facilities that reported mercury loading data also reported concentration data. No Illinois facilities within the study area reported mercury concentration data, but 138 facilities from the other three states did report concentration data. Several facilities reported mercury data for more than one outfall or monitoring point. For those facilities, the highest of the individual concentrations were selected. Several power plants reported both intake and discharge concentrations for their large cooling water streams. In these cases, the net increase observed in the discharge was selected. Finally, one small municipal facility (MUN-IN-006) showed consistently low concentration values for five of the six samples reported for 2007 (<5 ng/L). The sixth sample, however, was nearly 1,000 times higher than the others. Additional mercury concentration data from that facility were examined for 2006 and 2008. All were consistently low and in the same range as the other low data. Therefore the single high value was considered to be a reporting error and was dropped.

The issue of limited data points previously discussed in Section 3.3.1 is worth revisiting here. Although some mercury concentration values were found for 138 facilities, the number of data points for each facility varied. Many of the facilities had just a single mercury concentration value, and others had only a few data values. Although the mercury concentration information in Table 4-7 represents a valuable compilation, it is important to recognize that the shortage of individual mercury analyses may create some uncertainty.

The spread of mercury concentrations reported at some measurable value (i.e., >DL) is 0.03 to 18 ng/L for the average values and 0.25 to 550 ng/L for the maximum values. The lower end of each of these ranges is a very low number that may be not represent a precisely quantified measurement. For example, the 0.03 ng/L value was derived by averaging 11 months of 2007 values reported as 0.0 ng/L and 1 month reported as 0.3 ng/L. This particular value was reported at a Michigan power plant in the cooling water flow. The number represented a calculated net increase over the intake. For the month of June 2007, the plant report an intake value of 1.6 ng/L and an effluent value of 1.9 ng/L. The net was calculated as 1.9 – 1.6 = 0.3 ng/L. By averaging one low concentration with eleven zero concentrations, the resulting average was extremely low. The lower number in the maximum concentration range (0.25 ng/L) was reported for each month during 2007 by a small municipal discharger in Michigan. The fact that the value never varied suggests that the number may not be precise.

Table 4-7 presents the mercury concentration data in ranges. Counts are shown separately for municipal and industrial facilities and for the average and maximum values. For the average data, about 80% of the reported concentrations were 5.0 ng/L or less. For the maximum data, about 62% of the reported concentrations were 5.0 ng/L or less.

Table 4-7 Distribution of Mercury Concentration Data

Concentration Range (ng/L)	**No. of Facilities Reporting Average Concentrations in This Range**			**No. of Facilities Reporting Maximum Concentrations in This Range**		
	Industrial	*Municipal*	*Total*	*Industrial*	*Municipal*	*Total*
≤ 1.3[a]	8	32	40	7	12	19
1.31 – 5.0	15	53	68	10	57	67
5.1 – 10.0	5	10	15	10	20	30
>10.0	8	5	13	11	11	22
Total	36	100	136	38	100	138

[a] The lowest mercury water quality criterion (for wildlife protection in the Great Lakes) is set at 1.3 ng/L. Some permit limits are established at this value.

4.1.4 Selenium Results

Only nine facilities reported selenium data in their DMRs—five industrial facilities and four municipal facilities. The maximum values ranged from 0.006 lb/day to 2.66 lb/day. The total reported average load was 3.6 lb/day, and the total reported maximum load was 8.2 lb/day.

It is not possible to draw conclusions for selenium loadings to all of Lake Michigan from just nine data points. As a result of the low number of data points, there is little value to showing bar graphs for selenium loads.

4.1.5 Vanadium Results

Only five facilities reported vanadium data in their DMRs—four industrial facilities and one municipal. The maximum values ranged from 0.02 lb/day to 36.3 lb/day. The total reported maximum load was 37.7 lb/day. One of the facilities, IND-IN-003, contributed more than 98% of the average loading and more than 99% of the maximum loading.

Vanadium is not commonly limited or monitored in wastewater discharges. It is not possible to draw any conclusions for vanadium loadings to all of Lake Michigan from just five data points.

4.2 Permit Limit Data

Data compiled from permit loading limits give another perspective on the total load of target pollutants within the study area. Permit loading limits represent the upper limit of allowable discharges. The permit loading limit data set has considerably fewer values than the DMR data set:

- TSS—158 facilities vs. 375 in DMR data set,
- Ammonia—84 facilities vs. 290 in DMR data set,
- Mercury—40 facilities vs. 146 in DMR data set,
- Selenium—1 facility vs. 9 in DMR data set, and
- Vanadium—0 facilities vs. 5 in DMR data set.

DMR data should be available for every permit that has limits for a target pollutant. In addition, some permits that do not have limits for the target pollutants do have requirements to monitor for the target pollutants. In those cases, data will be found in the DMR data set but not in the permit limit data set. Other permits include concentration limits but not loading limits for the target pollutants. Loadings were calculated from the DMR concentration data but cannot be accurately estimated from the permit limit data set because permits rarely place a limit on flow.

To get a sense of how well the dischargers are complying with the permit loading limits, Table 4-8 compares the composite permit loading limit total for each target pollutant to the total from the DMR data set. The first row indicates how many facilities have both DMR and permit limit data in the master database. It is important to note that some permits that include limits for the metals do not put the limits into place until part way through the life of the permit. To be consistent with the DMR data, only permits that had loading limits effective during 2007 were included in this compilation. For example, quite a few permits had mercury limits that became effective in some year after 2007; these were not included in this compilation.

One permit that includes both selenium and vanadium loading limits does not make those limits effective until a compliance date after 2007. This explains the low representation of permit limits for those two pollutants. That permit, issued by IDEM, was the only permit in the entire Lake

Michigan drainage area that included a numerical loading limit for vanadium. The national NPDES application form does not include vanadium on the list of parameters that are required for monitoring. Very few dischargers provide vanadium data, and only an occasional permit contains vanadium limits.

The fourth row in Table 4-8 shows the ratio (in percent) of the composite total DMR load to the total composite allowed load. The results show that for those sets of data with more than one data point, the composite total DMR load is well below the total composite allowed load. The selenium average column (with just a single data point) does show a DMR loading larger than the permitted loading. From a practical standpoint, however, a 0.03 lb/day exceedance of the selenium permitted loading limit should have a negligible environmental impact.
The fifth and sixth rows of the table give a perspective on the number of individual facilities and the percentage of facilities that are complying with their permit limits. Excluding the selenium example mentioned above, the compliance rates for the other pollutants are very good. For TSS maximum and ammonia maximum, about 7% of the facilities are not meeting their permitted limits. All other columns show 99% or 100% compliance.

Table 4-8 Comparison of Permit Limits Data Set to DMR Data Set for Facilities Having Data in Both Sets

Factor	TSS avg	TSS max	NH_3 avg	NH_3 max	Hg avg	Hg max	Se avg	Se max	V avg	V max
No. facilities with both DMR and permit limit data[a]	164	163	73	87	31	11	1	0	0	0
Composite total of DMR data from facilities with both types of data (lb/day)	52,052	285,637	2,084	19,481	0.009535	0.005628	0.11	0	0	0
Composite total of permit limit data from facilities with both types of data (lb/day)	357,712	662,520	20,860	57,210	0.145892	0.064631	0.08	0	0	0
Ratio of Composite Total load from DMRs to total allowed load (%)	18%	43%	10%	34%	7%	9%	138%	n/a	n/a	n/a
No. facilities not meeting the permit limit data	0	11	1	6	0	0	1	0	0	0
% of facilities not meeting the permit limit data	0%	7%	1%	7%	0%	0%	100%	0	0	0

[a] The number of facilities shown in this table may be different than the numbers mentioned in the bulleted list above. Two factors account for the difference. First, some facilities may have an average limit but not a maximum limit, or vice versa. Second, some of the facilities show permit limit for multiple outfalls or monitoring points. These are captured separately for the purposes of this table.

4.3 Application Data

Data compiled from permit applications can provide information on pollutants that are not limited in the permit or reported through DMRs. Application data for the target pollutants are incomplete for many facilities in the database. For many other facilities, only concentrations were reported in the applications. Where possible, the concentrations were converted to loadings by using a representative flow value. The applications for some of the larger industrial facilities obtained during file reviews were submitted many years ago and may not accurately reflect current conditions.

The application data set has considerably fewer values than does the DMR data set for all of the target pollutants except selenium. The application data set has more values than the permit limit set for all of the target pollutants:

- TSS—163 facilities vs. 375 in DMR data set,
- Ammonia—187 facilities vs. 290 in DMR data set,
- Mercury—97 facilities vs. 146 in DMR data set,
- Selenium—53 facility vs. 9 in DMR data set, and
- Vanadium—3 facilities vs. 5 in DMR data set.

Table 4-9 shows the composite application totals for each target pollutant as well as the total from the DMR data set. The last line of the table compares the application totals to the DMR totals.

Table 4-9 Summary of Full Application Data Set

Factor	TSS avg	TSS max	NH_3 avg	NH_3 max	Hg avg	Hg max	Se avg	Se max	V avg	V max
Overall total reported on applications (lb/day)	132,192	509,207	26,426	47,518	0.0347	0.8678	4.01	25.75	0	0.97
Total discharge from DMRs (lb/day)	120,520	559,284	16,755	63,562	0.0509	0.1347	3.6	8.2	10.1	37.7
Ratio of total load from DMRs to total application load (%)	91%	110%	63%	134%	150%	16%	90%	32%	N/A	3887%

Six of the compared loadings are within a factor of two of each another. However, two of the columns show application totals much larger than DMR values. The most extreme example is the mercury maximum column, for which the applications total is more than six times higher than the DMR data. More than 80% of the applications total comes from a single facility that does not have any permit limits for mercury either in 2007 or currently (IND-IN-006) and, therefore, would not need to submit any DMR data for mercury. The application data for mercury at that facility were collected in the 1990s.

The second example is the selenium maximum column. The applications total is about three times as large as the DMR total. The most logical explanation is the vastly higher number

of facilities reporting data in the application data set compared to the DMR data set (44 vs. 9). A second explanation is that one medium-sized municipal facility (MUN-MI-087) had a selenium loading that was by far the largest in the database (it represented nearly 40% of the selenium maximum application total). That facility is not required to monitor selenium for its DMRs.

Neither of the two vanadium columns in the applications data set can be compared to the DMR data. No facilities reported an average vanadium value as part of their applications. Therefore it is impossible to calculate the ratio between DMR data and application data for that column. The standard NPDES application form does not request any vanadium analyses. Only three facilities tested even a single time for vanadium (i.e., a maximum value). The one facility that numerically dominated the vanadium totals in the DMR data set did not report any vanadium on its permit application—it was not asked to analyze for vanadium and therefore did not do so.

The application data set was examined in a second way, in a way similar to how the permit limit data set was analyzed. Table 4-10 shows information for those facilities that reported both application data and DMR data for the target pollutants.

Table 4-10 Comparison of Application Data Set to DMR Data Set for Facilities Having Data in Both Sets

Factor	TSS avg	TSS max	NH_3 avg	NH_3 max	Hg avg	Hg max	Se avg	Se max	V avg	V max
No. facilities with both application and DMR data[a]	150	167	132	143	28	64	2	5	0	1
Composite total of DMR data from facilities with both types of data (lb/day)	77,161	787,854	10,596	37,856	0.006214	0.037388	0.32	4.70	0	0.83
Composite total of application data from facilities with both types of data (lb/day)	123,539	487,866	20,617	40,002	0.019845	0.016594	0.11	2.48	0	0.95
Ratio of Composite Total load from DMRs to total application data (%)	62%	161%	51%	95%	31%	225%	290%	190%	0%	87%

[a] The number of facilities shown in this table may be different than the numbers mentioned in the bulleted list above. Three factors account for the difference. First, many facilities included analyses for the target pollutants on their permit applications, but the resulting permits did not include limits. Second, some facilities may have an average limit but not a maximum limit, or vice versa. Third, some of the facilities show permit limit for multiple outfalls or monitoring points. These are captured separately for the purposes of this table.

4.4 TRI Data

The TRI national database was searched for each of the 85 counties in which the facilities that discharge to the study area are located. Many of the counties had no releases to surface waters of

any of the TRI chemicals that correspond to the study's target pollutants. From the other counties, 31 release entries covering 4 chemicals were found. Table 4-11 summarizes the TRI data and converts the annual values to daily values to allow comparison to the other data reported in this chapter. As noted previously, only certain industrial facilities must report under TRI. Municipal facilities and those industrial facilities that are outside the scope of TRI reporting need not submit annual TRI reports.

Table 4-11 Data from TRI Database

TRI Chemical	No. Facilities Reporting under TRI	Total TRI Release to Surface Waters (lb/yr)	Average Daily Release to Surface Waters (lb/day)
Ammonia	21	48,625	133.2
Mercury compounds	4	4	0.01
Selenium compounds	1	140	0.4
Vanadium compounds	5	12,909	35.4

Given the absence of discharges from municipal facilities and many medium and small industrial facilities in the TRI database, it is not surprising that the reported TRI releases to surface water are far lower than those included on the NPDES DMR forms for ammonia, mercury, and selenium. One other complicating factor is the difference in terminology between the NPDES program and the TRI program regarding the metals. The NPDES program measures mercury as total recoverable mercury in a water sample. The TRI program has separate chemical categories for mercury and for mercury compounds. No facilities reported TRI values for mercury, but four facilities reported TRI values for mercury compounds. It is not clear what the difference is and whether the percentage of mercury in the measurement of mercury compounds is 100%. The same situation occurs for selenium and vanadium; only the metal compound version was reported.

Vanadium presents a different picture. While vanadium compounds are one of the listed chemicals subject to reporting under TRI, vanadium is not included on the list of chemicals that is required for sampling on the NPDES application form. As a result, most dischargers have never analyzed their effluent for vanadium. The observation that the DMR total load for vanadium is similar to the TRI load for vanadium can be attributed to a single facility that contributes a large percentage of the totals in both the DMR data set (98%) and the TRI data set (93%).

Comparison of the TRI data and NPDES DMR data for the same facility shows poor general agreement. Most of the facilities in the DMR database are not included in the TRI entries. Conversely, of the 31 TRI entries for facilities reporting surface water releases in counties within the Lake Michigan watershed, 21 did not have corresponding DMR loading data. Ten of the TRI entries do have corresponding DMR data; these are shown in Table 4-12. The TRI data are reported in lb/year. These numbers were divided by 365 to give average lb/day. In 8 of the 10 cases, the average daily DMR load was much larger than the corresponding TRI load.

For the two facilities with mercury entries, the annual TRI load was expressed in whole pounds; in both cases the reported value was 1 lb/year. It was not possible to determine the actual fractional number of pounds released to surface waters, particularly when the annual total is divided by 365 to estimate the daily value. Therefore, the TRI daily value for the mercury entries may not be suitable for comparison to the DMR value expressed with multiple decimal places.

The second case in which the TRI value is larger than the DMR value is for vanadium at facility IND-IN-003. This was discussed above.

Table 4-12 Comparison of TRI and NPDES DMR Loads for the Same Facilities

Facility ID	Pollutant	TRI Annual Load (lb/yr)	TRI Daily Load (lb/day)	NPDES Average Daily DMR Load (lb/day)	NPDES Maximum Daily DMR Load (lb/day)
IND-IN-003	Hg	1	0.00274	0.00030	0.00050
IND-IN-005	Hg	1	0.00274	0.0044	0.0086
IND-WI-002	NH3	8,635	23.7	236	272
IND-IN-007	NH3	280	0.8	35	166
IND-IN-003	NH3	1,500	4.1	35	530
IND-IN-002	NH3	1,980	5.4	143	404
IND-IN-009	NH3	1,010	2.8	166	586
IND-IN-006	NH3	14,900	40.8	533	1,647
IND-IN-009	Se	140	0.4	0.76	2.66
IND-IN-003	V	12,005	32.9	9.9	36.3

Chapter 5 Nonpoint Source Contributions

Nonpoint source contributions to Lake Michigan are considerably different than the point source contributions described in the previous chapter. First, they are released over wide areas rather than at discrete locations. This makes measurement of the concentrations and loads quite difficult. A second important consideration is the lack of formal regulatory programs that govern and control nonpoint source releases.

5.1 Introduction to Nonpoint Source Pollution

Nonpoint source pollution (NSP) generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification. Technically, the term "nonpoint source" means any source of water pollution that does not meet the legal definition of "point source" in Section 502(14) of the Clean Water Act, which is:

> ". . . any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture."

Nonpoint sources are not subject to federal permit requirements, and no federal regulations require data collection on nonpoint source releases. Section 319 of the Clean Water Act requires that states assess NSP problems and causes within the state and adopt and implement management programs to control the NSP. Data on NSP loadings are typically limited to studies of specific regions and pollutants. Some study results can be applied to Lake Michigan, but uncertainties and the margins of error associated with these approaches are high relative to those for point source pollutants, which are based on permit and reporting data. While this chapter includes some estimates of NSP loads in Lake Michigan, it should primarily be viewed as a source of information on the sources of NSP and the areas (i.e., watersheds) that discharge land-water-, and air-based NSP into the lake. This chapter addresses the same five target pollutants (TSS, ammonia, mercury, selenium, and vanadium) that were examined for point source pollution. The remainder of this chapter describes sources of NSP, the watersheds that carry NSP into Lake Michigan, and rough estimates of NSP and loadings for the target pollutants.

5.2 Sources of Nonpoint Source Pollution

The relative contributions of various sources of NSP (e.g., runoff, atmospheric deposition) to a waterway (e.g., Lake Michigan) depend on the specific characteristics of the watersheds and air sheds from which the pollutants come and on the pollutants themselves.

A "watershed" is the land area that supplies all of the water that eventually flows into a downstream "receiving water" such as a river, lake, or reservoir. The major sources of water in a watershed typically include rainfall runoff from the watershed surface and seepage into streams from groundwater sources. According to the EPA's Great Lakes National Program Office (EPA 2006a) roughly 44% of the land in the Lake Michigan Basin is used for agriculture, 41% is

forest, 9% is residential, and 6% is other. Along the shoreline, land use allocation is as follows: 20% agriculture, 39% residential, 24% recreational, 5% commercial, and 5% other (EPA 2006a).

Lake Michigan is sensitive to a wide range of pollutants, and major stresses on the lake include toxic and nutrient pollution (GLC 2007). The northern portion of the lake is colder and less developed than the more temperate southern portion, which also contains more urban areas. Lake Michigan is about 118 miles wide and 307 miles long, with about 1,600 miles of shoreline and a surface area of 22,400 square miles (mi^2). Its maximum depth is 925 feet, and its average depth is 279 feet. The drainage basin is roughly twice the size of its surface area, and it includes portions of Illinois, Indiana, Michigan, and Wisconsin. Sources of NSP in Lake Michigan include runoff of soils and farm chemicals from agricultural lands, waste from cities, discharges from industrial areas, and leachate from disposal sites. The large surface area of the lake makes it vulnerable to direct atmospheric pollutants that fall with the rain, snow, and dust, or exchange as gases in the lake water.

5.2.1 Runoff

Diffuse runoff is generally treated as NSP, whereas runoff that enters and is discharged from conveyances such as those described in the definition of point source is treated as a point source discharge. Runoff from agricultural practices, sewer overflows, and construction introduce sediments and nutrients into waterways; road runoff introduces salts, hydrocarbons, and metals.

5.2.1.1 Agricultural Runoff

Erosion, nutrient application, and wastewaters from confined animal facilities contribute to agricultural runoff. These sources are described below.

Erosion. Soil erosion can be characterized as the transport of particles that are detached by rainfall, flowing water, or wind. Land clearing and tillage make soils susceptible to erosion. Eroded soil is either redeposited in the same field or transported from the field in runoff or by wind. Sediment results from erosion. It is the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by wind, water, gravity, or ice. Sediment that leaves croplands and enters water bodies becomes agricultural NSP. The types of erosion associated with agriculture that produce sediment are sheet and rill erosion, ephemeral and classic gully erosion, wind erosion, and streambank erosion. Erosion also results from nonagricultural sources. For Lake Michigan, streambank erosion is considered the excessive loss of land along streams and rivers of the inland part of the Lake Michigan coastal watershed. Shoreline erosion is the loss of beach and other land along the Lake Michigan coastline. Loss of land due to excessive erosion is caused by a combination of factors, including the loss of riparian vegetation and floodplain roughness that protects the soil and dissipates the energy of the rivers, and the increased peak flow discharge in rivers, which increases the erosive power. Shoreline and streambank erosion is a natural process that can have either beneficial or adverse impacts on the creation and maintenance of riparian habitat, but excessive erosion of shorelines and stream banks can increase sediment loads, turbidity, and nutrients.

Sediment that originates from cropland (e.g., corn, soybean fields) has a higher pollution potential than sediment that originates from other agricultural land uses. This is because the topsoil of a crop field is usually richer in nutrients and other chemicals—resulting from past fertilizer and pesticide applications and from nutrient cycling and biological activity. Agricultural land used for hay and pasture is in vegetative cover throughout the year and, therefore, is not a significant source of erosion. Hay and pasture agricultural land use generally includes land used for recreational horses, perennial grass and legume cover, or year-round vegetative cover, or land enrolled in the Conservation Reserve Program.

Nutrient Application. The application of fertilizer to crops—especially food crops such as corn, soybeans, and wheat—is a common and generally necessary production practice to achieve economically viable crop yields. Nitrogen is a major nutrient applied to cropland with the potential to degrade water quality. Fertilizers can be washed from fields or improperly designed storage or disposal sites. Drainage ditches constructed on poorly drained soils enhance the movement of soluble nutrients. Sources and forms of nutrient application to agricultural land include the following (EPA 2003):

- Commercial fertilizer in a dry or fluid form,
- Manure from animal production facilities including bedding and other wastes added to the manure,
- Municipal and industrial treatment plant sludge,
- Municipal and industrial treatment plant effluent,
- Legumes and crop residues,
- Irrigation water,
- Wildlife, and
- Atmospheric deposition.

Wastewater and Runoff from Confined Animal Facilities. Wastewaters from confined animal facilities often contain nitrogen, sediments, and other pollutants. Although subject to federal and state point source regulations, confined animal facilities can result in nonpoint releases from improper waste management, over-application of wastes to fields, leaking lagoons, and flow of lagoon liquids to surface waters due to improper lagoon water management.

5.2.1.2 Urban and Suburban Runoff

The rate and volume of runoff from urban/suburban areas can often be much greater than that from agricultural runoff, resulting in streambank erosion and sediment in surface waters.

Urban and suburban environments produce large amounts of runoff because of the prevalence of building roofs, paved roads, and parking lots, which prevent precipitation from percolating into the ground. These impervious surfaces, along with sewers and stormwater-handling systems, channel large volumes of water into streams after major rain events. This runoff not only contributes pollutants to the stream, but also erodes the stream bed, thus increasing sediment loads.

Pollutants associated with stormwater runoff from impervious surfaces include sediments, nutrients, and metals. The pollutant most associated with runoff from construction sites or land disturbance is sediment, although other pollutants, including nutrients, are also associated with construction activities. Land clearing or excavation can cause soil loss and sedimentation. Runoff also occurs from on-site sewage disposal systems designed and installed for wastewater treatment. Failure of these systems, due to incorrect characterization of waste load allocations or inadequate accounting of limiting soil or geologic features during system design, can result in nonpoint discharges of nitrogen and other pollutants.

Other sources of urban runoff include everyday household activities, landscaping (e.g., the over-application of fertilizers, improper disposal of lawn trimmings), litter and debris, and domestic pet droppings. Runoff from roads, highways, and bridges contribute nonpoint sources of fertilizers (roadway maintenance) and metals (washed from the pavement).

EPA (2005) provides data on urban stormwater runoff concentrations. These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. The mean or median runoff concentrations from stormwater “hotspots” are 2 to 10 times higher. The only one of the target pollutants listed in EPA (2005) is TSS. The mean or median TSS value given is 80 mg/L.

5.2.2 Atmospheric Deposition

Airborne emissions from local and distant sources add pollutant loadings to waters through atmospheric deposition. Atmospheric inputs to water bodies occur through several mechanisms. Pollutants that are released to the air can be deposited directly to the water body by wet deposition (the removal of air pollutants from the air by rain or snow), dry deposition (the removal of aerosol pollutants through eddy diffusion and impaction, large particles through gravitational settling), or by gas exchange (the direct transfer of gaseous pollutants from the air to the water).

The tendency of a specific pollutant to enter a water body through wet deposition, dry deposition, or gas exchange relates to the physical and chemical properties of the pollutant and to current and local meteorology. For example, sources of atmospherically deposited mercury include emissions from industrial and combustion sources, emissions from natural sources (e.g., volcanoes), and re-emission from mercury-contaminated soils and water. Contributing sources can originate in the United States or other countries, and the emissions can be deposited near their sources or they can travel across international borders (EPA 2000a).

Air pollutants can also enter a water body through indirect deposition, which occurs when an air pollutant is deposited to a land area or tributary and is then carried into a water body by other routes, such as stormwater runoff or inflow from tributaries.

Studies have found that total aerial fluxes to the streams of a rural watershed can be considerably underestimated due to agricultural soil resuspension, and that background-only deposition often represents only a fraction of the total inputs to the waters of inhabited watersheds (Gelinas and Schmit 1998). Further, seasonal deposition patterns exist for most elements, with maximum

deposition rates in the spring and fall, and minimum rates in the winter (when soils are covered with snow) and in the summer (when soils are covered by vegetation).

The determination of the relative roles of particular contributing sources of air deposition to specific water bodies requires a variety of monitoring, modeling, and other analytical techniques. Pollutant loading estimates from air deposition suffer from significant uncertainties due to errors inherent in sampling methodologies, the assumptions about a specific chemical's behavior that are used to develop deposition estimates, and spatial and temporal limitations with monitoring networks.

In the Great Lakes, atmospheric deposition is a particularly important source of NSP. It has been estimated that atmospheric deposition may be responsible for up to 90% of many pollutants entering the Great Lakes (Sweet et al. 1998). This is because a large lake's surface provides a very large area for direct inputs from the atmosphere. Also, several large urban/industrial areas are located on the shore, so that prevailing winds carry air pollutants over the lake. For example, in the Chicago area, surface effluents and runoff do not generally enter Lake Michigan because they are diverted to tributaries that drain into the Mississippi Basin, but air emissions can move over and be deposited in the lake.

5.2.3 Hydromodification

Hydromodification is the alteration of the natural flow of water through a landscape to improve flood control, navigation, or drainage, or to reduce channel migration. Hydromodification can include straightening, widening, deepening, or relocating existing stream channels. It can also involve dam construction, excavation of borrow pits or canals, building of levees, underwater mining, streambed and shoreline modification, and other practices that change the depth, width, or location of waterways. Channel modification often produces unstable conditions that cause streambank erosion and deposition of sediment in the streambed.

5.2.4 Marina and Recreational Boating Nonpoint Pollution

Sources of nonpoint pollution from marinas and recreational boating include sewage waste disposal (on land and around the marinas and from vessels themselves) and improper boat operation, which can destroy shallow-water habitat and resuspend bottom sediment and pollutants.

5.2.5 Sediments

Contaminated river sediments also contribute to NSP. Many pollutants cling to sediment particles and eventually settle and deposit on river and lake bottoms. These deposits serve as sinks for various pollutants and allow them to collect at elevated levels. When disturbed (through biological, hydrological, or human activity), the pollutants can return to the water column. For example, it is estimated that the Grand Calumet River and the Indiana Harbor and Ship Canal contain between four and five million cubic yards of contaminated sediments. About 150,000 cubic yards of these sediments migrate into the southern end of Lake Michigan annually (Indiana DNR 2005).

5.3 Lake Michigan Basin and Its Watersheds

A watershed is the land area that drains water and sediments (runoff) into a stream, river, lake, estuary, or coastal zone. The water that drains into the watershed comes from the surface water draining off the land and the groundwater moving underneath the land. All the lands and waterways within a watershed are connected to each other, with smaller watersheds draining into larger watersheds. Watershed boundaries are defined by the topographic features that dictate natural drainage patterns within an area. They follow the highest ridgeline around the stream channels and meet at the lowest point of the land where water flows out of the watershed; they are the topographic dividing lines from which water flows in two different directions.
A watershed may be small and represent a single tributary within a larger system, or it may large, covering thousands of square miles. The path taken by the precipitation that falls within a watershed can impact a lake's water quality. For example, a high volume of runoff that quickly enters surface waters (e.g., from urban areas) can bring large amounts of nutrients and pollutants with it. Forests and wetlands can slow down the flow of rain and snowmelt, filtering pollutants from runoff.

Large watersheds—for example, the Lake Michigan Basin—are composed of several smaller watersheds, each of which contributes runoff to different locations that ultimately combine at a common delivery point. The size of the watershed, its topography, and how the land within the watershed is used determine the sources, amounts, and types of NSP that will enter the receiving body, in this case, Lake Michigan.

In the 1970s, the U.S. Geological Survey (USGS) developed a standardized watershed classification system (the Hydrologic Unit System) to delineate and map hydrologic boundaries and to enable various organizations and programs to share information and coordinate management of watersheds. Hydrologic units are defined by watershed boundaries, which are based on surface hydrologic features, and they are organized in a nested hierarchy. This system divides the nation into 21 two-digit regions (the Great Lakes Region is 04) and 222 four-digit subregions (four subregions drain into Lake Michigan). A subregion includes the area drained by a river system, a reach of a river and tributaries to that reach, a closed basin, or a group of streams forming a coastal drainage area.

Subregions are further divided into 378 six-digit "hydrologic accounting units," which are nested within or can be equivalent to the subregions. The six-digit units are sometimes referred to as river basins. There are 6 six-digit accounting units in the Lake Michigan Basin. The final level is the eight-digit "cataloging units," which are also sometimes referred to as watersheds.
A cataloging unit is a geographic area representing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. Within the four Lake Michigan subregions, there are 33 cataloging units. These units are important for assessing NSP, because information on land use, stressors, area, and primary nonpoint source contaminants is collected, reported, and often managed at the watershed (or eight-digit cataloging unit) level. Appendix A lists the subregions, accounting units, and cataloging units for Lake Michigan, along with information on size, land cover, NSP concerns, and primary contaminants. Figure 5-1 shows the boundaries of the 33 watersheds that drain into Lake Michigan, and Table 5-1 presents information on the Lake Michigan Drainage Basin area and population by state.

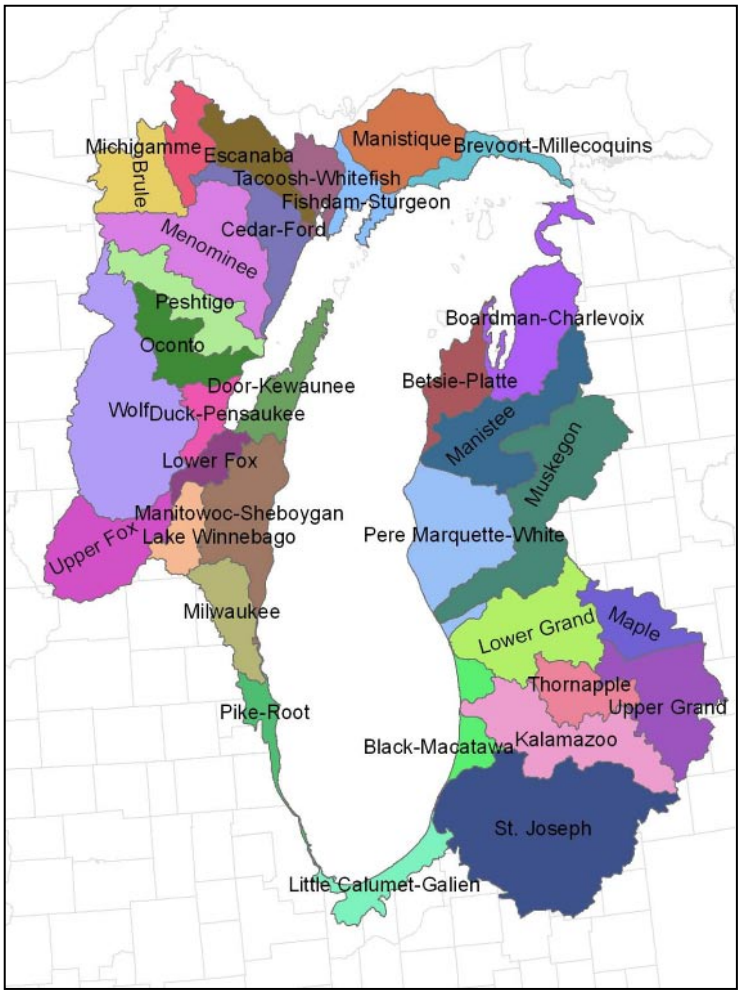

Figure 5-1 Watersheds Draining into Lake Michigan
Source: EPA 2009

Table 5-1 Lake Michigan Drainage Basin Area and Population by State

State	Drainage Area in Basin		Population in Basin	
	Square Miles	Percent	Persons	Percent
Illinois	100	<0.1	579,865[a]	9
Indiana	2,200	5	339,264	5
Michigan	28,300	63	3,007,954	47
Wisconsin	14,200	32	2,467,463	39
Total	44,800	100	6,394,546	100

[a] This value represents the Illinois population after the diversions of the Illinois River/Mississippi River drainage basin.
Sources: EPA 2000d for population; GLIN 2009 for drainage area.

In this report, the terms Lake Michigan Basin, Lake Michigan Drainage Basin, Lake Michigan Drainage Area, and Lake Michigan Watershed are used interchangeably and refer to the 44,800-mi^2 drainage area that includes parts of Wisconsin, Illinois, Indiana, and Michigan and consists of the four subregions listed below.

- *Northwestern*. This subregion is the 18,700-mi^2 drainage area from the Milwaukee River Basin boundary to the Manistique River Basin boundary. It contains the 6,340-mi^2 Fox River Basin (four "cataloging units") and the 12,400-mi^2 Northwestern accounting unit (12 cataloging units).

- *Northeastern*. This 11,300-mi^2 subregion contains the Northeastern Lake Michigan River Basin, which runs from the Grand River basin boundary to and including the Manistique River Basin and contains seven cataloging units.

- *Southeastern*. This 12,800-mi^2 subregion includes the seven cataloging units extending from and including the St. Joseph River Basin to and including the Grand River Basin.

- *Southwestern*. This subregion is the 1,970-mi^2 area that drains into the lake from the St. Joseph River Basin boundary to and including the Milwaukee River Basin. It includes three cataloging units (Little Calumet-Galien, Pike-Root, and Milwaukee).

Land use, which is a major determinant of the type and amount of NSP entering the lake, varies across the basin. In general, the northern part of the Lake Michigan Watershed is covered with forests and is sparsely populated. The forestry industry and recreational land uses dominate the northern part of the basin, including Green Bay and Michigan's Upper Peninsula. The Fox River-Green Bay area has the world's largest concentration of pulp and paper mills.

Moving south from the heavily forested northern area, land use gradually becomes predominantly agricultural in both the eastern and western portions of the basin. Moving farther south, agricultural land becomes increasingly interspersed with urban areas, and the extreme southern portion, which is a relatively narrow band of land adjacent to the lake, is heavily urbanized. Nearly half of the land in the Indiana-Illinois portion of the basin is urban. In these areas, intensive urban and industrial development has led to the filling and "hardening" of the shoreline and to the discharge of large amounts of pollutants into the air, water, and lands of that coastal region.

The Lake Michigan Basin accounts for 40% of the dairy cows in all of the Great Lakes, and there has been a trend toward consolidation and large-scale farming operations, resulting in a decrease in the number of acres used as farmland, but an increase in the intensity. Low-density sprawl is a dominant development trend in the basin (EPA 2000d). Among the largest rivers that drain into the lake are the Fox and Menominee in northeast Wisconsin, and the St. Joseph, the Kalamazoo, and the Grand in southwest Michigan. Table 5-2 summarizes land use in the overall basin and along the shoreline, and Figure 5-2 shows land use in the watershed.

Table 5-2 Land Use in Lake Michigan Basin

Land Use	Basin (% of Basin Area)	Shoreline (% of Shoreline
Agricultural	44	20
Residential	9	39
Forest	41	NS
Recreational	NS	24
Commercial	NS	5
Other	6	12

NS = not specified
Source: EPA 2006b

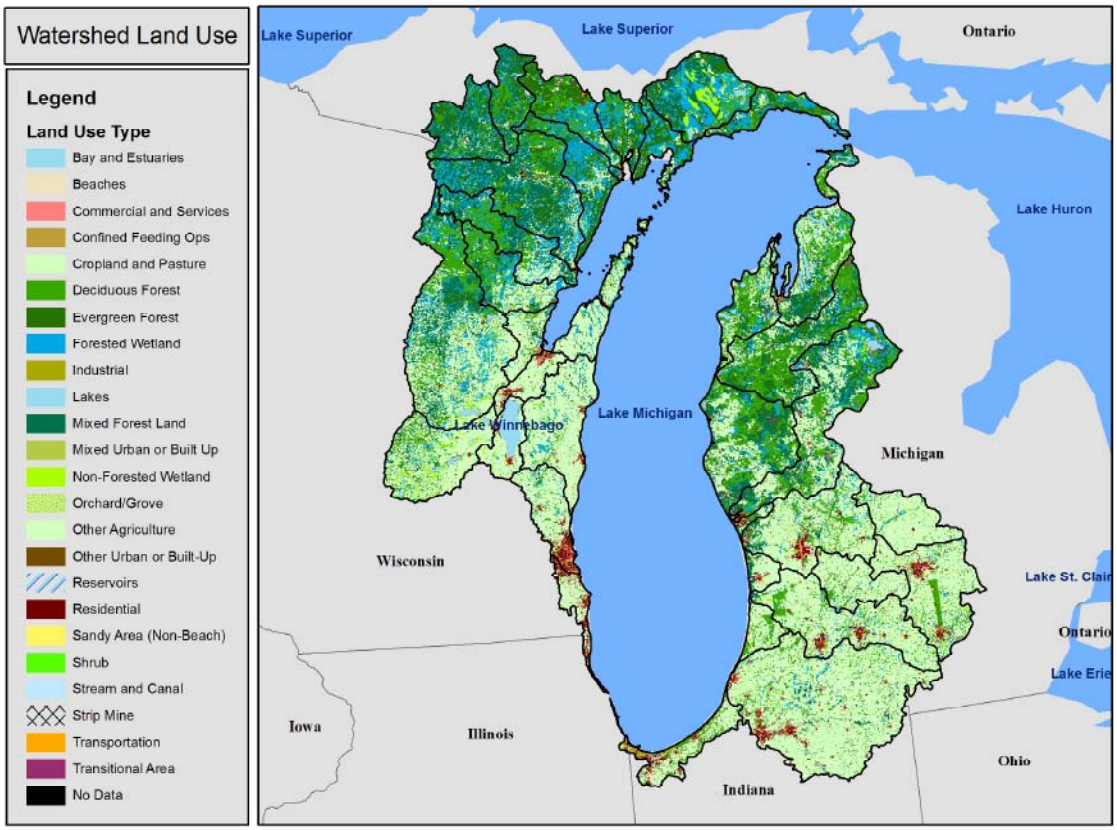

Figure 5-2 Land Use in the Lake Michigan Watershed
Source: EPA 2009

5.4 Approaches for Estimating NSP Loads

As noted, NSP loads are typically not measured. Besides the lack of a regulatory requirement that would necessitate monitoring or measurement, the technical, time, and financial resources needed to take, record, and store consistent, accurate, and reliable measurements for other than

very small areas would be very high. This is largely because flow rates and concentrations vary with numerous factors, such as land use, soil type, and time of year. For example, water quality data collected during drought conditions would lead to very different loadings estimates than would data collected during periods with normal or above normal precipitation. Further, the randomness of hydrological events, combined with the dispersed nature of drainage patterns, would make pollutant loads difficult to monitor over time.

An alternative approach to NSP load monitoring and measurement for identifying load amounts is to estimate pollutant loads by using computer models. Numerous water quantity and quality models have been developed for a variety of purposes, some of which specifically estimate NSP loads. The number and sophistication of these models has increased over the years, largely in response to the increased demand brought on by the EPA's Total Maximum Daily Load (TMDL) program. TMDL regulations require that all sources of pollution that contribute to a specific impairment be identified, quantified, and reduced to a level that will eliminate the impairment. The requirement to include nonpoint as well as point source pollutants has promoted a better understanding of the sources, quantities, and routes of nonpoint source pollutants than was available in the past. The increasing computational capabilities of personal computers; the increased understanding of the physical, chemical, and biological processes that affect nonpoint source pollution; and the development of geographical information systems (GIS) that can facilitate data entry, manipulation, and reporting have also contributed to the development and improvement of nonpoint source models.

Sections 5.4.1 and 5.4.2 discuss two types of models that theoretically can be used to help estimate NSP loads to Lake Michigan: watershed models and atmospheric dispersion models.

5.4.1 Watershed Models

Watershed models can range from those that use basic techniques to estimate average annual runoff and pollutant loads to those that predict detailed temporal and spatial distribution of pollutants entering a watershed. These watershed models and their outputs (e.g., pollutant loads) can be linked to receiving water models, which predict the transport, deposition, and fate of pollutants in surface waters and groundwater and predict the effect of a pollutant on other water quality parameters. Watershed models can be grouped into the following three categories that reflect the complexity of the model:

1. *Export coefficient models*. These models build relationships between land use and the load from nonpoint sources. Export coefficients can be derived from monitoring data and literature sources. Export coefficient models are suitable for estimating average annual loads in large areas.

2. *Loading function models*. These models, also known as regression models, use functional relationships that are based on long-term studies and statistical analyses to provide empirically based load estimates. A loading factor typically relates independent variables such as land use patterns and percent of surface imperviousness in a subarea to a dependent variable such as a per-acre pollutant loading.

3. *Physically based models*. These models use mathematical formulations to simulate physical, chemical, and biological processes to predict water movement (e.g., runoff, pollutant accumulation, percolation), sediment movement, mass transport, and load. The formulations are based on known relationships among events and can combine multiple sources of nonpoint source pollution. Figure 5-3 shows some of the generalized relationships that can be included in physically based models. Such models typically incorporate complex processes, require significantly more data than the export coefficient and loading function models, and are often more difficult to use.

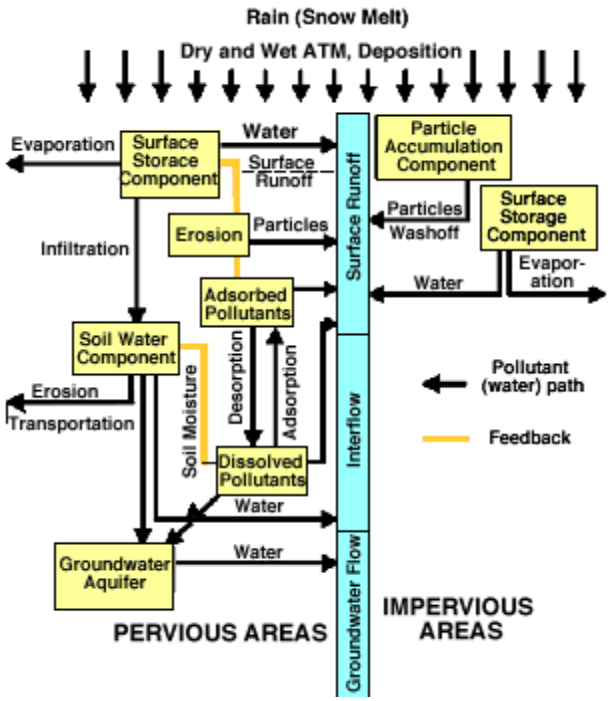

Figure 5-3 Schematic of Physically Based Model Showing Components and Potential Complexity
Source: EPA 2008a

Watershed models can vary in other ways, several of which are highlighted below:

- *Areal extent*. Some nonpoint source loading models can cover areas as small as a stream segment and some as broad as an entire watershed. Some models can cover a range of areal extents.

- *Temporal basis*. Some models are event based; that is, they simulate individual representative storms during the year, and to obtain annual loading estimates the results must be extrapolated to a yearly basis. Continuous models (those that simulate hourly or daily processes) can provide summary results on an annual basis.

- *Land use*. Most nonpoint source models predict either urban runoff or rural (including agricultural) runoff; some predict both. Many of the rural/agricultural runoff models were developed by the U.S. Department of Agriculture (USDA) to evaluate changes in runoff from conversion to different land use types (e.g., from forested to agricultural) or to identify the impacts of nutrient runoff. Some urban runoff models contain multiple algorithms to reflect that nature of the impervious surface (e.g., roads, roofs), and some include sewer runoff.

- *Pollutants estimated.* Many nonpoint source models have been developed for specific applications and therefore provide estimates for a single constituent only. For example, urban runoff models often focus on sediments, and agricultural runoff models frequently address a group of pollutants, such as nutrients or pesticides. Relatively few nonpoint source models predict metals loadings.

- *Data requirements*. Tremendous variation exists in the data required to run various nonpoint source models. Some require very detailed, site-specific data (e.g., time series data, specification of shoreline features, drainage area, rainfall, percent imperviousness, meteorological data, and other environmental information). Others allow the user either to input site-specific data or to use default data that are contained in or linked to the modeling system.

- *Ease of use*. Today, models are embedding GIS techniques that can result in a model's being more difficult to use (e.g., if the user must purchase and learn to use additional GIS software) or easier to use (e.g., if the GIS applications are embedded into the model and they facilitate data input and output). The amount, level, and format of data required to run a model are other considerations. Some models are linked to external databases, thereby minimizing data input (for general data). The availability of model documentation, case studies, etc. can also affect the suitability of individual models to a user's needs. As will be shown, a complex, or integrated, model is not necessarily more difficult to use than a simple model.

- *Availability*. Some models are not readily available (some are proprietary, some require the purchase of costly software or licenses to run, and some are difficult to obtain). A few can be downloaded from the Internet.

The following two sections summarize the conceptual processes that are typically embodied—in varying levels of detail—in watershed models that estimate NSP loads. Although the conceptual processes and relationships may appear straightforward, they can often require repeated calculations to simulate processes. The use of computers enables the running of continuous simulations to model chemical and biological processes and predict the resulting loads resulting from urban and rural runoff.

5.4.1.1 Rural NSP Loading Processes

Nonpoint source models for rural areas are often based on loading functions that estimate the load of a specific pollutant as the sum of two terms—one that represents the pollutant load

resulting from runoff and one that represents the pollutant load that is delivered in sediment. The runoff term is the product of the volume of runoff water and the dissolved pollutant concentration in that water. The sediment term (pollutant load from sediment flux) is the product of the volume of sediment flux times the concentration in sediment. These components are summarized conceptually below (EPA 1985). The actual calculations, however, can require the manipulation of vast amounts of data. The use of computers facilitates such manipulations and makes it possible to simulate random processes and predict resulting loads.

Estimation of runoff volume. Rural runoff volume is a function of the precipitation (rainfall and snowmelt) and a water-retention parameter, which in turn is a function of soil type, cover, and moisture. The water-retention parameter is often referred to as a "curve number," which describes the hydrologic condition of land surface at the time of a precipitation event. Since the curve number equation, which is used to estimate storm runoff, only applies to a single event, obtaining annual loads requires calculating the runoff for each storm in a year and summing the values for all the storms. To obtain average annual loads, models use continuous simulations to repeat the process for several years for a number of locations. Runoff can be calculated from an individual source area, such as a farmer's field or a forest road; the runoff for an entire watershed would be the sum of the runoff from all of the individual source areas in the watershed. Alternatively, a weighted average curve number can be used for an entire watershed. Because some pollutants can be delivered via groundwater flux, mass balance models of precipitation infiltration and groundwater delivery to streams are sometimes used to account for groundwater loading.

Estimation of sediment flux. Sediment flux (for determining the pollutant load that is associated with sediment transport) addresses the pollutant load that is contributed by erosion. While the source of sediment yield is upstream erosion of soil surfaces and stream channels, sediment yield at the outlet of the watershed is generally much less than the total upstream erosion because much of the transported sediment is deposited before it reaches the outlet. Average annual soil loss by sheet and rill erosion (the major source of solid-phase pollutants in surface waters) can be estimated by using the Universal Soil Loss Equation. This empirically derived equation, which is based on the results of statistical analyses of more than 10,000 modeled years of erosion field research data, is used to estimate soil loss (e.g., in tons per hectare). It is a function of a rainfall intensity, soil erodibility (which is related to soil texture and organic matter content), slope angle and length, the protection of the soil surface (by plant canopy, crop residues, etc.), and the effect of soil conservation practices on cropland erosion. The watershed sediment yield due to surface erosion is a function of the erosion from the source area calculated on the basis of the Universal Soil Loss Equation, the area of the source area, and a factor that accounts for the attenuation of sediment through deposition and filtering as it travels from source areas to the watershed outlet.

Estimating pollutant concentrations. As noted, the estimated pollutant load is the product of the runoff (or sediment flux) times the concentration of pollutant in that runoff (or in the sediment). Pollutant-specific concentrations are best determined by direct measurement, but where this is not feasible, representative concentrations can be used, or various procedures can be used to estimate concentrations. For example, nutrient concentrations in sediments can be estimated by applying a nutrient enrichment ratio to the nutrient concentration in in-situ soil. For metals, published sources of metal concentration in surficial soils can be used.

For loads transported by runoff, it is generally assumed that since all runoff from a watershed is transported to the outlet, all of the pollutants in that runoff are also transported to the outlet. Hence, the annual dissolved chemical load in rural runoff is the sum of the loads for each source area. (The load for a given source area is the product of the dissolved pollutant concentration in that source area times the runoff from the source area times the area of the source area.)

For solid-phase pollutant loads, i.e., those that come with the sediments, the average annual watershed load is the sum of the runoff loads from all sources in the watershed. However, as noted, since these chemicals travel with the sediment, a significant portion of the chemical load is deposited before the sediment flux reaches the outlet. As a result, the estimated loads must be adjusted by an attenuation factor for transport loss.

5.4.1.2 Urban NSP Processes

The pollutant-specific annual NSP load from urban runoff in a given area, or watershed, is the sum of the annual loads of the pollutant that are contributed by each land use in the urban area. Factors that can influence urban runoff loads include population density, drainage area, annual precipitation, percent of the drainage area that is impervious to infiltration, street cleaning frequency, and others. Stormwater runoff can also be calculated by the curve number approach (using appropriate curve numbers for urban areas).

Urban NSP loads from sediment depend on atmospheric and other deposition sources and removal. Often, models correlate sediment buildup with factors such as time of year, curb height, street width, traffic speed, atmospheric deposition rate, traffic emission rate, and frequency of street cleaning. These factors are then used to estimate the amount of washoff of material that occurs in response to a precipitation event. Washoff is correlated with rainfall intensity and the amount of available accumulated solids. Although pollutant concentrations in sediment can be obtained from samples and from published estimates in the literature, stormwater runoff and sediment accumulation depend on dynamic processes that are not easily computed.

5.4.1.3 Watershed Models with Potential Application to Estimating NSP Loads to Lake Michigan

Several NSP loading models were reviewed for their potential use in estimating NSP loads of TSS, ammonia, mercury, selenium, and vanadium to Lake Michigan. Table 5-3 lists 12 such models, identifies key characteristics of those models, and includes a determination regarding the suitability of each model for this study. Appendix B provides summaries of each of these models, including information on areal extent, temporal basis, land use modeled, pollutants estimated, data requirements, ease of use, and availability. On the basis of this model review, it was determined that the Better Assessment Science Integrating point and Nonpoint Sources (BASINS) model was suitable for estimating NSP loads of TSS, ammonia, and mercury to Lake Michigan. EPA's Office of Water developed the BASINS environmental analysis system to support environmental and ecological studies in a watershed context. BASINS is a GIS-based system that integrates a suite of watershed and water quality models with different approaches. It includes national databases, assessment tools, a watershed delineation tool, classification utilities, and characterization reports. It also incorporates several watershed loading and transport

models, such as HSPF, SWAT, and PLOAD. The system is designed to be flexible and to support a variety of scales. It uses the Windows environment and allows users to access national environmental data, apply assessment and analysis tools, run several calculations and processes through hundreds of iterations, and obtain results in the form of maps, charts, graphs, and reports in a relatively short time. Different models in the BASINS suite have different temporal scales; for example, the PLOAD export coefficient model provides NSP loadings on an annual basis for three of the five target pollutants (TSS, mercury, and ammonia). The BASINS system and most of its components have been used for many TMDL developments.

The latest version of BASINS (4.0) runs on a non-proprietary, open source GIS system architecture, so that users no longer need to purchase expensive GIS software to use the model. Access to data in 4.0 is Web-based; the user specifies the geographic area of interest, and the software downloads selected data from EPA, USGS, and other Internet locations. After the GIS data are downloaded, they are automatically extracted, projected to a user-specified map, and combined in a project file. Because of its ability to handle the large volumes of data needed to model NSP in the Great Lakes Basin, its ability to import the current data needed to run the NSP model (PLOAD), its user-friendly interface, its pollutant coverage (e.g., including TSS, mercury, and ammonia), its graphic output capabilities, and its proven use in a variety of applications, the BASINS modeling system is used in this report to estimate NSP loads for TSS, ammonia, and mercury. The results of these estimations are provided in Sections 5.5.1, 5.5.2, and 5.5.3, respectively.

Table 5-3 Models Reviewed for Use in Estimating NSP Loads of Target Pollutants to Lake Michigan

Model	Type	NSP Sources	Pollutants Modeled	Role in Estimating NSP in Current Study
Watershed Models				
Agricultural Nonpoint Source Pollution (AGNPS) Model	Loading function	Agricultural	Nutrients, sediments, chemical oxygen demand, and pesticides	Not used. Only simulated single events (real or hypothetical storms), significant data requirements, operates at a small scale.
Annualized Agricultural Nonpoint Source Pollution (AnnAGNPS) Model	Loading function	Agricultural	Pesticides, nutrients, sediments	Not used. Requires detailed data inputs beyond scope of current study. Limited application studies.
Better Assessment Science Integrating point and Nonpoint Sources (BASINS)	Integration of various models	Various land uses	Several	Used to estimate NSP for TSS, ammonia, mercury.

Generalized Watershed Loading Functions (GWLF)	Hybrid loading function and export coefficient	Runoff	Sediments	Not used. Requires detailed data inputs beyond scope of current study.
Hydrological Simulation Program – FORTRAN (HSPF)	Loading function	Land and soil contaminant runoff	Conventional and toxic organic pollutants	Not used. Requires extensive calibration, a high level of expertise for application, and detailed time series data inputs.
Mercury Loading Model	Hybrid export-coefficient and physically based	Runoff	Mercury	Not used. Lack of documentation and requires use of additional GIS software.
PLOAD	Simple or export-coefficient (user selects)	Runoff	Several	Used within BASINS; PLOAD is incorporated into the BASINS model.
Simple Method	Loading function	Stormwater	Several	Not used. Model works best for small areas (<1 mi^2).
Soil and Water Assessment Tool (SWAT)	Physically based	Agricultural, others	Pesticides, nutrients, sediments	Not used. Requires detailed data inputs beyond scope of current study.
Spreadsheet Tool for Estimating Pollutant Load (STEPL)	Loading function	Agricultural, urban runoff	Nutrients, sediments	Not used. Requires detailed data inputs beyond scope of current study.
Storm Water Management Model (SWMM)		Runoff in urban areas	Several	Not used. Requires detailed data inputs beyond scope of current study; optimized for urban areas.
Atmospheric Deposition Models				
Lagrangian	Uses chemical physical properties and local meteorology	Atmospheric deposition	Toxic compounds that do not react from point of emission to point of deposition; e.g., heavy metals, dioxins	Not used directly. However, Lagrangian models may have been used by authors to estimate loadings in previous studies described in Sections 5.4.3 and 5.4.4.
Eulerian	Uses three-dimensional grids to average deposition rates	Atmospheric deposition	Chemicals with complex nonlinear chemistry, e.g.., mercury	Not used directly. However, Eulerian models may have been used by authors to estimate loadings in previous studies described in Sections 5.4.3 and 5.4.4.

5.4.2 Atmospheric Deposition Models

Conceptually, the NSP load from atmospheric deposition is the sum of the following components: direct wet deposition, direct dry deposition, gas absorption, indirect deposition (the atmospheric component of tributary loading), resuspension of particles from the lake into the air, and a fog component.

For wet deposition, where precipitation scavenges particulates and adsorbs gases that contain various pollutants, loads depend on the concentration of the pollutant in the precipitation, the precipitation rates, and the projected receptor area. The precipitation component can be estimated by multiplying the volume-weighted mean concentration in precipitation times the precipitation rate and the area of the lake (if the concentrations are known).

The pollutant load from direct dry particle deposition is a function of the particle settling velocity (which depends on air viscosity, acceleration of gravity, particle density, particle diameter, and density of air), the concentration of atmospheric particulates, the receptor area, and the fraction of the pollutant in the particulates. Dry deposition can be estimated by multiplying the measured particulate concentration by a deposition velocity.

For gas-phase pollutants, the load is a function of gas deposition velocity, receptor area, and ambient concentration of the gas-phase pollutant. Gas absorption, or the net gas-phase transfer component, balances the absorption to and the volatilization from the water surface; variables that affect flux can include mass transfer velocity, concentration gradient, wind speed, temperature.

For tributary loadings, single average concentrations can be used, but large spatial gradients in concentration may lead to errors in loading estimates. For example, urban influences at a smaller scale may be important for trace elements (Hoff et al. 1994). It has been estimated that roughly 10% of the material that results from wet and dry deposition in the watershed reaches lakes by fluvial transport (Hoff et al. 1994). The use of this assumption would eliminate the difficulties required by needing to know or to estimate tributary concentrations and flows to estimate the load from tributaries.

The relative contributions of these different components vary with the pollutant. For example, mercury, unlike other trace metals such as selenium, exists predominantly in the vapor phase in the atmosphere. Thus, while selenium is generally assumed to have a negligible gas-phase component, the gas-phase contribution of mercury is significant (Hoff et al. 1994).

Computer models are generally used to estimate the pollutant-specific deposition rates for specific regions, depending on the characteristics of the pollutant and the local meteorological conditions. These models rely on emissions inventories (information on releases of pollutants to the air over a specified time for specified pollutants and geographic areas) and meteorological data. As with runoff models, air deposition models often are developed for a particular purpose and/or type of pollutant. For example, air deposition models have been used to estimate acid deposition from sulfur dioxide and nitrogen oxides.

An air deposition model is generally one of two types: Lagrangian or Eulerian. Lagrangian models track emission plumes as they spread out toward a receptor on the basis of their chemical and physical properties or the local meteorology. They are generally used for toxic compounds that do not react or change form from the point of emission to the point of deposition. An example is the Regional Lagrangian Model of Air Pollution (RELMAP), which is used to estimate deposition rates for unreactive pollutants such as heavy metals or dioxins.

Eulerian models calculate deposition on the basis of three-dimensional grids over which input and deposition rates are averaged; they are often used to capture the complex nonlinear chemistry associated with certain chemicals such as mercury. An example of an Eulerian model is the Regulatory Modeling System for Aerosols and Deposition (REMSAD), which is used to model nationwide wet and dry deposition for mercury, ammonia, and other pollutants. This model is typically run for a year's worth of meteorological data, and it simulates the movement of emissions from sources on the basis of calculated transport and transformation rates and deposits them in grids. Running air deposition models can be resource intensive, and the data on which they rely may not always be available. As a consequence, no air deposition models are used directly in the estimation of NSP in this study. (Sections 5.4.3 and 5.4.4 refer to study results by other authors, and it is possible that those studies employed air deposition models, but there is no explicit use of such models in the current study.)

5.5 Nonpoint Pollutant Sources and Loadings Estimates

This section describes the nonpoint sources of TSS, ammonia, mercury, selenium, and vanadium entering Lake Michigan. It also provides some very rough estimates of annual NSP loads. These estimates are based on several sources, including previous studies conducted by scientists and researchers from government, academia, and regional organizations. In a few cases, these studies pertain specifically to Lake Michigan; in others we have applied the methodologies used in other areas to Lake Michigan. We have also used EPA's BASINS model to estimate NSP loads for the contaminants of interest for this study that are modeled in BASINS, i.e., TSS, ammonia, and mercury.

We cannot overemphasize that the estimates provided in this section are very rough approximations. Numerous assumptions are built into the estimating algorithms, and countless unknowns are not accounted for. Scientists have hypothesized about many factors that affect NSP loads, but the evidence to support or refute these hypotheses is minimal and rarely reflected in the estimates. These unknowns are important to keep in mind when comparing estimated NSP loads, which embody numerous assumptions and unknowns, with point source loads, which are carefully measured in compliance with site-specific requirements. Listed below are just a few of the considerations that may affect NSP loads entering Lake Michigan:

- The amount of nonpoint source pollution from runoff entering a tributary may be many times, or even orders of magnitude, greater than the loads that actually enter the lake, and numerous factors will influence the share of tributary load that ends up in the lake.

- The portion of atmospheric deposition that enters the runoff depends on the chemical and physical behaviors of the contaminant. For example, the partitioning of mercury between

the vapor and particulate phases in the atmosphere and on surfaces is complex and depends on variables that include relative humidity, temperature, wind velocities, and the amount of mercury entering the runoff. Transformation processes within a watershed will affect the temporal patterns between mercury deposition onto the watershed and mercury loading into the receiving water (Gabriel et al. 2002).

- Characterization of stormwater runoff indicates that even hard surfaces may retain a significant portion of mercury and other heavy metals, preventing transport in runoff, while vegetative or permeable surfaces may act as permanent sinks for some portion of the contaminants (Gabriel et al. 2002).

- Existing models rarely account for complex hydrologic conditions, such as high water tables with surface-to groundwater interactions, or for cross-media transfers of pollutants.

5.5.1 TSS

TSS consists of organic and inorganic solid materials suspended in water; included are silt, plankton, industrial wastes, soil, algae, and fine particles of plant material. Suspended solids can result from erosion from urban runoff and agricultural land, construction sites, mining operations, logging operations, industrial wastes, bank erosion, stream erosion, algae growth, and wastewater discharges. Direct atmospheric deposition of particulates onto surface waters is not typically considered a source of TSS. This is because direct deposition of particulates is generally allocated to the specific chemical or pollutant that is deposited, e.g., vanadium. Table 5-4 shows a variety of TSS sources and highlights how TSS are generated.

Table 5-4 Nonpoint Sources of TSS

Source	Generation Modes
Agriculture	Cropping too close to ditches, drains, and watercourses can accelerate bank erosion. Access to watercourses by livestock can lead to the loss of riparian vegetation and deterioration of shoreline leading to sediment pollution.
Dams and reservoirs	Act as settling basins for silt and other suspended materials.
Dredging	Destabilizes substrate and the associated benthic community. Alters water circulation patterns and submarine mudflows. Can redistribute sediments at disposal sites, sometimes smothering benthic organisms. Produces localized changes in water chemistry, including reduced dissolved oxygen levels, and increased turbidity.
Erosion	Primary source of suspended solids in coastal zones. Accelerated by human activities that remove vegetative cover and expose soil.
Flooding	High concentrations of suspended solids may persist in rivers.

Source	Generation Modes
Forest fires	Runoff from burned catchments increases due to accelerated overland flow rates (from reduced infiltration capacity).
Logging activities	Accelerates surface erosion and sedimentation, which continue after logging activity ceases.
Mining	Runoff from mine spoils, coal washing, granite crushing, etc., can increase suspended sediment concentrations.
Recreational boating and navigation	Resuspends sediments, thereby increasing turbidity. Wave wash erodes material from riverbanks and lake shorelines.
Roads	Road construction and associated culvert installation result in dramatic short-term increases in suspended sediment. Disruption and/or removal of riparian vegetation. Destabilized shoreline and sediment from backfill associated with bridge construction and stream crossings.
Urban development	Increased soil exposure and sediment loads from topsoil removal. Releases sediments and other compounds from storm sewers and street runoff.
Wind/wave/current action	Resuspension and transport of substrate sediments.
Ice breakup and movement	Ice scouring increases shoreline erosion. Releases sediments from melting ice and snow. Increases sediment transport.

Source: Kerr 1995

Sediments from different sources vary in the kinds and amounts of pollutants that are adsorbed to the particles. For example, sheet, rill, ephemeral gully, and wind erosion mainly move soil particles from the surface or plow layer of the soil. Sediment that originates from surface soil has a higher pollution potential than that from subsurface soils. The topsoil of a field is usually richer in nutrients and other chemicals because of past fertilizer and pesticide applications, as well as nutrient cycling and biological activity. Topsoil is also more likely to have a greater percentage of organic matter. Sediment from gullies and stream banks usually carries less adsorbed pollutants than sediment from surface soils.

Rough estimates of annual TSS loads to Lake Michigan derived from published studies and from the BASINS model are presented below. The procedures used by the authors of this study to obtain these estimates are described here. A literature review was conducted to identify any existing estimates of annual NSP TSS loads to Lake Michigan or any studies containing data that could be used to make some approximations. Absent any studies providing annual NSP TSS loads, data from the literature on TSS yields in the Great Lakes Region, land use allocations, estimates of total TSS loads to Lake Michigan, and source coefficients for various land uses developed by using the SPARROW (Spatially Referenced Regression On Watershed Attributes) model were used to estimate annual NSP TSS loads. In addition, since the BASINS model can be used to estimate annual TSS NSP loads, the export coefficient option was used to apply land-use-specific TSS coefficients to the total number of acres for each land use identified in each watershed in the Lake Michigan Basin and then aggregated to provide an overall estimate of

annual NSP TSS loads to the lake. The following paragraphs describe these procedures in more detail.

USGS/EPA estimates of TSS yields in the Great Lakes Region. In 2003, the USGS and the EPA began a cooperative study to describe the distribution of concentrations and annual TSS yields (load per unit area of the basin) throughout the Great Lakes region and adjacent areas (Robertson et al. 2006). Annual loads were calculated by summing daily loads. Daily loads were calculated on the basis of relationships among constituent loads, stream flow, and time of year for each of 550 sites from 1971 to 2002. Total annual loads were then calculated for all years that had no missing daily values, and median annual loads and concentrations were then computed for each site. For all sites, the median TSS yield was 35,400 kg/km^2/yr, and the mean was 85,100 kg/km^2/yr. The minimum was 22 kg/km^2/yr and the maximum was 3,373,000 kg/km^2/yr. Regression analyses that relate yields to various environmental factors showed that annual yields were most highly correlated with amount of precipitation and the resulting runoff. Yields were also correlated with factors related to high TSS concentrations, that is, soil properties (clay and organic-matter content, erodibility, and permeability), basin slope, and land use (percentage of agriculture). The percentages of wetlands and agricultural lands in the basin also correlated with TSS yields.

The authors (Robertson et al. 2006) developed five different zone categories (Figure 5-4) to delineate areas with similar environmental characteristics and reference (or background) median concentrations and yields. The median TSS yield data varied with zone, ranging from 785 kg/km^2/yr in Zone 5 to 108,000 kg/km^2/yr in Zone 4. The zones bordering the southern part of Lake Michigan are (in roughly equal amounts) Zones 3, 4, and 5, with median TSS yields of 27,600, 108,000, and 785 kg/km^2/yr, respectively. The zones bordering the rest of the Lake are primarily in Zone 1 (median annual TSS yield of 4,720 kg/km^2/yr), with a small portion in Zone 5 (Figure 5-4). These results have been used in conjunction with those of a separate study that estimated TSS loadings to the St. Joseph River Basin Watershed (Kieser & Associates 2003) to estimate total TSS nonpoint source loads to Lake Michigan.

To estimate nonpoint source TSS loads entering *southern* Lake Michigan, the average TSS loading rates developed by Kieser & Associates (2003) for the St. Joseph River Watershed sediment model were used. Kieser & Associates used earlier data reported by Robertson indicating that the St. Joseph River Basin watershed contributed 102,000 kg/km^2 of TSS to Lake Michigan each year. By subtracting from this total the roughly 1.4% of TSS load that is contributed by point sources (Kieser & Associates 2003), the NSP loading is estimated to be roughly 101,600 kg/km^2 (about 579,000 lb/mi^2.) This estimate is consistent with the USGS loadings described above. The application of this average NSP loading rate to the 4,685-mi^2 St. Joseph River Watershed and the 604-mi^2 Calumet-Galien Watershed suggests that roughly 3.06×10^9 lb of nonpoint source TSS enter southern Lake Michigan per year from these two watersheds. (As noted earlier, most of the water in the Chicago Watershed drains away from Lake Michigan, so this 3.06×10^9 lb estimate does not include any nonpoint source TSS coming from the Chicago watershed.)

A very rough estimate of the annual TSS loads to the rest of the lake can be made by applying the TSS Zone 1 yield (4,720 kg/km^2/yr, or 26,900 lb/mi^2/yr) to the remaining land area in the

Lake Michigan Basin (39,511 mi^2—or the total Lake Michigan watershed area [44,800 mi^2] less that of the St. Joseph River Watershed [4,685 mi^2] and the Calumet-Galien Watershed [604 mi^2]). By adding this result (1.06×10^9 lb) to the TSS load estimate for southern Lake Michigan (3.06×10^9 lb), an overall annual TSS load to the lake of 4.12×10^9 lb is estimated.

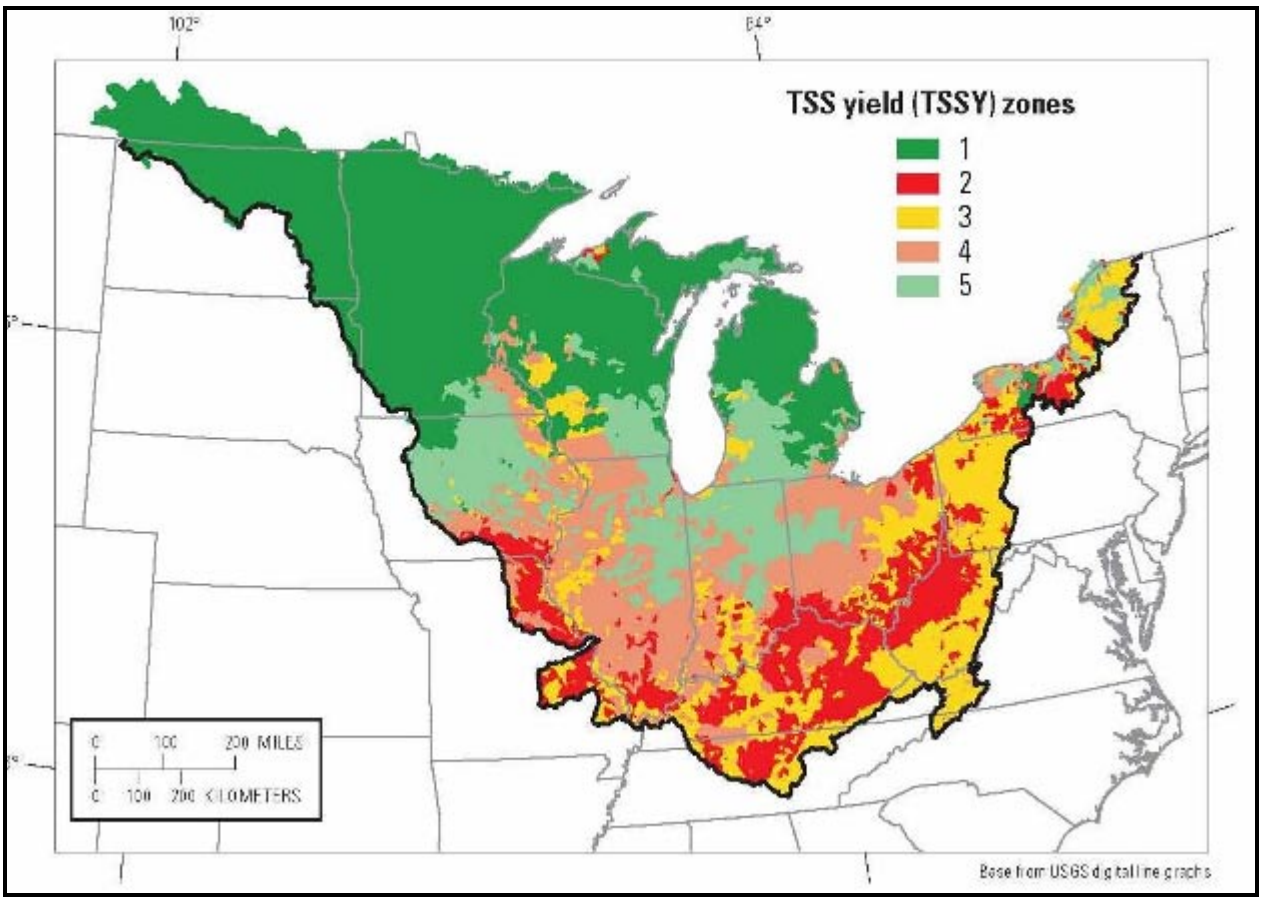

Figure 5-4 USGS TSS Yield Zones (Zone 1 has the lowest yield, and Zone 5 has the highest yield)
Source: Robertson et al. 2006

Estimates Based on USGS Preliminary SPARROW Model for TSS. In 2008, G.E. Schwarz reported results from using the SPARROW model to estimate annual TSS yields (in $kg/km^2/yr$) for specific land-use types. The following information comes from that study (Schwarz 2008). The SPARROW analysis is based on flux estimates compiled from more than 1,800 long-term monitoring stations operated by the USGS over the period 1975-2007. The model used the Reach File 1 stream network,[13] which consists of about 62,000 reach segments that have been modified to include more than 4,000 reservoirs. (Reservoirs are major sites for sediment attenuation and

[13] Reach File is database of information on stream flow, hydrographic features, and environmental characteristics for about 700,000 miles of streams and open waters in the conterminous United States. It has been used extensively by EPA for water quality modeling.

thus can affect delivered amount of suspended sediment.) The model identifies six sediment sources, including the stream channel and five classes of land use: urban, forested, federal nonforested, agricultural, and other (noninundated) land. Independent variables affecting the delivery of sediment from lands to streams include erodibility, slope, rainfall, and soil permeability. The first three factors increase delivery, while soil permeability reduces sediment delivery. Streamflow was found to affect the amount of sediment mobilized from the stream channel.

This methodology uses numerous mathematical models, detailed calculations, and data sources to estimate sediment yields, and it specifically address the loss of sediment as it moves through the streams. In general, the SPARROW model calculates the load leaving a reach as the sum of the load generated within upstream reaches and transported to the reach via the stream network, plus the load originating within the reach's incremental watershed and delivered to the reach segment, minus the instream losses. The model specifies two instream sediment-attenuation processes: attenuation in streams and reservoir attenuation. Reservoir attenuation is a function of the reservoir settling velocity, the ratio of streamflow to reservoir surface area, and other factors. Schwarz found that with the exception of reservoirs, the preliminary results do not indicate sediment attenuation in streams, implying that sediment transport in streams is not in a steady state. He noted that additional investigation will be necessary to determine if this is a real result or if additional reach attributes, currently not accounted for in the model, could identify a subset of reaches where sediment attenuation occurs.

Schwarz's preliminary estimation results for the SPARROW suspended sediment model are shown in Table 5-5. As noted by Schwarz, the results reflect the large uncertainty associated with sediment modeling. The root mean square of 1.414 implies that the predicted sediment flux or concentration in any given reach has an error of about 140%, implying that the prediction of sediment flux or concentration in any given reach segment is imprecise. However, as Schwarz notes, "although this error compromises the ability to describe water-quality conditions in any given reach, it does not preclude using the model to characterize water quality in a large grouping of reaches. As long as the error across reaches is sufficiently independent, the assessment of mean water quality in a group of reaches becomes more precise as the size of the group increases."

On the basis of this suggestion—that the model results could be used to characterize water quality in a large grouping of reaches—we have prepared some very rough estimates of TSS loads to Lake Michigan by applying the source coefficients in Table 5-4 to the land use allocations in the Lake Michigan Basin reported in Section 5.2. The results are shown in Table 5-6. Note that the total annual TSS NSP load estimated by using results of the SPARROW/Schwarz study (3.36×10^9 lb/yr), are similar to those estimated by using the results of the USGS/EPA/Kieser studies (4.12×10^9 lb/yr) described in the preceding paragraphs.

Table 5-5 Preliminary Estimates for SPARROW TSS Model

Parameter	Estimate	Units
Source Coefficient		
Urban land	47,130	$kg/km^2/yr$
Forested land	634	$kg/km^2/yr$
Federal non-forested land	64,344	$kg/km^2/yr$
Agricultural land	18,047	$kg/km^2/yr$
Other land	11,343	$kg/km^2/yr$
Streambed (reach length)	28.80	kg/m/yr
Land-to-Water Delivery Factor		
Slope	0.804	–
R-factor (rainfall factor)	0.821	–
K-factor (soil erodibility)	1.292	–
Stream Attenuation Factor		
Flow [< 500 ft^3/s] (Reach)	0.154	–
Flow [> 500 ft^3/s] (Reach)	0.721	–
Reservoir settling velocity	36.49	m/yr
Number of Observations:		1,828
Root Mean Square error		1.414

Source: Schwarz 2008

Table 5-6 Estimated TSS Loads Using SPARROW Model Results

Land Use	Share in Basin (%)	km^2 in Basin	Source Coefficient (kg/km^2)	TSS load (kg)	TSS Load (lb)
Agriculture	44	51,054	18,047	9.21×10^8	2.03×10^9
Forest	41	47,573	634	3.02×10^7	6.65×10^7
Urban (residential)	9	10,443	47,130	4.92×10^8	1.09×10^9
Other	6	6,962	11,343	7.9×10^7	1.74×10^8
Total	100	116,032		1.52×10^9	$3.36E \times 10^9$

Sources: Schwarz 2008 for source coefficients; EPA 2006a for land use shares

Estimated TSS Loads from BASIN. As described in Section 5.4.2, the latest version of EPA's BASINS model incorporates several existing and tested NSP models, extensive databases (e.g., land use, runoff coefficients), and GIS capabilities to enable the relatively straightforward calculation of estimated annual loads for TSS, mercury, and ammonia on a personal computer. In this application, we used the export coefficient option for estimating TSS loads into Lake Michigan (the alternative, simple method works better for smaller areas, e.g. of a square mile or less.) By using the export-coefficient model, BASINS applied land-use specific TSS coefficients (see Appendix C) to the total number of acres for each land use identified in each of the 33 eight-digit watersheds in the Lake Michigan Basin to develop an estimate of total TSS loads to each

watershed. (Figure 5-2 shows the land use distribution in the Great Lakes Watershed that is incorporated in the BASINS system.)

The results, shown in Table 5-7 and Figure 5-5, indicate a total estimated nonpoint source TSS load to the Lake Michigan Basin of 2.75 x 10^{10} lb/yr. Nearly one fifth of the estimated nonpoint TSS load comes from the St. Joseph Watershed. This is logical, because this watershed (4,760 mi^2) is the largest of the 33 watersheds in the Lake Michigan Basin; and nearly three-fourths of the watershed's land is agricultural and 5% is developed. Both of these land uses have large TSS export coefficients (2,000 and 500 lb/acre/yr, respectively). Other watersheds with high TSS loads include the Wolf (second largest in the basin with 3,720 mi^2—nearly one-half of which is agriculture) and the Kalamazoo (2,020 mi^2; 59% agricultural, 4% developed), the Lower Grand (1,990 mi^2; 59% agricultural, 6% developed), the Upper Grand (1,730 mi^2; 65% agricultural) and the Manitowoc-Sheboygan (1,650 mi^2; 77% agricultural).

Table 5-7 Estimated Annual TSS Loads to Lake Michigan Based on BASINS Model Run

Watershed, State	TSS Load	
	Pounds	**Percent of Total**
Manitowoc-Sheboygan, Wisconsin	1.73 x 10^9	6
Door-Kewaunee, Wisconsin	7.00 x 10^8	3
Duck-Pensaukee, Wisconsin	4.40 x 10^8	2
Oconto, Wisconsin	4.06 x 10^8	1
Peshitgo, Wisconsin	3.38 x 10^8	1
Brule, Michigan, Wisconsin	9.82 x 10^7	0
Michigamme, Michigan	3.14 x 10^7	0
Menominee, Michigan, Wisconsin	3.65 x 10^8	1
Cedar-Ford, Michigan	1.75 x 10^8	1
Escanaba, Michigan	9.02 x 10^7	0
Tacoosh-Whitefish, Michigan	9.01 x 10^7	0
Fishdam-Sturgeon, Michigan	7.88 x 10^7	0
Upper Fox, Wisconsin	1.35 x 10^9	5
Wolf, Wisconsin	2.13 x 10^9	8
Lake Winnebago, Wisconsin	4.23 x 10^8	2
Lower Fox, Wisconsin	4.57 x 10^8	2
Little Calumet-Galien, Illinois, Indiana, Michigan	5.57 x 10^8	2
Pike-Root, Illinois, Wisconsin	3.42 x 10^8	1
Milwaukee, Wisconsin	7.92 x 10^8	3
St. Joseph, Indiana, Michigan	4.93 x 10^9	18
Black-Macatawa, Michigan	5.51 x 10^8	2
Kalamazoo, Michigan	2.01 x 10^9	7
Upper Grand, Michigan	1.68 x 10^9	6
Maple, Michigan	1.07 x 10^9	4

Watershed, State	TSS Load	
	Pounds	Percent of Total
Lower Grand, Michigan	1.82×10^9	7
Thornapple, Michigan	9.45×10^8	3
Pere Marquette-White, Michigan	8.68×10^8	3
Muskegon, Michigan	1.22×10^9	4
Manistee, Michigan	4.98×10^8	2
Betsie-Platte, Michigan	3.46×10^8	1
Boardman-Charlevoix, Michigan	7.42×10^8	3
Manistique, Michigan	1.29×10^8	0
Brevoort-Millecoquins, Michigan	6.29×10^7	0
Total	2.75×10^{10}	

5.5.2 Ammonia

Ammonia emissions come from a variety of rural and urban sources, many of which are diffuse or unregulated. Examples of nonpoint ammonia sources include fertilizers, livestock wastes, untreated septic effluent, and decaying organisms. These and other sources of urban and rural ammonia emissions are identified in Table 5-8.

Despite the variety of ammonia sources, EPA emissions inventory data indicate that livestock management and fertilizer application contributed about 85% of total ammonia emissions in the United States in 1998, and that publicly owned treatment works, mobile sources, and combustion sources combined contributed about 15% of the total (EPA 2000b). Table 5-9 shows estimated ammonia emissions in the United States from several sources.

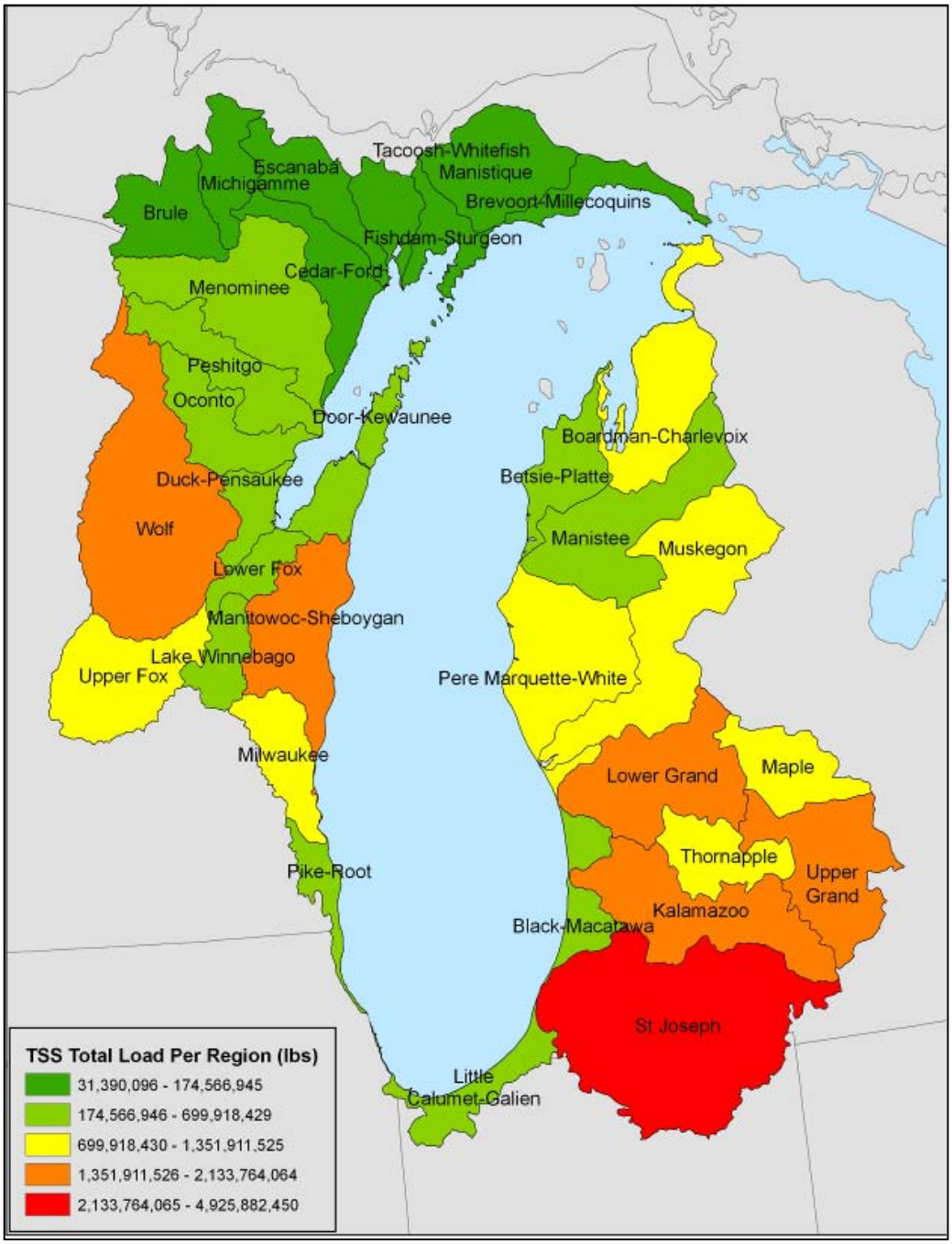

Figure 5-5 Estimated TSS Loads from Lake Michigan Watersheds, Based on BASINS Model Run

Table 5-8 Nonpoint Sources of Ammonia Emissions

Rural Sources	Urban Sources
• Decomposition of livestock and poultry wastes • Natural biological cycling (due to biotic processes in soils and waters) • Fertilizer application • Landfills • Composting • Geothermal emissions • Combustion—biomass (forest fires and agricultural fires)	• Mobile sources • Wastewater treatment plants (including sewage sludge) • Fossil fuel combustion—industrial, commercial, and residential • Nitrogenous materials manufacturing (fertilizers, etc.) • Fossil fuels processing (coke production, catalytic cracking) • Ammonia injection as a control measure (power generation plants) • Ammonia refrigeration • Domestic sources (solvent use, cleaners, untreated wastes, etc.) • Commercial ammonia use (printing processes—blueprints, solvents, cleaners, etc.)

Source: EPA 1995

Table 5-9 Ammonia Emissions in the United States, 1995

Source	Amount (lb)
Livestock	7×10^9
Fertilizer	2×10^9
Humans	2×10^8
Industry	1×10^8
Vehicles	1×10^8

Source: Anderson et al. 2003

Studies of coastal waters, particularly the Chesapeake Bay, indicate that small particles of ammonia can be transported short and long distances through the air before falling onto the surrounding land and water. Volatilized ammonia can travel hundreds of miles from its origin. European scientists have found that nitrogen pollution in the Mediterranean Sea is caused in large part by ammonia emissions in northern Europe (Gay and Knowlton 2005). Because an area's airshed can be considerably larger than its watershed (Figure 5-6 shows the airshed and watershed of the Great Lakes region), sources both within and beyond the watershed need to be considered when estimating airborne ammonia emissions.

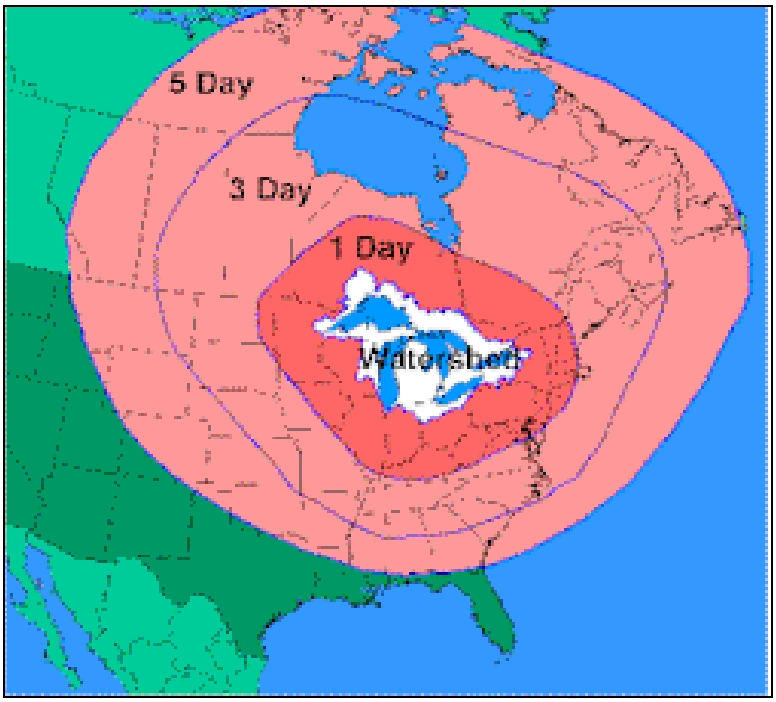

Figure 5-6 Great Lakes Region Airshed and Watershed
Source: EPA 2006a

Rough estimates of annual ammonia loads to Lake Michigan derived from published studies and from the BASINS model are presented below. The procedures used to obtain these estimates are summarized here. A literature review was conducted to identify any existing estimates of annual NSP ammonia loads to Lake Michigan or any studies containing data that could be used to make some approximations. Absent any studies providing annual NSP ammonia loads, data from the literature on global emission factors for ammonia and on direct atmospheric deposition rates to the Delaware Inland Bays were used to estimate gaseous ammonia emission deposited directly into Lake Michigan each year. An approach using National Atmospheric Deposition Program data was employed to estimate total annual atmospheric deposition loads of ammonia to the lake. Finally, the BASINS model was used to estimate annual ammonia NSP loads to the lake. The following paragraphs describe these methods and their results in more detail.

Application of site-specific study results to Lake Michigan gaseous ammonia deposition. Relatively little research has been reported on local or regional ammonia emissions in the United States. Although research is increasing, and measurement equipment and methods are being developed, the high costs associated with measurement and the lack of continuous measurement capability has hindered the development of reliable annual emission factors. Typically, data are collected over short durations, and extrapolations beyond the sampling periods and conditions are prone to error (Arogo et al. 2001). Nonetheless, some site-specific studies have been conducted. Two are reported here to provide a rough estimate of potential ammonia emissions to Lake Michigan from air deposition. The first study (Anderson et al. undated) reports an estimated global average emission factor of 3.6 $kg/km^2/yr$ for ammonia emissions from undisturbed soil and vegetation. The second (Scudlark et al. 2001) calculated a direct

atmospheric deposition rate of gaseous ammonia to the Delaware Inland Bays of 3.0 to 4.8 kg/ha/yr.

By taking the midpoint of this range and converting it to kg/mi^2, we calculate a deposition rate range of 9.3 kg/mi^2 (undisturbed soil) to 1,010 kg/mi^2 (an area with intense poultry production). Lacking deposition factors specific to Lake Michigan, not knowing the amount of land used for poultry farming in the watersheds that drain into Lake Michigan, and lacking estimated deposition rates for sources other than poultry farming, we use a weighted average rate of 9.4 kg/mi^2 (21 lb/mi^2), assuming 0.01% of the area is at the high end of the estimate range and 99.99% is at the lower end. By multiplying this weighted average estimate by the estimated surface area of Lake Michigan (22,400 mi^2) we obtain a very rough annual estimate of about 463,000 lb (210,560 kg) of gaseous ammonia emissions deposited directly into the lake each year. This estimate does not account for indirect deposition.

Application of National Atmospheric Deposition Program data to estimate total atmospheric deposition loads of ammonia. An approach for estimating direct ammonium deposition to the lake uses data collected by the National Atmospheric Deposition Program (NADP), a cooperative effort among federal, state, tribal, and local governmental agencies, educational institutions, private companies, and non-governmental agencies to measure atmospheric deposition and study its effects on the environment.

The NADP collects and reports data on several atmospheric pollutants, including wet deposition of ammonium ion (NH_4^+). Figure 5-7 is an isopleth map showing NH_4^+ wet deposition measurements for 2007. This map indicates that on average, roughly 3.5 kg/ha was deposited over Lake Michigan in 2007. Converting this average deposition rate to pounds per square mile and multiplying it by the 22,400-mi^2 surface area of Lake Michigan indicates that roughly 44,700,000 lb of NH_4^+ entered Lake Michigan via wet deposition in 2007. The National Park Service, which maintains more than 40 NADP monitoring sites across the country, has estimated that roughly 86% of the total direct deposition of NH_4^+ comes from wet deposition and the remainder from dry deposition (National Park Service 2006). Assuming that this ratio applies to Lake Michigan, the total wet and dry deposition for 2007 to the lake is estimated to be 52,000,000 lb (44,700,000 lb from wet deposition and 7,300,000 lb from dry deposition.) Note that while calculations of NSP loads from runoff likely overestimate the amount that actually enters the lake, the calculations of ammonium from atmospheric deposition may underestimate the actual amounts, because the NADP samplers may underestimate deposition in areas of high snowfall, clouds, or fog (National Park Service 2006).

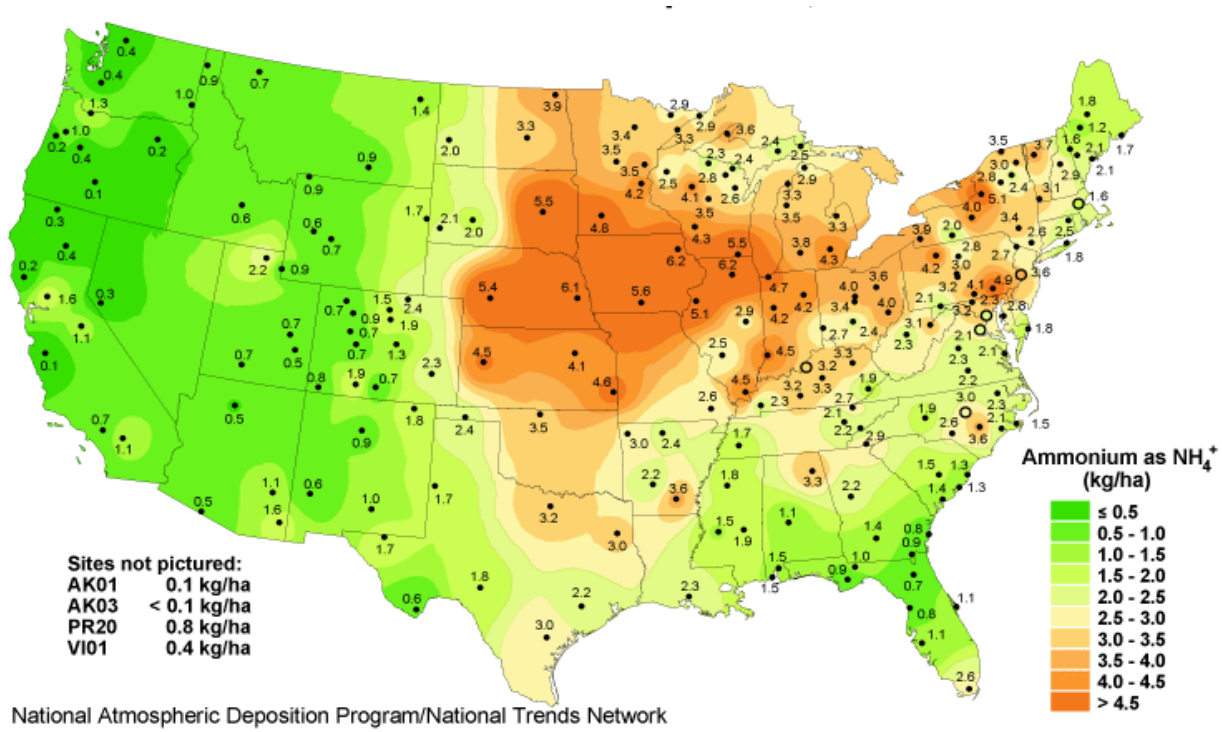

Figure 5-7 Ammonium Ion Wet Deposition, 2007
Source: NADP 2009

Estimated Ammonium Loads from BASINS. The BASINS model, which allows users to estimate pollutant loads for watersheds on a personal computer by using the export-coefficient approach in conjunction with extensive databases and GIS capabilities (see Section 5.4.2), was used to estimate NSP loads of NH_4^+. The results, shown in Table 5-10 and in Figure 5-8, indicate that roughly 32,500,000 lb of ammonium is deposited annually in the Lake Michigan Basin. As was the case with the nonpoint source TSS load estimates derived from BASINS, the St. Joseph Watershed contributes the highest portion of the loads (16% of total NH_4^+ loads). Other watersheds contributing relatively large shares of NH_4^+ loads are the Wolf (8%), Kalamazoo (7%), and the Manitowoc-Sheboygan, Upper Grand, and Lower Grand watersheds (each contributing about 6% of the total). These watersheds are the largest of the 33 in the basin, and all have significant amounts of agricultural and developed land uses, both of which have relatively high export coefficients (see Appendix C). As with other BASINS estimates, these should be considered maximum values since some portion of the ammonium released to the tributaries in the watershed will likely not reach Lake Michigan. (Note that the Wolf and Upper Grand Watersheds have no shoreline on the lake.)

Table 5-10 Estimated Annual NH_4^+ Loads to Lake Michigan Based on BASINS Model Run

Watershed, State	NH_4^+ Load	
	Pounds	% of Total
Manitowoc-Sheboygan, Wisconsin	1,800,000	6
Door-Kewaunee, Wisconsin	754,000	2
Duck-Pensaukee, Wisconsin	471,000	1
Oconto, Wisconsin	557,000	2
Peshitgo, Wisconsin	527,000	2
Brule, Michigan, Wisconsin	285,000	1
Michigamme, Michigan	164,000	1
Menominee, Michigan, Wisconsin	769,000	2
Cedar-Ford, Michigan	367,000	1
Escanaba, Michigan	266,000	1
Tacoosh-Whitefish, Michigan	210,000	1
Fishdam-Sturgeon, Michigan	188,000	1
Upper Fox, Wisconsin	1,490,000	5
Wolf, Wisconsin	2,570,000	8
Lake Winnebago, Wisconsin	501,000	2
Lower Fox, Wisconsin	486,000	1
Little Calumet-Galien, Illinois, Indiana, Michigan	641,000	2
Pike-Root, Illinois, Wisconsin	393,000	1
Milwaukee, Wisconsin	870,000	3
St. Joseph, Indiana, Michigan	5,140,000	16
Black-Macatawa, Michigan	590,000	2
Kalamazoo, Michigan	2,130,000	7
Upper Grand, Michigan	1,790,000	6
Maple, Michigan	1,090,000	3
Lower Grand, Michigan	1,960,000	6
Thornapple, Michigan	975,000	3
Pere Marquette-White, Michigan	1,140,000	4
Muskegon, Michigan	1,580,000	5
Manistee, Michigan	775,000	2
Betsie-Platte, Michigan	459,000	1
Boardman-Charlevoix, Michigan	957,000	3
Manistique, Michigan	446,000	1
Brevoort-Millecoquins, Michigan	176,000	1
Total	32,517,000	100

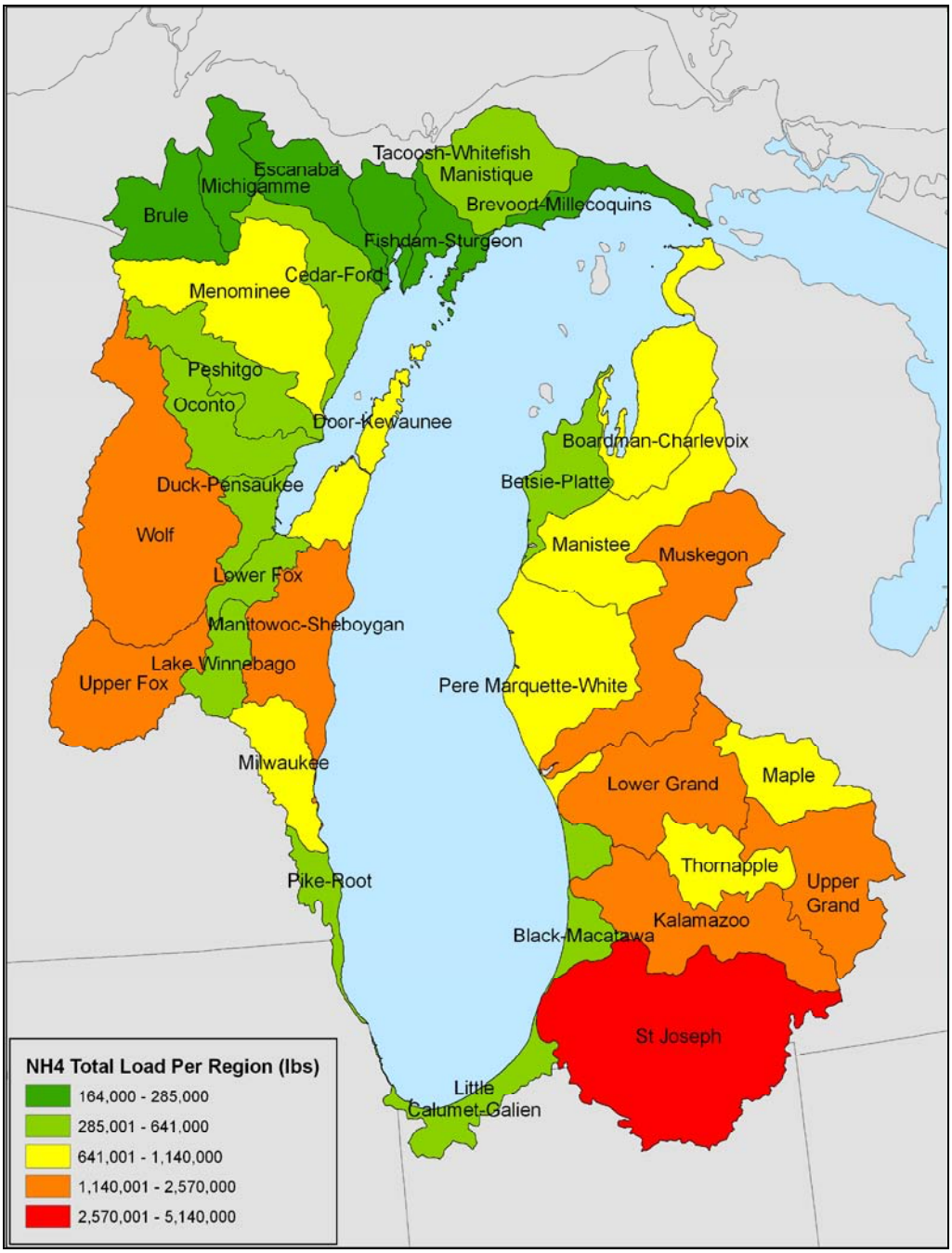

Figure 5-8 Estimated NH_4^+ Loads from Runoff
Source: EPA BASINS Model Run

5.5.3 Mercury

Nonpoint source mercury loads come from atmospheric deposition, urban runoff via tributaries, and sediment resuspension.

Rough estimates of annual mercury loads to Lake Michigan derived from published studies and from the BASINS model are presented below. The procedures used to obtain these estimates are summarized here. A literature review was conducted to identify existing estimates of annual NSP mercury loads to Lake Michigan. The Lake Michigan Mass Balance Project provided estimates of total atmospheric mercury deposition to Lake Michigan and mercury loadings via tributaries. These estimates were compared with those derived in the current study by using NADP deposition rates to estimate loads from wet atmospheric deposition and the BASINS model to estimate watershed loads.

Atmospheric Deposition. Sources of mercury emissions that contribute to atmospheric deposition include fuel combustion, vehicle emissions, mining, and industrial sources. An ambient air monitoring program in which the Michigan Department of Environmental Quality, the Minnesota Pollution Control Agency, and the Wisconsin Department of Natural Resources developed and used quantitative tools to identify sources of mercury to the atmosphere found that in the two study states that border Lake Michigan (Michigan and Wisconsin), the greatest contributions to atmospheric mercury emissions were from fuel combustion (about 3,300 lb/yr, or 73% of total annual mercury emissions in Michigan and about 2,800 lb/yr, or 43% of total annual mercury emissions in Wisconsin) (Morgan et al. 2003). Industrial sources contributed the next highest amounts—about 509 lb/yr, or 11% of total annual mercury emissions, in Michigan and about 2,300 lb/yr, or 35% of total annual mercury emissions, in Wisconsin. Mobile sources contributed about 268 lb/yr, or 6% of total annual mercury emissions, in Michigan and about 1,200 lb/yr, or 19% of total annual mercury emissions, in Wisconsin. Table 5-11 shows the contributions of individual sources within these general categories.

The same study identified several other fugitive mercury emission sources in the Great Lakes area—auto shredders, fluorescent light bulb recyclers, hospital waste facilities, scrap yards, and thermometer manufacturers. Table 5-12 shows the upwind and downwind concentrations of mercury that were measured near these facilities.

Table 5-11 Estimated Anthropogenic Mercury Air Emissions in Michigan and Wisconsin 1999

	Michigan		Wisconsin	
Emission Source Categories	**Emissions (lb/yr)**	**% of State Total**	**Emissions (lb/yr)**	**% of State Total**
FUEL COMBUSTION				
Coal Combustion				
Electric utilities	2,591	56.7	2,284	35
Residential	6	<1	1	<1
Industrial/commercial	134	2.9	221	3
Coke Combustion				
Electric utilities			46	1

Emission Source Categories	Michigan Emissions (lb/yr)	Michigan % of State Total	Wisconsin Emissions (lb/yr)	Wisconsin % of State Total
LPG Combustion				
Residential			11	<1
Natural Gas Combustion				
Electric utilities	6	<1	1	<1
Industrial/commercial	238	5.2	22	<1
Residential	91	2	33	<1
Oil Combustion				
Electric utilities	61	1.3	0	<1
Industrial/commercial	92	2	53	1
Residential	88	1.9	8	<1
Solid Waste Combustion				
Electric utilities			7	<1
Industrial/commercial			93	1
Wood combustion				
Electric utilities	4	<1	0	<1
Industrial/commercial	5	<1	55	1
FUEL COMBUSTION TOTAL	**3,316**	**72.5**	**2,836**	**43**
INCINERATION				
Hospital waste	6–10	<1		
Municipal waste	176	3.8	188	3
Sewage	162	3.5		
INCINERATION TOTAL	**348**	**7.6**	**188**	**3**
INDUSTRIAL SOURCES				
Brick manufacturing	1	1		
Cement manufacturing	67	1.5	9	<1
Chlor-Alkali production			1,082	16
In-process fuel use			17	<1
Landfill area			1	<1
Lime manufacturing			13	<1
Miscellaneous manufacturing			153	2
Miscellaneous site remediation			946	14
Pulp and paper			48	<1
Secondary Metal production			46	<1
Steel manufacturing (electric arc furnaces)	104	2.3		
Natural gas production	2	< 1		
Secondary metal production	332	6.6		
Thermometer manufacturing	3	<1		
Unclassified			8	<1
INDUSTRIAL SOURCE TOTAL	**509**	**11.1**	**2,324**	**34.5**
AREA SOURCES				
Cremation	10	<1	4	<1
Lamp manufacturing/breakage	69	1.5	31	<1
AREA SOURCE TOTAL	**132**	**2.8**	**35**	**0.5**

Emission Source Categories	Michigan		Wisconsin	
	Emissions (lb/yr)	% of State Total	Emissions (lb/yr)	% of State Total
MOBILE SOURCES				
On road	262	5.7	1,046	16
Nonroad	6	<1	175	3
MOBILE SOURCE TOTAL	**268**	**5.7**	**1,221**	**19**
TOTAL Mercury Air Emissions	**4,573**	**100**	**6,604**	**100**

Source: Morgan et al. 2003

Table 5-12 Comparative Mercury Concentrations near Mercury Emissions Sources in Michigan, Minnesota, and Wisconsin

Facility	State	Upwind Concentration (ng/m^3)	Downwind Concentration (ng/m^3)	Comments
Auto shredder	MI	2-3	60-200	
Demolition landfill	MN	2-3	1-97	Dusty site and gusty winds
Fluorescent bulb recycler	MI	2-3	10-50 (30 m downwind)	>1,000 from dumpsters with waste glass
Hospital waste autoclave	MI	2-3	60-260	
Hospital waste Incinerator	MI	2-3	20	
Mercury recycling facility	WI	2-3	>1,400	
Oil refinery	MN	1-3	No change	
Scrapyard	MN	1-3	15-50	100 in hot spots
Thermometer manufacturer	MI	2-3	15-50	>50,000 from vents

Source: Morgan et al. 2003

Runoff. Typical sources of nonpoint source mercury in runoff in the Lake Michigan Basin include roads, parking lots, and landfills. Research indicates that several factors influence whether mercury that is deposited to watersheds or tributaries will be transported to the lake itself. The principal factors that affect mercury loading to the aquatic ecosystem include the following:

- Amount of annual precipitation;
- Influence of the urban air plume (in terms of local deposition of the contaminated plume);
- Storms and other events, such as snowmelt, that influence stream flow and the resuspension of particle-bound mercury in sediments; and
- Prevailing land use.

Some of these factors appear to influence the amount of mercury in throughfall (i.e., precipitation that has washed through the forest canopy) and litterfall (i.e., fallen leaves) as well as the amount of mercury that is sequestered in organic soils, preventing its transport through the watershed (EPA 2000a).

Mercury Deposition Rates and Loads. In 2000, EPA published its Third Report to Congress on the deposition of air pollutants to the Great Waters (EPA 2000a).[14] In discussing mercury emissions in that report, EPA reported results from Pirrone et al. (1998), who estimated atmospheric emissions and deposition of mercury in North America and compared these estimates to vertical profiles of mercury accumulation rates in sediment cores from four Great Lakes sites. The results of that analysis illustrate that atmospheric deposition remains a significant contributor of mercury to the Great Lakes, although a variety of other sources (including direct discharges) also contribute to mercury inputs. Based on sediment core data and emissions estimates, Pirrone et al. calculated the atmospheric deposition flux of mercury to North America to be between 14.3 and 19.8 $\mu g/m^2/yr$ (1.43 to 1.98 $ng/cm^2/yr$), whereas in the Great Lakes region, the atmospheric deposition flux of mercury was calculated to be higher, at 135 $\mu g/m^2/yr$ (13.5 $ng/cm^2/yr$). This difference is likely due to local anthropogenic emissions and subsequent deposition of mercury in the Great Lakes region. Furthermore, mercury accumulation rates in sediment cores from the Great Lakes from pre-industrial to modern times increased from 0.7 to 235 $ng/cm^2/yr$ in Lake Ontario, from 0.8 to 65 $ng/cm^2/yr$ in Lake Michigan, and from 3 to 175 $ng/cm^2/yr$ in Lake Erie. All of these values are larger than those reported in sediment cores from small remote lakes in the northeastern United States, indicating that mercury from local and regional sources is deposited in the Great Lakes region rather than simply from the regional background in the northeastern United States.

In the 1990s, federal, state, and academic scientists evaluated Lake Michigan-wide contaminant transport for four pollutants, one of which was mercury.[15] The Lake Michigan Mass Balance Project (LMMBP) was a coordinated effort to monitor tributary and atmospheric pollutant loads, develop source inventories of toxic substances, and evaluate the fates and effects of these pollutants in Lake Michigan. LMMB results indicate that atmospheric loadings contributed about 1,600 lb/yr (729 kg/yr) or 80% of the total annual mercury loads to Lake Michigan, based on data collected in the mid-1990s (Table 5-13). This modeling effort indicated that the Chicago/Gary urban area was responsible for at least 19% of the total atmospheric deposition to Lake Michigan (Landis 1998). It should be noted that reactive mercury deposition is not included in this estimate of the urban influence, and, thus, the percentage likely represents an underestimate of the true impact of the Chicago/Gary urban area (EPA 2000a).

[14] The Clean Air Act directed EPA, in cooperation with the National Oceanic and Atmospheric Administration, to identify and assess the extent of atmospheric deposition of air pollutants to the Great Lakes, the Chesapeake Bay, Lake Champlain, and coastal waters, collectively known as the Great Waters, and for EPA to report its findings to Congress in periodic reports.

[15] The others were polychlorinated biphenyls, trans-Nonachlor, and atrazine.

Table 5-13 Preliminary Estimates of Total Atmospheric Mercury Deposition to Lake Michigan

Deposition	Annual Total (kg)	Annual Mean ($\mu g/m^2$)
Wet	614 ± 186	10.6 ± 3.2
Aerosol dry	69 ± 38	1.2 ± 0.7
Reactive gaseous mercury	506	8.8
Dissolved gaseous mercury reemitted to atmosphere	–460	–8.0
Total	729	12.6

Source: EPA 2000a

Of the 409 lb/yr (186 kg/yr) of mercury in tributary loadings, the highest amounts came from the Fox, Kalamazoo, St. Joseph, and Grand watersheds (see Figure 5-9).

Mercury loadings via tributaries to the lake were also evaluated as part of the LMMB project. As reported in Hurley et al. (2000), full-scale sampling of 11 tributaries whose watersheds account for about 55% of the Lake Michigan drainage basin was conducted during two hydrologic years, from March 1994 through October 1995. Hurley et al. discuss the riverine concentrations and fluxes of total mercury and methylmercury (shown in Table 5-14 as Hg_T and MeHg, respectively). Because inorganic mercury has been shown to be converted to the bioaccumulative methylmercury form in watersheds, the importance of specific tributaries in delivering the bioaccumulative form of mercury to nearshore regions of Lake Michigan was also assessed. During 1995, all 11 study tributaries were also sampled for methylmercury.

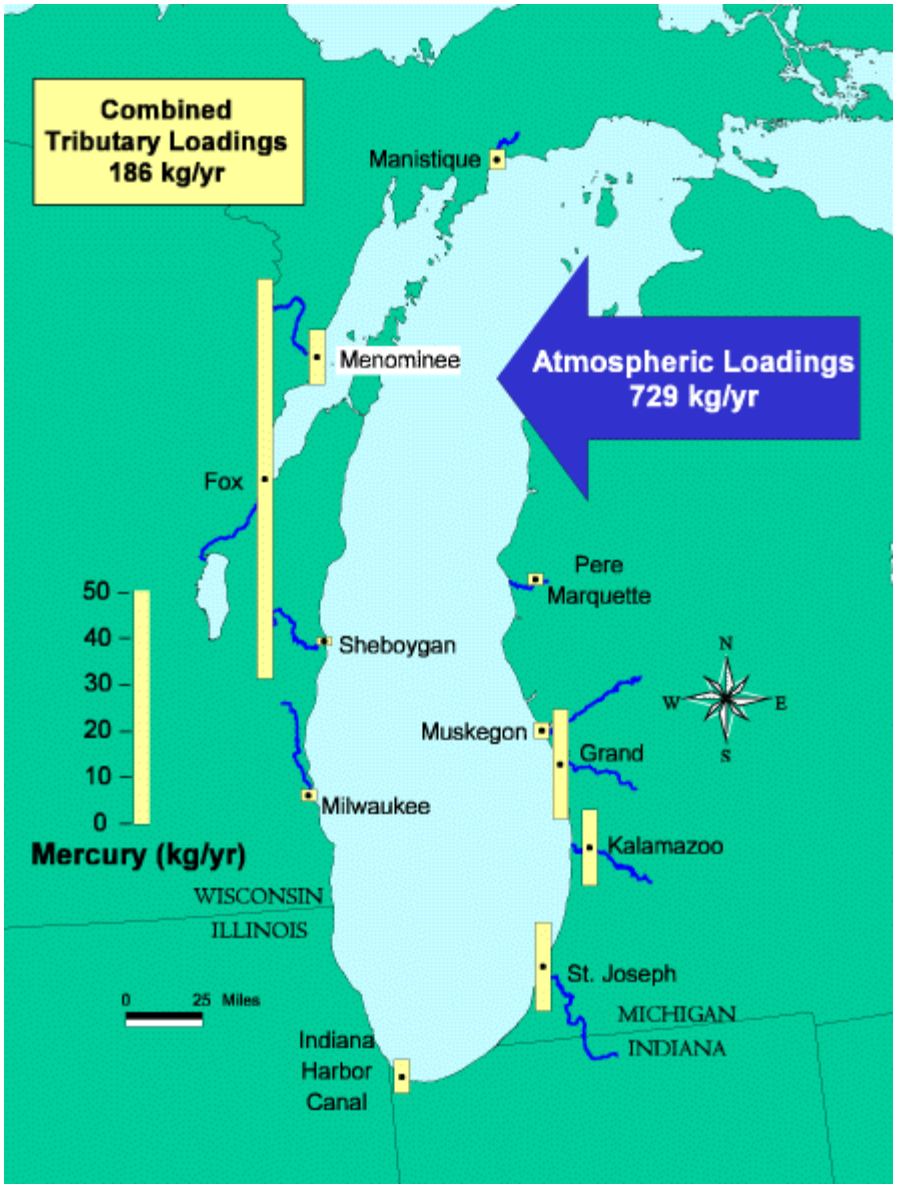

Figure 5-9 NSP Mercury Loads to Lake Michigan Based on LMMB Study
Source: EPA 2006a

Table 5-14 Watershed Characteristics, Mercury Concentrations, and Estimated Loads for 11 Lake Michigan Tributaries, 1995

	Drainage Area (km^2)	*Land Use/Land Cover*				Samples (n)	*Mean Conc*			Estimated Load	
Tributary		Urban	Agric	For.	Wet.		Hg_T (ng L^{-1})	MeHg (ng L^{-1})	% as MeHg	lb/yr	%
Fox (Lower Fox)	16,429 (1,135)	2.8 (16.9)	52.0 (76.2)	26.4 (3.5)	13.0 (0.7)	18	21.9	0.162	0.74	168.0	45%
Grand	14,395	5.5	75.5	13.9	3.7	21	3.82	0.111	2.91	70.3	19%
Grand Calumet River/Indiana Harbor Ship Canal	179	78.2	1.5	3.0	6.2	9	10.23	0.050	0.48	14.7	4%
Kalamazoo	5,125	6.1	75.1	12.6	4.2	17	10.94	0.150	1.37	34.6	9%
Manistique	3,798	0.3	5.1	50.1	39.7	12	3.88	0.119	3.07	7.7	2%
Menominee	10,556	0.7	7.1	73.0	16.4	12	4.02	0.242	6.02	19.2	5%
Milwaukee	2,259	21.7	66.2	7.0	3.7	21	4.51	0.150	3.33	2.4	1%
Muskegon	7,092	2.8	33.4	47.8	11.2	12	0.98	0.086	8.78	6.2	2%
Pere Marquette	1,775	0.7	17.2	71.4	8.4	14	2.42	0.112	4.63	4.2	1%
Sheboygan	1,089	3.8	80.7	6.6	7.6	21	5.45	0.360	6.61	1.5	0%
St. Joseph	12,155	5.5	80.5	9.3	2.4	16	5.32	0.106	1.99	42.8	12%
Total Load										371.6	

Note: Values of watershed components for the Fox River are expressed both as an entire watershed and the Lower region from Lake Winnebago to Green Bay.
Sources: Hurley et al. 2000 for concentration data, EPA 2000c for loading data

The highest concentrations of total mercury occurred in the Fox River Basin (21.9 ng/L). The next highest concentrations were found in the industrialized Indiana Harbor Ship Canal and Kalamazoo tributaries (10.3 and 10.9 ng/L, respectively). In contrast to total mercury concentrations, concentrations of methylmercury were not highest in the anthropogenically influenced sites. The lowest methylmercury concentrations (in all 11 tributaries studied) were in the Indiana Harbor Ship Canal. Hurley et al. (2000) suggest that although total mercury concentrations were elevated, the form of mercury in these contaminated sites was not available for transformation to the bioaccumulative methylmercury form. They also note that the results suggest differing reactivities of total mercury in contrasting watersheds. They report that wetlands are significant sites of mercury methylation and that forested regions can also contribute to methylmercury inputs. They say that in addition to using simple watershed coverages to explain mercury dynamics, it is most likely important to consider hydrologic flow paths and connectivity of specific land cover types to the main river channel. The authors note that despite elevated total mercury levels in the Indiana Harbor Ship Canal, where particles contain over 1 μg/g mercury on a dry weight basis, relatively little methylmercury is produced.

Taken together, the above results suggest substantially different reactivities of inorganic mercury among tributaries (Hurley et al. 2000).

The 1972 Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada committed the two countries to address the water quality issues of the Great Lakes. "To restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem," the United States and Canada agreed to develop and implement, in consultation with state and provincial governments, Lakewide Management Plans (LaMPs) for open waters and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). The LaMPs are intended to identify the critical pollutants that affect the beneficial uses and to develop strategies, recommendations, and policy options to restore the beneficial uses. The Clean Water Act holds EPA accountable for the Lake Michigan LaMP. In the Lake Michigan LaMP it issued in 2000, EPA (2000c) summarized findings regarding mercury loadings to Lake Michigan. The report discussed some of the same studies reported above, as well as some other pertinent findings, which are summarized below.

EPA (2000c) reported estimated mercury loads from the same 11 Lake Michigan tributaries addressed in the LMMB study. Those loads ranged from 1.5 lb/yr (Sheboygan) to 168 lb/yr (Fox) (Table 5-14). It also reported that although loadings in a given tributary may be high, the amount of mercury that actually reaches the lake may be significantly lower. According to EPA, despite higher total mercury concentrations in the Fox River and Indiana Harbor, the St. Joseph and Kalamazoo Rivers appear to be dominant in terms of total mercury flux to the open waters of Lake Michigan. Although the Fox River was observed to discharge, by far, the highest loads of mercury, these loads are primarily deposited in the Green Bay estuary and not the lake proper. Nearshore particle sinks (such as Green Bay) combined with a relatively short residence time for mercury in the water column limit the amount of tributary load that actually reaches the lake.

Role of Sedimentation. Because mercury may be released from sediments and resuspended in water, contaminated sediments are a source of nonpoint source mercury in the lake. Hurley et al. (1998) reported on another study in which they investigated the transport and partitioning processes of total mercury in the Fox River, the area with by far the highest mercury concentrations of the 11 tributaries previously mentioned. Hurley et al. noted that the Lower Fox River (the portion of the Fox-Wolf River drainage basin located between Lake Winnebago and the mouth at Green Bay) has the highest density of paper mills in the world. They also note that EPA has listed the Lower Fox River as an AOC. On the basis of sampling of water and sediments in the Fox River and at the mouth of the river, they found that total mercury concentrations increased downstream from Lake Winnebago to the mouth at Green Bay and that most of this was in the particulate phase. The increasing water column total mercury concentrations and the particulate enrichment downstream were consistent with trends in total mercury in sediment levels in the river. They suggested that resuspended sediments were likely the predominant source of mercury from the Fox River into Green Bay. They also found that despite the elevated total mercury concentrations, methyl mercury concentrations were relatively low, suggesting limited bioavailability of total mercury associated with sediments.

Few if any additional studies have been identified that estimate mercury loads to Lake Michigan since those conducted, largely as part of the LMMB study, in the mid 1990s. Therefore, we used two separate approaches to provide an indication of the estimated contribution of runoff to Lake Michigan nonpoint source mercury loads: (1) running EPA's BASINS model to estimated loads from runoff and (2) using NADP deposition rates to estimate loads from wet atmospheric deposition.

Loading estimates derived from EPA BASINS Model. As explained above in Section 5.4.2, the latest version of EPA's BASINS model can be used to estimate NSP loads on a watershed basis. We used the export-coefficient approach in BASINS to estimate mercury NSP loads to the Lake Michigan Basin (see Appendix C for the mercury export coefficients that were used). The results of this application indicate that 321,420 lb of mercury is released to Lake Michigan watersheds annually (Table 5-15 and Figure 5-10). The watersheds with the highest nonpoint source mercury loadings were the St. Joseph (11%), Wolf (8%), Muskegon (6%), Kalamazoo (5%), and Lower Grand (5%). Others with relatively high contributions include the Manitowoc-Sheboygan, Upper Grand, Manistee, and Boardman-Charlevoix (each contributing about 4% to the total load). As previously noted, not all of the load that is generated in the watersheds can be expected to reach the lake, so these estimates should be considered upper bounds.

Table 5-15 Estimated Mercury Loads to Lake Michigan Using BASINS

Watershed, State	Mercury Load	
	Pounds	Percent of Total
Manitowoc-Sheboygan, Wisconsin	11,600	4
Door-Kewaunee, Wisconsin	5,360	2
Duck-Pensaukee, Wisconsin	3,360	1
Oconto, Wisconsin	6,810	2
Peshitgo, Wisconsin	7,700	2
Brule, Michigan, Wisconsin	6,870	2
Michigamme, Michigan	4,680	1
Menominee, Michigan, Wisconsin	15,200	5
Cedar-Ford, Michigan	6,440	2
Escanaba, Michigan	6,160	2
Tacoosh-Whitefish, Michigan	4,310	1
Fishdam-Sturgeon, Michigan	3,710	1
Upper Fox, Wisconsin	11,000	3
Wolf, Wisconsin	24,500	8
Lake Winnebago, Wisconsin	4,310	1
Lower Fox, Wisconsin	4,270	1
Little Calumet-Galien, Illinois, Indiana, Michigan	7,870	2
Pike-Root, Illinois, Wisconsin	5,450	2
Milwaukee, Wisconsin	8,850	3
St. Joseph, Indiana, Michigan	34,900	11
Black-Macatawa, Michigan	4,620	1

Watershed, State	Mercury Load	
	Pounds	Percent of Total
Kalamazoo, Michigan	15,500	5
Upper Grand, Michigan	13,900	4
Maple, Michigan	6,280	2
Lower Grand, Michigan	15,400	5
Thornapple, Michigan	5,980	2
Pere Marquette-White, Michigan	14,600	5
Muskegon, Michigan	18,600	6
Manistee, Michigan	12,800	4
Betsie-Platte, Michigan	5,700	2
Boardman-Charlevoix, Michigan	11,500	4
Manistique, Michigan	9,430	3
Brevoort-Millecoquins, Michigan	3,760	1
Total	321,420	100

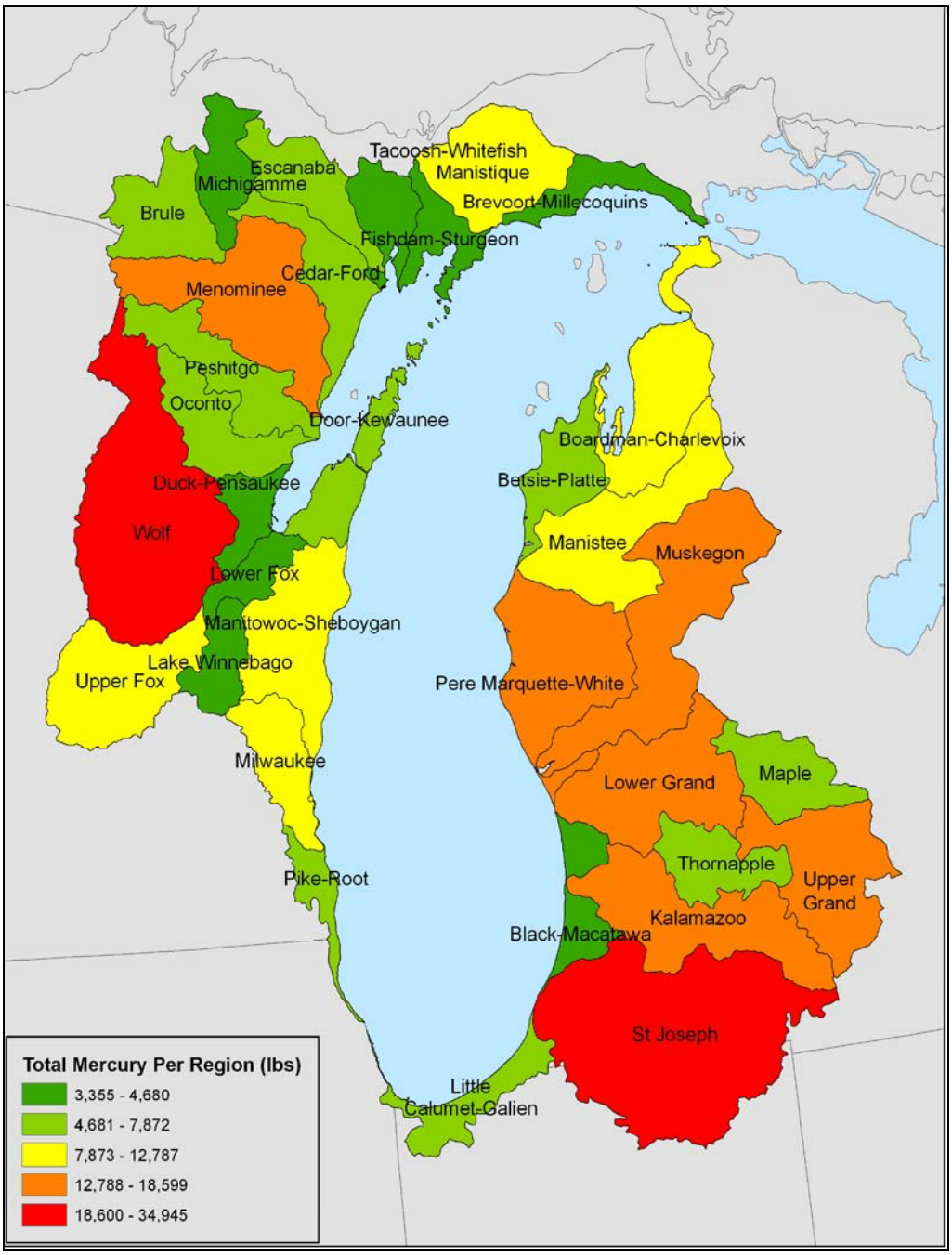

Figure 5-10 Estimated Mercury Loadings Based on EPA's BASINS Model
Source: EPA BASINS Model Run

Estimated Loads from Wet Deposition. Nationwide estimates of mercury wet deposition rates for 2007 as prepared by the NADP are shown in Figure 5-11. The figure shows there are two ranges of mercury deposition rates for Lake Michigan. In the northern portion, the range is 6-8 µg/m^2, and in the southern portion, the range is 8-10 µg/m^2. Assuming that the average deposition rate is 7 µg/m^2 (0.04 lb/mi^2) for the northern half, and 9 µg/m^2 (0.05 lb/mi^2) for the southern half, and that each half contains roughly 11,200 mi^2, the annual load of mercury from wet deposition is estimated at 1,021 lb.

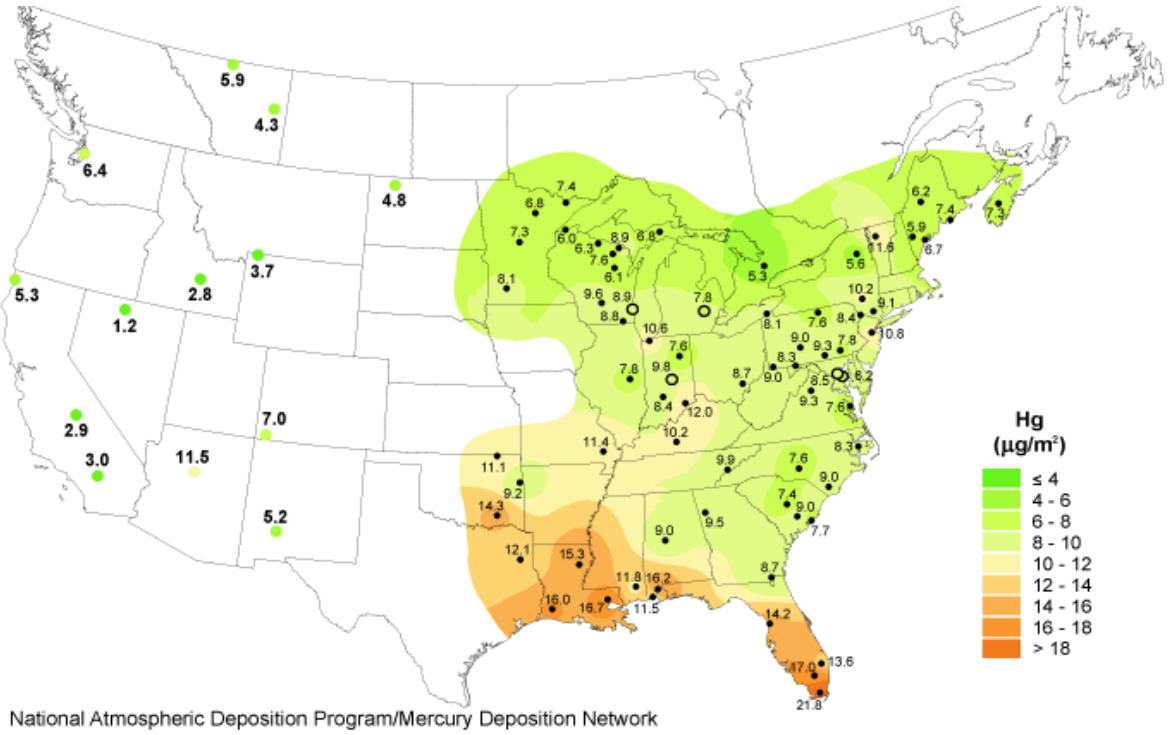

Figure 5-11 Total Mercury Wet Deposition, 2007
Source: NADP 2009

5.5.4 Selenium

The primary known sources of environmental selenium contamination include coal, phosphate, and metal mining; fly ash from coal combustion; petroleum refining; natural geologic processes; municipal landfills; and irrigation drainage (Michigan DEQ 2009). In the Lake Michigan Basin, selenium is released to the air from fossil fuel (coal and oil) combustion and from metals smelting and refining. Other sources of selenium emissions in the Lake Michigan Basin include glass manufacturing, electronics and electrical manufacturing, milling operations, duplicating equipment, pigments, fungicides, and solid waste (EPA 2000c) The Lake Michigan LaMP reported that in 1994, 0.93 ton of selenium was deposited as dry deposition from sources in Chicago, Illinois, and Gary, Indiana, and that these loads were estimated to be 2-10 times those of other regional sources in the Lake Michigan area. Contaminated sediments are considered nonpoint sources of selenium, because selenium is released from them and resuspended in the water.

A literature search was conducted to identify studies that provided estimates of selenium NSP loads directly or that contained data useful in developing such estimates. No studies provided direct estimates, but data on selenium concentrations from three atmospheric deposition monitoring stations were used to provide rough annual NSP estimates. Details on this approach are provided below.

Sweet et al. (1998) measured the concentrations of selenium in precipitation and on airborne particles at three Integrated Atmospheric Deposition Network (IADN) monitoring stations on Lakes Superior, Michigan, and Erie during 1993 and 1994 to estimate annual wet and dry deposition fluxes at these sites. Because the sites were selected to measure regional atmospheric inputs to the lakes rather than local, urban-influenced inputs, the selected monitoring sites were within 1 km of the shore in areas where prevailing winds come off the lake. The Lake Michigan IADN monitoring station is located about 100 meters above and 1 km east of the lake on property that is part of Sleeping Bear Dunes National Lakeshore, operated by the National Park Service.

The study found that wet deposition of metals is more closely related to precipitation amount than to the concentration of metals in the precipitation, and that dry deposition fluxes are controlled by the concentration of trace metals on large particles. The study estimated dry deposition of selenium to Lake Michigan to be 52 $\mu g/m^2/yr$ and wet deposition to be 520 $\mu g/m^2/yr$. Converting these estimates to pounds per year (i.e., 0.296 $lb/mi^2/yr$ for dry and 2.96 $lb/mi^2/yr$ for wet deposition, and multiplying by the surface area of Lake Michigan (22,400 mi^2) produces an estimated annual deposition of about 72,900 lb of selenium (6,630 lb dry and 66,300 lb wet). These estimates can be considered conservative because they do not include indirect deposition. Also, as noted, the monitoring station for Lake Michigan is located far from urban, industrialized areas that likely contribute relatively significant amounts of selenium emissions to the air; these urban emissions may not be reflected in the deposition rates measured at the station.

Because the BASINS model does not include selenium as one of the pollutants for which loads are estimated, we were unable to use it to estimate selenium loads to the lake.

5.5.5 Vanadium

Vanadium is a major trace element found in fossil fuels, and thus nonpoint sources of vanadium include atmospheric deposition of emissions from fossil fuel combustion. The vanadium metal industry, as well as iron and steel, chemical, and phosphate industry operations, may also contribute to nonpoint source vanadium pollution, as may sewage sludge and animal waste disposal. Vanadium emitted from various sources is believed to return to the earth as particulate fallout or as dissolved constituents in rainwater (Abassi et al. 1998). Nonpoint sources of vanadium resulting from atmospheric deposition can show seasonal patterns, with wide peaks in deposition during the winter months resulting from the use of vanadium-enriched heating oil between October and April (Gelinas and Schmit 1998).
The literature was reviewed for estimates of vanadium NSP loading to Lake Michigan, as well as for data that could be used to make such estimates. Finding no estimates of annual NSP

vanadium loads, information on dry and wet deposition rates of vanadium were used to estimate annual atmospheric deposition of that metal to Lake Michigan. The approach used for making these estimates is described below. The BASINS model does not contain data for vanadium and therefore was not used to estimate annual vanadium loads to the lake.

In their 1998 study to estimate wet and dry deposition rates (described in Section 5.5.4 of this report), Sweet et al. estimated dry deposition for vanadium to Lake Michigan to be 69 $\mu g/m^2/yr$ and wet deposition to be 72 $\mu g/m^2/yr$. Converting these estimates to lb/yr (i.e., 0.39 $lb/mi^2/yr$ for dry and 3.93 $lb/mi^2/yr$ for wet deposition and multiplying by the surface area of Lake Michigan (22,400 mi^2) produces an annual deposition estimate of about 96,800 lb of vanadium (8,810 dry and 88,000 wet.) These estimates can be considered conservative in that they do not include indirect deposition, nor do they likely reflect the higher urban concentrations that probably occur in the more industrialized and urban parts of the Lake Michigan Basin.

In 1998, Gelinas and Schmit estimated bulk atmospheric deposition of vanadium (and other major and trace elements) to a rural watershed in Canada. In their study, which was aimed at identifying the influence of contributions from resuspension (e.g., agricultural soil and road dust resuspension, direct emissions from vehicle use, and small towns) on the background regional fluxes, they estimated that the background atmospheric deposition rate for vanadium was 0.38 $mg/m^2/yr$. By converting this value to $lb/mi^2/yr$ (2.2 $lb/mi^2/yr$), we estimate that the annual deposition to the 44,800-mi^2 Lake Michigan Watershed is about 97,000 lb.

Gelinas and Schmit (1998) also found that (at nonbackgound deposition sites) the average deposition rate for agricultural sites was 1.43 $mg/m^2/yr$, and the average deposition rate for greater Montreal sites (e.g., urban areas) was 2.85 $mg/m^2/yr$. By using these rates, we estimate the agricultural deposition component to be 161,000 lb (assuming 19,712 mi^2 of agricultural land in the Lake Michigan Watershed, or 44% of the total watershed area) and the urban deposition component to be 6,480 lb (assuming 400 mi^2 of urban area in the watershed). The total annual nonpoint source vanadium load from these three components (background, agricultural, and urban) is estimated to be 264,500 lb. This estimate should be considered an upper bound, because the actual amount of the vanadium deposited in the watershed that actually enters the lake is unknown.

5.6 NSP Summary

Nonpoint source pollution contributes significant quantities of TSS, ammonia, mercury, selenium, and vanadium to Lake Michigan. Primary sources include runoff (agricultural and urban), atmospheric deposition (wet and dry, indirect and indirect) and sediments. Thirty-three watersheds drain the 44,800-mi^2 Lake Michigan Basin. Land use in the basin is roughly 44% agriculture, 41% forest, 9% residential, and 6% other.

In this study we have reported some very rough estimates of the annual NSP loads of the five target pollutants to the lake. These loads are based on estimates (1) reported in previous studies of portions or all of Lake Michigan; (2) extrapolations from studies of NSP in other locations; and (3) the results of running EPA BASINS model to estimate NSP loads by watershed. The estimated loads from these sources are shown in Table 5-16.

Table 5-16 Summary of Annual NSP Load Estimates to Lake Michigan

Pollutant	Estimated Annual Load (lb)	Notes
TSS	3,360,000,000 – 27,500,000,000	• Low value is based upon application of land-use-specific annual TSS loading rates derived from the SPARROW model (Schwarz 2008) • A mid range estimate (4,120,000,000) is based on application of zone-specific loading rates (Robertson et al. 2006) and of St. Joseph watershed-specific loading rates (Kieser and Associates 2003) • High value is based on application of EPA BASINS model
Ammonia	32,500,000 – 52,500,000	• Low value is based on application of EPA BASINS model • High value is based on application of NH_4+ regional deposition rates from NADP and extrapolation of gaseous ammonia deposition rates from other areas to Lake Michigan (Scudlark et al. 2001 and Anderson et al. undated)
Mercury	2,000 – 322,400	• Low value from mid-1990s LMMB study; 1,600 lb from atmospheric deposition and 409 lb from tributaries • High value based on (1) application of EPA's BASINS model, resulting in 321,420 lb/yr from runoff, plus (2) application of NADP deposition rates, resulting in 1,021 lb/yr from wet deposition. Note that not all of the runoff component will necessarily reach the lake
Selenium	72,900	• Direct deposition to lake (66,300 lb from wet deposition, plus 6,630 lb from dry deposition) based on deposition rates derived by Sweet et al. (1998)
Vanadium	96,800– 264,500	• Low value is from direct deposition to lake (88,300 lb from wet deposition, plus 8,810 lb from dry deposition) based on deposition rates derived by Sweet et al. (1998) • High value is based on extrapolating derived Canadian background, agricultural, and urban vanadium deposition rates (Gelinas and Schmit 1998)

Chapter 6 Discussion

The target pollutants (TSS, ammonia, mercury, selenium, and vanadium) can enter Lake Michigan from many sources. Chapter 4 presents the detailed discharge data for point source pollutants from a selected group of 381 significant industrial and municipal facilities for all of the target pollutants. Chapter 5 provides a review of nonpoint sources and makes estimates for loadings of the target pollutants. This chapter offers an overview of the study area and tries to place the loadings into context. This chapter also offers discussion on the uncertainty of the assumptions, data, and analyses used to generate estimates.

6.1 Comparison of Quantified Sources

Table 6-1 provides a comparison of the point source loads (represented by the average DMR data, and for vanadium both the average DMR data and the TRI data) and the lower end of the range of nonpoint source loads, as estimated at the end of Chapter 5. The last column of Table 6-1 calculates the ratio between the two values. In all cases the nonpoint source loading is larger than the point source loading. If the midpoint or upper end of the range for the nonpoint source estimate had been used rather than the lower end of the range, the ratios of nonpoint source to point source loads would be considerably larger.

Table 6-1 Comparison of Point and Nonpoint Source Loads to Lake Michigan

Pollutant	Average Point Source Estimate (lb/day)	Average Nonpoint Source Estimate – Lower End of Range (lb/day)	Ratio of Nonpoint Source Estimate to Point Source Estimate
TSS	120,520	9,205,479	76 to 1
Ammonia	16,755	89,041	5.3 to 1
Mercury	0.049	5.5	112 to 1
Selenium	3.6	199.7	55 to 1
Vanadium	10.1 (35.4[a])	265.2	26 to 1 (7.5 to 1[a])

[a] The vanadium value in parentheses is taken from the TRI data set rather than from the DMR data set.

6.1.1 TSS

The TSS load is dominated by the nonpoint source contributions. The nonpoint source lower end estimate is 76 times larger than the point source load. If the upper end of the nonpoint source range was used for comparison, the nonpoint source load would be more than 600 times larger than the point source load.

TSS discharges from nonpoint sources tend to be intermittent, with large releases occurring during heavy precipitation and minimal releases occurring other times. With some exceptions, point source discharges for TSS are relatively consistent. EPA (2005) suggests that the average TSS concentration in urban runoff (presumably averaged over the duration of the rain event) is 80 mg/L. In the event of a 0.5-inch rainfall over a 1-mi^2 area with the assumption that half of the stormwater runs off (and that the other half infiltrates, evaporates, or is captured and treated), the total runoff volume would be 8.7 million gallons, or 32.8 million liters. If TSS averages

80 mg/L, the total runoff load would be 2,627 kg/mi^2, or about 5,780 lb/mi^2. If an urban/suburban area covers 20 mi^2, the resulting runoff from a 0.5-inch rainfall would be similar to the average daily point source discharge from the entire study area.

As a point of context, it is useful to demonstrate how much material is represented by the daily point source load of 120,520 lb/day. Water weighs 8.33 lb/gal. The specific gravity of soils is about 2.6. Therefore, a gallon of soil weighs about 21.7 lb. The daily point source load represents a solids load equivalent to 5,554 gallons of soil. A typical household trash can holds 30 gallons; this quantity of soil would fill about 185 trash cans each day. In this context, the TSS load spread across the entire study area should not have much effect on overall water quality. Locally, however, large loadings of solids can smother stream/river/lake beds and harm the aquatic plants and animals that live there.

6.1.2 Ammonia

The ammonia nonpoint source lower end estimate is 5.3 times larger than the point source load. If the upper end of the nonpoint source range was used for comparison, the nonpoint source load would be about 8.5 times larger than the point source load.

These comparisons can be misleading. Ammonia affects water quality two ways. At high enough concentrations, it can cause toxic conditions. A direct comparison of point source ammonia to nonpoint source ammonia is relevant for the toxic impacts of ammonia. However, the second water quality effect of ammonia is more relevant for the lake ecosystem. Ammonia is a nitrogen compound. It can be converted in the water body to other forms of nitrogen (e.g., to nitrate or nitrite). All of these nitrogen forms are nutrients that can contribute to eutrophication of the water body. In the nutrient context, it is more appropriate to compare the total nitrogen load from point and nonpoint sources rather than just the ammonia loads. The nonpoint source total nitrogen load is likely to be far higher than the nonpoint source ammonia load. No lake-wide estimates were made for total nitrogen. However, in the Phase I study (Veil et al. 2008), the nonpoint source load for total nitrogen was 28,000 lb/day compared to the nonpoint source load for ammonia of 619 lb/day (45 times larger). Very few NPDES permits place limits on total nitrogen, so it is not possible to generate a good estimate for a total nitrogen point source load.

6.1.3 Mercury

The mercury nonpoint source lower end estimate is 112 times larger than the point source load. If the upper end of the nonpoint source range was used for comparison, the nonpoint source load would be more than 17,000 times larger than the point source load.

Although nonpoint sources are almost certainly much larger than point sources, the actual ratio of the sources may be misleading because many point source dischargers have not yet begun sampling of the discharges for mercury. Issues relating to monitoring, reporting, and entering point source concentrations for mercury in units of ng/L were discussed in Section 3.3.2. More extensive and robust data are becoming available as permit limits and monitoring requirements on mercury become effective.

6.1.4 Selenium

The selenium nonpoint source estimate is 55 times larger than the point source load. Unlike the case for four other target pollutants, the nonpoint source estimate for selenium is available as just a single number rather than a range.

This comparison should not be taken as a highly accurate estimate, however. The point source load for selenium is based on only nine values. Other facilities are discharging selenium too, but are not required to monitor selenium through their NPDES permits.

6.1.5 Vanadium

The vanadium nonpoint source lower end estimate is 26 times larger than the point source load derived using DMR data. When compared to the larger point source load estimate from the TRI data set, the nonpoint source load is just 7.5 times larger than the point source load.

If the upper end of the nonpoint source range was used for comparison, the nonpoint source load would be about 71 times larger than the point source load derived using DMR data. When compared to the larger point source load estimate from the TRI data set, the nonpoint source load is about 20 times larger than the point source load.

As discussed for selenium in the previous section, the vanadium comparison should not be taken as a highly accurate estimate. The point source load for vanadium is based on only five values. Other facilities may be discharging vanadium too, but are not required to monitor vanadium through their NPDES permits. The separate point source estimate derived from TRI data is approximately 3.5 times larger than the point source estimate derived using the DMR data. While this may provide a better estimate of point source vanadium loads, the actual point source load for vanadium is unknown, primarily because the NPDES permit program rarely evaluates vanadium in discharges.

6.2 Other Unquantified Sources

Using the available data and literature, this study has generated loading estimates for some of the target pollutants. Some of the pollutants (e.g., selenium and vanadium) are not monitored frequently in either point or nonpoint discharges. Even though point source loading estimates were generated for those pollutants, they were based on only a few data points. The actual total point source loading is probably higher, but without data, it cannot be accurately estimated.

Several other examples of contributing sources that have not been quantified are described below.

6.2.1 TSS

A source of TSS not included in these estimates is resuspension of sediments. Wind and wave action or scouring from vessel propeller wash can cause sediments to become resuspended in the

water column. Although these are not new releases of sediment, they may affect aquatic organisms in a manner similar to new releases.

6.2.2 Ammonia

Animal excrement is a ubiquitous source of nitrogen. Chapter 5 mentions livestock manure and pet droppings. Other sources of animal waste include fish waste released in the water column and bird and wildlife droppings released on land. These sources are not quantified but could represent a sizable load of nitrogen, some of which will be in the form of ammonia. Anecdotally, gatherings of seagulls on the roofs or parking lots of manufacturing facilities have caused runoff to show elevated nitrogen and BOD.

6.2.3 Metals

Many urban water bodies have received decades of industrial and municipal discharges that have caused metals to accumulate in the nearby sediments. As the overlying water column becomes cleaner over time, some of those metals may be released from sediments back to the water column.

The hydrologic cycle between ground and surface waters may shift throughout the year as local rainfall causes the water table to rise and fall. During some times of the year, surface water can infiltrate through the bed of the water body and enter shallow groundwater. At other times of the year, if surface flows are low, the groundwater can exfiltrate through the bed of the water body back into the surface water. If a surface water body is located near a source of groundwater contamination, it is possible that groundwater exfiltration can contribute metals to the surface water.

Neither of these mechanisms lends itself well to data collection. The interchanges undoubtedly occur at certain locations and times, but it is not possible to quantify them.

6.3 Uncertainty

The loading estimates shown in Table 6-1 are based on many assumptions and extrapolations. The estimates start with data that have varying degrees of precision and accuracy.

6.3.1 Point Source Uncertainty

The individual facility point source data, especially the DMR data, can be considered accurate representations of releases to Lake Michigan. They are based on multiple discrete samples from well-defined locations. For TSS and ammonia, where many of the facilities have data values in the DMR data set, the point source loading totals appear to be comprehensive and representative. The study was designed to include all or most of the significant dischargers in the analysis.

When averaging data values at a single facility over time or adding data from multiple facilities to form composite load estimates, one or a few data points much higher than normal can skew the average and maximum for an entire data set. The most obvious example in this study was the

very high TSS value reported for facility IND-IN-006, which apparently was a valid measurement. However, in some cases, these are clearly analytical or entry errors.

The total of the maximum values is an overestimate because the maximum values from different facilities did not occur during the same month. It was not possible within the scope of this study to compile data separately for each month in 2007 and calculate the month with the highest maximum load.

More than a third of all the point source facilities reported mercury discharges. However, mercury data contain two sources of uncertainty. First, until the past few years, the mercury analytical method commonly used had a detection level so high that many samples were reported as <DL. More recently issued permits specify use of analytical methods capable of detecting and thus reporting mercury at lower levels. Second, as discussed in Section 3.3.1, more recently issued permits require mercury monitoring. To the extent that at least some of the permits did not require mercury monitoring during all of 2007 (the year of focus for this study), those facilities were characterized by one or only a few actual data points.

Most permits do not require monitoring for vanadium and selenium. At some of the facilities whose permits did require monitoring for metals, a high proportion of the results were reported as <DL. This presents a challenge in accurately characterizing average metals discharges for those facilities.

Even if the metals are present in the discharge, the lack of monitoring data prevents including entries in the database for those facilities.

6.3.2 Nonpoint Source Uncertainty

Because nonpoint sources are not typically regulated through formal programs, no routine, ongoing monitoring data are available. Most often, nonpoint source discharge data are generated through targeted one-time or infrequent research programs. Data are collected from a few sampling points and are extrapolated to make estimates for larger geographic areas.

As nonpoint source information was compiled from the literature, which already had been subject to the original authors' assumptions and extrapolation, an additional layer of assumptions and extrapolation was added. This may compound the uncertainty but is the only practical approach that could be used to generate estimates under the time and budget constraints of the study.

Chapter 7 Findings and Conclusions

7.1 Findings

Both point and nonpoint sources contribute loads of the target pollutants to the Lake Michigan watershed.

7.1.1 Point Sources

- NPDES program data, particularly the results from the DMRs, are useful in developing point source loadings discharged to Lake Michigan. Target pollutants that are monitored frequently provide a higher level of data robustness compared to those that are not yet being monitored with consistent frequency (i.e.., the metals).

- NPDES program managers from Illinois, Indiana, Michigan, and Wisconsin provided lists of all municipal and industrial facilities discharging to the Lake Michigan region. The lists included 2,341 point source discharges with permits. To limit detailed evaluation to those discharges that had more than modest levels of the target pollutants, various screening methods were used to remove facilities from the final list. The final combined list from the four states that received detailed evaluation included 381 facilities. That list of facilities composed the loadings database.

- TSS data were readily available from 375 of the 381 facilities in the database. Ammonia data were available from 290 of the facilities. Mercury data were available from 146 of the facilities. For the other two target pollutants (selenium and vanadium), only a few facilities reported DMR data. The resulting composite loadings are displayed in Table 7-1.

Table 7-1 Summary of Point Source Data from DMR Data Set

Source Type	TSS avg lb/day	TSS max lb/day	NH3 avg lb/day	NH3 max lb/day	Hg avg lb/day	Hg max lb/day	Se avg lb/day	Se max lb/day	V avg lb/day	V max lb/day
Composite Loading of All Municipal Facilities	56,050	208,483	14,824.8	56,565.6	0.024876	0.062761	0.131	0.425	0.183	0.458
Composite Loading of All Industrial Facilities	64,469	350,801	1,930.7	6,996.2	0.023851	0.052192	3.437	7.746	9.919	37.279
Total Composite Loading	120,520	559,284	16,755.4	63,561.8	0.048727	0.114953	3.567	8.171	10.102	37.737

- Data from the permit limits data set and the application data set showed mixed agreement with the DMR data set.

- Because the DMR data set reflects actual monitoring of the discharges during 2007, it is probably the best source of data for estimating point source loadings.

- The TSS average and maximum loading data reflect the very strong influence of a single facility that had unusually high TSS discharges during one month.

- Data collected from the TRI system generally do not compare well with NPDES data because only a few industrial facilities and no municipal facilities reported TRI releases of the target pollutants to surface waters. However, because the DMR data set for vanadium had only a few data values, and the TRI vanadium compounds data set provided a larger loading estimate, the TRI data set reported for vanadium compounds was a valid substitute for the DMR data set.

7.1.2 Nonpoint Sources

- Nonpoint source pollution contributes significant quantities of TSS, ammonia, mercury, selenium, and vanadium to Lake Michigan. Primary sources include runoff (agricultural and urban), atmospheric deposition (wet and dry, indirect and indirect), and sediments.

- Thirty-three watersheds drain the 44,800-mi^2 Lake Michigan Basin. Land use in the basin is roughly 44% agriculture, 41% forest, 9% residential, and 6% other.

- Very rough estimates of the annual NSP loads of the target key pollutants to the lake were developed. These loads are based on estimates (1) reported in previous studies of portions or all of Lake Michigan; (2) extrapolations from studies of NSP in other locations; and (3) the results of running EPA BASINS model to estimate NSP loads by watershed. The estimated loads from these sources are shown in Table 7-2.

Table 7-2 Estimated Annual and Daily NSP Loads to Lake Michigan

Pollutant	Estimated Annual Load (lb)	Estimated Daily Load (lb/day)
TSS	3,360,000,000 – 27,500,000,000	9,205,479 – 75,342,466
Ammonia	32,500,000 – 52,500,000	89,041 – 143,836
Mercury	2,000 – 322,400	5 – 883
Selenium	72,900	200
Vanadium	96,800– 264,500	265 – 725

7.2 Conclusions

Point and nonpoint source data are compared in Table 7-3.

Table 7-3 Point and Nonpoint Source Loading Data

Pollutant	Composite Total of Facility Average Loads (lb/day)	Composite Total of Facility Maximum Loads (lb/day)	Average Nonpoint Source Estimate – Lower End of Range (lb/day)	Ratio of Nonpoint Source Estimate to Point Source Estimate
TSS	120,520	559,284	9,205,479	76 to 1
Ammonia	16,755	63,562	89,041	5.3 to 1
Mercury	0.049	0.135	5.5	112 to 1
Selenium	3.6	8.2	200	55 to 1
Vanadium	10.1 (35.4[a])	37.7	265.2	26 to 1 (7.5 to 1[a])

[a] The vanadium value in parentheses is taken from the TRI data set rather than from the DMR data set.

- The projected TSS, mercury, selenium, and vanadium loads to the Lake Michigan watershed from nonpoint sources are at least one order of magnitude higher than the point source loads, even when the lower end estimates are used for nonpoint sources.

- If the higher end estimates are used for nonpoint sources, the ratio between nonpoint and point sources becomes considerably higher.

- The nonpoint source ammonia load is only 5.3 times higher than the point source load.

- Many other sources of pollutants that remain unquantified or poorly quantified (e.g., urban runoff, combined sewer overflows, groundwater exfiltration into surface water bodies, sediment re-release of metals into the overlying water column, excrement from birds and fish) make substantial contributions of the target pollutants.

- Many different facilities discharge significant point source loads of the target pollutants. Although large municipal and industrial facilities typically discharge larger quantities than smaller facilities, no single facility discharges the highest load of all the target pollutants.

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Appendix A. Watersheds of the Lake Michigan Basin

Table A-1 Watersheds of the Lake Michigan Basin

Watershed	Number Name	Area (mi^2)	Identified Nonpoint Concerns[a]	Dominant Land Cover	Stressors, Primary Contaminants[b]
Subregion 0403 -- Northwestern Lake Michigan: The drainage into Lake Michigan from the Milwaukee River Basin boundary to the Manistique River Basin boundary. Michigan, Wisconsin. Area = 18,700 mi^2					
	Accounting Unit 040301 -- Northwestern Lake Michigan: The drainage into Lake Michigan from the Milwaukee River Basin boundary to the Manistique River Basin boundary, excluding the Fox River Basin. Michigan, Wisconsin. Area = 12,400 mi^2				
	04030101 **Manitowoc-Sheboygan, WI**	1650	Runoff from specific and diffuse sources, particularly upland erosion, or erosion from fields that are not adjacent to streams, contaminated sediment, channelization and dams, construction site erosion.	Farmland – 77%, forest – 11%	Nonpoint source pollution. Runoff has degraded water quality throughout the basin. Mercury in impaired waters. Suspended solids are a primary contaminant.
	04030102 **Door-Kewaunee, WI**	776		Farmland – 65%, forest – 18%, wetlands – 11%	
	04030103 **Duck-Pensaukee, WI**	483	Green Bay is the only urbanized area in the watershed.	Farmland – 66%, forest – 22%, wetlands – 6% 35 miles of shoreline	
	04030104 **Oconto, WI**	1040		Forest – 49%, farmland – 28%, wetlands – 19% ~ 5 miles of shoreline	Mercury in impaired waters.
	04030105 **Peshtigo, WI**	1170	The watershed flows into Green Bay in Wisconsin.	Forest – 53%, farmland 21%, wetlands 21%	Mercury in impaired waters.
	04030106 **Brule, MI, WI**	1060		Forest – 59%, wetlands – 27%, farmland – 10%	
	04030107 **Michigamme, MI**	734	Michigamme River system flows into the Menominee River watershed.	Forest – 66%, wetlands – 25%	Mercury in impaired waters.

Watershed		Number Name	Area (mi^2)	Identified Nonpoint Concerns[a]	Dominant Land Cover	Stressors, Primary Contaminants[b]
		04030108 **Menominee, MI, WI**	2310	The Menominee River forms the boundary between Wisconsin and the Upper Peninsula of Michigan in Marinette, Florence, Forest, Vilias, Menominee, Dickinson, and Iron counties before draining its contents into Lake Michigan.	Major economic activities are logging, paper making, tourism, and potato farming.	Mercury, sediments, nonpoint pollution.
		04030109 **Cedar-Ford, MI**	1010		Wetlands – 48%, forest – 38%, farmland -11% 53 miles of shoreline	
		04030110 **Escanaba, MI**	935		Forest – 47%, wetlands 42%, farmland, 4%	Mercury in impaired waters.
		04030111 **Tacoosh-Whitefish, MI**	656	Upper Peninsula of Michigan	Wetland – 45%, forest – 43%, farmland 8%	
		04030112 **Fishdam-Sturgeon, MI**	556		Wetlands – 59%, forest – 39%, farmland – 7% 53 miles of shoreline	Mercury in impaired waters.
		04030201 **Upper Fox, WI**	1610		Farmland – 62%, forest – 23%, wetlands, 9%	Nonpoint source pollution. Water quality problems from contaminated sediments, runoff in urban and agricultural areas.
		04030202 **Wolf, WI**	3720	Forested and relatively undeveloped	Farmland – 43%, forest - 37%, wetlands 14%	Mercury in impaired waters.

Watershed		Number Name	Area (mi^2)	Identified Nonpoint Concerns[a]	Dominant Land Cover	Stressors, Primary Contaminants[b]
		04030203 **Lake Winnebago, WI**	570	Over 200 square miles of the watershed are lakes, the largest being Lake Winnebago. The watershed is located between the Upper and Lower Fox Rivers in Wisconsin. The eastern portion of the watershed was selected as a nonpoint source priority watershed project in 1989. The primary goals of this watershed project are to reduce phosphorus and sediment loading to Lake Winnebago and decrease the loading of heavy metals from urban nonpoint sources.	Farmland – 53%, water 36%, developed 4%, forest 4%	
		04030204 **Lower Fox River, WI**	438	The Lower Fox River originates at the outlet of Lake Winnebago and flows northeast for 39 miles, where it empties into the bay of Green Bay. The Lower Fox River has the most paper mills of any river in the world. Lower Fox Basin contains the highest concentration of dairy cows in the State of Wisconsin	Farmland – 73%, developed 17%, forest 7%	Primary contaminants and stressors include mercury, suspended solids, urban and rural runoff, water quality problems from contaminated sediment, runoff in urban and agricultural areas. Ammonia and sediment in impaired waters.
Subregion 0404 -- Southwestern Lake Michigan. The drainage into Lake Michigan from the St. Joseph River Basin boundary to and including the Milwaukee River Basin. Illinois, Indiana, Michigan, Wisconsin. Area = 1970 mi^2						
	Accounting Unit 040400 -- Southwestern Lake Michigan, IL, IN, MI, WI; Area = 1970 mi^2					
		04040001 **Little Calumet-Galien, IL, IN, MI**	705	Urban areas include Chicago, Gary, Michigan City, Hammond, Portage, and Valparaiso. 90% of the river's flow originates as municipal and industrial effluent, cooling and process water and stormwater overflows.	Farmland – 40%, forest – 28%, developed – 18%, wetlands – 8% More than 113 miles of shoreline on the west side of Lake Michigan.	Mercury, ammonia in impaired waters, mercury-contaminated sediments. Suspended solids as a primary contaminant.

Watershed		Number Name	Area (mi^2)	Identified Nonpoint Concerns[a]	Dominant Land Cover	Stressors, Primary Contaminants[b]
		04040002 **Pike-Root (Waukegan) IL,WI**	399	The watershed stretches from south of Milwaukee to north of Chicago. It includes the cities of Racine and Kenosha, WI and Waukegan, IL. The Waukegan River, which is part of the basin, is the only river in Illinois that flows into Lake Michigan.	While over 50% of the watershed is used for agricultural purposes, 30% is urbanized.	Mercury in impaired waters.
		04040003 **Milwaukee. WI**	861	High urban density. Runoff from specific and diffuse sources, contaminated sediment, habitat modifications (such as channelization and dams) have degraded water quality throughout the basin.	Farmland 59%, developed 18%, forest – 15%. 35 miles of shoreline	Urban and rural runoff are identified stressors. Mercury and ammonia in sediments.
Subregion 0405 -- Southeastern Lake Michigan: The drainage into Lake Basin to and including the Grand River Basin, IN, MI. Area = 12800 mi^2						
	Accounting Unit 040500 -- Southeastern Lake Michigan. Indiana, Michigan. Area = 12800 mi^2					
		04050001 **St. Joseph, IN, MI**	4670	The St. Joseph River Watershed is located in the southwest portion of the Lower Peninsula of Michigan and northwestern portion of Indiana. It spans the Michigan-Indiana border and empties into Lake Michigan at St. Joseph, Michigan.	Farmland – 72%, forest – 17%, wetlands – 6%, developed – 4%	Mercury and ammonia in impaired waters.
		04050002 **Black-Macatawa, MI**	600	There is excess sedimentation due to nonpoint sources, mainly agricultural, in the Macatawa watershed and its tributaries. Soil erosion and sedimentation is a major problem throughout due to agricultural land use and urbanization and has modified drainage patterns, increased direct surface runoff and erosion.	Farmland 55%, forest – 31%, developed – 5%	Soil erosion and sedimentation.
		04050003 **Kalamazoo, MI**	2030		Farmland – 59%, forest – 27%, wetlands – 7%, developed – 4%	Stressors and primary contaminants include suspended solids, mercury, urban and rural runoff. Mercury in impaired waters.

Watershed		Number Name	Area (mi^2)	Identified Nonpoint Concerns[a]	Dominant Land Cover	Stressors, Primary Contaminants[b]
		04050004 **Upper Grand, MI**	1730	Three urban areas – Landing, East Lansing, Jackson	Farmland – 65%, forest – 29%, wetlands – 8%	Mercury in impaired waters.
		04050005 **Maple, MI**	924	Feeds into the Lower Grand River	More than 81% agricultural, forest – 12%	
		04050006 **Lower Grand, MI**	1990		Farmland – 59%, forest – 27%, developed – 6%, wetlands – 6%	Mercury in impaired waters.
		04050007 **Thornapple, MI**	874	The Thornapple River watershed flows into the Lower Grand River watershed.	Farmland – 67%, forest – 25%, wetlands – 5% No shoreline	Mercury in impaired waters.
Subregion 0406 -- Northeastern Lake Michigan-Lake Michigan: the drainage into Lake Michigan from the Grand River Basin boundary to and including the Manistique River Basin, and Lake Michigan, including its Bays and Islands. IL, IN, MI, WI; Area = 33,600 mi^2						
	Accounting Unit 040601 -- Northeastern Lake Michigan: The drainage into Lake Michigan from the Grand River Basin boundary to and including the Manistique River Basin. Michigan. Area = 11300 mi^2					
		04060101 **Pere Marquette-White, MI**	2100		Forest – 57%, farmland – 22%, wetlands – 19% 90 miles of shoreline	Stormwater nonpoint pollution, erosion. Sediments, industrial contamination. Mercury in impaired waters.
		04060102 **Muskegon, MI**	2680	The Muskegon River Watershed is one of the of the largest watersheds in the State of Michigan and spans across the better part of nine counties.	Vegetated – 48%, cultivated – 26%, wetlands – 15% < 10 miles of shoreline	Mercury, NPS pollution.
		04060103 **Manistee, MI**	1970		Forest – 89%, farmland – 10%; less than half of mile of shoreline	Mercury
		04060104 **Betsie-Platte, MI**	819		Forest – 55%, farmland – 13%, grassland – 11%, wetlands – 10%	Mercury, sedimentation.

Watershed		Number Name	Area (mi^2)	Identified Nonpoint Concerns[a]	Dominant Land Cover	Stressors, Primary Contaminants[b]
		04060105 **Boardman-Charlevoix, MI**	1480		forest – 50%, farmland – 18%, wetlands – 13%, grassland – 10% 217 miles of shoreline	
		04060106 **Manistique, MI**	1650		Wetlands – 51%, forest – 37% grassland – 17% <0.5 mile of shoreline	Mercury in impaired waters.
		04060107 **Brevoort-Millecoquins, MI**	578		Forest – 45%, wetlands – 41%, farmland – 5% 102 miles of shoreline	
	Accounting Unit 040602 -- Lake Michigan: Lake Michigan, including its bays and islands. IL, IN, MI, WI; Area = 22300 mi^2					
		04060200 -- **Lake Michigan. IL, IN, MI, WI.**	22,300			
		Chicago Area Waterway System		The Chicago River once flowed into Lake Michigan. To facilitate a reversal of the flow of the Chicago River to divert water from Lake Michigan to the Chicago Area Waterway System (CAWS), the Chicago Sanitary and Ship Canal, the Calumet-Sag Channel, and the North Shore Channel were constructed.		

[a] From EPA 2008b

[b] From EPA 2008b, not all identified primary contaminants and stressors are included; only those targeted for this study (ammonia, mercury, selenium, vanadium, sedimentation), and nonpoint pollution if identified by LaMP.

Appendix B. Models Used to Estimate NSP Loads

The Simple Method. An empirical approach developed to estimate pollutant export from urban development sites in the Washington, D.C., area, this loading function model estimates stormwater pollutant loads by multiplying the annual runoff by the average pollutant concentration in the runoff. The user can calculate loads for specific land-use types (e.g., residential, commercial, industrial, roadway) or general types, such as new suburban areas, older urban areas, or highways.

The approach requires the following information:

Pollutant-specific stormwater runoff concentration. (Stormwater pollutant concentrations can be estimated from local or regional data or from national data sources.)
Watershed drainage area or area of the site.
Percent of the area that is impervious. (Different impervious percentages are used for different land uses within the area.)
Annual precipitation.

The general formula for calculating annual stormwater load is:
$L = R * C * A * F$
Where:
L = Annual load (lb)
R = Annual runoff (inches)
C = Pollutant concentration (mg/L)
A = Area (acres)
F = Unit conversion factor

Annual runoff (R) is calculated according to the formula:
$R = P * P_j * Rv$
Where:
R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

The runoff coefficient is calculated by using the equation:
$Rv = 0.05 + 0.009(I)$
Where:
I is the percent of site imperviousness

The simple method works best for small areas (less than a square mile). Therefore, while conceptually straightforward, the simple method would not be an optimal approach for estimating NSP loads from the entire Lake Michigan Watershed and was therefore not used in this analysis.

Spreadsheet Tool for Estimating Pollutant Load (STEPL). STEPL is another relatively simple model. Developed by EPA, this model is used by several states to calculate nutrient and sediment

loads from different land uses and the load reductions that would result from the implementation of various best management practices. The model uses simple algorithms to estimate nutrient and sediment loads caused by runoff, erosion, and sedimentation from different land uses. It computes surface runoff, nutrient loads, and sediment delivery based on various land uses and management practices. Nonpoint sources include cropland, pastureland, farm animals, feedlots, urban runoff, and failing septic systems. Conceptually, STEPL would be appropriate for estimating NSP loads to Lake Michigan. However, detailed data (e.g., county, nearest weather station, acreage for individual land-use types, numbers and types of agricultural animals, and septic system data) must be entered at the watershed level. Furthermore, the only pollutant load estimate made by STEPL that correlates with the BP target pollutants is sediment. Because of these limitations, STEPL was not used to estimate NSP loads in this analysis.

Generalized Watershed Loading Functions (GWLF). Developed by Cornell University as "a compromise between the empiricism of export coefficients and the complexity of chemical simulation models" the GWLF is a loading function model that simulates runoff and sediment delivery based on land use by using the curve number, Universal Soil Loss Equation, and average nutrient concentrations. Although suitable for generalized watershed loading estimation, the model requires detailed data (e.g., daily precipitation and temperature, groundwater seepage coefficients, sediment delivery ratios; urban nutrient accumulation rates, dissolved nutrient concentrations in runoff, and solid-phase nutrient concentrations in sediment.) Furthermore, as with STEPL, the only target pollutant for which the GWLF provides estimates is sediment. As a consequence, the GWLF was not used to estimate NSP loads in this analysis.

Soil and Water Assessment Tool (SWAT). SWAT is a watershed model developed for the USDA-Agricultural Research Service (USDA-ARS) to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time. SWAT does not use regression equations to characterize the relationships between input and output variables. Rather, it is a physically based model that requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring over the watershed. It uses the information to model the physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. The model has been applied widely to study hydrology, nonpoint source pollution, and TMDLs since early 1990s. However, its focus is on pesticides, nutrients, and sediments—again not the target pollutants for this study. Further, it has extensive data requirements, including daily precipitation, maximum/minimum air temperature, solar radiation, wind speed, and relative humidity. In addition, a large watershed can be divided into hundreds of modeling units, requiring many hundreds of input files, which are difficult to manage and modify without a solid interface. For these reasons, SWAT was not investigated for further application to the study.

Agricultural Nonpoint Source Pollution (AGNPS) Model. AGNPS was developed by the USDA-ARS to estimate pollution loads from agricultural watersheds and to assess the effects of different management programs. AGNPS is an event-based model designed to simulate surface water runoff, nutrients, sediments, chemical oxygen demand, and pesticides from point and nonpoint sources of agricultural pollution. It predicts soil erosion and nutrient transport/loadings from agricultural watersheds for real or hypothetical storms. Erosion modeling is based on the

Universal Soil Loss Equation applied on a storm basis. The model's hydrology is based on the curve number technique. Each AGNPS elemental area, typically about 100 meters square, requires 22 parameters (coefficients) to describe its antecedent conditions, physical characteristics (e.g., soil type and slope steepness), management practices, and rainfall. Because it only simulates single events, has significant data requirements, operates at a small scale, and has limited coverage of the pollutants of interest in this study, AGNPS was not deemed appropriate for estimating NSP in this study.

Annualized Agricultural Nonpoint Source Pollution (AnnAGNPS) Model. AnnAGNPS is a continuous simulation watershed-scale program based on the single-event model AGNPS summarized above. AnnAGNPS simulates quantities of surface water, sediment, nutrients, and pesticides leaving the land areas and their subsequent travel through the watershed. Runoff quantities are based on runoff curve numbers, while sediment is determined by using a Revised Universal Soil Loss Equation. Special components are included to handle concentrated sources of nutrients (feedlots and point sources), concentrated sediment sources (gullies), and added water (irrigation). Output is expressed on an event basis for selected stream reaches and as source accounting (contribution to outlet) from land or reach components over the simulation period. There have been few application studies of the model. While AnnAGNPS can provide annualized load estimates (as opposed to its predecessor ANGNPS), its lack of ability to estimate NSP loads for the pollutants of interest in this report precluded it from use in this study.

Hydrological Simulation Program – FORTRAN (HSPF). HSPF is a comprehensive package for simulating watershed hydrology and water quality for conventional and toxic organic pollutants. With its predecessors dating back to the 1960s, HSPF is an integrated, basin-scale model that combines watershed processes with in-stream fate and transport in one-dimensional stream channels. HSPF simulates watershed hydrology, land and soil contaminant runoff, and sediment-chemical interactions. Pollutants interact with suspended and bed sediment through soil-water partitioning. Land processes for pervious and impervious areas are simulated through water budget, sediment generation and transport, and water quality constituents' generation and transport. Interception, infiltration, evapotranspiration, interflow, groundwater loss, and overland flow processes are represented by empirical equations. HSPF also simulates the in-stream fate and transport of a wide variety of pollutants, such as nutrients, sediments, tracers, dissolved oxygen/biochemical oxygen demand, temperature, bacteria, and user-defined constituents. The model requires extensive calibration, a high level of expertise for application, and detailed time series data inputs. While the model has been used successfully in numerous applications, including EPA's Chesapeake Bay Program management initiative, its objectives (and its attendant user expertise and data requirements) go way beyond the relatively simple needs of this study (i.e., estimating pollutant loads); it was therefore deemed inappropriate for use in the current study.

Storm Water Management Model (SWMM). Developed by EPA to analyze surface runoff and flow routing through complex urban sewer systems, SWMM is a dynamic rainfall-runoff simulation model that is applied primarily to urban areas and for single-event or continuous simulation. Flow routing is performed for surface and subsurface conveyance and groundwater systems, and the model has options for simulation, including traditional buildup and washoff formulation, rating curves, regression techniques, and the use of the Universal Soil Loss

Equation to simulate soil erosion. The need for detailed data requirements to be input by the user and the fact that the model is optimized for urban areas limit the applicability of the model for estimating loads from all land use types to Lake Michigan, and therefore was not used to estimate NSP in this study.

SPAtially Referenced Regression On Watershed Attributes (SPARROW). Developed by the USGS, SPARROW predicts long-term average values of water characteristics, such as concentrations and amounts of selected constituents that are delivered to downstream receiving waters. The SPARROW model combines the attributes of physical and empirical models; it incorporates nonlinear physically based functions, mass-balance requirements, and simulations of certain physical processes. It uses statistical methods to explain constituent mass or load in relation to upstream sources and watershed properties (soil characteristics, precipitation amounts, and land cover) that influence the transport of constituents to streams and their delivery to receiving water bodies. Water quality and streamflow data collected at numerous monitoring sites are used to estimate the annual load of a constituent that is transported by the stream. Geospatial data sets relate land use features with load estimates to provide information on constituent sources and natural factors that can affect fate and transport. The model was originally developed to assess nutrient-source contributions, transport, and water quality conditions. Subsequently the model has been used to simulate both nitrogen and phosphorous loadings at the national level. In 2007, SPARROW was used to estimate the spatial distribution of total dissolved solids. It has also been used recently to estimate annual TSS yields for specific land-use types (Schwarz 2008). The land-use specific yields estimated in Schwarz (2008) are used in conjunction with land use allocations reported by the Lake Michigan Mass Balance Study (EPA 2006a) and described in Section 5.2 of this report to estimate NSP TSS loads to Lake Michigan (see Section 5.1.1).

Mercury Loading Model. This model, developed by EPA, summarizes mercury loads from various sources in each subwatershed of a study area. It calculates sediment load, runoff, atmospheric deposition, and mercury concentration in watershed soils by using grid-based land use and elevation data. The model is more complex than a simple export-coefficient model that does not capture temporal variability, but not as complex as a detailed simulation model that attempts a mechanistic, time-dependent representation of pollutant load generation and transport. The model simulates precipitation-driven runoff and sediment delivery at a grid-based landscape. Solid loads from runoff are used to estimate pollutant delivery to the receiving water body from the watershed. This estimate is based on mercury concentrations in wet and dry deposition and processed by soils in the watershed and ultimately delivered to the receiving water body by runoff, erosion, and direct deposition. The mercury model requires the input of the appropriate wet and dry deposition rates or maps for mercury and the climate conditions of a watershed. It uses three major algorithms to calculate mercury load: (1) an erosion and sediment transport algorithm for the calculation of mercury load from sediment; (2) a hydrology algorithm for the calculation of mercury load from surface runoff, and (3) a chemistry algorithm for calculating mercury concentration in soil. The Mercury Loading model has been used to develop mercury TMDLs for the Middle and Lower Savannah River basins and many other areas in EPA Region 4. This model would apply to the current study in that it clearly addresses one of the key pollutants. However, current documentation was not available, and the model requires additional

GIS software, meaning that even downloading and testing the model for potential applicability was not feasible within the scope of the project and therefore was not used in this study.

PLOAD. PLOAD is a simplified GIS-based model that estimates annual average nonpoint loads of user-specified pollutants at the watershed level. Users can choose to calculate the NSP loads by using one of two methods: (1) the simple method approach or (2) an export-coefficient approach. If the simple method is chosen, PLOAD uses two equations to calculate the loads for each pollutant. First, a runoff coefficient (inches of runoff per inch of rain) is calculated on the basis of a user-supplied impervious factor (percent of imperviousness) for that land use type. Alternatively, the percent imperviousness can be extracted from the impervious terrain factor table that is part of the model. The pollutant load, in pounds, is then calculated as a function of the following inputs: precipitation (inches/year), ratio of storms producing runoff (default = 0.9), land-use-specific runoff coefficient (calculated in the first step), land-use-specific event mean concentration (EMC),[16] and area of specified land use. The precipitation and storm ratio values are entered by the PLOAD user interactively. The loading rates are derived from the EMC tables, while the land use areas are interpreted from the land use and watershed GIS data.

The second option, the export-coefficient approach, is provided for agricultural and undeveloped land uses or larger watersheds for which the simple method may not apply. In this approach, the average pollutant-specific NSP load in a watershed is calculated by multiplying an "export coefficient"—the amount of load of a specific pollutant (e.g., TSS) per unit area per time (e.g., pounds per acre per year)—by the land area. Export coefficients vary with type of land use (e.g., agricultural, urban, forest).

If the export-coefficient method is selected for calculating pollutant loads, then the pollutant-specific load (in pounds) is calculated for a specific watershed by summing, for each land use in the watershed, the product of the pollutant loading rate for that land-use type and the area of the land use type in the watershed. The loading rates are derived from export coefficient tables, which are contained in the modeling system. The land-use areas are interpreted from the land use and watershed GIS data, which are linked to the model. PLOAD requires/uses pre-processed GIS data for land use, watershed data, tabular data for pollutant loading rates, and impervious terrain factors. Additional refinement can be added by using relatively higher coefficients for areas (e.g., subwatersheds) that are closer to the receiving water body to account for different rates of capturing pollutants between the pollutant source and the receiving body. Because some pollutants tend to sorb to particulate material, loadings estimates can be adjusted by applying sediment delivery ratios, which relate the amount of sediment delivered to the water body to the size of the watershed. Outputs can be in maps or tables; PLOAD was designed to be generic so that it can be applied as a screening tool in a range of applications, including NPDES stormwater permitting, watershed management, or reservoir protection projects. PLOAD has been incorporated into EPA's BASINS model (described below), and it is used in this study (as part of BASINS) as a means for estimating NSP loads of TSS, ammonia, and mercury to Lake Michigan.

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[16] EMC is the average concentration of pollutant in runoff per storm event. The pollutant load for each storm event is the product of the EMC and the volume of runoff per average storm. The annual mass load of the pollutant is the product of the total mass load per rainfall and the average number of storm events per year. Alternative pollutant yield in pounds is based on the concentration of that pollutant per volume of stormwater runoff.

Better Assessment Science Integrating point and Nonpoint Sources (BASINS). EPA's Office of Water developed the BASINS environmental analysis system to support environmental and ecological studies in a watershed context. BASINS is a GIS-based system that integrates a suite of watershed and water quality models with different approaches. It includes national databases, assessment tools, a watershed delineation tool, classification utilities, and characterization reports. It also incorporates several watershed loading and transport models, such as HSPF, SWAT, and PLOAD. The system is designed to be flexible and to support a variety of scales. It uses the Windows environment and allows users to access national environmental data, apply assessment and analysis tools, run several calculations and processes through hundreds of iterations, and obtain results in the form of maps, charts, graphs, and reports in a relatively short time. Different models in the BASINS suite have different temporal scales; for example, the PLOAD export coefficient model provides NSP loadings on an annual basis for three of the five target pollutants (TSS, mercury, and ammonia). The BASINS system and most of its components have been used for many TMDL developments.

The latest version of BASINS (4.0) runs on a non-proprietary, open source GIS system architecture, so that users no longer need to purchase expensive GIS software to use the model. Access to data in 4.0 is Web-based; the user specifies the geographic area of interest, and the software downloads selected data from EPA, USGS, and other Internet locations. After the GIS data are downloaded, they are automatically extracted, projected to a user-specified map, and combined in a project file. Because of its ability to handle the large volumes of data needed to model NSP in the Great Lakes Basin, its ability to import the current data needed to run the NSP model (PLOAD), its user-friendly interface, its pollutant coverage (e.g., including TSS, mercury, and ammonia), its graphic output capabilities, and its proven use in a variety of applications, we have used the BASINS modeling system in this report to estimate NSP loads for TSS, ammonia, and mercury. The results of these estimations are provided in Sections 5.5.1, 5.5.2, and 5.5.3, respectively.

Appendix C. Export Coefficients Used in BASINS Model Runs to Estimate Loads from TSS, Mercury, and Ammonia

Table C-1 Export Coefficients Used in BASINS Model Runs to Estimate Loads from TSS, Mercury, and Ammonia (NH_4+) (in pounds per acre per year)

LAND USE	TSS	Mercury	NH_4+
Urban or Built-up Land	500.0	0.04	1.0
Residential	500.0	0.04	1.0
Commercial and Service	500.0	0.04	1.0
Industrial	500.0	0.04	1.0
Transportation, Communications, and Utilities	500.0	0.04	1.0
Industrial and Commercial Complexes	500.0	0.04	1.0
Mixed Urban or Built-up Land	500.0	0.04	1.0
Other Urban or Built-up Land	500.0	0.04	1.0
Agricultural Land	2,000.0	0.01	2.0
Cropland and Pasture	2,000.0	0.01	2.0
Orchards, Groves, Vineyards, Nurseries, Ornamental Horticultural	2,000.0	0.01	2.0
Confined Feeding Operations	2,000.0	0.01	2.0
Other Agricultural Land	2,000.0	0.01	2.0
Range Land	50.0	0.01	0.2
Herbaceous Rangeland	50.0	0.01	0.2
Shrub and brush Rangeland	50.0	0.01	0.2
Mixed Rangeland	50.0	0.01	0.2
Forest Land	50.0	0.01	0.3
Deciduous Forest Land	50.0	0.01	0.3
Evergreen Forest Land	50.0	0.01	0.3
Mixed Forest Land	50.0	0.01	0.3
Water	25.0	0.01	0.5
Streams and Canals	25.0	0.01	0.5
Lakes	25.0	0.01	0.5
Reservoirs	25.0	0.01	0.5
Bays and Estuaries	25.0	0.01	0.5
Wetland	25.0	0.01	0.5
Forested Wetland	25.0	0.01	0.5
Nonforested Wetland	25.0	0.01	0.5
Barren Land	20.0	0.01	0.2
Dry Salt Flats	20.0	0.01	0.2
Beaches	20.0	0.01	0.2
Sandy Area not Beaches	20.0	0.01	0.2
Bare Exposed Rock	20.0	0.01	0.2
Strip Mines Quarries, and Gravel Pits	20.0	0.01	0.2
Transitional Areas	20.0	0.01	0.2
Tundra	0.0	0.0	0.0
Shrub and Brush Tundra	0.0	0.0	0.0
Herbaceous Tundra	0.0	0.0	0.0
Bare Ground Tundra	0.0	0.0	0.0
Wet Tundra	0.0	0.0	0.0
Mixed Tundra	0.0	0.0	0.0
Perennial Snow or Ice	0.0	0.0	0.0

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