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Water-Resources-Related Information for the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, 1970–2002

Water-Resources Investigations Report 03–4240

U.S. Department of the Interior
U.S. Geological Survey

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By Morgan A. Schneider, Michelle A. Lutz, and Others

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Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

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Conversion Factors, Datums, and Abbreviated Water-Quality Units

Multiply	By	To obtain
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
cubic feet per second (ft^3/s)	0.02583	cubic meter per second (m^3/s)

Temperature, in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = [1.8(°C)] + 32.$$

Vertical datum: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water- and sediment-quality units: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L), micrograms per liter (µg/L), micrograms per gram (µg/g), or milligrams per cubic meter (mg/m^3). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million. One microgram per liter is equivalent to one milligram per meter cubed. Micrograms per gram (µg/g) is a unit expressing the concentration of chemical constituents in solution as weight (micrograms) of solute per unit mass (gram) of water.

Specific conductance is expressed in microsiemens per centimeter (µS/cm), the electrical conductivity of water measured between opposite faces of a centimeter cube of aqueous solution at a specified temperature.

List of Abbreviations

AO	Aesthetic Objective
as As	as quantified as measured arsenic
BOD	Biochemical oxygen demand (no duration implied)
BOD5	Biochemical oxygen demand, 5-day
as $CaCO_3$	as quantified as measured calcium carbonate
CCC	Criterion Continuous Concentration
as Cd	as quantified as measured cadmium
as Cl	as quantified as measured chloride
CMC	Criterion Maximum Concentration
as Cr	as quantified as measured chromium
as Cu	as quantified as measured copper
DO	dissolved oxygen
EPT	Ephemeroptera, Plecoptera, and Trichoptera
GIS	Geographic Information Systems
HBI	Hilsenhoff Biotic Index
as Hg	as quantified as measured mercury
IBI	Index of Biotic Integrity
IMAC	Interim Maximum Acceptable Concentration
IQR	Interquartile range
ISQG	Interim Sediment Quality Guideline
ISS	Inline Storage System ("the deep tunnel")
as K	as quantified as measured potassium
MAC	Maximum Acceptable Concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MMSD	Milwaukee Metropolitan Sewerage District
as N	as quantified as measured nitrogen
as Na	as quantified as measured sodium
as Ni	as quantified as measured nickel
as NO_3	as quantified as measured nitrate
as P	as quantified as measured phosphorus
PAHs	Polycyclic aromatic hydrocarbons
as Pb	as quantified as measured lead
PCBs	Polychlorinated biphenyls
PEC	Probable Effect Concentration
PEL	Probable Effect Level
PPCPs	pharmaceutical and personal care products
SC	specific conductance
SDWR	Secondary Drinking Water Regulation
SEWRPC	Southeastern Wisconsin Regional Planning Commission
SMCL	Secondary Maximum Contaminant Level
SQGs	Sediment Quality Guidelines
SRP	soluble reactive phosphorus
STORET	STOrage and RETrieval System
TEC	Threshold Effect Concentration
TSS	Total suspended solids
TTAL	Treatment Techniques Action Level
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOCs	Volatile organic compounds
WDNR	Wisconsin Department of Natural Resources
as Zn	as quantified as measured zinc

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Water-Resources-Related Information for the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, 1970–2002

By Morgan A. Schneider, Michelle A. Lutz, and Others

Abstract

The Milwaukee Metropolitan Sewerage District (MMSD) Corridor Study is a three-phase project designed to improve the understanding of water resources in the stream corridors of the MMSD planning area by initially compiling existing data and using the compiled information to develop 3-year baseline and long-term monitoring plans. This report is one of the products of Phase I of the Corridor Study.

A literature review of surface-water-quality, surface-water-quantity, and ecology studies conducted from 1970 through 2001 was completed and is summarized in this report. An inventory of Geographic Information System spatial coverages available for the MMSD planning area has been assembled.

A database of water, sediment, and tissue (fish, shellfish, and others) chemistry, macroinvertebrates, fish, algae, habitat, geomorphic, and other physical and ecological data was compiled from data sets from MMSD, U.S. Geological Survey, Wisconsin Department of Natural Resources, and the U.S. Environmental Protection Agency. More than 2.7 million results are available in the MMSD Corridor Study database and the compilation of multiple datasets allows for retrieving data from a central database rather than from each of the source datasets. Data for 1970 through 2002 were collected for the 420-square-mile planning area by various agencies using different field data-collection and laboratory-analysis methods. Chemical constituents and ecological components that are important to an urban setting and well represented in the database were selected for further investigation. Each constituent or component is described in this report with some or all of the following: a text summary, map of sampling locations, and in some cases median concentrations, statistical distributions of concentrations by subwatershed, table of summary statistics by subwatershed, and graphs of temporal and (or) seasonal trends.

Physical data presented in the report include streamflow, stream stage, and precipitation data. Chemical indicators of water quality presented in the report include field measurements and miscellaneous constituents (pH, alkalinity, specific conductance, hardness, dissolved oxygen, biochemical oxygen demand, and chloride), sediment (total suspended solids and suspended sediment), nutrients (total nitrogen, nitrate, Kjeldahl nitrogen, total phosphorus, and dissolved phosphorus), trace elements (cadmium, mercury, copper, lead, arsenic, chromium, nickel, and zinc), pesticides (historically used pesticides and pesticides still in use), and polychlorinated biphenyls. Ecological indicators of water quality discussed in the report include community surveys of macroinvertebrates and fish, chlorophyll *a* concentrations, habitat assessments and channel-measurement data, and fecal coliform and *E. coli* bacterial counts.

In addition to the compilation of the database, a major purpose of this investigation was to identify additional sampling that should be conducted under the baseline monitoring phase, which will be the second phase of the Corridor Study. Additional sampling may include:

- Some subwatersheds, such as those in the headwaters.
- Emerging contaminants such as pharmaceuticals and personal care products (PPCPs), human hormones, organic wastewater contaminants, and other constituents that result from human activity.
- *E. coli*, which can serve as an indicator of health risk to swimmers and other recreationl water users.
- Pesticides in all media.
- PCBs.
- Trace elements in water, bed sediment, and tissues (fish, shellfish, and others).
- Samples during winter months or during early snowmelt episodes to address constituents such as chloride and some nutrients that have seasonal variability and that may be affected by factors such as road deicing during the winter.
- Samples for macroinvertebrate and fish-community data and habitat assessments.
- Physical data such as stream-channel cross-section profiles, bridge-scour assessments, flood-plain maps, structures, and shoreline conditions.

Introduction

Stream-water quality and the ecological health of urban stream corridors are complex issues that drive research, regulation, and use of rivers and streams. Personnel from agencies and universities involved in such pursuits in the southeastern Wisconsin area have worked cooperatively to assess the recent history of urban streams and to use that knowledge to evaluate future stream-improvement projects to determine their likely success before implementation, thus allowing projects with greatest potential to receive priority. With the expertise of those from the planning, regulatory, and nonregulatory fields, as well as academicians and engineers, the Milwaukee Metropolitan Sewerage District (MMSD) Corridor Study has been approached from a broad-based perspective with the intention of promoting sound resource-based management decisions.

The MMSD Corridor Study is a collaborative project undertaken by MMSD, Wisconsin Department of Natural Resources (WDNR), Southeastern Wisconsin Regional Planning Commission (SEWRPC), U.S. Geological Survey (USGS), University of Wisconsin–Milwaukee, Marquette University, and Wisconsin Lutheran College. The primary purpose of the study is to ascertain the current state of water quality and ecological health in the stream "corridors" of the MMSD planning area (fig. 1) and provide knowledge and tools with which to assess the potential success of future projects.

A stream "corridor" is defined as the land within the greatest distance from the watercourse marked by:

- the SEWRPC primary or secondary environmental corridor boundary
- the 100-year regulatory floodplain boundary
- the edge of an adjoining wetland, or
- 75 feet from the watercourse channel or shoreline.

The objectives of the MMSD Corridor Study are:

1. Evaluate historic results and forecast potential effects of planned MMSD projects. Select analytical tools and procedures to assess the outcome of past MMSD projects and develop an understanding from which to forecast the effects of potential future projects. Types of projects to be evaluated include, but are not limited to, historical and planned flood control projects that involve the modification of watercourse channels and/or their corridor by deepening, widening, or enclosing; the placement or removal of material or structures on the channel or its corridor; habitat enhancements; structure removal; land purchases for conservation purposes; and water pollution abatement projects.
2. Create a comprehensive inventory of corridor conditions. Develop an improved understanding of the interrelationship of stream physiographic, hydrologic, hydraulic, biologic, water quality, sediment quality, habitat, and land-use variables, and develop procedures to integrate these variables.
3. Establish a baseline assessment of existing watercourse and corridor conditions. Detect impairments for each reach.
4. Determine the existing and potential water-use objectives for watercourse reaches.
5. Follow-up on flood control, habitat, and water-quality improvement or protection projects to verify anticipated results, evaluate current technologies, and identify adjustments for future projects.
6. Provide long-term surveillance of stream and corridor conditions to monitor project results, track changes in impaired and unimpaired reaches, provide additional inventory information, and facilitate early detection of newly impaired reaches.

The study is divided into three phases. Phase I involved the development of a database to contain data collected in the MMSD planning area since 1970. The MMSD Corridor Study database contains data from MMSD, USGS, WDNR, and the U.S. Environmental Protection Agency (USEPA). Additional data sets, including some provided by local universities and volunteer groups, will likely continue to be incorporated into the database as the study progresses. The database is available for query to those within the cooperating agencies to assist in informal decision-making processes. Data in the database can be examined to provide insight into the success of past MMSD and other agency projects, and to assess future data needs.

Phase II involves a rigorous field effort to fill the data needs highlighted during the Phase I review. The baseline inventory will include assessments of surface-water chemistry, sediment chemistry, and ecological factors (fish, habitat, macroinvertebrates, algae, bacteria) at a number of sites in the MMSD planning area. Staff from multiple agencies will likely cooperatively collect the data. Data collected during the baseline monitoring effort will reveal more information regarding the state of the stream corridors not available from the database developed in Phase I and will assist water-resources managers in regulatory agencies in decision-making.

Phase III will involve a long-term data collection effort at a subset of the baseline monitoring sites. The length of time over which sample collection will take place for the long-term monitoring effort has not been decided but may be indefinite. Long-term monitoring will document changes in the health of aquatic ecosystems in the stream corridors of the MMSD planning area.

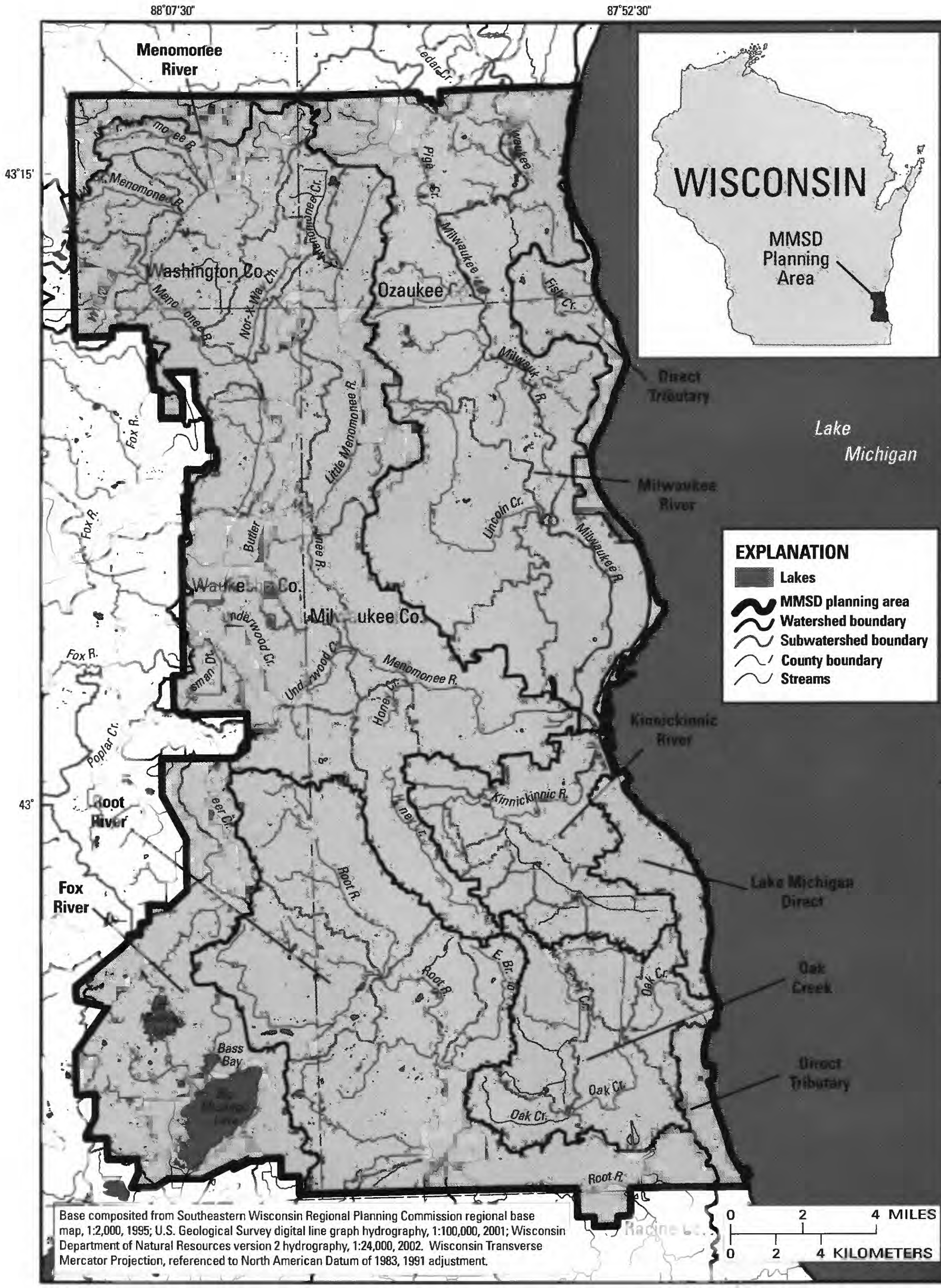

Figure 1. Location of the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Purpose and Scope

This report summarizes the data in the MMSD Corridor Study database and other information developed in Phase I of the MMSD Corridor Study that began in January 2001 and ended in March 2003. The database was compiled from agencies maintaining electronically accessible data describing water, sediment, and tissue chemistry, macroinvertebrates, fish, algae, habitat, geomorphic, and other physical and ecological measurements. Data were assembled for 1970 through 2002 for sites within the MMSD planning area. Also, 274 studies published from 1970 through 2001 and describing an aspect of water quality, water quantity, or ecology from within the MMSD planning area were reviewed. Spatial data available from federal, state, and local agencies for the MMSD planning area were inventoried.

Physical, chemical, and ecological data from the database are summarized in this report with some or all of the following: a text summary, map of sampling locations, and in some cases median concentrations, statistical distributions of concentrations by subwatershed, table of summary statistics by subwatershed, and graphs of temporal and (or) seasonal trends. Physical data presented in the report include streamflow, stream stage, and precipitation data. Chemical indicators of water quality presented in the report include field measurements and miscellaneous constituents (pH, alkalinity, specific conductance, hardness, dissolved oxygen, biochemical oxygen demand, and chloride), sediment (total suspended solids and suspended sediment), nutrients (total nitrogen, nitrate, Kjeldahl nitrogen, total phosphorus, and dissolved phosphorus), trace elements (cadmium, mercury, copper, lead, arsenic, chromium, nickel, and zinc), pesticides (historically used pesticides and pesticides still in use), and polychlorinated biphenyls. Ecological indicators of water quality discussed in the report include community surveys of macroinvertebrates and fish, chlorophyll *a* concentrations, habitat assessments and channel-measurement data, and fecal coliform and *E. coli* bacterial counts.

Milwaukee Metropolitan Sewerage District Planning Area

Within the MMSD planning area, concentrations of various constituents in surface water, sediment, and tissues; the diversity and populations of fish and macroinvertebrates; and the state of habitat and stream morphology may be influenced by multiple factors. Selected physical features of the planning area that may influence the chemistry and ecology are described below.

Location and Surface-Water Features

The MMSD planning area (fig. 1) is a 420-mi^2 area covering Milwaukee County and parts of Washington, Ozaukee, Waukesha, and Racine Counties. MMSD collects and analyzes wastewater from all Milwaukee County municipalities (except South Milwaukee), as well as 10 communities in the surrounding 4 counties.

Seven major watersheds (fig. 2) and parts or all of 40 subwatersheds (fig. 3) make up the planning area (Southeastern Wisconsin Regional Planning Commission, 2002a; Southeastern Wisconsin Regional Planning Commission, 2002b). The Milwaukee River watershed accounts for a little less than 25 percent of the total planning area. More than 85 percent of the entire Milwaukee River watershed is outside of the planning area. The Menomonee River watershed makes up a little more than 30 percent of the planning area and is almost entirely within the planning area. The Upper Root River watershed accounts for 17 percent of the planning area; a little more than a third of the entire Root River watershed area is within the planning area. The Upper Fox River watershed makes up approximately 10 percent of the planning area and is the only part of the planning area that does not drain to Lake Michigan (it drains eventually to the Mississippi River). The Kinnickinnic and Oak Creek watersheds are completely within the planning area and constitute 6 and 7 percent of the total planning area, respectively. The remaining 5 percent of the planning area drains directly to Lake Michigan.

Texture of Surficial Deposits

Surficial deposits in the MMSD planning area consist predominantly of clayey till, ground and end moraine (fig. 4). There are some areas of sandy loamy till in the northwest corner of the MMSD planning area and “outwash sand and gravel” and “lake clay and silt” in various parts of the planning area (Lineback and others, 1983).

Land Use/Land Cover and Population

The MMSD planning area is heavily urbanized in the center but largely agricultural in the northern and southern parts of the study area (fig. 5). Two-thirds of the planning area is urban land use, consisting of commercial, industrial, and other areas (17 percent); residential areas (26 percent); transportation infrastructure and rights-of-way (21 percent); and recreational areas (3 percent). Twenty percent of the planning area is agricultural. Another 3 percent of the planning area is forested. Wetlands make up 7 percent of the planning area, and another 2 percent is open water (generalized from Southeastern Regional Planning Commission, 1995b).

The population (fig. 6) of the MMSD planning area is 1,092,624, according to data from the 2000 census, for which a population density of 2,618 people per square mile was calculated (U.S. Bureau of the Census, 2001). In 1990, the planning-area population was slightly less than in 2000, at 1,090,046 people (U.S. Bureau of the Census, 1991).

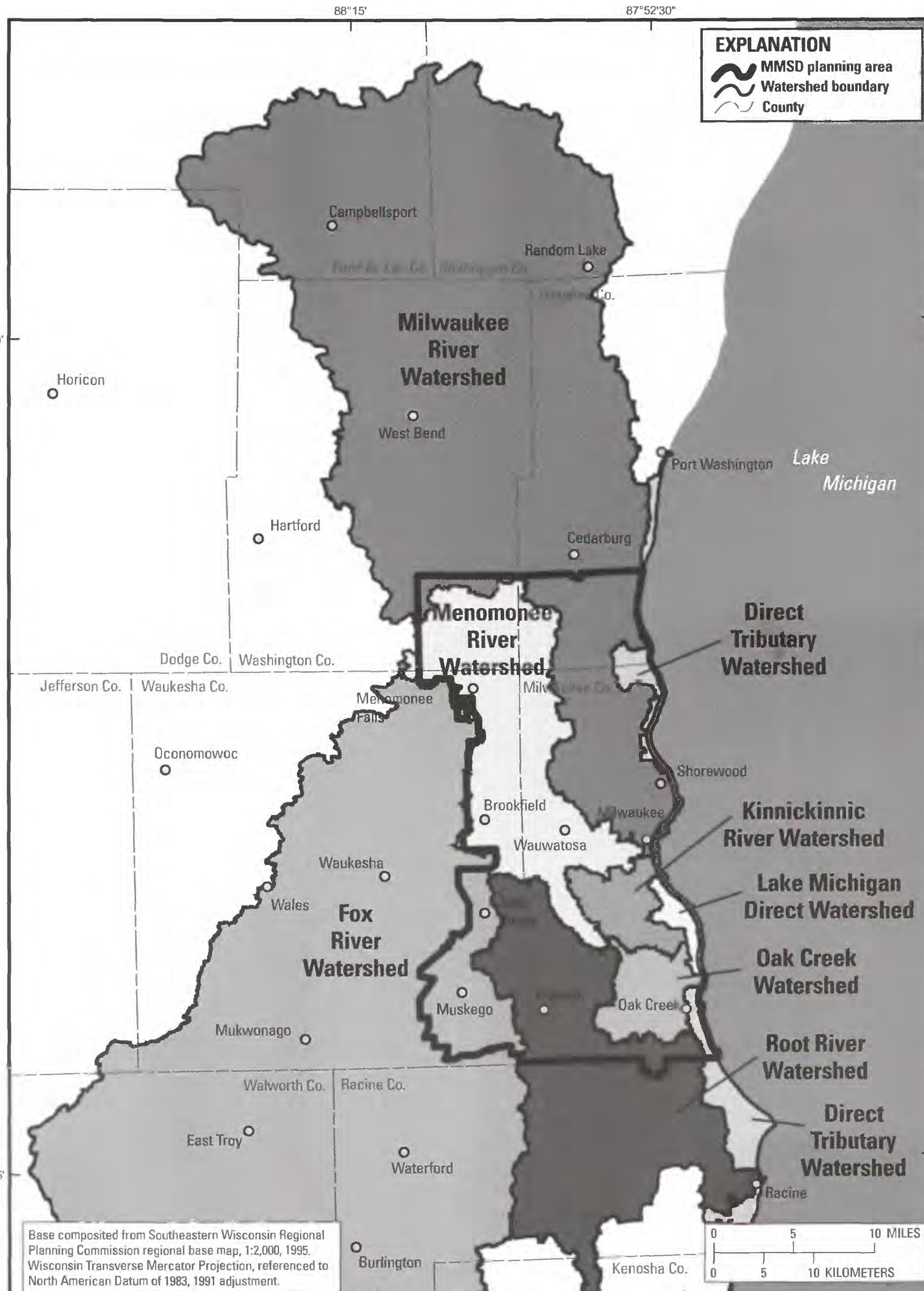

Figure 2. Watersheds near the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

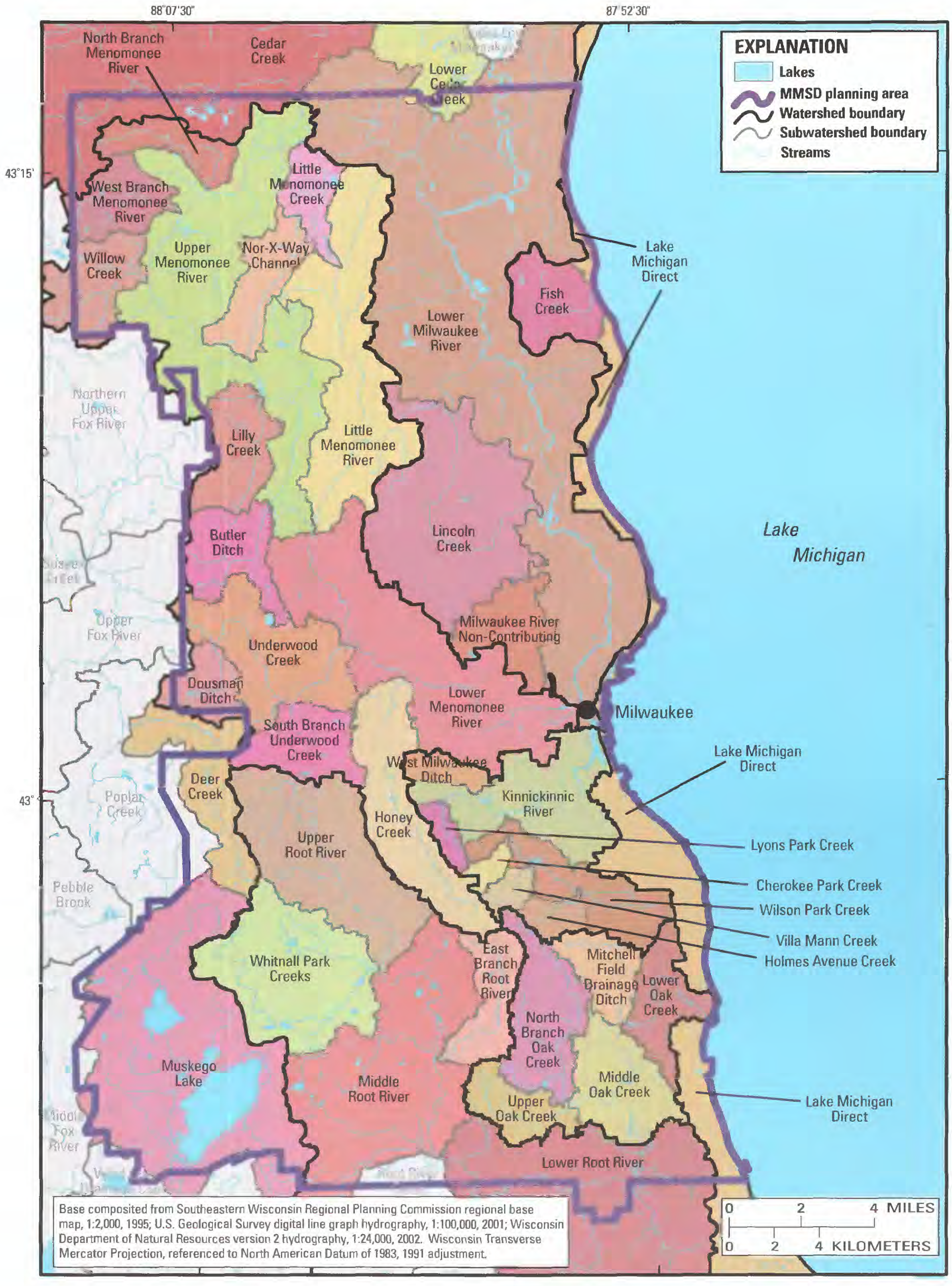

Figure 3. Subwatersheds near the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Figure 4. Quaternary surficial deposits in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

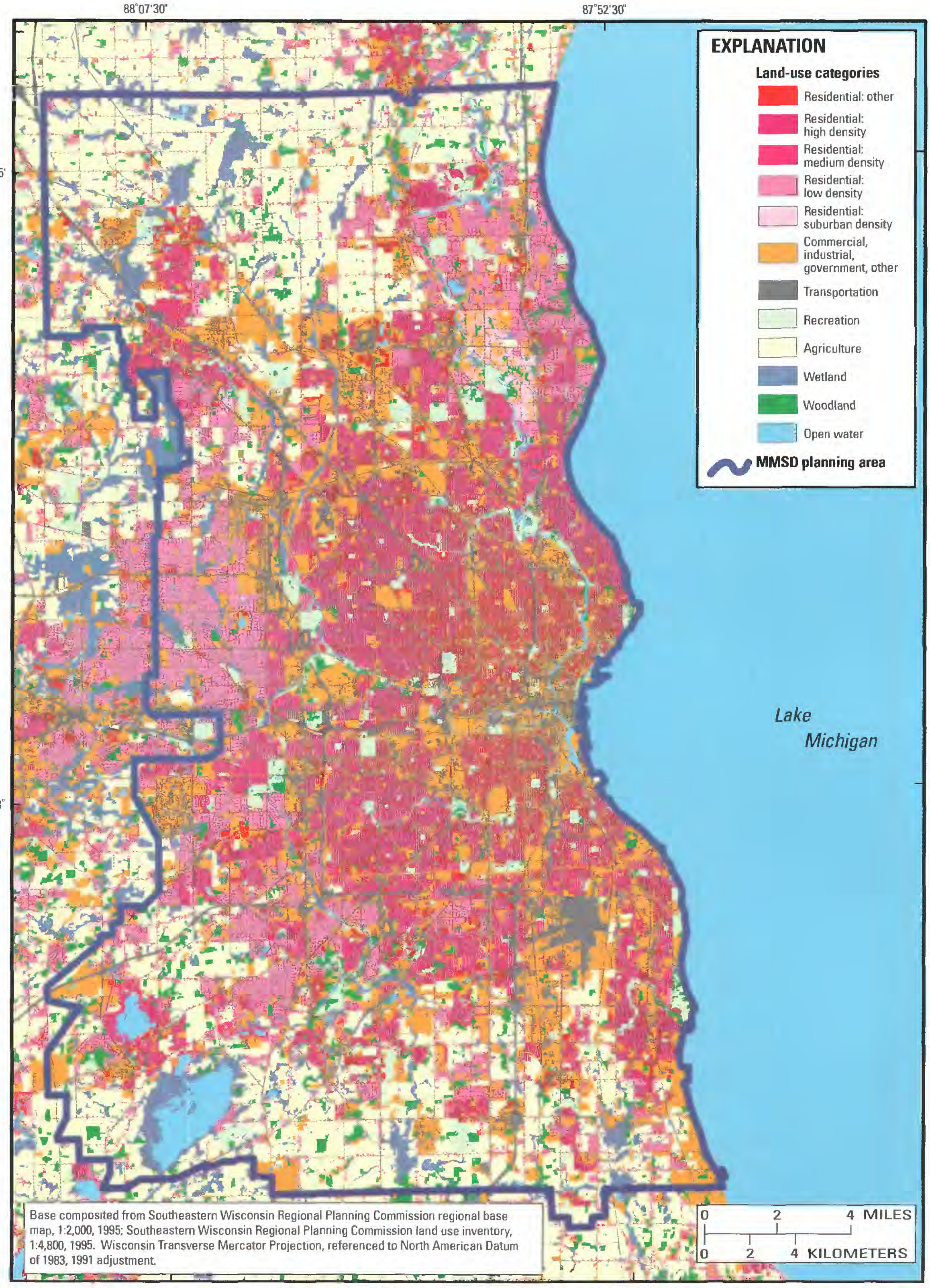

Figure 5. Land-use inventory for the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis., for 1995.

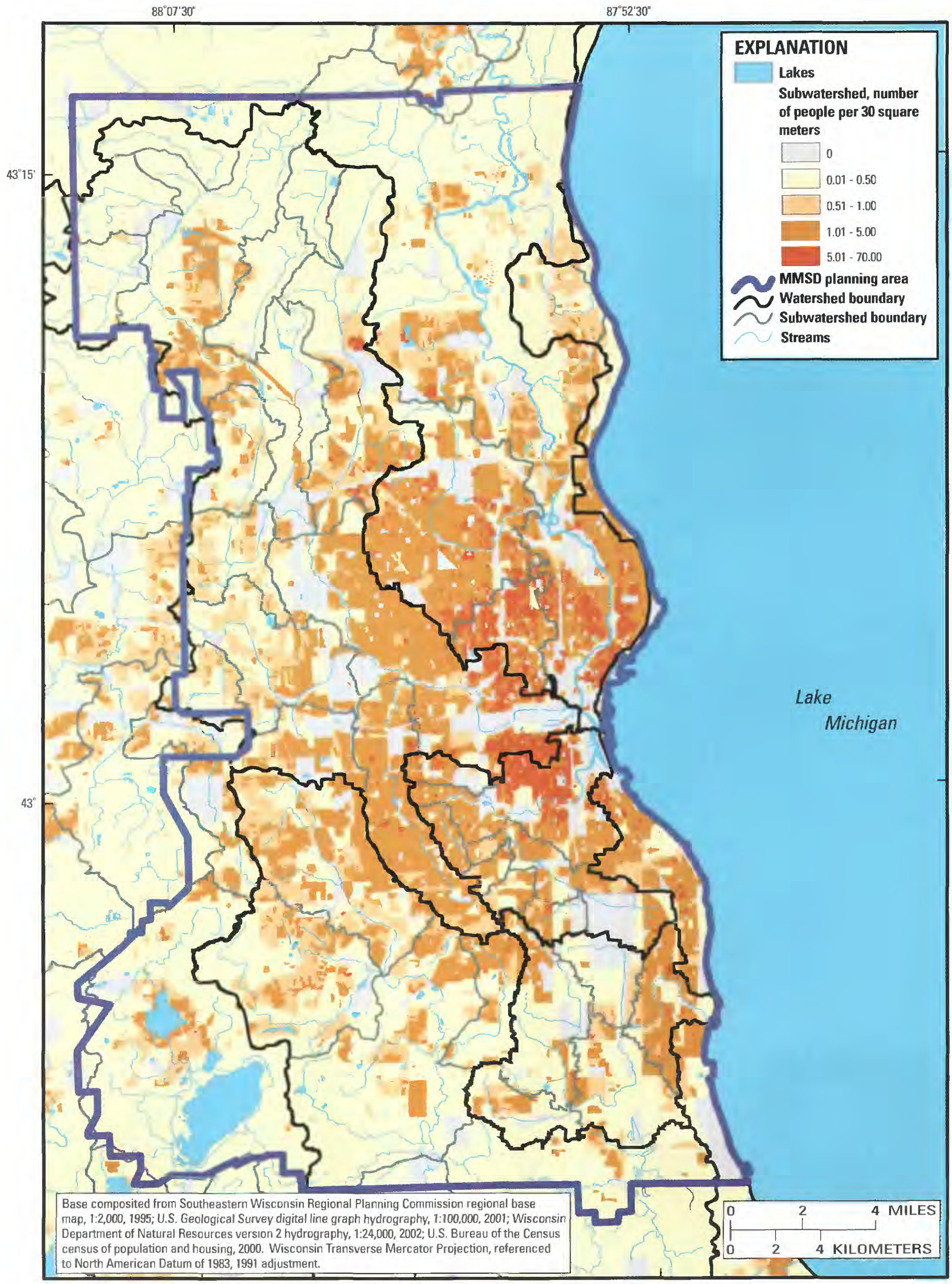

Figure 6. Population density in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Compilation of Water-Resources-Related Information

A literature review was completed for surface-water (quality and quantity) and aquatic-biology studies in the major watersheds in the planning area. The studies compiled were those readily available from literature searches through university libraries and inquiries to local, State, and Federal agencies, and academic institutions. An effort was made to find documents from all relevant and available studies, although some sources likely were missed.

An inventory of spatial data for the planning area was assembled for regional, statewide, and national GIS (Geographic Information Systems) coverages that were relevant to the MMSD Corridor Study. Inquiries were made to local, State, and Federal agencies to compile a list of pertinent GIS information; however, spatial data covering only a small part of the MMSD planning area were not included. Additional GIS coverages are available from local units of government for parts of the MMSD planning area but this list includes primarily data for the entire MMSD planning area. Coupling sampling-site information as stored in the MMSD Corridor Study database with spatial data such as land use, point-source discharge locations, or census data can provide a more complete picture of the state of surface-water resources in the MMSD planning area than can the contents of the database alone.

Surface-Water Studies

A total of 195 documents that describe the surface-water quality of the planning area were found, and a total of 133 documents regarding surface-water quantity studies were located. Results of the surface-water quality and quantity reviews are summarized as to spatial extent (local, regional, statewide) and major thrust of the study in tables 1 and 2 (at back of report).

Each water-quality study document was reviewed to determine whether it contained information related to one or more of the following categories: lake or stream information, field measurements (pH, specific conductance, water temperature, dissolved oxygen), major ions and (or) dissolved solids, nutrients, pesticides, dissolved and (or) total organic carbon, sediment, bacteria and (or) viruses, trace elements, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, inorganic and organic contaminants, wastewater-treatment plants, urban issues, modeling, or other significant water-quality issues.

Of the surface-water quality documents reviewed in this report, 45 percent (87) were from studies completed since 1990 and the remainder were published between 1970 and 1989. More studies had a local focus (126) than a statewide or regional scope (69). More than 70 percent (139) of studies addressed stream issues, the remainder described lake or harbor conditions. Many study documents contained data or a discussion of analysis for field measurements (98 studies), major ions or dissolved solids (89), nutrients (112), pesticides (29), dissolved or total organic carbon (13), sediment (85), bacteria or viruses (57), trace elements (73), or contaminants such as VOCs, PAHs, PCBs, dioxins, inorganic or organic contaminants (57). Several documents referenced wastewater treatment with discussions on the Inline Storage System (Ab Razak, 1999), creation of a model to determine the effect of combined sewer overflows on dissolved oxygen (Kreutzberger and others, 1980), and plans for sanitary service to various communities in the Milwaukee area, including Oak Creek (Southeastern Wisconsin Regional Planning Commission, 1994). Studies addressing urban issues included topics such as the effect of aircraft and runway deicers from General Mitchell International Airport on biochemical oxygen demand and dissolved oxygen concentrations in Wilson Park Creek and the Kinnickinnic River (Corsi and others, 2001a), the effects of spraying methoxychlor to control Dutch elm disease on stream-water quality in the Lincoln Creek watershed (Kleinert, 1971), and the control of nonpoint-source pollution in the Milwaukee River (Wisconsin Department of Natural Resources and others, 1990b). Studies that involved models included a calibrated Lincoln Creek model designed to evaluate the effect of snow removal and deicing practices on the water quality of urban waters (Bartošová and Novotny, 1999); a model for the Milwaukee area designed to predict effects of industry on water quality (Stanley and Erickson, 1977); and a model created to estimate nonpoint-source pollution and its sources based on eight watersheds in Milwaukee County (Sung, 1983).

Each water-quantity study document was reviewed to determine whether it contained information related to one or more of the following categories: lake or stream information, streamflow or stream stage, extreme flows (floods or drought), hydrologic budget, erosion and (or) sedimentation, runoff calculations, modeling, precipitation and (or) climate, geomorphology, urban issues, or other significant water-quantity issues.

Slightly less than half of the surface-water-quantity study documents (57) had been published since 1990. Two-thirds (91) of the studies had a local focus, whereas the rest discussed surface-water quantity issues regionally or statewide. About 80 percent (106) of the documents referred to streams, and a few focused on the Milwaukee Harbor or lakes (primarily Little or Big Muskego Lakes). About 75 study documents (56 percent) discussed streamflow, and 28 documents (21 percent) referenced extreme high and (or) low flows. Slightly less than 25 percent of the documents (31) discussed erosion and sedimentation issues in surface water in the MMSD planning area, and another 25 percent (39) considered the geomorphology of streams. Urban issues such as stormwater pollution (Bannerman and others, 1983a; Bannerman and others, 1983b), the effects of urban development on streams (Cherkauer 1975a, Cherkauer 1975b), and the effects of runoff from construction sites and erosion of streambanks in the Kinnickinnic River watershed (Taylor, 1994) were examined. Modeling studies included an examination of the effects of removing the North Avenue Dam on the Milwaukee River (Hajda, 1993), the influence of ground water on the Menomonee River (Konrad and others, 1979), and the effect of snowmelt runoff in urban areas (Novotny, 1986). Five documents by MMSD described plans for interceptor facilities in various communities around Milwaukee that would be used to convey sanitary waste to the sewage treatment plant. SEWRPC and the WDNR completed numerous studies describing flooding potential, water quality, and nonpoint-source pollution on watersheds in the MMSD planning area (15 SEWRPC studies and 11 WDNR studies).

Ecological Studies

A total of 136 study documents were found that relate to ecology in the planning area. Each document is summarized in table 3 (at back of report) with regard to spatial extent (local, regional, statewide) and major thrust of the study.

Ecology study documents were reviewed to determine whether they contained information for any of the following categories: lake or stream information, fish, macroinvertebrates, algae and (or) macrophytes, amphibians and (or) reptiles, birds, mussels, wildlife, toxic bioassays, endangered and (or) threatened species, tolerant or intolerant species, nonnative or invasive species, habitat, wetlands, human effects and (or) urban issues, community surveys, management issues, water-quality interpretations based on ecology, biotic index scores, or other significant ecological issues.

The number of documents published before 1990 and since were evenly split. A slight majority of the studies (77) were of statewide or regional scope, whereas the remainder addressed local issues. Study documents described many sorts of organisms associated with the stream corridors, including fish (58), macroinvertebrates (35), algae and (or) macrophytes (29), amphibians and (or) reptiles (14), birds (16), mussels (3), and various wildlife (16). Twenty-five percent of the documents (34) discussed habitat conditions, and another 10 percent (14) referred to wetlands. Sixteen documents presented biotic index scores or made interpretations of water quality based on ecology of the sampling site. Management issues covered included the effects of dredging Little Muskego Lake (Druckenmiller, 1980), effects of removal of concrete lining in the Menomonee River, Southbranch Creek, and Lincoln Creek on habitat (Harza Engineering Company, 2001), methods used for controlling algae and macrophyte growth in the Milwaukee River and Little Muskego Lake (Lueschow, 1972), and an evaluation of the nonpoint-source pollution-abatement program on the Root River (Rice, 1992). A handful of documents discussed species-related issues, including endangered or threatened species, nonnative species, and tolerant versus intolerant species.

Geographic Information System Data Set Inventory

Spatial data such as land use, infrastructure, geology, and hydrography were located for the MMSD planning area. Selected GIS coverages available for the MMSD planning area that may affect surface-water resources are described in table 4 (at back of report).

Coverages available for the MMSD planning area include boundary data for counties, municipalities, and the MMSD planning area. Digital-elevation-model data at different scales describe the elevation of the land surface. Most soils data are part of a national layer; however, there is GIS information describing soil associations, permeability, and surficial deposits from data originally compiled for Wisconsin. SEWRPC actively maintains coverages of watersheds, subwatersheds, and subbasins for southeastern Wisconsin. Coverages for various infrastructure like roads, railroads, dams, and sewers are available for the state or in greater detail in some cases for the southeastern Wisconsin area. Various land-use/land-cover data are available for different years and at different resolutions. Aerial photography for southeastern Wisconsin is available for approximately 5-year intervals dating back to the 1960s.

Data Used in the Report

Water, sediment, tissue-chemistry, as well as physical and ecological assessment data available in electronic form were compiled as part of this study. Interpretation of historical data will provide a basis to design a baseline-monitoring network for Phase II of the Corridor Study. In fact, the primary reasons for the compilation of the data set for Phase I are to identify the trends and seasonal variations in water resources and to identify areas where data collection opportunities exist to more completely describe water resources in the planning area.

Spatial, Temporal, and Analytical Extent of Data

Data compiled for the Corridor Study were constrained with regard to time, space, and subject matter. The timespan of the compilation includes data collected from 1970 through 2002. Spatially, the compilation is for the MMSD planning area (fig. 1); in particular, data was collected for the stream corridors, streams, and areas immediately adjacent to the stream. Water-quality data were included for rivers, canals, estuaries, lakes, storm sewers, facilities such as private industries and municipal wastewater treatment plants, and precipitation. Other than precipitation samples, 98 percent of the samples collected were from rivers, canals or estuaries. Slightly more than 1 percent of the samples were from lakes, and less than half a percent were from storm sewers and facilities. Data for Lake Michigan were not included in this study. The types of data collected include surface-water, sediment, tissue-chemistry (including fish, shellfish, and others), fish, habitat, macroinvertebrate, algal, bacterial, meteorological, and streamflow data.

Legacy Data Sources

Data sets of water-resources-related information were compiled from many different legacy databases, which are defined as databases maintained separately by other agencies to store data they either collect themselves (MMSD, USGS) or compile from multiple other data-collection agencies (USEPA). The majority of data compiled into the MMSD Corridor Study database at the time of publication (2003) came from MMSD, USGS, USEPA, and WDNR. Major data sets included in the Corridor Study are described in table 5. Additional data from University and volunteer data sets were not incorporated; however, plans are to include as much relevant and accessible data as possible in the future. Updates of ongoing data-collection efforts, such as described in table 5, will be incorporated in the Corridor Study database.

Design of Database-Management System

The MMSD Corridor Study database resides at the USGS District office in Middleton, Wis. on an Oracle platform. The structure of the database is shown in figure 7. Water quality, ecology, and hydrology data are all stored within one database, allowing for query of various kinds of data from multiple different agencies from one location. The database is designed to allow for fast query response time. The central table, "Results," contains the most detailed information such as a nitrate value. The tables attached to the "Results" table provide further descriptive information such as on what day the nitrate sample was collected ("Samples"), and the lab analysis method used to analyze the sample for nitrate ("Lab Analysis Methods"). Likewise, "Sites" describes the sampling location where trout were collected and "Taxonomy" describes the taxonomic code used by the WDNR to identify the fish. Where the information was easily accessible, sample-collection methods, laboratory-analysis methods, and information describing the laboratory that performed the analysis were included with the data.

Limitations of Data and Their Implications for Data Analyses

Analysis of data within the MMSD database must be done with caution and an understanding of the limitations of data compiled from different sources. Data compiled as part of this study were collected over more than 30 years, from sampling sites distributed over 400 mi^2, by many agencies for various purposes using different field and laboratory methods. Data-collection and laboratory-analysis methods, the purpose for collecting a sample, and reporting limits were easily available for only part of the data. Many water-quality constituents were reported with multiple reporting limits for the same constituent. Some constituent concentrations were reported as zero when the concentration determined from analysis was below a reporting limit. Laboratory-analysis methods have improved for many constituents, resulting in capability to determine concentrations at lower limits than was possible previously.

Challenges to combining data sets included varying definitions of sampling sites, minimal documentation of constituents, insufficient laboratory-analysis method description, and lack of sampling-purpose information in an easily accessible format.

Information describing the locations of sampling sites varied among the data sets. Latitude and longitude were required for all sampling-site locations. A general site name was assigned to all sampling-site locations. Overlapping sites were given the same general name to allow for easier comparison of data at a location where multiple sites had been established by different agencies. Sites were determined to share a sample location through a visual examination of where a site plotted on a map (based on its latitude and longitude) and the name and location description given to the site.

Trying to compare data between data sets on the basis of a short constituent name or abbreviation required scrutiny by several professionals familiar with water, sediment, and tissue chemistry. Constituents within various data sets were combined on the basis of available information for constituents and methods. The properties and constituents described in this report including information regarding the original name, measurement units, and code from the legacy source database are listed in table 6.

Laboratory-analysis methods were not available for all data. Comparison of data between data sets should be taken on a relative basis because the method of analysis can influence results. Analysis methods from 30 years ago likely differed in some respects from those methods used currently. Methods used by one agency may also differ from those of other agencies. Reporting levels were available for some but not all data, and they changed for constituents within the same database source as well as among database sources. In addition, the type of reporting limit varied between method detection limits, minimum detection limits, laboratory reporting limits, etc.

The purpose for collecting a sample (sample purpose) was available for some data but not for most. Some samples may have been collected as part of a routine sampling schedule that does not take into account the amount of discharge. Other samples may have been collected as part of an event-

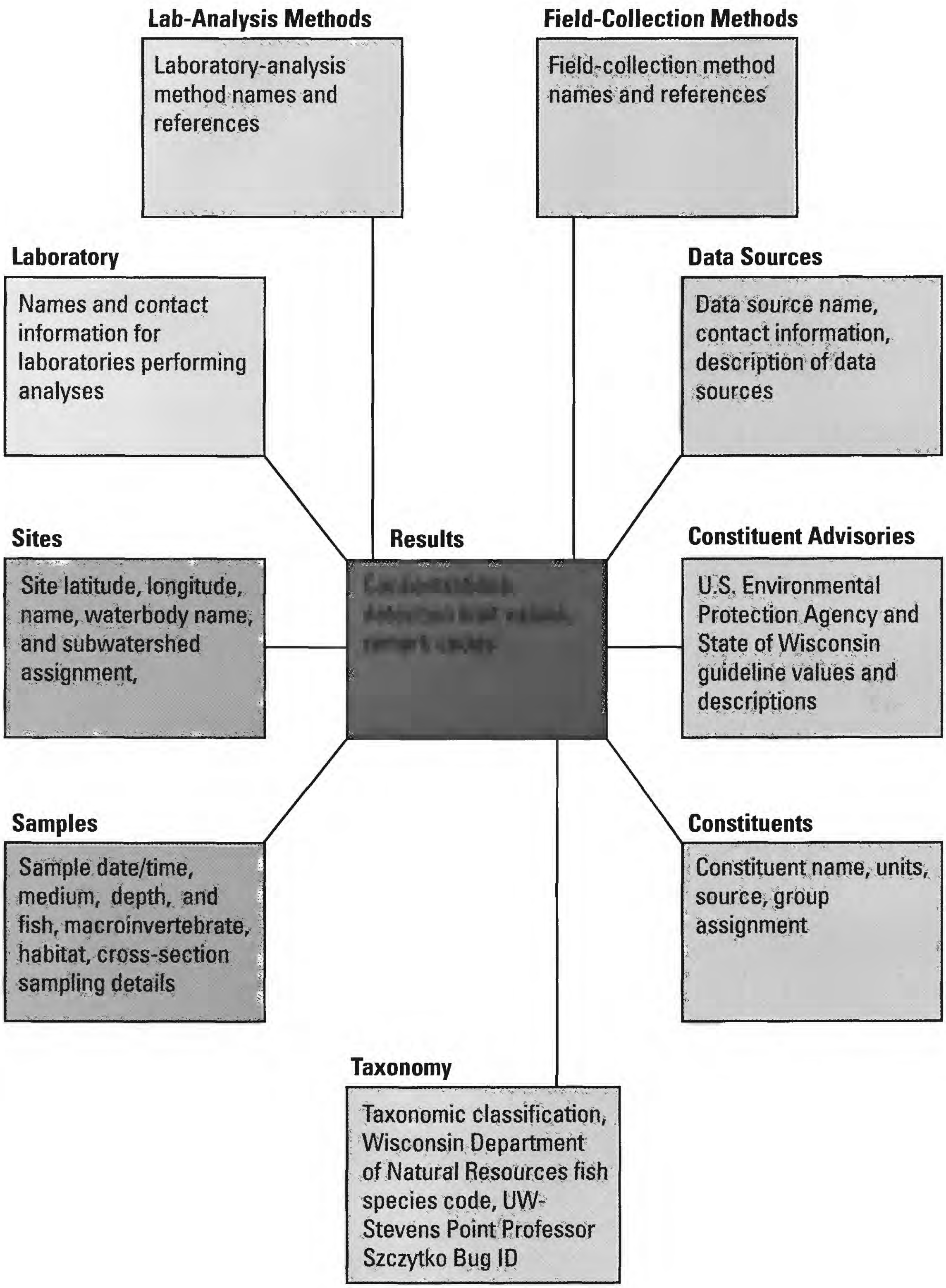

Figure 7. Milwaukee Metropolitan Sewerage District Corridor Study database design.

Table 5. Data sources for the Milwaukee Metropolitan Sewerage District Corridor Study database

[Data sources incorporated into the data base at the time the Phase I Report was written; MMSD, Milwaukee Metropolitan Sewerage District; PCBs, polychlorinated biphenyls; PAHs, poly aromatic hydrocarbons; USGS, U.S. Geological Survey; USEPA, U.S. Environmental Protection Agency; STORET, STOrage and RETreival System; WDNR, Wisconsin Department of Natural Resources; UWSP, University of Wisconsin–Stevens Point]

Data source name	Agency serving data	Number of sampling sites	Number of sampling visits	Number of results	Date of earliest sample	Date of latest sample	Description of source data set
MMSD Water Quality	MMSD	50	24,137	586,749	1975	2001	Water-quality data collected typically March through November (ice-out conditions) at sites throughout the MMSD planning area and in Lake Michigan (Lake Michigan data not included in the MMSD Corridor Study data base). Data include nutrients, field measurements, major ions, PCBs, PAHs, mercury, bacteria, and others. MMSD Water Quality data are available on the Great Lakes Water Institute Waterbase Web site and can be accessed at URL http://waterbase.glwi.uwm.edu/mmsd.html
MMSD Stream Elevation	MMSD	4	216,422	216,422	1994	2001	Stream-elevation data collected hourly at four sites throughout the MMSD planning area.
MMSD Precipitation	MMSD	20	1,411,757	1,411,757	1993	2001	Precipitation-gage data collected at 5-minute intervals at four locations around the MMSD Planning area. Precipitation data are stored at hourly increments, cummulative over a day, in the Corridor Study data base.
MMSD Sediment	MMSD	209	3,653	15,322	2000	2001	MMSD cross-section and pebble/sieve count information for many sites in the Menomonee River watershed collected as part of the MMSD Menomonee River Sediment Transport Study (Inter-Fluve, 2001).
USGS Water Quality	USGS	96	8,918	107,181	1970	2002	Water-quality data collected by the USGS as part of many different projects around the country. Data include field measurements, major ions, nutrients, pesticides, organics, fecal coliform, and many others. Water-quality data can be accessed from the NWISWeb site at URL http://wi.water-data.usgs.gov/nwis/nwis
USGS Streamflow	USGS	42	113,524	113,524	1970	2001	Streamflow data collected at 15-minute intervals at many sites around the country (stored only as daily mean values in the MMSD Corridor Study data base). Streamflow data can be accessed from the NWISWeb site at URL http://wi.water-data.usgs.gov/nwis/nwis
USEPA STORET Legacy	USEPA	324	6,268	26,930	1970	1998	Water-quality data base compiled by USEPA from data collected by many different agencies (mainly the WDNR in the Milwaukee area). The legacy data base contains data up to 1/1/1999, when a new version of the STORET data base was released. Data include field measurements, nutrients, major ions, organics, pesticides, and others. STORET Legacy data can be accessed at the URL http://www.epa.gov/storpubl/legacy/gate-way.htm

Table 5. Data sources for the Milwaukee Metropolitan Sewerage District Corridor Study database—Continued

[Data sources incorporated into the data base at the time the Phase I Report was written; MMSD, Milwaukee Metropolitan Sewerage District; PCBs, polychlorinated biphenyls; PAHs, poly aromatic hydrocarbons; USGS, U.S. Geological Survey; USEPA, U.S. Environmental Protection Agency; STORET, STOrage and RETreival System; WDNR, Wisconsin Department of Natural Resources; UWSP, University of Wisconsin–Stevens Point]

Data source name	Agency serving data	Number of sampling sites	Number of sampling visits	Number of results	Date of earliest sample	Date of latest sample	Description of source data set
USEPA STORET Modern	USEPA	18	515	2,120	1999	2001	Water-quality data base compiled by the USEPA from data collected by many different agencies (mainly the WDNR in the Milwaukee area). The modern data base contains data starting 1/1/1999, when a new version of the STORET data base was released. Data include field measurements, nutrients, major ions, organics, pesticides, and others. STORET Modern data can be accessed at the URL http://oaspub.epa.gov/storpubl/ware-housemenu
WDNR Biology Data base—Fish	WDNR	268	277	2,608	1970	2001	WDNR Biology Data base created in 2001 to hold fish, habitat, macroinvertebrate and other biology related data for the WDNR. Community taxonomy, counts, sex, and length included. The WDNR biology data base is online but available only to WDNR employees at this time.
WDNR Biology Data base—Habitat	WDNR	44	6,345	204,957	1991	2001	WDNR Biology Data base created in 2001 to hold fish, habitat, macroinvertebrate and other biology related data for the WDNR. Various habitat measures including streambank erosion, riparian vegetation, and stream subtrate are included. The WDNR biology data base is online but available only to WDNR employees at this time.
WDNR Milwaukee Fish	WDNR	18	36	8,166	1996	2001	Microsoft Access data base of fish in the Milwaukee River. Community and count information included.
WDNR Sediment	WDNR	167	343	15,631	1984	1995	Microsoft Access data base of water and sediment samples analyzed for PCBs.
WDNR—UW Stevens Point Professor Szczytko Macroinvertebrates	UWSP	189	328	5,729	1979	1999	Macroinvertebrate data analyzed by UW - Stevens Point Professor Stan Szczytko. Most data were collected by the WDNR, but some samples are from USGS and other agencies. Community, count, and index information available. Macroinvertebrate data are available online at the UW - Stevens Point Aquatic Entomology Lab Web site and can be accessed at the URL http://www.uwsp.edu/water/biomonitor-ing/index3.htm

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m^3, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
pH	Standard units	1	pH	pH	std. units @ 25°	USEPA STORET Modern	1
			pH, Dissolved	pH, Dissolved	std. units @ 25°	USEPA STORET Modern	pH (dissolved)
			pH, Std. Units	pH, Std. Units	standard units	MMSD Water Quality	pH
			pH, Wh, Field	pH, Water, Whole, Field, Standard Units	standard units	USGS QWDATA	00400
Alkalinity	mg/L as $CaCO_3$	1	Alkalinity, Carbonate as $CaCO_3$, Total	Alkalinity, Carbonate as $CaCO_3$, Total	mg/L as $CaCO_3$	USEPA STORET Modern	17 (total)
			Alkalinity, Dis, It, F	Alkalinity, Water, Dissolved, Total, Incremental Titration, Field, mg/L as $CaCO_3$	mg/L as $CaCO_3$	USGS QWDATA	39086
			T Alk $CaCO_3$ mg/L	Alkalinity, Total (mg/L as $CaCO_3$)	mg/L as $CaCO_3$	USEPA STORET Legacy	00410
			Total Alkalinity mg/L	Total Alkalinity mg/L	mg/L as $CaCO_3$	MMSD Water Quality	Alkalinity
Hardness	mg/L as $CaCO_3$	1	Hardness mg/L	Hardness mg/L	mg/L as $CaCO_3$	MMSD Water Quality	Hardness
			Hardness Total	Hardness Total (mg/L as $Ca03CaCO_3$	mg/L as $CaCO_3$	USGS QWDATA	00900
			Hardness, Carbonate, Total	Hardness, Carbonate, Total	mg/L	USEPA STORET Modern	259 (total)
			Tot Hard $CaCO_3$ mg/L	Hardness, Total (mg/L as $CaCO_3$)	mg/L as $CaCO_3$	USEPA STORET Legacy	00900
Specific conductance	µS/cm	1	Conductance, Specific	Specific Conductance	µmho/cm @ 25°C	USEPA STORET Modern	139
			Specific Conductance	Specific Conductance (Microsiemens/cm at 25 Deg C)	µS/cm @ 25°C	USGS QWDATA	00095
			Specific Conductance	Specific Conductance Microsiemens/cm at 25 Deg C	µS/cm	USGS QWDATA	90095
			Specific Conductivity µmhos/cm	Specific Conductivity µmhos/cm	µmho/cm	MMSD Water Quality	Conductivity
Dissolved oxygen, mg/L	mg/L	1	Dissolved Oxygen mg/L	Dissolved Oxygen mg/L	mg/L	MMSD Water Quality	DO
			Dissolved Oxygen, Dissolved	Dissolved Oxygen (DO), Dissolved	mg/L	USEPA STORET Modern	201 (dissolved)
			DO mg/L	Oxygen, Dissolved mg/L	mg/L	USEPA STORET Legacy	00300
			Oxygen Dissolved	Oxygen Dissolved (mg/L)	mg/L	USGS QWDATA	00300

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots—Continued

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m^3, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
Biochemical oxygen demand, 5 day	mg/L	1	Biochemical Oxygen Demand, 5 Day mg/L	Biochemical Oxygen Demand, 5 Day mg/L	mg/L	MMSD Water Quality	BOD5
			Bod 5 Day mg/L	Bod, 5 Day, 20 Deg C mg/L	mg/L	USEPA STORET Legacy	00310
			Bod 5-Day At 20 Deg	Biochemical Oxygen Demand, 5-Day At 20 Degrees Celsius (mg/L)	mg/L	USGS QWDATA	00310
			Bod, Total, 5 Day	Bod, Biochemical Oxygen Demand, Total, 5 Day	mg/L	USEPA STORET Modern	34 (total)
Solids, total suspended	mg/L	1	Solids, Total Suspended	Total Suspended Solids (TSS)	mg/L	USEPA STORET Modern	456
			Solids, Total Suspended, Dissolved	Total Suspended Solids (TSS), Dissolved	mg/L	USEPA STORET Modern	456 (dissolved)
			Total Solids mg/L	Total Solids mg/L	mg/L	MMSD Water Quality	Tot_solids
Suspended-sediment	mg/L	1	Concentration, S, Sed	Sediment, Suspended Concentration (mg/L)	mg/L	USGS QWDATA	80154
Chloride, total	mg/L as Cl	1	Chloride mg/L	Chloride mg/L	mg/L	MMSD Water Quality	Chloride
			Chloride Total mg/L	Chloride, Total In Water mg/L	mg/L	USEPA STORET Legacy	00940
			Chloride, Total	Chloride, Total	mg/L	USEPA STORET Modern	107 (total)
Nitrogen, total	mg/L as N	1	Nitrogen Total	Nitrogen Total (mg/L as N)	mg/L as N	USGS QWDATA	00600
		0.2259	Nitrogen, Total -NO_3	Nitrogen, Total (mg/L as NO_3)	mg/L as NO_3	USGS QWDATA	71887
Nitrogen, kjeldahl (ammonia plus total organic nitrogen), total	mg/L as N	1	Nitrogen Amm+Org Tot	Nitrogen Ammonia Plus Organic Total (mg/L as N)	mg/L as N	USGS QWDATA	00625
			Nitrogen, Kjeldahl, Total	Nitrogen, Kjeldahl, Total	mg/L	USEPA STORET Modern	333 (total)
			Tot Kjel N mg/L	Nitrogen, Kjeldahl, Total, (mg/L as N)	mg/L as N	USEPA STORET Legacy	00625
			Total Kjeldahl Nitrogen mg/L	Total Kjeldahl Nitrogen mg/L	mg/L as N	MMSD Water Quality	TKN

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots—Continued

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m^3, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
Nitrogen, nitrate, dissolved	mg/L as N	1	Nitrate Nitrogen	Nitrate Nitrogen	mg/L as N	MMSD Water Quality	NITRATE
			Nitrogen Nitrate D.	Nitrogen Nitrate Dissolved (mg/L as N)	mg/L as N	USGS QWDATA	00618
			Nitrogen Nitrate T.	Nitrogen Nitrate Total (mg/L as N)	mg/L as N	USGS QWDATA	00620
			Nitrogen, Nitrite + Nitrate, Dissolved	Nitrogen, Nitrite (NO_2) + Nitrate (NO_3), Dissolved	mg/L	USEPA STORET Modern	336 (dissolved)
			$NO_2 + NO_3$ Dissolved	Nitrogen Nitrite Plus Nitrate Dissolved (mg/L as N)	mg/L as N	USGS QWDATA	00631
			$NO_2 + NO_3$ Total	Nitrogen Nitrite Plus Nitrate Total (mg/L as N)	mg/L as N	USGS QWDATA	00630
			NO_2&NO_3 N-Diss mg/L	Nitrite Plus Nitrate, Diss. 1 Det. (mg/L as N)	mg/L as N	USEPA STORET Legacy	00631
			NO_3-N Diss mg/L	Nitrate Nitrogen, Dissolved (mg/L as N)	mg/L as N	USEPA STORET Legacy	00618
		0.2259	N, Nitrate Total	Nitrogen, Nitrate, Total (mg/L as NO_3)	mg/L as NO_3	USGS QWDATA	71850
			Nitr. NO_3 as NO_3 Dis	Nitrogen, Nitrate, Dissolved (mg/L as NO_3)	mg/L as NO_3	USGS QWDATA	71851
Nitrogen, organic nitrogen, total[a]	mg/L as N	1	Nitrogen Organic T.	Nitrogen Organic Total (mg/L as N)	mg/L as N	USGS QWDATA	00605

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots—Continued

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m^3, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
Nitrogen, ammonia, dissolved[a]	mg/L as N	1	Ammonia Nitrogen	Ammonia Nitrogen	mg/L as N	MMSD Water Quality	Ammonia
			NH_3+NH_4^- N Diss mg/L	Nitrogen, Ammonia, Dissolved (mg/L as N)	mg/L as N	USEPA STORET Legacy	00608
			NH_3+NH_4^- N Total mg/L	Nitrogen, Ammonia, Total (mg/L as N)	mg/L as N	USEPA STORET Legacy	00610
			Nitrogen Ammonia D.	Nitrogen Ammonia Dissolved (mg/L as N)	mg/L as N	USGS QWDATA	00608
			Nitrogen Ammonia T.	Nitrogen Ammonia Total (mg/L as N)	mg/L as N	USGS QWDATA	00610
			Nitrogen, Ammonia, Dissolved	Nitrogen, Ammonia (NH_3), Dissolved	mg/L	USEPA STORET Modern	330 (dissolved)
			Nitrogen, Ammonia, Total	Nitrogen, Ammonia (NH_3), Total	mg/L	USEPA STORET Modern	330 (total)
		0.7765	Nitr, NH_4 as NH_4 Dis	Nitrogen, Ammonia, Dissolved (mg/L as NH_4)	mg/L as NH_4	USGS QWDATA	71846
			Nitrogen, NH_4, Total	Nitrogen, Ammonia, Total (mg/L as NH_4)	mg/L as NH_4	USGS QWDATA	71845
Phosphorus, total	mg/L as P	1	Phos-Tot mg/L P	Phosphorus, Total (mg/L as P)	mg/L as P	USEPA STORET Legacy	00665
			Phosphorus as P, Total	Phosphorus as P, Total	mg/L as P	USEPA STORET Modern	1473 (total)
			Phosphorus Total	Phosphorus Total (mg/L as P)	mg/L as P	USGS QWDATA	00665
			Total Phosphorus mg/L	Total Phosphorus mg/L	mg/L as P	MMSD Water Quality	Tot_phos
		0.001	Phosphor Wtr Tot Rec Ug/L	Phosphorus (P), Water, Total Recoverable Ug/L	µg/L	USEPA STORET Legacy	00662
		0.3262	Phosphorus Tot PO_4	Phosphorus Total (mg/L as PO_4)	mg/L as PO_4	USGS QWDATA	71886
Phosphorus, dissolved	mg/L as P	1	Phosphorus as P, Dissolved	Phosphorus as P, Dissolved	mg/L as P	USEPA STORET Modern	1473 (dis-solved)
			Phosphorus Diss.	Phosphorus Dissolved (mg/L as P)	mg/L as P	USGS QWDATA	00666
			Total Soluble Phosphorus mg/L	Total Soluble Phosphorus mg/L	mg/L as P	MMSD Water Quality	Tot_sol_phos
Cadmium, total, sediment	mg/g as Cd	1	Cadmium Bot. Mat.	Cadmium Total In Bottom Material (µg/g as Cd)	µg/g as Cd	USGS QWDATA	01028
			Cd Mud Dry Wgt mg/kg-Cd	Cadmium, Total In Bottom Deposits (mg/kg, Dry Wgt)	mg/kg	USEPA STORET Legacy	01028

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots—Continued

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m³, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
Cadmium, total, water	µg/L as Cd	1	Cadmium Cd.Tot µg/L	Cadmium, Total (µg/L as Cd)	µg/L as Cd	USEPA STORET Legacy	01027
			Cadmium Total	Cadmium Total (µg/L as Cd)	µg/L as Cd	USGS QWDATA	01027
			Cadmium, Total	Cadmium, Total	µg/L	USEPA STORET Modern	74 (total)
			Total Cadmium (Analyzed By Graphite Furnace Atomic Absorption) µg/L	Total Cadmium (Analyzed By Graphite Furnace Atomic Absorption) µg/L	µg/L	MMSD Water Quality	Cadmium
Mercury, total, sediment	mg/g as Hg	1	Mercury Btm	Mercury, Recoverable From Bottom Material, µg/g as Hg	µg/g as Hg	USGS QWDATA	71921
			Mercury Sed mg/kg Dry Wgt	Mercury, Tot. In Bot. Depos. (mg/kg as Hg Dry Wgt)	mg/kg as Hg	USEPA STORET Legacy	71921
Mercury, total, water	µg/L as Hg	1	Mercury (Total) AA Cold Vapor	Mercury (Total) AA Cold Vapor	µg/L	MMSD Water Quality	340
			Mercury Hg.Total µg/L	Mercury, Total (µg/L as Hg)	µg/L as Hg	USEPA STORET Legacy	71900
			Total Mercury	Total Mercury	µg/L	MMSD Water Quality	HG
Copper, total, sediment	mg/g as Cu	1	Copper Bot. Mat.	Copper Total In Bottom Material (µg/g as Cu)	µg/g as Cu	USGS QWDATA	01043
			Copper Mud Dry Wt	Copper Mud Dry Wt	mg/kg	USEPA STORET Legacy	01043
Copper, total, water	µg/L as Cu	1	Copper Cu.Tot µg/L	Copper, Total (µg/L as Cu)	µg/L as Cu	USEPA STORET Legacy	01042
			Copper Total	Copper Total (µg/L as Cu)	µg/L as Cu	USGS QWDATA	01042
			Copper, Total	Copper, Total	µg/L	USEPA STORET Modern	140 (total)
			Total Copper µg/L	Total Copper µg/L	µg/L	MMSD Water Quality	Copper
Lead, total, sediment	mg/g as Pb	1	Lead Sed mg/kg Dry Wgt	Lead In Bottom Deposits (mg/kg as Pb Dry Wgt)	mg/kg as Pb	USEPA STORET Legacy	01052
			Lead Total Bot. Mat.	Lead Total In Bottom Material (µg/g as Pb)	µg/g as Pb	USGS QWDATA	01052

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots—Continued

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m^3, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
Lead, total, water	µg/L as Pb	1	Lead Pb.Tot µg/L	Lead, Total (µg/L as Pb)	µg/L as Pb	USEPA STORET Legacy	01051
			Lead Total	Lead Total (µg/L as Pb)	µg/L as Pb	USGS QWDATA	01051
			Lead. Total	Lead, Total	µg/L	USEPA STORET Modern	285 (total)
			Total Lead (Analyzed By Graphite Furnace Atomic Absorption) µg/L	Total Lead (Analyzed By Graphite Furnace Atomic Absorption) µg/L	µg/L	MMSD Water Quality	Lead
Arsenic, total, sediment	mg/g as As	1	Arsenic Bot. Mat.	Arsenic Total In Bottom Material (µg/g as As)	µg/g as As	USGS QWDATA	01003
			Arsenic Sed mg/kg Dry Wgt	Arsenic In Bottom Deposits (mg/kg as As Dry Wgt)	mg/kg as As	USEPA STORET Legacy	01003
Arsenic, total, water	µg/L as As	1	Arsenic As.Tot µg/L	Arsenic, Total (µg/L as As)	µg/L as As	USEPA STORET Legacy	01002
			Arsenic Total	Arsenic Total (µg/L as As)	µg/L as As	USGS QWDATA	01002
			Total Arsenic (Analyzed By Graphite Furnace Atomic Absorption) µg/L	Total Arsenic (Analyzed By Graphite Furnace Atomic Absorption) µg/L	µg/L	MMSD Water Quality	Arsenic
Nickel, total, sediment	mg/g as Ni	1	Nickel Bot. Mat.	Nickel Total In Bottom Material (µg/g as Ni)	µg/g as Ni	USGS QWDATA	01068
			Nickel Sed mg/kg Dry Wgt	Nickel, Total In Bottom Deposits (mg/kg, Dry Wgt)	mg/kg	USEPA STORET Legacy	01068
Nickel, total, water	µg/L as Ni	1	Nickel Ni.Total µg/L	Nickel, Total (µg/L as Ni)	µg/L as Ni	USEPA STORET Legacy	01067
			Nickel Total	Nickel Total (µg/L as Ni)	µg/L as Ni	USGS QWDATA	01067
			Total Nickel µg/L	Total Nickel µg/L	µg/L	MMSD Water Quality	Nickel
Chromium, total, sediment	mg/g as Cr	1	Chromium Mud Dry Wt	Chromium Mud Dry Wt	mg/kg	USEPA STORET Legacy	01029
			Chromium Total B.M.	Chromium Total In Bottom Material (µg/g as Cr)	µg/g as Cr	USGS QWDATA	01029
Chromium, total, water	µg/L as Cr	1	Chromium Cr.Tot µg/L	Chromium, Total (µg/L as Cr)	µg/L as Cr	USEPA STORET Legacy	01034
			Chromium Total	Chromium Total (µg/L as Cr)	µg/L as Cr	USGS QWDATA	01034
			Total Chromium µg/L	Total Chromium µg/L	µg/L	MMSD Water Quality	Chromium

Table 6. Properties and constituents used in calculating statistics for summary-statistics tables, maps, and boxplots—Continued

[#/100 mL, number of colonies per 100 milliliters; mg/L, milligrams per liter; mg/m^3, milligrams per cubic meter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; µg/g, micrograms per gram; µg/L, micrograms per liter; the original constituent description information is taken from the source with minor alterations and may contain abbreviations]

Generalized constituent name	Units for generalized constituent name	Correction factor for generalized constituent name	Original constituent name	Original constituent description	Original units	Source of constituent	Original constituent code
Zinc, total, sediment	mg/g as Zn	1	Zinc Bottom Material	Zinc Total In Bottom Material (µg/g as Zn)	µg/g as Zn	USGS QWDATA	01093
			Zinc Mud Dry Wgt	Zinc Mud Dry Wgt	mg/kg	USEPA STORET Legacy	01093
Zinc, total, water	µg/L as Zn	1	Total Zinc µg/L	Total Zinc µg/L	µg/L	MMSD Water Quality	Zinc
			Zinc Total	Zinc Total (µg/L as Zn)	µg/L as Zn	USGS QWDATA	01092
			Zinc Zn, Tot µg/L	Zinc, Total (µg/L as Zn)	µg/L as Zn	USEPA STORET Legacy	01092
			Zinc, Total	Zinc, Total	µg/L	USEPA STORET Modern	545 (total)
Chlorophyll *a*, corrected for pheophytin	mg/m^3	1	Chlorophyll "A" mg/m^3	Chlorophyll "A" mg/m^3	mg/m^3	MMSD Water Quality	Chlorophyll
E. coli	#/100 mL	1	*E. coli*	*E. coli*	#/100 mL	MMSD Water Quality	EColiQT
Fecal coliform	#/100 mL	1	Coliform Fecal 0.7	Fecal Coliform.7 Um-Mf (Col./ 100 mL)	cols./100 mL	USGS QWDATA	31625
			Fec Coli M-Fcagar /100 ml	Fecal Coliform, Membr Filter, M-Fc Agar,44.5c,24hr	#/100 mL	USEPA STORET Legacy	31613
			Fec Coli Mpnecmed /100 ml	Fecal Coliform, Mpn, Ec Med,44.5c (Tube 31614)	MPN	USEPA STORET Legacy	31615
			Fecal Coli.Mfc Mf.W	Fecal Coliform, Mfc Mf Method, Water, Colonies/100 mL	cols./100 mL	USGS QWDATA	31616
			Fecal Coliform Bacteria Mpn/ 100 mL	Fecal Coliform Bacteria Mpn/100 ml	MPN/100 mL	MMSD Water Quality	F_coliform_M PN

[a]This constituent was not analyzed or discussed in the report, however it was used to calculate total nitrogen.

driven program, either for high or low flows. Some samples may have been collected as part of a monitoring program, whereas others may have been targeted to sample in an area known to be contaminated.

Screening of Data

Some data for many chemical constituents were reported as less than a "reporting limit," which could have been a method detection limit, minimum detection limit, laboratory reporting limit, etc. Often, multiple reporting limits were reported for each constituent. Reporting limits are indicated in the summary statistics tables and statistical distribution figures. In addition, the number of results with concentrations below a reporting limit are indicated in the summary-statistics tables.

Data with concentrations reported as "less than" were evaluated according to the following rules when creating the summary-statistics tables, statistical-distribution figures, maps of locations of constituent sampling and median concentrations, and graphs of seasonality and trends:

1. Where a remark flag indicated the actual concentration was less than the reported concentration, concentrations were set to half the original concentration or half the reporting-limit concentration where the original concentration was reported as zero. Concentrations reported as zero without a reporting limit were left as zero. These concentrations were then used in the calculation of all summary statistics and in generation of statistical-distribution figures.
2. In graphing statistical-distribution data on a log scale, concentrations of zero were set to the next lowest concentration of $1x10^x$. For example, if a concentration of total phosphorus was reported as zero because the actual concentration was below the reporting limit and the minimum concentration above zero was 0.02, the concentrations of zero would be set to 0.01 for use in the statistical-distribution figures because plotting concentrations of zero is not allowed on a log scale.
3. Concentrations and other measurements were rounded. The number of decimal places to which they have been rounded is indicated in the headnote of each summary-statistics table. Some data sets indicated values with significant figures, others did not. For the purposes of this report, the decision was made to report rounded values to a certain decimal place rather than to a specific number of significant figures.

When comparing similar constituents from different legacy sources, concentrations with different units were converted to like units (table 6). This included changes such as converting milligrams per liter to micrograms per liter and converting milligrams per liter as NO_3 to milligrams per liter as N.

Outliers for specific conductance (concentrations less than 20 µS/cm) and pH (concentrations less than 4.0 standard units) were not considered when creating the summary statistics tables, statistical-distribution figures, maps, or graphs.

Most concentrations for total nitrogen are sums of various reported nitrogen species because few legacy data sets included much data as total nitrogen. In cases where concentrations for total nitrogen and many other nitrogen species were available for the same sample, the total nitrogen value was taken. Otherwise, total nitrogen was calculated either as the sum of dissolved nitrate and dissolved Kjeldahl nitrogen or the sum of dissolved nitrate and total organic nitrogen and dissolved ammonia. A brief comparison of actual and calculated total nitrogen concentrations (for samples with total as well as nitrogen-species data) showed considerable similarity.

In some cases, there was more than one dissolved nitrate species from which to choose. The species of nitrate chosen was according to the following order of precedence: dissolved nitrite plus nitrate as N, total nitrite plus nitrate as N, dissolved nitrate as N, dissolved nitrate as NO_3 (converted to "as N" for calculations), total nitrate as N, and total nitrate as NO_3 (converted to "as N" for calculations). Nitrite concentrations are typically very low in comparison to nitrate, so nitrite plus nitrate concentrations were considered to be comparable to nitrate concentrations. There may also have been more than one type of dissolved ammonia from which to choose. The species of ammonia chosen was according to the following order of precedence: dissolved ammonia as N, dissolved ammonia as NH_4 (converted to "as N" for calculations), total ammonia as N, total ammonia as NH_4 (converted to "as N" for calculations).

Where one of the nitrogen species involved in the total nitrogen calculation was reported as below a reporting limit, the concentration was halved according to the rules discussed previously; however, which particular nitrogen species was below a reporting limit is not noted in this report because of the complexity of the calculation process.

Evaluation of Historical Data

The water properties and constituents discussed in the following sections were selected because of their relevance to the study, spatial and temporal distribution of samples, and sufficiency of data for interpretation, either spatially or temporally.

Descriptions of data for each property and constituent in this report generally include a text description, a map showing the location of sampling sites, and some further information describing the data (median concentrations, counts of samples collected at a site). Also included are summary statistics tables, statistical distribution figures for most constituents, and, in some cases, graphs showing seasonality and (or) trends.

Guidelines used by the USEPA, WDNR, and Canada for drinking water and (or) for the protection of aquatic life where available are discussed for each property or constituent. Water from rivers is not used as drinking water in the Milwaukee area, which gets most of its drinking water from Lake Michigan; however, drinking-water guidelines are used for a relative comparison to concentrations because of a lack of other established criteria. The guidelines referenced in this report are summarized in table 7. Where guideline concentrations were near or within the range of concentrations measured for a property or constituent, the guideline concentration is indicated in the statistical distribution figure, and sites with median concentrations that exceeded the lowest guideline concentration are indicated on the maps.

All surface-water, sediment, and tissue-chemistry constituents were analyzed for seasonality and trends by examining data from five sites (fig. 8). The five sites were Kinnickinnic River at 1st Street, Lincoln Creek at 47th Street, Menomonee River at 70th Street, Milwaukee River at Wells Street, and Oak Creek at Ryan Road. These sites were chosen because they had a relatively large amount of data for many constituents and were well distributed over several watersheds in the MMSD planning area. In a few cases, sufficient data were not available for the five sites. In some cases, data for other sites were examined for trends but data for most sites were insufficient for trend analysis. Graphs for seasonality and (or) trends are included only where statistically significant seasonality or trends were detected.

Maps generally include sampling-site locations and, where appropriate, median concentrations and the number of samples collected from 1970 through 2002. Median concentrations are depicted at the sampling-site locations by means of color schemes that group the overall median concentrations by quartile ranges. Subwatersheds with data for a constituent are also shaded to indicate overall median concentration for the subwatershed based on the same quartile ranges as the sampling site. Some maps indicate the number of samples collected by the size of the site-location symbol (categories are listed in the map explanation and generally include 1 to 10 samples, 11 to 100 samples, and more than 100 samples). The number of sites in a subwatershed and the total number of samples collected for those sites give readers a way to visually determine the credibility of assigning a median concentration to a subwatershed. The ranges of median concentrations at sampling sites are generally larger than the median concentrations for subwatersheds; therefore, the same range of colors shown for sampling sites may not be shown for subwatersheds. Subwatersheds that do not have any shading are those where no data were collected in the subwatershed for that constituent. In places where sampling locations on the main map are numerous and appear very close together, an additional blown-up area near downtown Milwaukee is shown to allow readers to more easily determine the locations of and median concentrations at those sampling sites.

Summary statistics listed for each property and constituent include counts of samples collected, earliest and latest sample dates, reporting-limit concentrations, and minimum, maximum, mean, and percentiles. In cases where many concentrations were below a reporting limit and reporting limits were numerous, statistical-distribution figures were not drawn and some summary statistics were left out of the table. Subwatersheds in which all or more than half of the samples had concentrations below a reporting limit are described in the text for each constituent.

Because of constraints on the size of this report, maps illustrating concentrations and sampling sites by time period were not included. Additional figures were included to show locations of sites that have been measured or sampled since 1998 and may be part of a current monitoring program (especially for water chemistry, streamflow, stream stage, and precipitation).

Streamgages where streamflow and stage data were collected and meteorological stations where precipitation data were collected since 1998 were relatively well distributed over the MMSD planning area (fig. 9). The upper reaches of the Menomonee River watershed, middle reaches of the Lower Milwaukee River subwatershed, and parts of the Root River and Oak Creek watersheds were not as well covered by streamgages as other parts of the planning area are (fig. 9). Typically the smaller subwatersheds in the headwaters of major rivers have not been gaged (fig. 9). Precipitation gages have been clustered toward the central part of the planning area (fig. 9).

Inorganic, nutrient, and physical field-measurement data collected since 1998 have been fairly extensive (fig. 10). Nevertheless, some of the smaller subwatersheds in the headwaters of major streams like the Nor-X-Way Channel, Underwood Creek, Whitnall Park Creeks, and North Branch Oak Creek had not been sampled since 1998 for inorganic constituents, nutrients, or physical properties (fig. 10). In some other subwatersheds, including the Little Menomonee River and Middle Root River, these properties and constituents were measured or sampled at only one or two sites (fig. 10).

Pesticide, organics, and trace-elements data were collected since 1998 at sites sparsely distributed across the planning area (fig. 11). Subwatersheds in the headwaters of the major rivers generally had not been sampled for any of these constituents since 1998 (fig. 11). The number of sites where pesticide data had been collected was especially limited in the Fox River, Oak Creek, and much of the Menomonee and Kinnickinnic watersheds (fig. 11). Sites where organics data had been collected were a little more widespread, but the Fox River and Menomonee River watersheds were still underrepresented (fig. 11). Distribution of sites where trace-elements data were collected was similar to that for organics data; however, there were additional sites in the Fox River where trace-elements data were collected (fig. 11).

Sites where bacteria (fecal coliform and *Escherichia coli*), biological (fish, macroinvertebrates, algae), and habitat-assessment and channel-measurement data have been collected since 1998 were located throughout most of the MMSD planning area, with the exception of some headwaters subwatersheds (fig. 12). Sites where bacteria had been sampled were limited in the Fox River and Menomonee River watersheds and in most headwater subwatersheds. Collection of biological data was distributed over most of the planning area except parts of the Menomonee River watershed and some headwaters subwatersheds (fig. 12). Locations where habitat assessments or channel measurements were made were sparsely distributed throughout the MMSD planning area except in the headwaters subwatersheds (fig. 12). The Menomonee River was particularly well covered; however, most sites were involved in a one-time sediment transport study (Inter-Fluve, Inc., 2001) for which channel measurement information was available but no other habitat information had been collected. (fig. 12)

Table 7. U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and Canadian water- and sediment-quality guidelines

[CWA, Clean Water Act; MMSD, Milwaukee Metropolitan Sewerage District]

Reference	Type	Abbreviation	Definition
U.S. Environmental Protection Agency, 2002a	Drinking water	MCL	Maximum Contaminant Level—"The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLG [see below] as feasible using the best available analytical and treatment technologies and taking cost into consideration. MCLs are enforceable standards."
		MCLG	Maximum Contaminant Level Goal—"A non-enforceable health goal which is set at a level at which no known or anticipated adverse effect on the health of persons occurs and which allows an adequate margin of safety."
		SDWR	Secondary Drinking Water Regulation—"Non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water."
U.S. Environmental Protection Agency, 2000a	Ambient water quality for rivers and streams	Nutrient Criteria	Nutrient Criteria for Level II Ecoregion VII, Level III Ecoregion 53 — "EPA's ecoregional nutrient criteria are intended to address cultural eutrophication-- the adverse effects of excess nutrient inputs . . . . These criteria provide EPA's recommendations to States and authorized Tribes for use in establishing their water quality standards consistent with section 303(c) of CWA . . . . The Clean Water Act establishes a national goal to achieve, wherever attainable, water quality which provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." The value used in the MMSD Corridor Study report for comparison to median concentrations is the "25th Percentiles based on all seasons data for the Decade" listed in "Table 3c, Reference conditions for level III ecoregion 53." These nutrient criteria limits are currently in a "proposed" status and have not been finalized.
U.S. Environmental Protection Agency, 1986	Ambient water quality for fresh recreational water	Ambient water quality for bacteria	Ambient water quality guideline for bacteria—". . . upper limits for densities of indicator bacteria in waters that are associated with acceptable health risks for swimmers."
U.S. Environmental Protection Agency, 2002e	Guideline values regarding effects on aquatic communities	CMC	Criteria Maximum Concentration—". . . an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. . . . Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States."
		CCC	Criterion Continuous Concentration—". . . an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. . . . Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States."
Wisconsin Department of Natural Resources, 2003b	Drinking water	NR 809 MCL	NR 809 Maximum Contaminant Level—"Maximum Contaminant Levels (MCLs) contained in Chapter 809, Wisconsin Administrative Code. MCLs are the highest level of a contaminant that is allowed in drinking water."
Wisconsin Department of Natural Resources, 2001a	Aquatic life	Aquatic life criteria	Wisconsin State statute NR 102, Water Quality Standards for Wisconsin Surface Waters, in part lists standards of criteria for fish and aquatic life (NR 102.04 (4)), including criteria for dissolved oxygen for different stream classifications.

Table 7. U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and Canadian water- and sediment-quality guidelines—Continued

[CWA, Clean Water Act; MMSD, Milwaukee Metropolitan Sewerage District]

Reference	Type	Abbreviation	Definition
Health Canada, 2002	Drinking water	MAC	Maximum Allowable Concentration—"MACs have been developed for parameters, or substances, which are known or suspected to cause deleterious health effects. This term assumes the parameter would be consumed over a lifetime at that concentration." (Canadian Ground Water Association, 1999)
		IMAC	Interim Maximum Allowable Concentration—"IMACs are listed for substances for which not enough information is known to determine a Maximum Acceptable Concentration." (Canadian Ground Water Association, 1999)
		AO	Aesthetic Objective—"AOs are for specific parameters which affect water quality based on smell, taste or color. There are substances which fall under aesthetic objectives which in high enough quantities may impose a health risk." (Canadian Ground Water Association, 1999)
Canadian Council of Ministers of the Environment, 2002b	Aquatic life - water	Aquatic life criteria	Water quality guideline for the protection of aquatic life in freshwater—"Guideline values are meant to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term" (Canadian Council of Ministers of the Environment, 1999)
Canadian Council of Ministers of the Environment, 2002a	Aquatic life - sediment	ISQG	Interim Sediment Quality Guideline—"The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely . . . . The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline." An interim guideline is recommended if there is a limited amount of information on methods used to establish guideline values. (Canadian Council of Ministers of the Environment, 2001)
		PEL	Probable Effect Level—"(PEL), defines the level above which adverse effects are expected to occur frequently." (Canadian Council of Ministers of the Environment, 2001)
MacDonald and others, 2000	Aquatic life - sediment	TEC	Threshold Effect Concentration—Threshold effect concentration, ". . . below which adverse effects are not expected to occur . . . . most of the TECs . . . provide an accurate basis for predicting sediment toxicity."
		PEC	Probable Effect Concentration—Probable effect concentration, ". . . above which adverse effects are expected to occur more often than not . . . . most of the PECs . . . provide an accurate basis for predicting sediment toxicity."

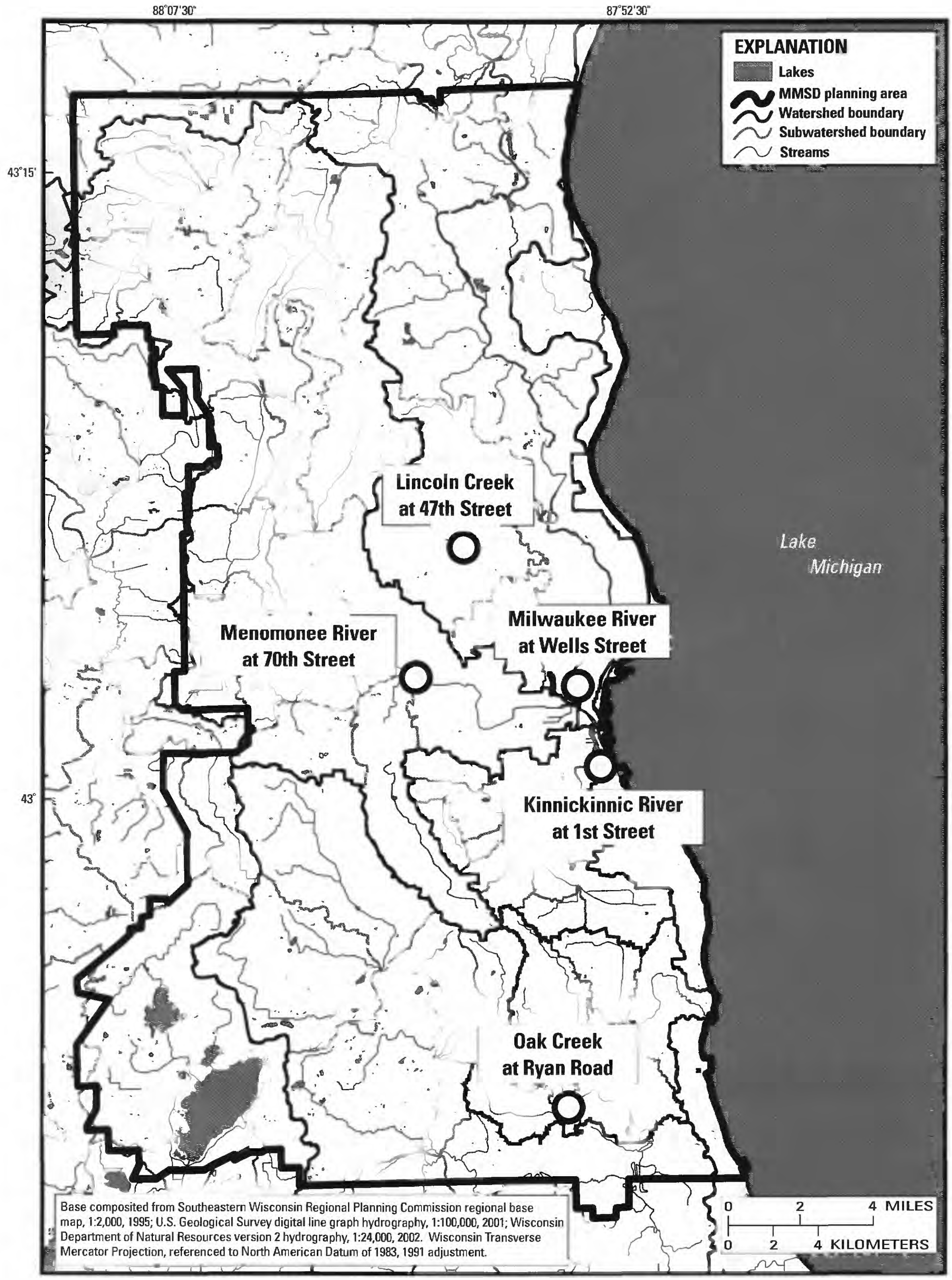

Figure 8. Locations of sites typically examined for seasonality and temporal trends in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

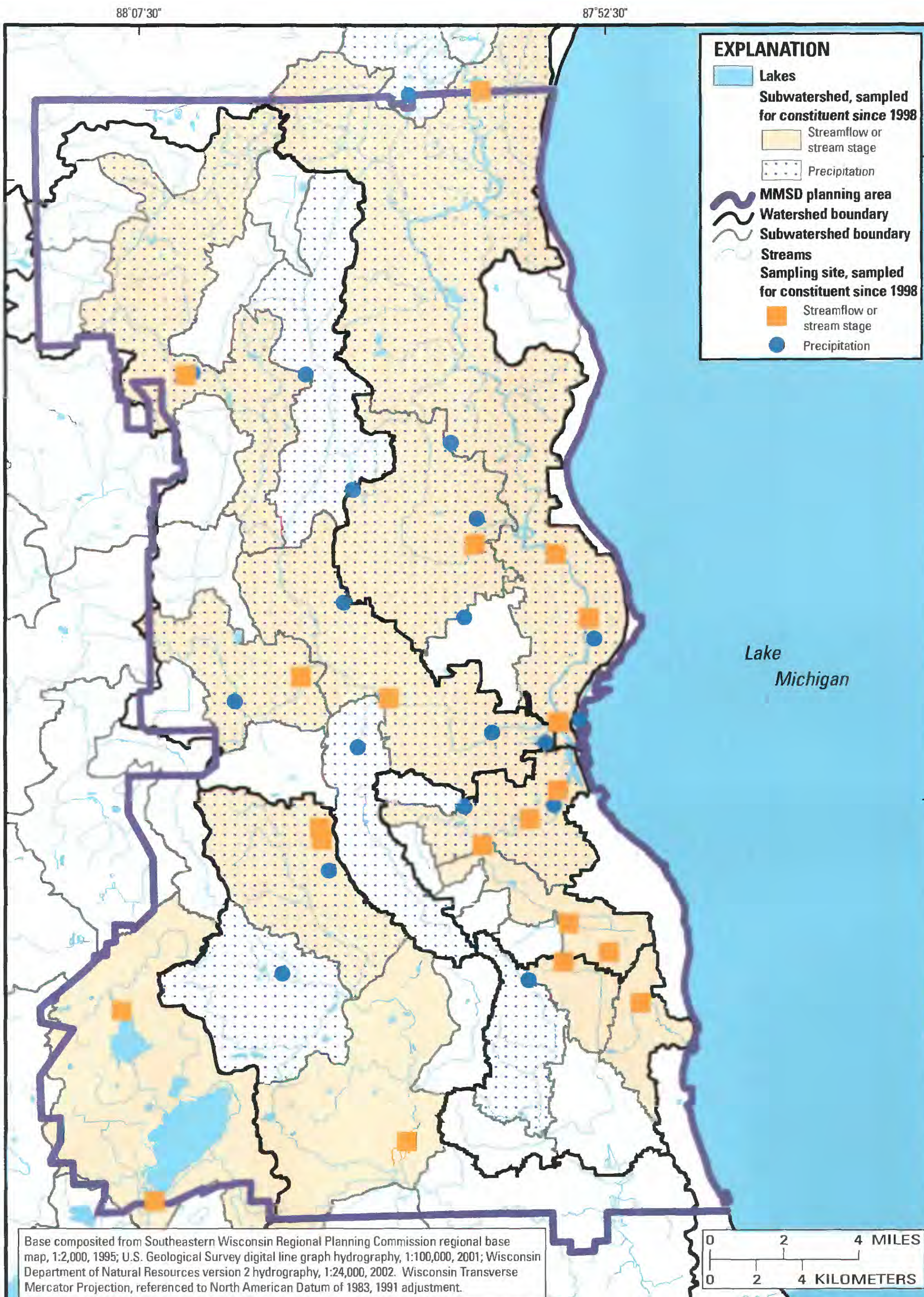

Figure 9. Locations of sites sampled for streamflow, stream stage, or precipitation since 1998 in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Figure 10. Locations of sites sampled for physical properties, nutrients, or inorganic constituents since 1998 in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

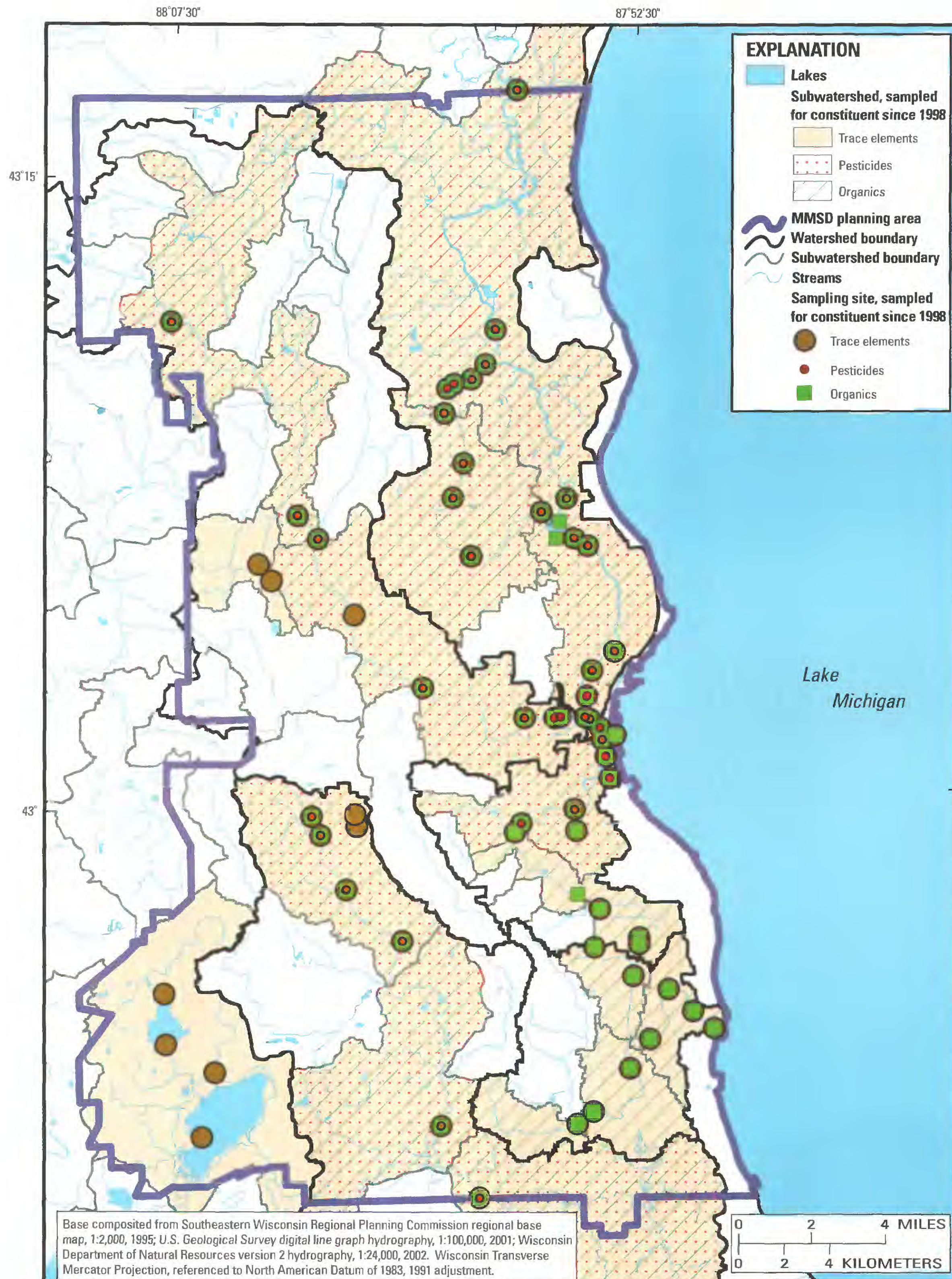

Figure 11. Locations of sites sampled for trace elements, pesticides, or organics since 1998 in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

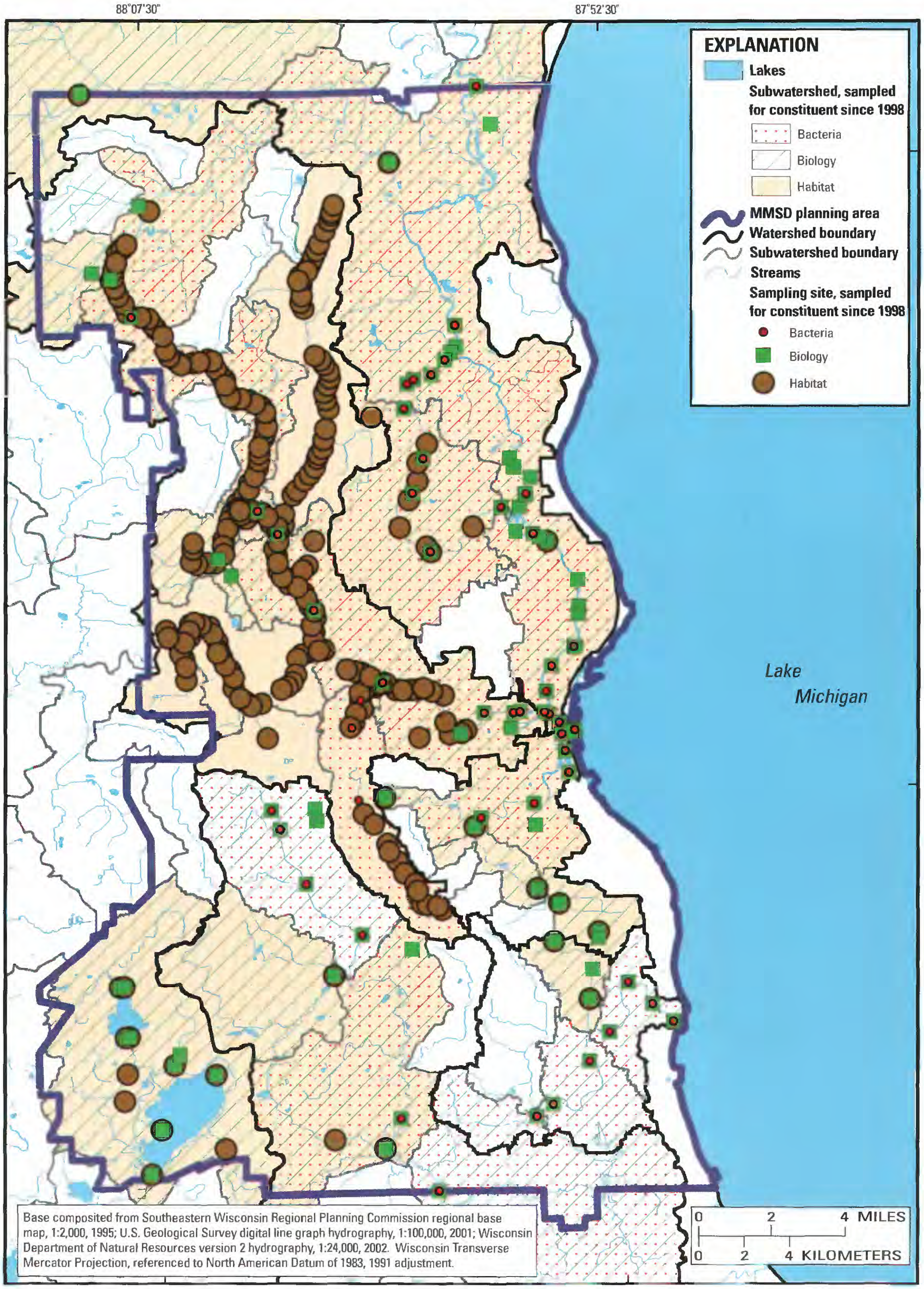

Figure 12. Locations of sites sampled for bacterial, biological, or habitat data since 1998 in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Physical Data

Rainfall and streamflow strongly affect stream chemistry, geomorphology, and aquatic communities. Water quality can vary greatly in response to streamflow. Flooding, erosion, and sedimentation are major issues related not only to instream water quality but also to structural damage and other negative effects in downstream areas. In addition, a great demand has been placed on water resources in Wisconsin by increased multiple uses such as maintenance of fish and wildlife habitat, irrigation of crops, dilution and assimilation of wastes, production of hydroelectric power, and maintenance of adequate flows for boating.

Streamflow, Stream Stage, and Precipitation

The USGS and MMSD record stream stage (the height of the water above an arbitrary reference point) and precipitation in the study area to estimate streamflow and to gain information for modeling/predictive purposes. MMSD also uses stage data to study the effects of river stage on sewer systems. Stage measurements are continuously recorded by equipment inside a gagehouse located on the stream bank, and they are relayed via telephones or satellites to USGS offices. Measurements of the volume of water passing a given stream cross section in a given period of time ("streamflow" or "discharge", reported as cubic feet per second, or ft^3/s) are made to develop a mathematical relation between river stage and flow. Actual measurements are made over the entire stage range to verify and update the relation, which may change over time in response to changes in channel characteristics.

USGS has estimated streamflow data at 42 sites within the MMSD planning area for various periods of record beginning in 1970 and continuing until present (fig. 13, table 8). "Daily mean discharge" is stored in the MMSD Corridor Study database in cubic feet per second.

USGS streamflow data are available in real time on the World Wide Web for a broad range of users that include flood forecasters, government officials, consultants, industry, and recreational users such as fishermen and kayakers (U.S. Geological Survey, 2003).

MMSD collected stream-elevation data at four sites in the MMSD planning area beginning in 1993 and continuing to the present (fig. 13, table 8). Hourly elevations (in feet referenced to the National Geodetic Vertical Datum of 1929) are stored in the MMSD Corridor Study database. These data were not used to estimate stream discharge.

All major watersheds in the MMSD planning area currently have at least one streamgage where streamflow is computed (fig. 13). Several of the subwatersheds do not; however, in most cases, there is a streamgage downstream in another watershed so that surface waters are well accounted for in the planning area. The upper reaches of the Menomonee River watershed, middle reaches of the Lower Milwaukee River subwatershed, and parts of the Root River and Oak Creek watersheds were not as well covered by streamgages as are other parts of the planning area. Typically, the smaller subwatersheds in the headwaters of major rivers have not been gaged.

Daily mean streamflows (fig. 14) at the Milwaukee River and Oak Creek stations have a seasonal pattern, with higher daily mean flows from March through May. This seasonality of higher daily flows is related to snowmelt and spring rains and resultant higher antecedent soil moisture. At the other three stations this seasonality is less apparent, perhaps because of a higher proportion of impervious surface at these sites. Therefore, high flows may occur at these sites even during drier seasons because overland runoff is the primary factor driving streamflow at these urban sites, not soil moisture.

Plots of streamflow over time (fig. 15) show little evidence of long-term trends in the planning area. Yearly fluctuations can be seen, however, and the same patterns are not observed at all stations, indicating variation across the planning area.

MMSD measured precipitation at 20 gages in the planning area (table 8). Precipitation gages were clustered toward the center part of the planning area, leaving the northern and southern parts with less coverage (fig. 13). MMSD also uses precipitation data for regulatory reporting (storm duration, intensity, and frequency of recurrence) for performance review of the ISS (Inline Storage System, otherwise known as "the deep tunnel"). Data are stored as cumulative inches per day at an hourly increment. Collection of precipitation data began in 1993 and continues to present.

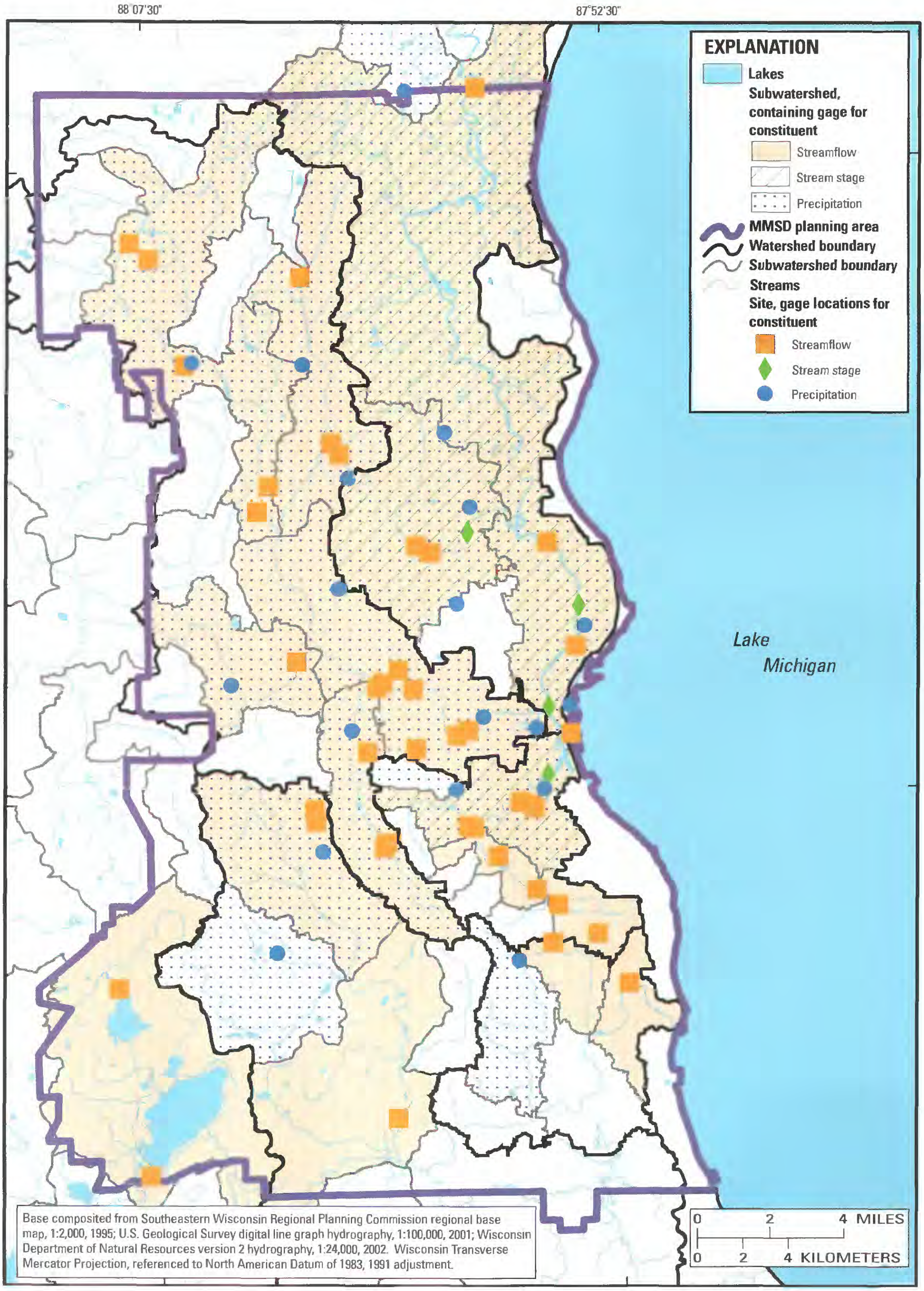

Figure 13. Locations of streamflow, stream stage, and precipitation gages in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

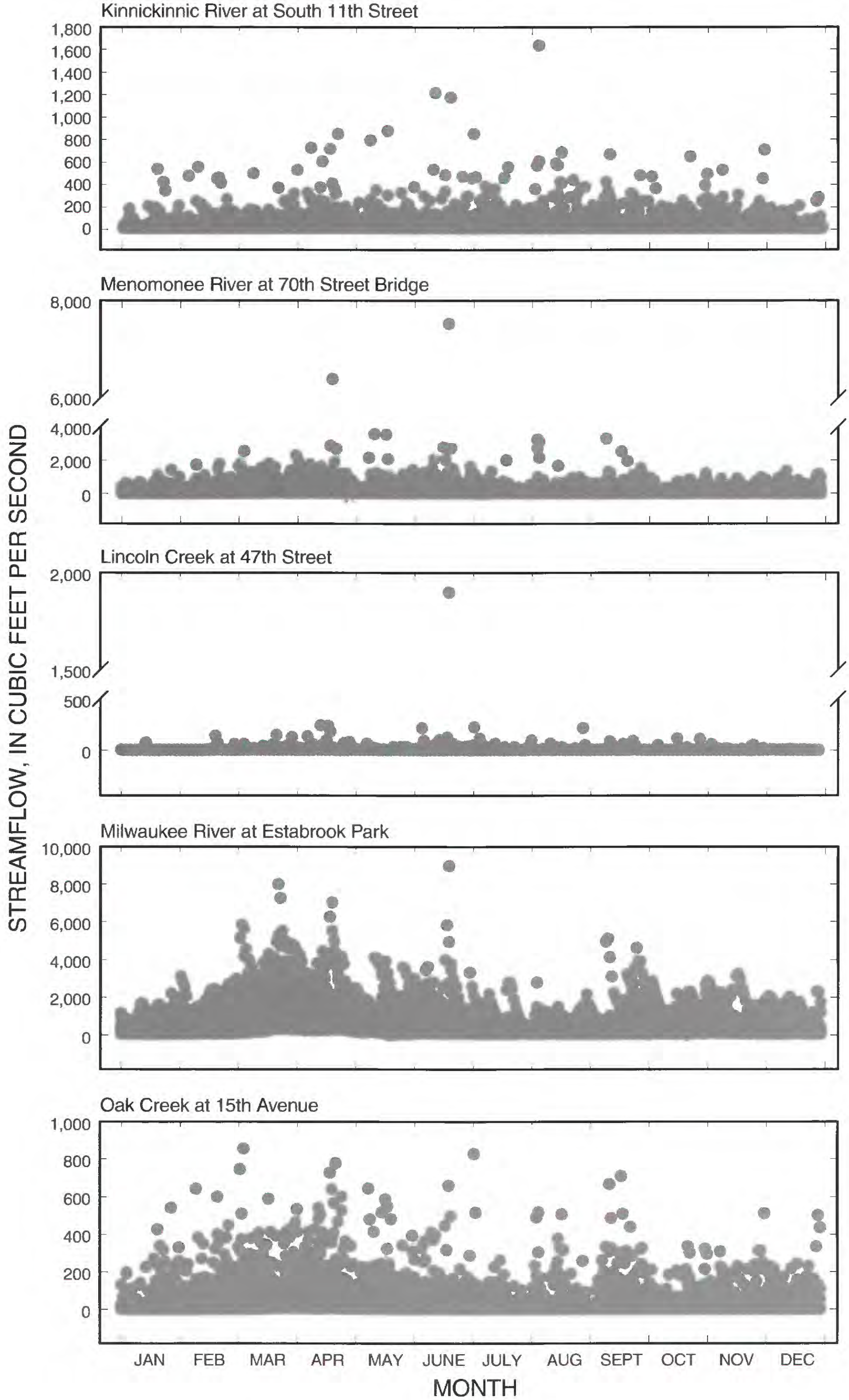

Figure 14. Seasonality of streamflow for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

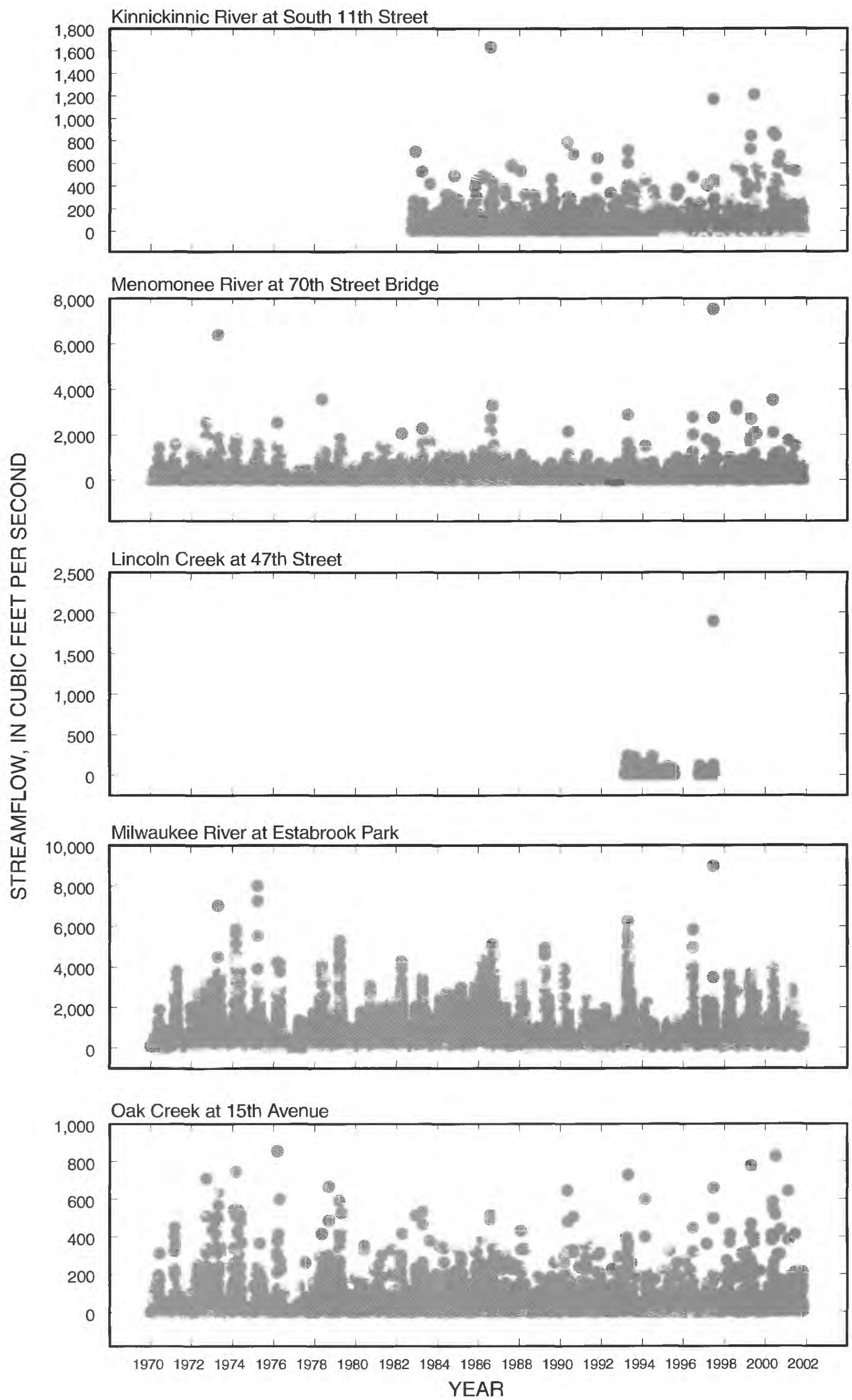

Figure 15. Trends of streamflow for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 8. Summary statistics for streamflow, stream stage, and precipitation, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; MMSD, Milwaukee Metropolitan Sewerage District; --, no data available]

		USGS				MMSD							
		Streamflow				Stream stage				Precipitation			
Watershed	Subwatershed	Sites per subwatershed	Count of results	Earliest date	Latest date	Sites per subwatershed	Count of results	Earliest date	Latest date	Sites per subwatershed	Count of results	Earliest date	Latest date
Fox River	Muskego Lake	2	3,532	10/01/1987	11/06/2001	--	--	--	--	--	--	--	--
Kinnickinnic River	Kinnickinnic River	4	9,650	07/01/1976	11/06/2001	1	41,682	06/02/1994	08/05/2001	1	74,573	01/01/1993	08/05/2001
	West Milwaukee Ditch	--	--	--	--	--	--	--	--	1	74,572	01/01/1993	08/05/2001
	Wilson Park Creek	5	5,295	11/12/1996	11/06/2001	--	--	--	--	--	--	--	--
Lake Michigan Tributary	Lake Michigan Tributary	--	--	--	--	--	--	--	--	1	73,962	01/01/1993	08/05/2001
Menomonee River	Honey Creek	4	2,592	12/01/1974	06/29/1982	--	--	--	--	1	74,572	01/01/1993	08/05/2001
	Little Menomonee River	4	5,285	11/01/1974	09/30/1990	--	--	--	--	2	149,145	01/01/1993	08/05/2001
	Lower Menomonee River	6	16,608	01/01/1970	11/06/2001	--	--	--	--	3	223,749	01/01/1993	08/05/2001
	Upper Menomonee River	4	13,086	11/01/1974	11/06/2001	--	--	--	--	1	74,658	01/01/1993	08/05/2001
	Underwood Creek	1	9,655	11/01/1974	11/06/2001	--	--	--	--	1	73,106	01/01/1993	08/05/2001
Milwaukee River	Lower Cedar Creek	--	--	--	--	--	--	--	--	1	35,239	01/01/1997	08/05/2001
	Lincoln Creek	3	1,272	03/26/1981	06/30/1997	1	60,104	09/06/1994	08/05/2001	2	149,146	01/01/1993	08/05/2001
	Lower Milwaukee River	4	20,481	01/01/1970	11/06/2001	2	114,636	06/02/1994	08/05/2001	2	149,146	01/01/1993	08/05/2001
Oak Creek	Mitchell Field Drainage Ditch	1	1,654	11/12/1996	11/06/2001	--	--	--	--	--	--	--	--
	North Branch Oak Creek	--	--	--	--	--	--	--	--	2	110,747	01/01/1993	08/05/2001
	Lower Oak Creek	1	11,633	01/01/1970	11/06/2001	--	--	--	--	--	--	--	--
Root River	Middle Root River	1	11,633	01/01/1970	11/06/2001	--	--	--	--	--	--	--	--
	Upper Root River	2	1,148	03/02/1999	09/30/2000	--	--	--	--	1	74,573	01/01/1993	08/05/2001
	Whitnall Park Creeks	--	--	--	--	--	--	--	--	1	74,569	01/01/1993	08/05/2001

Chemical Indicators of Water Quality

The chemistry of the water, sediment, and tissues collected in surface waters of the MMSD planning area reflect naturally occurring conditions as well as the influence of the surrounding urban environment.

Selected Field Measurements and Miscellaneous Constituents

Aquatic organisms are strongly influenced by certain physical properties and chemical constituents of water that are commonly measured in the field, such as dissolved oxygen, biochemical oxygen demand, and particulate matter in the water column. These properties and constituents can be influenced by natural environmental factors and the urban setting.

pH

The pH of water affects the physiological functions of plants and animals and is an important indictor of the overall health of water bodies. The measurement of pH indicates whether a water is acidic or basic; more precisely, pH is the indication of hydrogen ion concentration in water and is directly related to the ratio of hydrogen (H+) and hydroxyl (OH-) activities at any given temperature (U.S. Geological Survey, 1998). pH is reported on a scale of 0 to 14, with a measurement of 7 considered neutral. The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen (Hem, 1985). If hydrogen activity is greater than hydroxyl activity, the solution is considered acidic (pH less than 7.0); if hydroxyl activity is greater than hydrogen activity, the solution is considered basic, or alkaline (pH greater than 7.0).

Natural and anthropogenic sources can both affect pH. Carbon dioxide (CO_2) enters waterways through the atmosphere, runoff, release from bacteria, and respiration from aquatic plants, and it forms a weak acid when it dissolves in the water. River water in areas not influenced by pollution generally has a pH in the range of 6.5 to 8.5. Release of acidic and alkaline compounds from rocks and soils can influence pH. Water draining from marshes and forests is often slightly acidic because of acids produced by decaying vegetation (Murphy, 2002c). Anthropogenic sources of acidity can include exhaust from cars and powerplant emissions which increase the concentrations of nitrogen oxides and sulfur dioxide in the air; these chemicals react in the atmosphere to form nitric and sulfuric acid.

Water with a pH that is very high (greater than 9.5) or very low (less than 4.5) are unsuitable for most aquatic organisms. Young fish and immature aquatic insects are extremely sensitive to pH less than 5.0 and may die. Low pH can also affect aquatic life by altering stream chemistry. Low pH accelerates the release of metals from rock and sediments, and these metals can affect fish metabolism. pH above 9.0 can harm fish by denaturing cellular membranes (Murphy, 2002c). The USEPA Secondary Drinking Water Regulation (SDWR) and Canadian drinking water Aesthetic Objective (AO) both recommend a pH between 6.5 and 8.5 for drinking-water supply. Low pH can impart a bitter metallic taste and be corrosive to plumbing; high pH can result in a slippery feel and soda taste and can increase deposits in plumbing. The Canadian water-quality guideline for protection of aquatic life specifies a pH of 6.5–9.0.

A site in the Muskego Lake subwatershed on Big Muskego Lake was the only site with a median pH measurement above the Canadian aquatic life guideline of 9.0 standard units (fig. 16). The highest median pH measurements frequently were measured at lake sites. Sites with the highest median measurements were in the Kinnickinnic River, Lincoln Creek, Honey Creek, Muskego Lake, and Butler Ditch subwatersheds (fig. 16).

Maximum measurements of pH for the subwatershed were above the guideline of 9.0 standard units in the Muskego Lake, Kinnickinnic River, Lower Menomonee River, Upper Menomonee River, Lincoln Creek, Lower Milwaukee River, and Lower Oak Creek subwatersheds (fig. 17, table 9). Minimum measurements of pH for the subwatershed were below the guideline of 6.5 standard units in the Kinnickinnic River, Lower Menomonee River, Upper Menomonee River, Lower Milwaukee River, Mitchell Field Drainage Ditch, Muskego Lake, Upper Root River, and Wilson Park Creek subwatersheds (fig. 17, table 9).

Data to determine seasonality were available at four of the five intensive sites; data were unavailable for Oak Creek at Ryan Road from early December to mid-March (fig. 18). The Milwaukee River and Menomonee River sites had similar variability with increasing pH to early spring (early May), decreasing pH to around August, and slightly increasing pH until the end of the year. Oak Creek data had a downward trend to near August and then an upward trend through the end of the data (early December). These seasonal variations follow the growing season for aquatic plants and could be due to the increased respiration of aquatic plants. There was much more variability at Lincoln Creek; pH increased from October to early March, but throughout the spring and summer it demonstrated no consistent pattern.

Trend analysis at the sites showed similar changes at the Kinnickinnic River, Menomonee River, Lincoln Creek and the Milwaukee River (fig. 19): a slight upward trend (in readings) in the early to mid-1980s was followed by a slight downward trend until the latter 1990s (98–99) and a slight upward trend through 2002. Data collection at from Lincoln Creek started in 1992; the pH trend was downward to the late 1990s then slightly upward through 2002. At Oak Creek at Ryan Road, the trend was different than at the other four sites: slight downward trend from the start of the record through 2002.

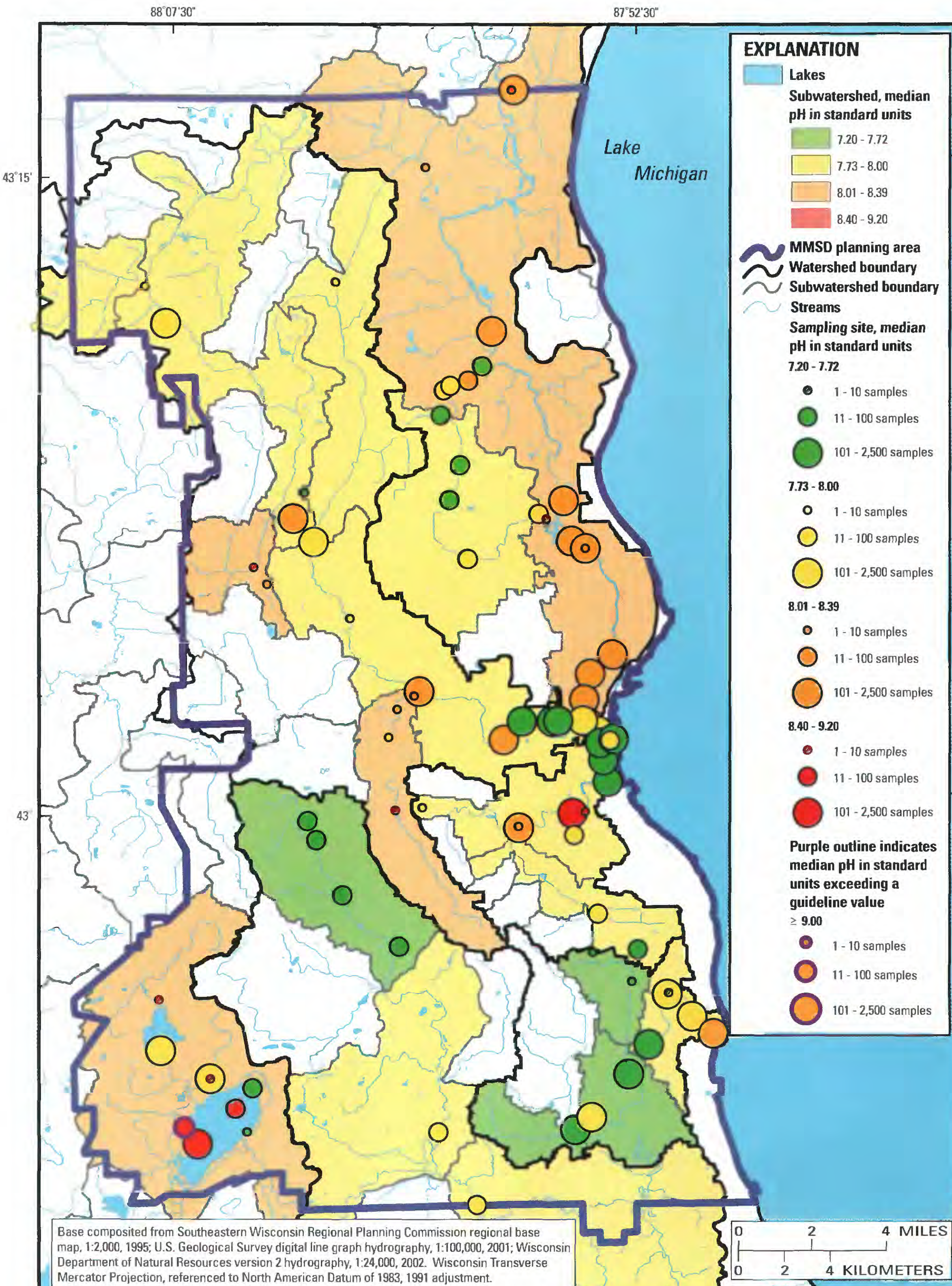

Figure 16. Sites sampled for pH in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

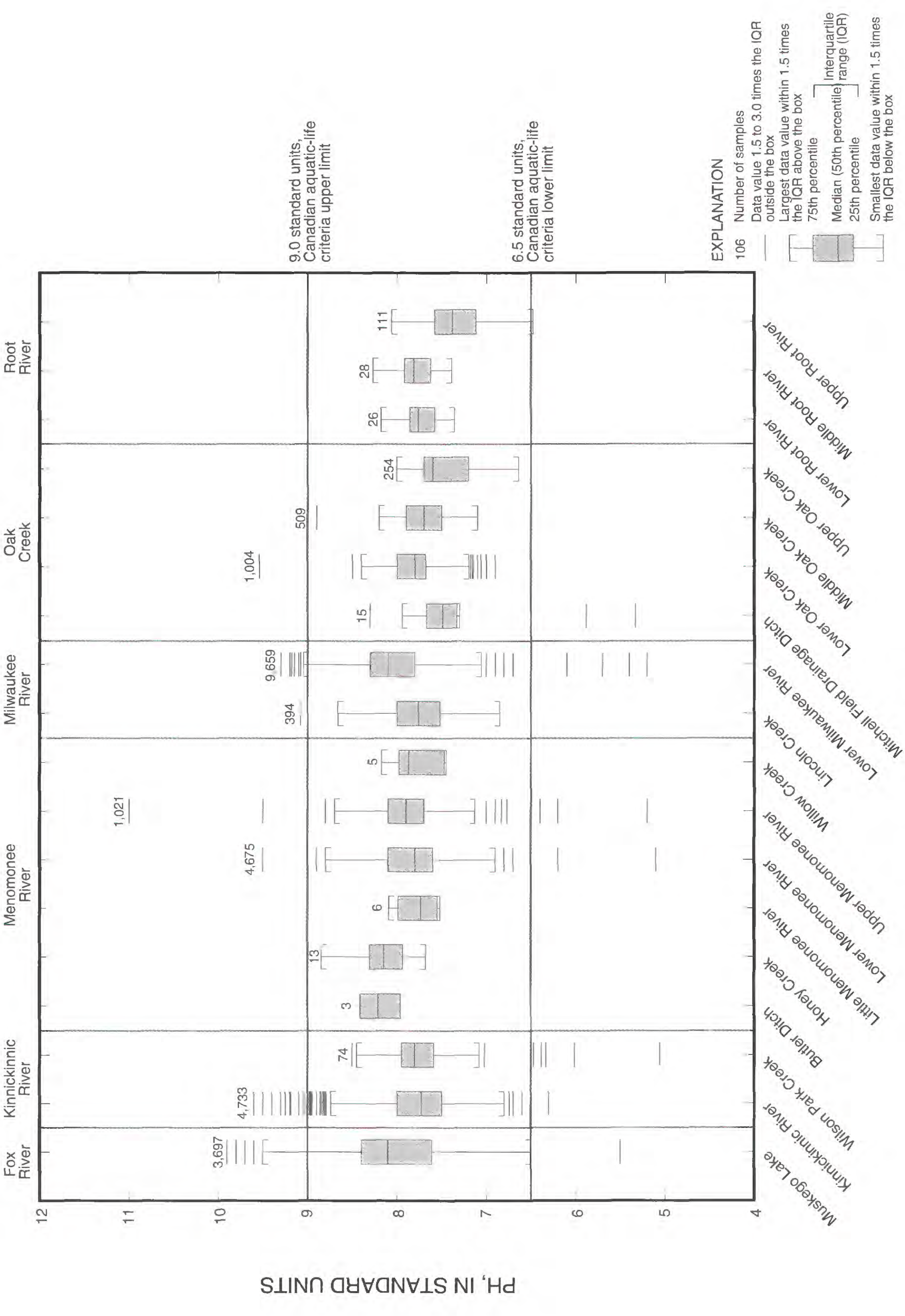

Figure 17. Statistical distribution of pH measurements in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

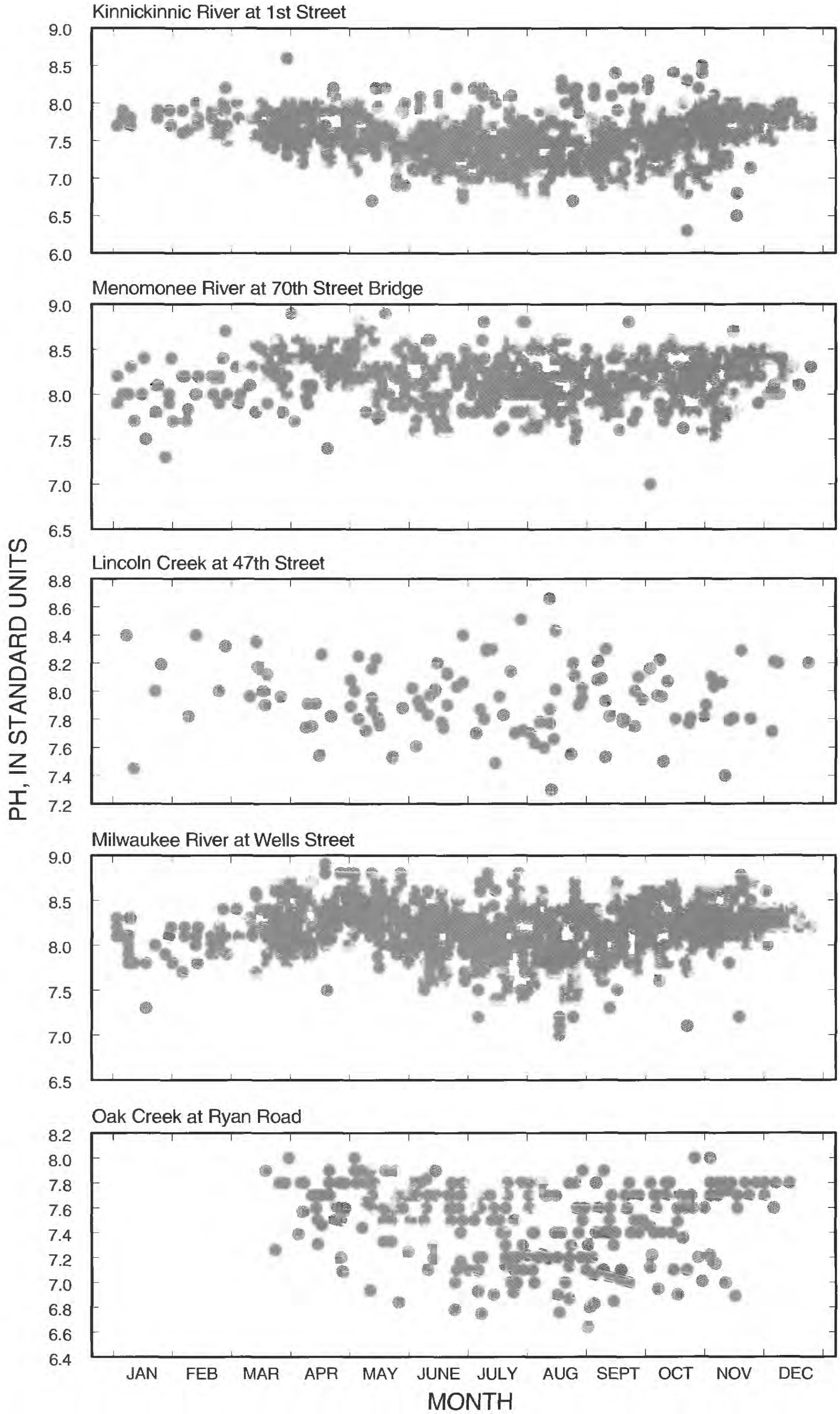

Figure 18. Seasonality of pH for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

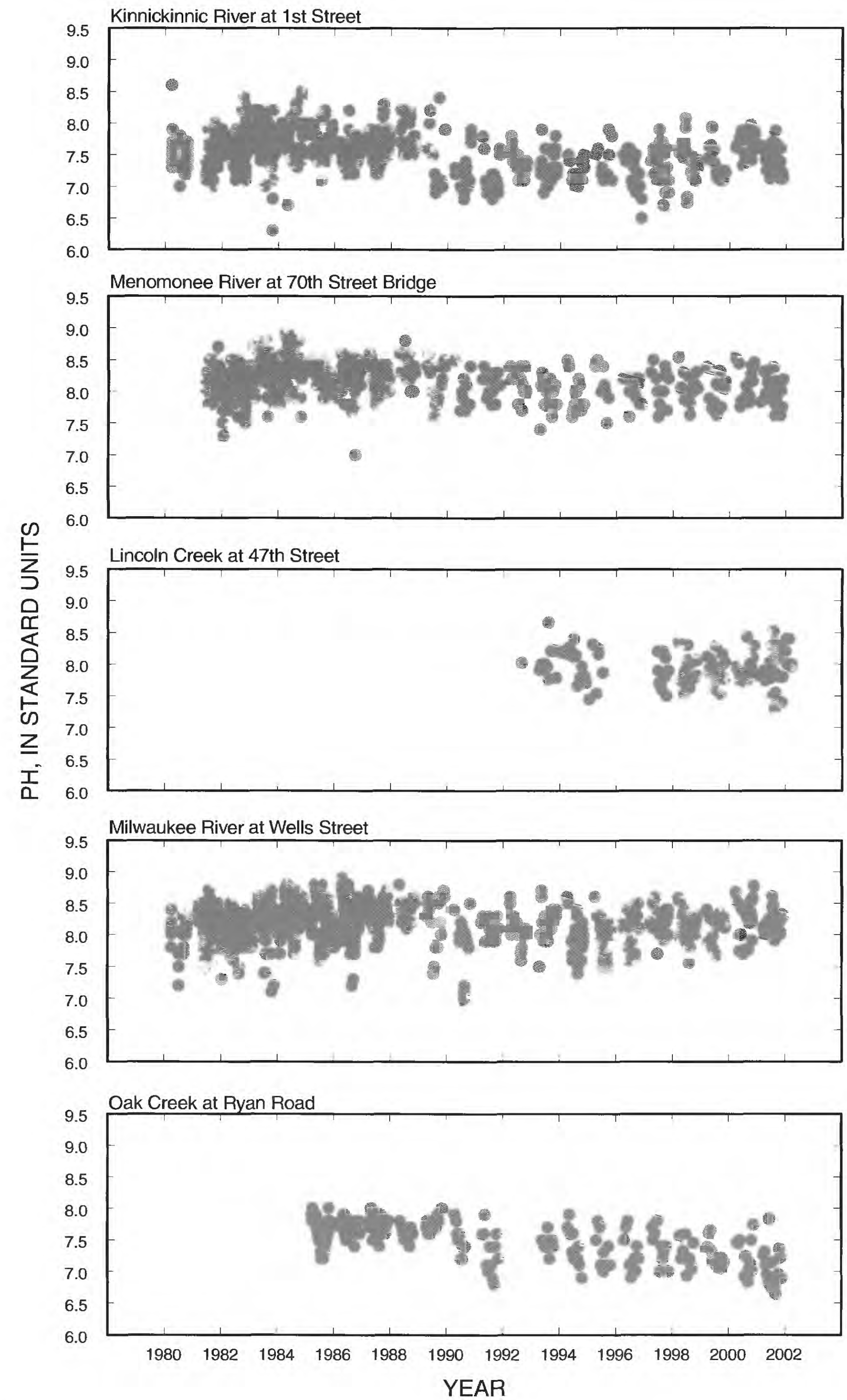

Figure 19. Trends of pH for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 9. Summary statistics for pH, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; values are in standard units; values rounded to nearest hundredth]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	16	0	3,687	10	3,697	0	10/17/1986	08/29/2001	5.50[a]	7.40	7.61	8.10	8.07	8.40	8.70	9.90
Kinnickinnic River	Kinnickinnic River	7	4,725	2	6	4,733	0	05/21/1979	11/27/2001	6.30[a]	7.30	7.50	7.73	7.79	8.00	8.40	9.60
	Wilson Park Creek	3	0	0	74	74	0	01/11/1999	09/22/2000	5.06	7.09	7.59	7.81	7.67	7.95	8.09	8.50
Menomonee River	Butler Ditch	2	0	0	3	3	0	04/21/1999	04/24/2001	7.96	8.01	8.09	8.21	8.19	8.31	8.37	8.41
	Honey Creek	4	12	1	0	13	0	07/10/1995	08/21/2001	7.68	7.72	7.94	8.15	8.15	8.31	8.52	8.85
	Little Menomonee River	2	0	6	0	6	0	07/10/1995	10/18/2001	7.52	7.54	7.59	7.74	7.77	7.94	8.04	8.09
	Lower Menomonee River	7	4,675	0	0	4,675	0	05/21/1979	11/27/2001	5.10	7.40	7.60	7.80	7.82	8.10	8.30	9.50
	Upper Menomonee River	3	1,021	0	0	1,021	0	05/24/1982	11/27/2001	5.20[a]	7.60	7.70	7.90	7.92	8.10	8.30	11.00
	Willow Creek	1	0	5	0	5	0	05/24/2001	10/18/2001	7.45	7.46	7.47	7.87	7.79	7.98	8.09	8.17
	Lincoln Creek	6	340	54	0	394	0	08/31/1992	03/20/2002	6.85	7.39	7.52	7.76	7.78	8.00	8.21	9.08
Milwaukee River	Lower Milwaukee River	17	9,317	335	7	9,659	0	01/25/1973	03/20/2002	5.20[a]	7.60	7.80	8.10	8.08	8.30	8.50	9.30
Oak Creek	Mitchell Field Drainage Ditch	2	0	0	15	15	0	01/11/1999	09/22/2000	5.33	6.45	7.34	7.49	7.34	7.66	7.89	8.30
	Lower Oak Creek	4	1,003	1	0	1,004	0	03/21/1985	11/19/2001	6.90[a]	7.50	7.68	7.80	7.83	8.00	8.20	9.54
	Middle Oak Creek	2	509	0	0	509	0	03/21/1985	11/19/2001	7.10	7.40	7.50	7.70	7.69	7.90	8.00	8.90
	Upper Oak Creek	1	254	0	0	254	0	03/21/1985	11/19/2001	6.64	7.03	7.21	7.60	7.48	7.70	7.80	8.00
Root River	Lower Root River	1	26	0	0	26	0	08/25/1999	10/10/2001	7.36	7.55	7.61	7.77	7.76	7.86	7.97	8.18
	Middle Root River	1	28	0	0	28	0	08/25/1999	10/10/2001	7.39	7.51	7.63	7.82	7.79	7.92	8.04	8.27
	Upper Root River	4	111	0	0	111	0	08/25/1999	10/10/2001	6.48	7.00	7.15	7.38	7.35	7.58	7.69	8.06

[a]The minimum value was below 4.00 standard units, below which concentrations were considered to be outliers, and was replaced with the next highest minimum value equal to or above 4.00 standard units.

Alkalinity

Alkalinity is an expression of buffering capacity, or the capacities of solutes in water to neutralize a strong acid. Alkalinity is not a reflection of pH but instead refers to the ability of water to resist changes in pH. Most natural waters contain substantial amounts of dissolved carbon dioxide species, which are the principal components of alkalinity.

Natural and anthropogenic factors both affect alkalinity. Rainwater is naturally acidic (pH less than 7.0) because of exposure to carbon dioxide in the atmosphere: its alkalinity is generally less than 10.0 mg/L as $CaCO_3$ and can be less than 1.0 mg/L as $CaCO_3$, depending on the pH (Hem, 1985). High alkalinity concentrations in ground water are not uncommon, and concentrations greater than 1,000 mg/L as $CaCO_3$ can occur in ground water that is low in calcium and magnesium. As surface water, ground water or rainwater percolates through and moves over soils and rock formations containing calcite or dolomitic limestones, these formations and soils will dissolve (leach) calcium and bicarbonate salts to the water, increasing alkalinity (Wurts and Durborow, 1992). Industrial or sewage effluent can increase alkalinity in streams. Many cleaning agents and food residues contain carbonate and bicarbonate.

There are no water quality guidelines for alkalinity. Concentrations of 20–200 mg/L as $CaCO_3$ are typical of freshwater. Alkalinity between 100 and 200 mg/L as $CaCO_3$ will stabilize stream pH. Concentrations below 10 mg/L as $CaCO_3$ indicate the system is poorly buffered and is very susceptible to changes in pH from natural and anthropogenic sources (Murphy, 2002a).

Sites with the highest median alkalinity concentrations were in the Upper Menomonee River, Lower Milwaukee River, Upper Root River, Middle Root River, Upper Oak Creek, and Lower Oak Creek subwatersheds (fig. 20). Sites with the lowest median alkalinity concentrations were in the Little Menomonee River, Lower Menomonee River, Lower Milwaukee River, Lincoln Creek, Honey Creek, Kinnickinnic River, and Muskego Lake subwatersheds (fig. 20).

The Upper Root River, Upper Oak Creek, Upper Menomonee River, Middle Root River, and Lower Oak Creek subwatersheds had the highest median alkalinity concentrations (fig. 20). Median concentrations in the Little Menomonee River, Honey Creek, Kinnickinnic River, and Muskego Lake subwatersheds were the lowest (fig. 20). The highest maximum alkalinity concentrations were measured in the Lower Milwaukee River (1,112 mg/L as $CaCO_3$) and Kinnickinnic River subwatersheds (989 mg/L as $CaCO_3$) (fig. 21, table 10). The Upper Root River subwatershed had the highest median alkalinity concentration (325 mg/L as $CaCO_3$) (fig. 21, table 10).

Seasonality analysis indicates that alkalinity was slightly lower in midsummer than during winter. The Kinnickinnic River and Menomonee River showed similar seasonal variability (fig. 22): concentrations decreasing starting in January, rise slightly near May, decline throughout the summer, increase near October, and decline again near December. The Milwaukee River site showed similar seasonal variability, but with a much more gradual slope to its declines and rises. Both Lincoln Creek and Oak Creek had multiple cycles of increasing and decreasing alkalinity throughout the year but the fluctuations were much more pronounced at Lincoln Creek. There were frequent rises and declines from April through November at Lincoln Creek; the changes in trends at Oak Creek were more subtle and occurred from May/June to October/November.

Temporal trends were not as noticeable as seasonal variability was at the five sites (fig. 23). There appeared to be a slight downtrend in alkalinity concentrations for the period of record at the Kinnickinnic River, Menomonee River, and possibly Oak Creek. There was a slight uptrend in alkalinity concentrations at Lincoln Creek, and no perceptible change at the Milwaukee River at Wells Street.

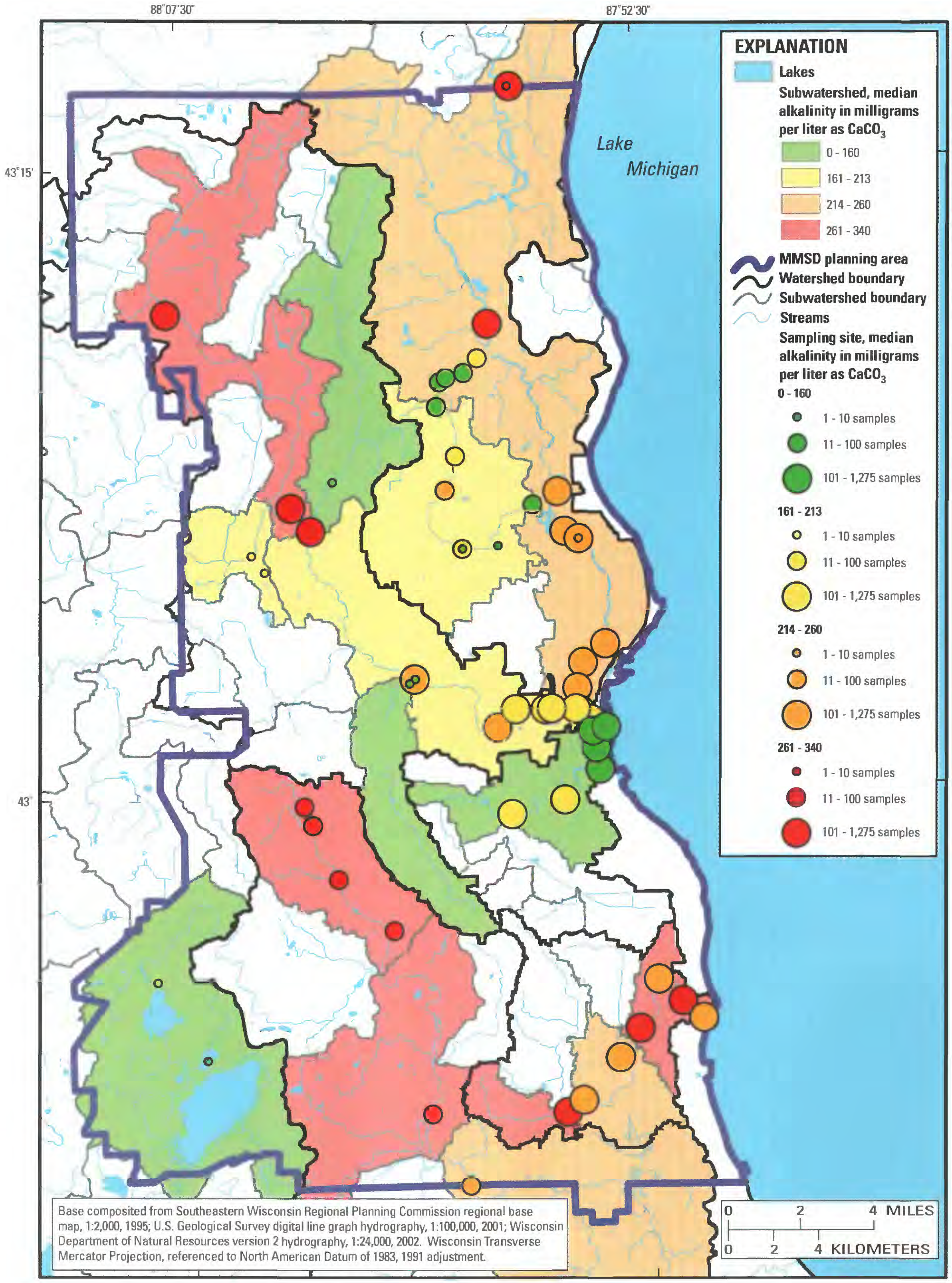

Figure 20. Sites sampled for alkalinity in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

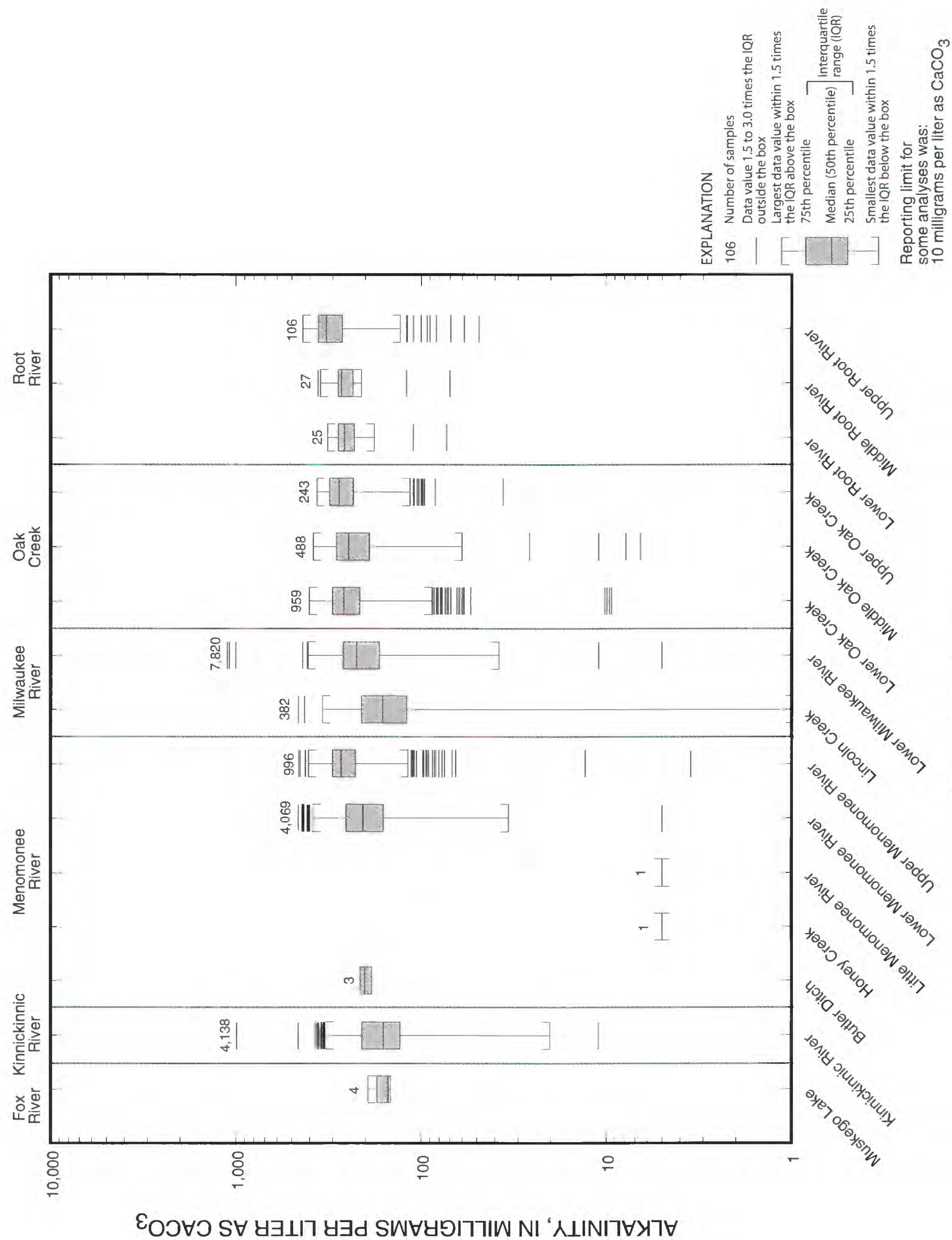

Figure 21. Statistical distribution of alkalinity concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

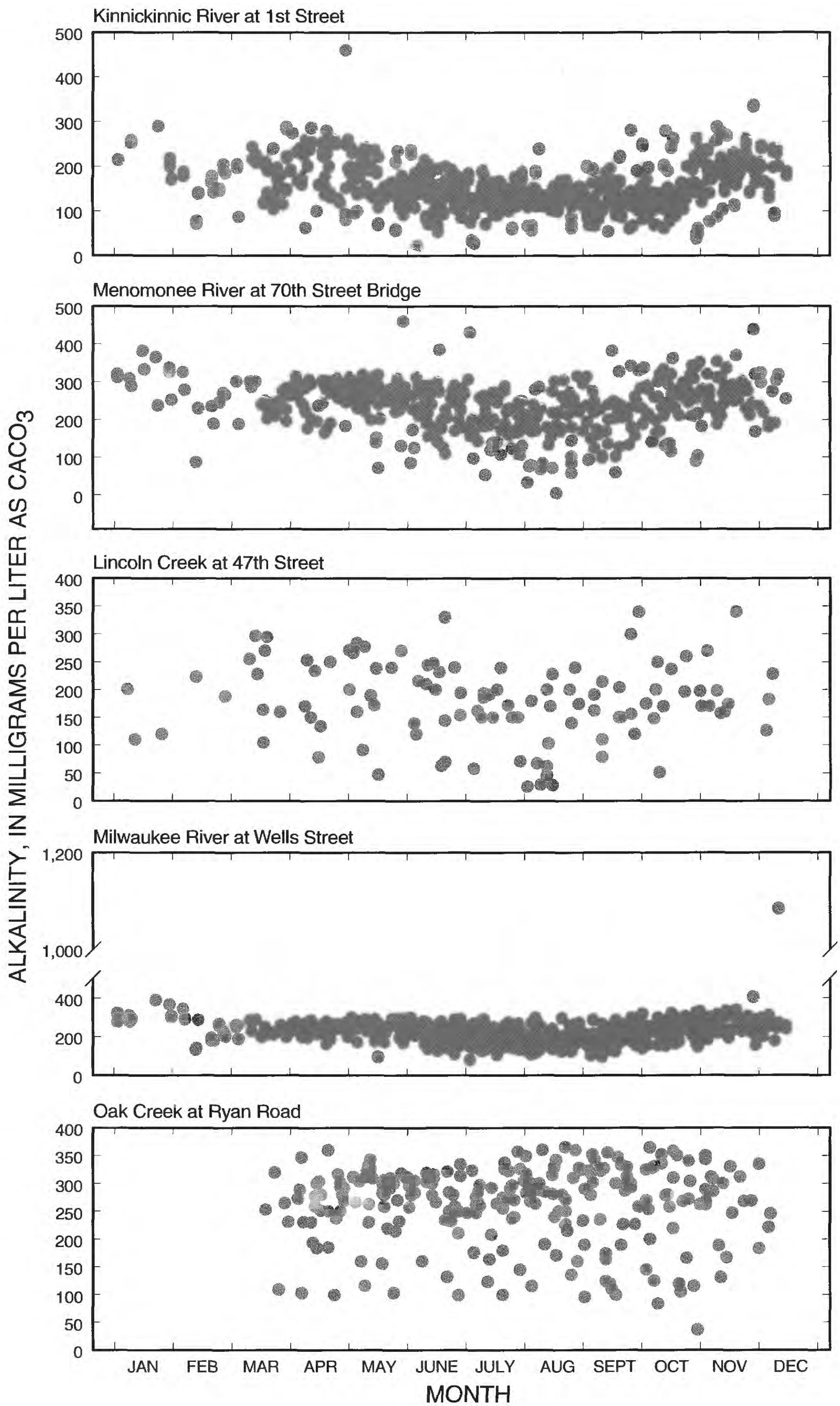

Figure 22. Seasonality of alkalinity for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

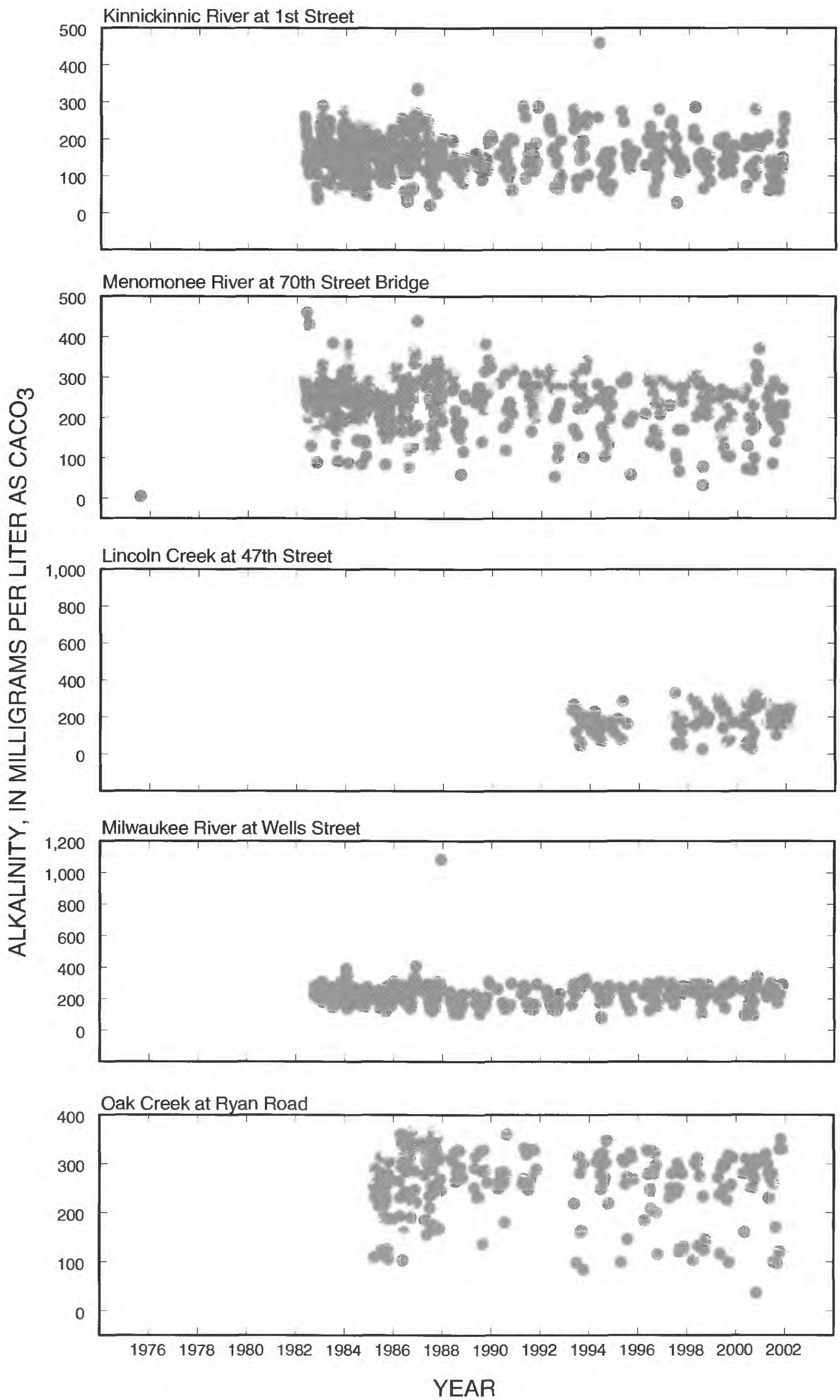

Figure 23. Trends of alkalinity for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 10. Summary statistics for alkalinity, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as calcium carbonate (mg/L as $CaCO_3$); values rounded to the nearest whole number; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half of the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	2	0	0	4	4	0	--	04/18/2001	08/29/2001	146	148	150	152	161	162	181	193
Kinnickinnic River	Kinnickinnic River	5	4,138	0	0	4,138	0	--	04/26/1982	11/27/2001	11	112	130	160	170	209	244	989
Menomonee River	Butler Ditch	2	0	0	3	3	0	--	04/21/1999	04/24/2001	185	188	194	202	200	208	211	213
	Honey Creek	1	0	0	1	1	1	10	06/25/1975	06/25/1975	--	--	--	--	--	--	--	RL
	Little Menomonee River	1	0	0	1	1	1	10	07/19/1977	07/19/1977	--	--	--	--	--	--	--	RL
	Lower Menomonee River	6	4,068	0	1	4,069	1	10	08/20/1975	11/27/2001	5	128	160	206	206	254	282	460
	Upper Menomonee River	3	996	0	0	996	0	--	10/04/1982	11/27/2001	4	180	226	271	260	300	326	457
Milwaukee River	Lincoln Creek	7	331	45	6	382	0	--	04/16/1993	03/20/2002	0	69	120	162	168	210	260	460
	Lower Milwaukee River	15	7,681	137	2	7,820	0	--	04/26/1982	03/20/2002	5	131	168	224	217	264	290	1,112
Oak Creek	Lower Oak Creek	4	959	0	0	959	0	--	03/21/1985	11/19/2001	9	150	215	262	250	300	326	401
	Middle Oak Creek	2	488	0	0	488	0	--	03/21/1985	11/19/2001	7	135	190	246	235	287	318	382
	Upper Oak Creek	1	243	0	0	243	0	--	03/21/1985	11/19/2001	36	147	232	278	261	312	333	365
Root River	Lower Root River	1	25	0	0	25	0	--	08/25/1999	10/10/2001	73	188	230	260	245	280	298	320
	Middle Root River	1	27	0	0	27	0	--	08/25/1999	10/10/2001	70	174	241	270	253	280	307	360
	Upper Root River	4	106	0	0	106	0	--	08/25/1999	10/10/2001	49	120	266	325	294	358	390	435

Specific Conductance

Specific conductance (SC) is the measure of the electrical conductivity of water at a certain temperature. Specifically, it is defined as the reciprocal of the resistance, in ohms, measured between opposite faces of a centimeter cube of an aqueous solution at a specific temperature (Hem, 1985). The higher the concentration of dissolved ions, the higher the SC. These ions can include dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron. Therefore, SC can be an indirect measurement of dissolved solids (Murphy, 2002d). Conductance of the same water changes greatly with changes in temperature, complicating interpretation of data sets; normalizing the conductance to a temperature eliminates this complication.

Natural factors affecting SC include the release of ions from rocks and soils when water moves over them. In particular, rocks containing calcite, calcium, and carbonate tend to dissolve in water and increase SC. Anthropogenic sources include agricultural runoff containing fertilizer (with phosphate and nitrate) and road runoff containing leaked automobile fluids and chemicals used for deicing roads. Distilled water has a SC of at least 1 μS/cm at 25°C. Rainwater usually has a higher SC than distilled water because it dissolves gases and other airborne particulates. There are no specific regulatory guidelines for SC.

Sites with the highest median SC were concentrated in the southern half of the MMSD planning area (fig. 24.). Most sites with the lowest median concentrations were clustered in the Muskego Lake and Kinnickinnic River subwatersheds, with additional scattered sites in six other subwatersheds (fig. 24).

Subwatersheds with the highest median SC were also in the southern half of the planning area and were the Underwood Creek, Honey Creek, Upper Root River, Middle Root River, Upper Oak Creek, Middle Oak Creek, Lower Oak Creek, and Wilson Park Creek subwatersheds (fig. 24). Subwatersheds with median SC in the lower quartile were Butler Ditch and the Kinnickinnic River (fig. 24). Maximum SC greater than 10,000 μS/cm was measured in the Wilson Park Creek and Lincoln Creek subwatersheds (fig. 25, table 11). Median SC greater than 1,000 μS/cm was measured in the Wilson Park Creek, Honey Creek, Underwood Creek, Lower Oak Creek, Middle Oak Creek, Upper Oak Creek, Middle Root River, and Upper Root River subwatersheds (table 11). The lowest median SC, less than 650 μS/cm, was measured in Muskego Lake, Kinnickinnic River, Butler Ditch, and Lower Milwaukee River subwatersheds (table 11).

Four of the five sites where seasonality in SC was examined (except for Oak Creek at Ryan Road) showed similar seasonal variability with higher concentrations measured during winter (fig. 26). This pattern would parallel the use of deicing compounds on paved surfaces. Oak Creek was more difficult to interpret, because there were no measurements from December through March.

Temporal trend analysis for the Milwaukee River and Oak Creek sites showed similar trends with year-to-year variation, possibly corresponding to changes in road-salt use or other factors (fig. 27).

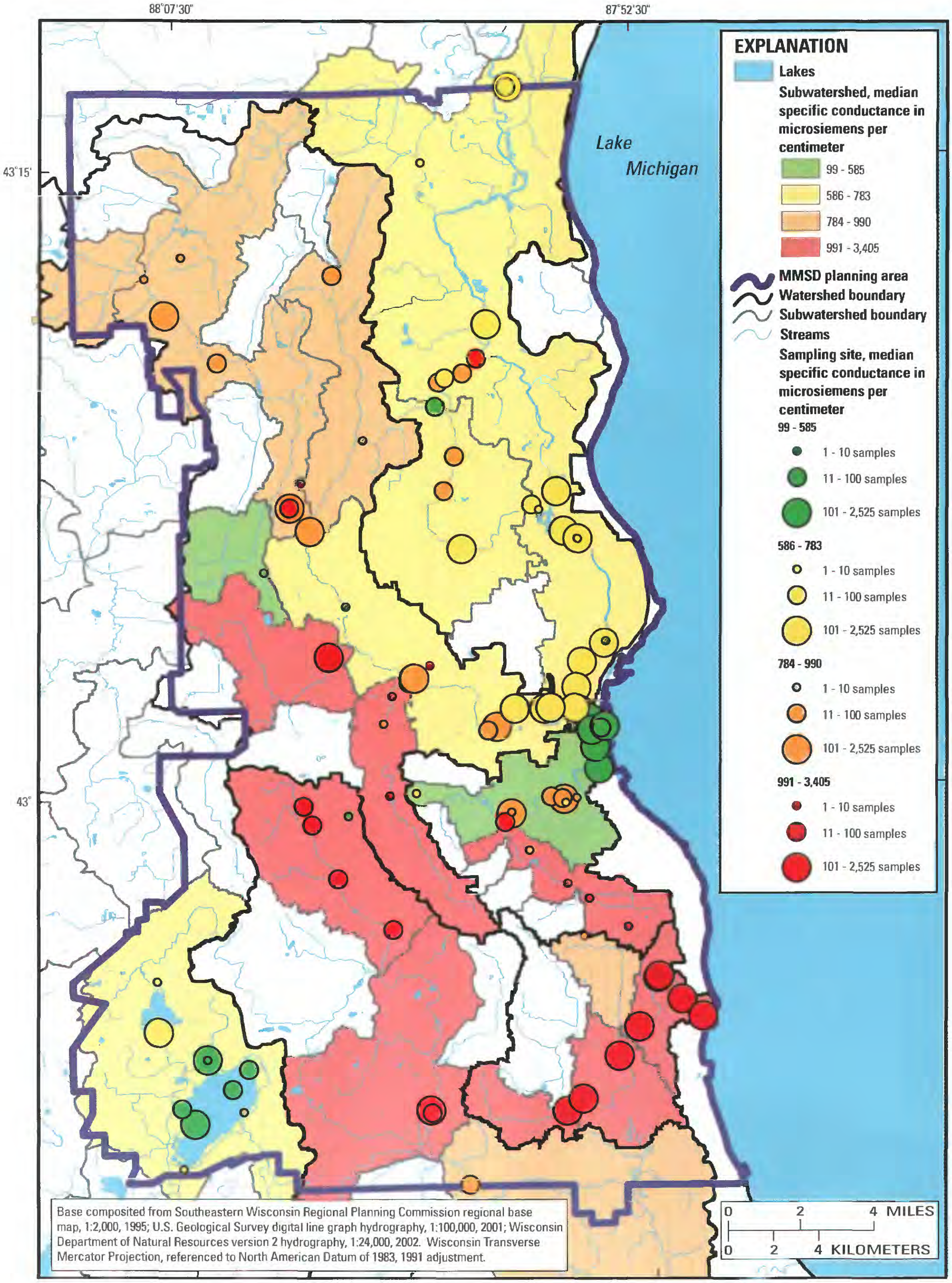

Figure 24. Sites sampled for specific conductance in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

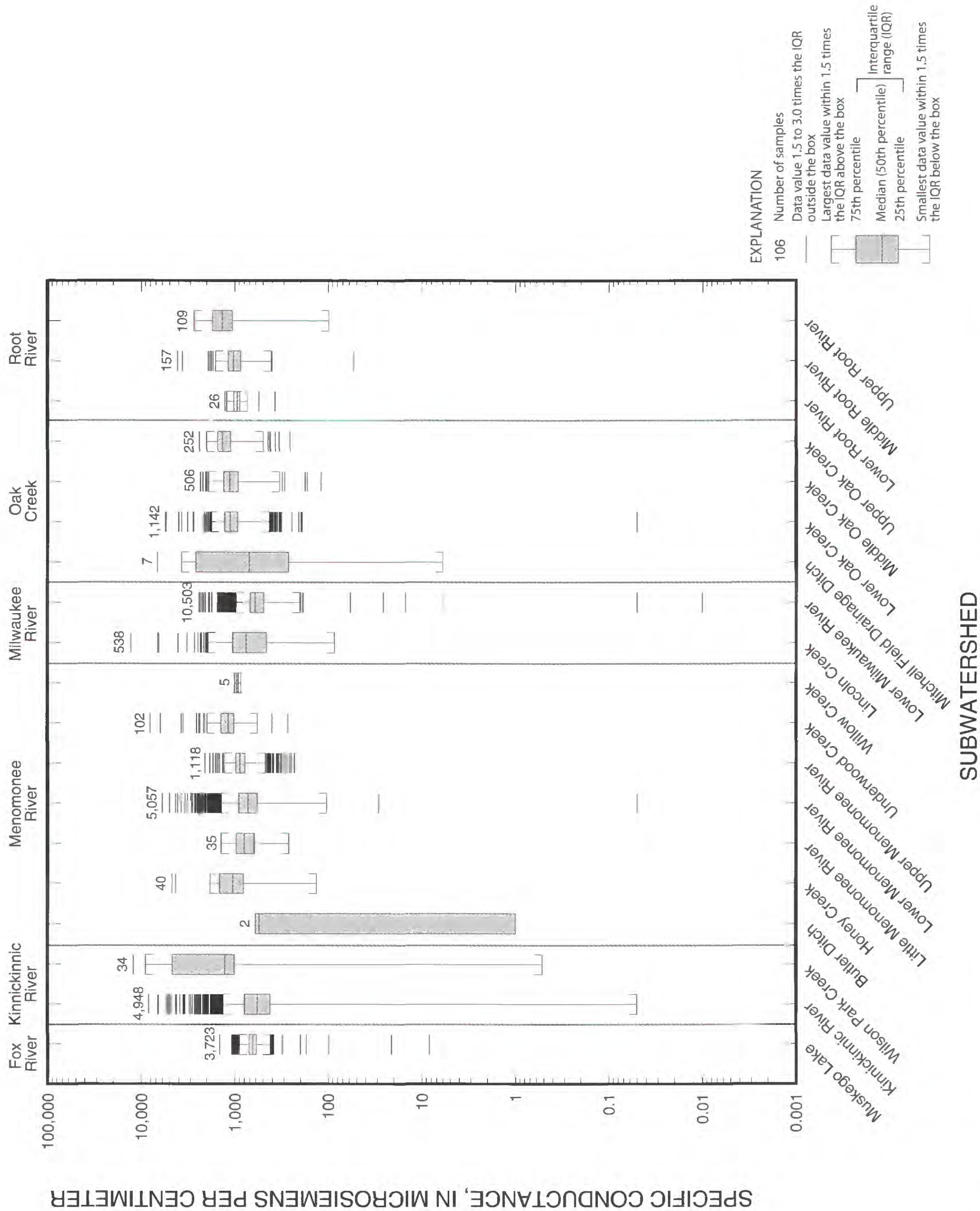

Figure 25. Statistical distribution of specific conductance concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

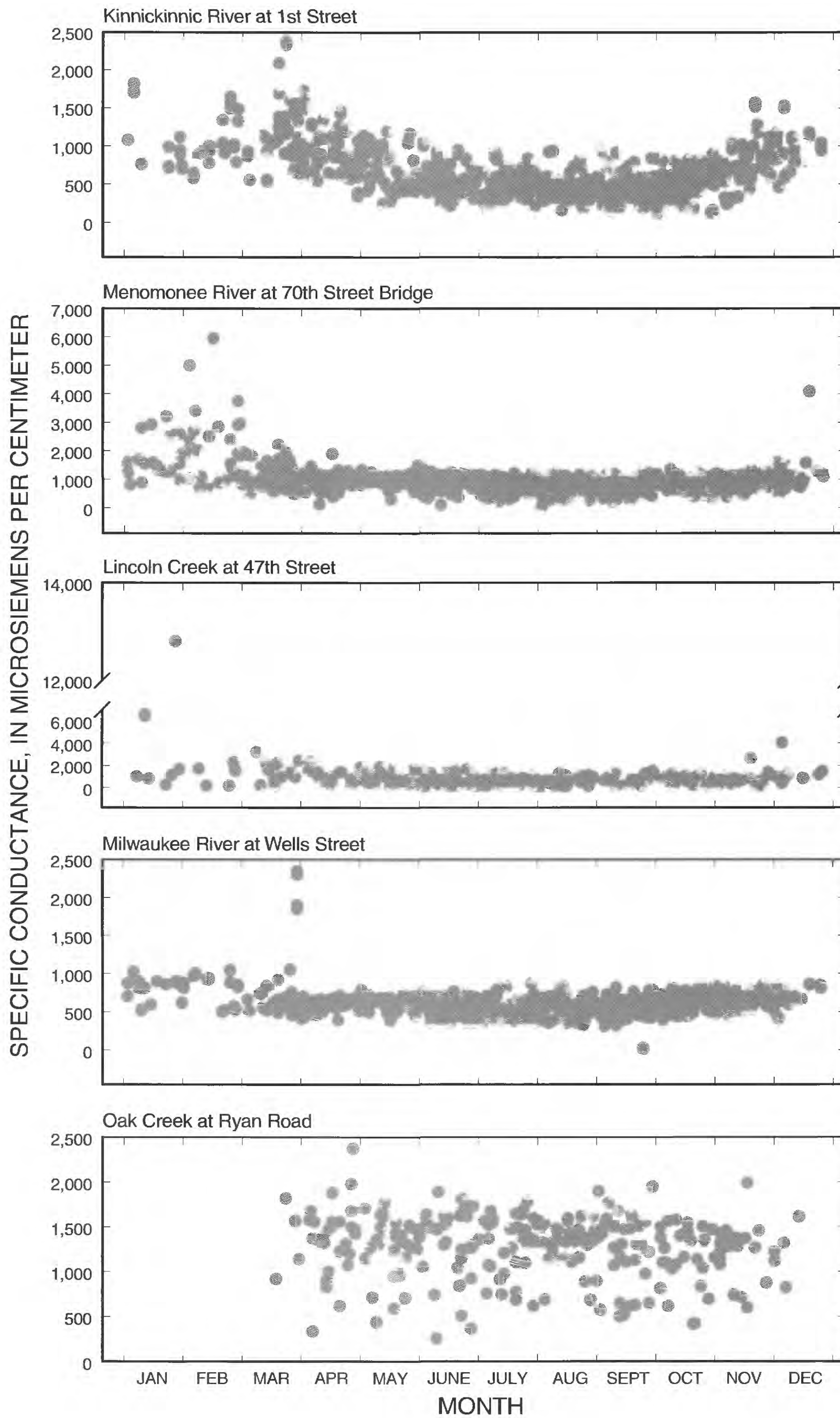

Figure 26. Seasonality of specific conductance for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

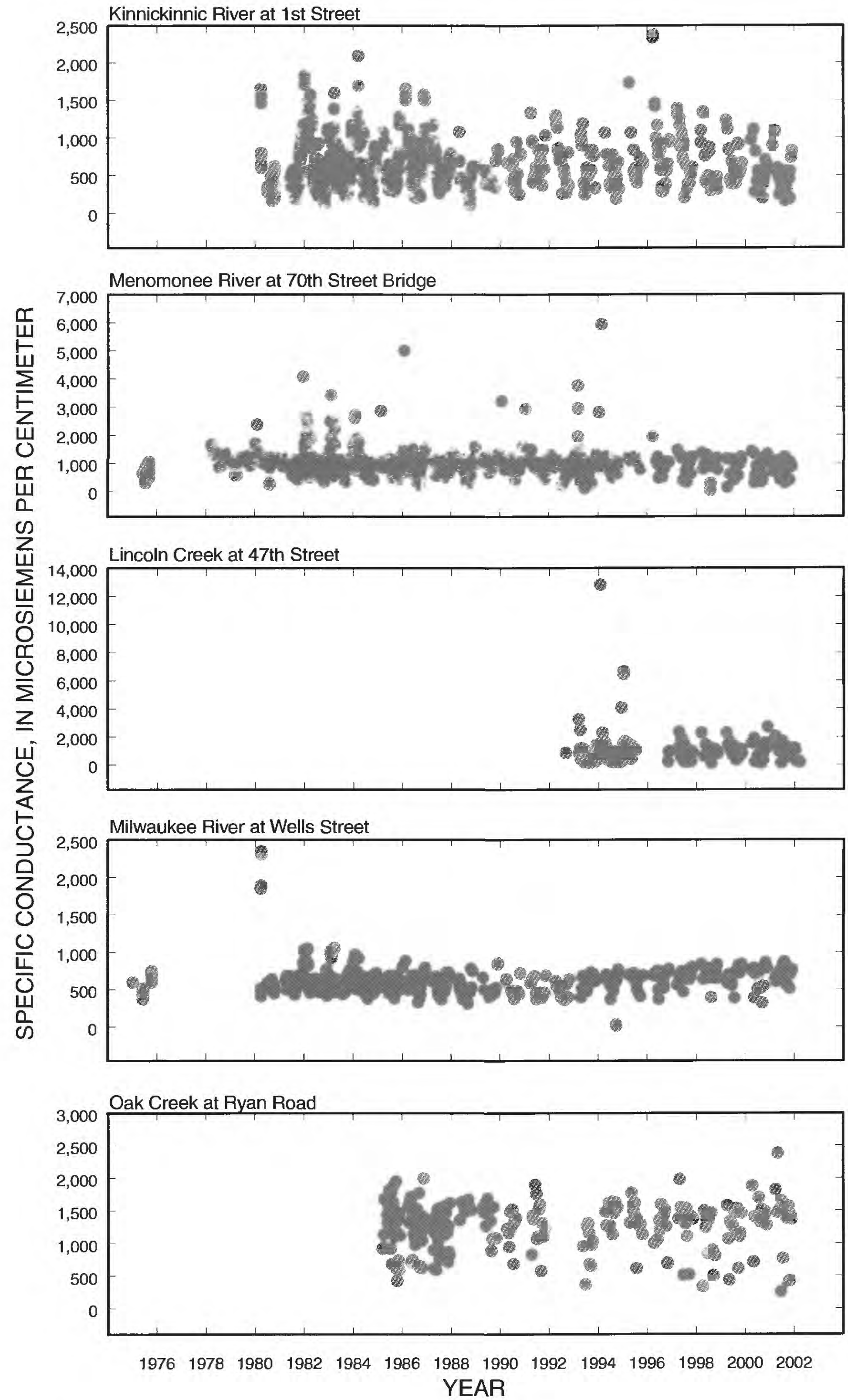

Figure 27. Trends of specific conductance for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 11. Summary statistics for specific conductance, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; values are expressed in microsiemens per centimeter (µS/cm); values rounded to the nearest whole number]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all samples	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentilel	90th percentiel	Maximum
Fox River	Muskego Lake	17	0	3,714	9	3,723	0	10/17/1986	08/29/2001	21[1]	505	594	648	654	713	814	1,450
Kinnickinnic River	Kinnickinnic River	10	4,828	114	6	4,948	0	01/15/1975	11/27/2001	64[1]	350	420	576	666	785	1,062	8,280
	Wilson Park Creek	5	0	34	0	34	0	11/06/1996	01/16/2002	88[1]	789	1,053	1,290	2,842	4,470	6,088	12,100
Menomonee River	Butler Ditch	1	0	0	2	2	0	04/21/1999	04/19/2001	552[1]	557	565	577	577	590	597	602
	Honey Creek	4	12	28	0	40	0	12/19/1977	08/21/2001	135	584	821	1,051	1,303	1,448	1,803	4,700
	Little Menomonee River	3	0	35	0	35	0	03/13/1978	10/18/2001	265	528	638	800	809	955	1,125	1,400
	Lower Menomonee River	9	4,840	217	0	5,057	0	06/10/1975	11/27/2001	29[1]	458	581	729	771	907	1,067	5,950
	Upper Menomonee River	5	1,021	97	0	1,118	0	03/14/1978	11/27/2001	232	644	781	888	872	985	1,060	2,091
	Underwood Creek	1	0	102	0	102	0	12/19/1977	08/04/1994	270	901	1,020	1,180	1,394	1,408	1,913	8,000
	Willow Creek	1	0	5	0	5	0	05/24/2001	10/18/2001	867	886	914	935	937	969	989	1,002
Milwaukee River	Lincoln Creek	6	339	199	0	538	0	08/31/1992	03/20/2002	86	239	461	757	849	1,054	1,423	12,800
	Lower Milwaukee River	17	9,819	677	7	10,503	0	01/25/1973	03/20/2002	26[1]	394	492	608	598	685	763	2,400
Oak Creek	Mitchell Field Drainage Ditch	1	0	7	0	7	0	11/06/1996	01/14/2002	251[1]	271	448	796	1,986	2,625	4,910	6,710
	Lower Oak Creek	4	999	143	0	1,142	0	10/29/1976	11/19/2001	191[1]	674	939	1,128	1,111	1,280	1,410	5,500
	Middle Oak Creek	2	506	0	0	506	0	03/21/1985	11/19/2001	120	646	929	1,139	1,125	1,322	1,525	2,330
	Upper Oak Creek	1	252	0	0	252	0	03/21/1985	11/19/2001	256	716	1,110	1,350	1,286	1,523	1,640	2,375
Root River	Lower Root River	1	26	0	0	26	0	08/25/1999	10/10/2001	371	771	883	946	950	1,025	1,183	1,275
	Middle Root River	2	28	129	0	157	0	10/25/1976	10/10/2001	54	729	870	1,030	1,084	1,177	1,458	4,100
	Upper Root River	5	108	1	0	109	0	03/11/1999	10/10/2001	99	592	1,064	1,361	1,364	1,728	2,001	2,820

[1]The minimum value was below 20 mS/cm, below which specific conductances were considered to be outliers, and was replaced with the next highest minimum value equal to or above 20 µS/cm.

Hardness

Hardness is defined in terms of the presence of calcium and magnesium cations in water. Hardness is not attributed to a single constituent and is reported in terms of an equivalent concentration of calcium carbonate, "as quantified as $CaCO_3$." Waters with a total hardness (as $CaCO_3$) in the range of 0–60 mg/L are considered soft; 60–120 mg/L moderately hard; 120–180 mg/L hard; and greater than 180 mg/L, very hard (Murphy, 2002b). When hardness and alkalinity are similar, the only cations present in significant concentrations in the water are calcium and magnesium. When hardness is much greater than alkalinity, the water contains considerable amounts of other cations (Murphy, 2002b). Calcium is an important part of plant cell walls, shells, and skeletal structure development of many aquatic species. Low calcium concentrations can cause osmotic problems and affect shell development or cuticle secretion in aquatic invertebrates.

Both natural and anthropogenic factors can effect the hardness of water. Hardness concentrations vary greatly because of differences in geology. Soft waters are mainly from igneous rocks that are resistant to weathering and therefore do not release many cations. Hard water results from contact with calcerous (calcite-rich) rocks and sediments. Anthropogenic sources include industrial effluent and wastewater-treatment plant effluent, both of which may produce significant amounts of calcium and magnesium. There are no guideline concentrations for hardness.

The highest median concentrations of hardness were measured at sites in the southern part of the MMSD planning area (fig. 28). Sites in the Upper Root River, Middle Root River, Lower Root River, Upper Oak Creek, Middle Oak Creek, Lower Oak Creek, Mitchell Field Drainage Ditch, and Wilson Park Creek subwatersheds had median concentrations in the upper quartile (fig. 28). Sites with median concentrations in the lower quartile were clustered in the central part of the planning area and were primarily in the Little Menomonee River, Underwood Creek, Lower Menomonee River, Lower Milwaukee River, Kinnickinnic River, and Lincoln Creek subwatersheds (fig. 28).

Median hardness concentrations for subwatersheds in the upper quartile were also in the southern part of the planning area and included all the subwatersheds listed above with median concentrations for sites in the upper quartile except the Mitchell Field Drainage Ditch subwatershed (fig. 28). Subwatersheds with the median concentrations in the lower quartile were the Underwood Creek, Little Menomonee River, and Lincoln Creek subwatersheds (fig. 28). The Wilson Park Creek, Lower Milwaukee River, Lower Oak Creek, and Upper Oak Creek subwatersheds all had maximum hardness concentrations greater than or equal to 1,000 mg/L as $CaCO_3$ (fig. 29, table 12). The highest median concentrations were measured in the Upper Oak Creek (450 mg/L as $CaCO_3$) and Upper Root River (430 mg/L as $CaCO_3$) subwatersheds (fig. 29, table 12). The median hardness concentrations for the Little Menomonee River (63 mg/L as $CaCO_3$) and Underwood Creek (130 mg/L as $CaCO_3$) subwatersheds were the lowest compared to median concentration at other subwatersheds (fig. 29, table 12).

No consistent seasonal pattern was observed in hardness (data not shown). There appeared to be a slight long-term downtrend in concentrations at all sites (except for Lincoln Creek) through the entire period of their records (fig. 30); Lincoln Creek appeared to have a slight uptrend in concentration.

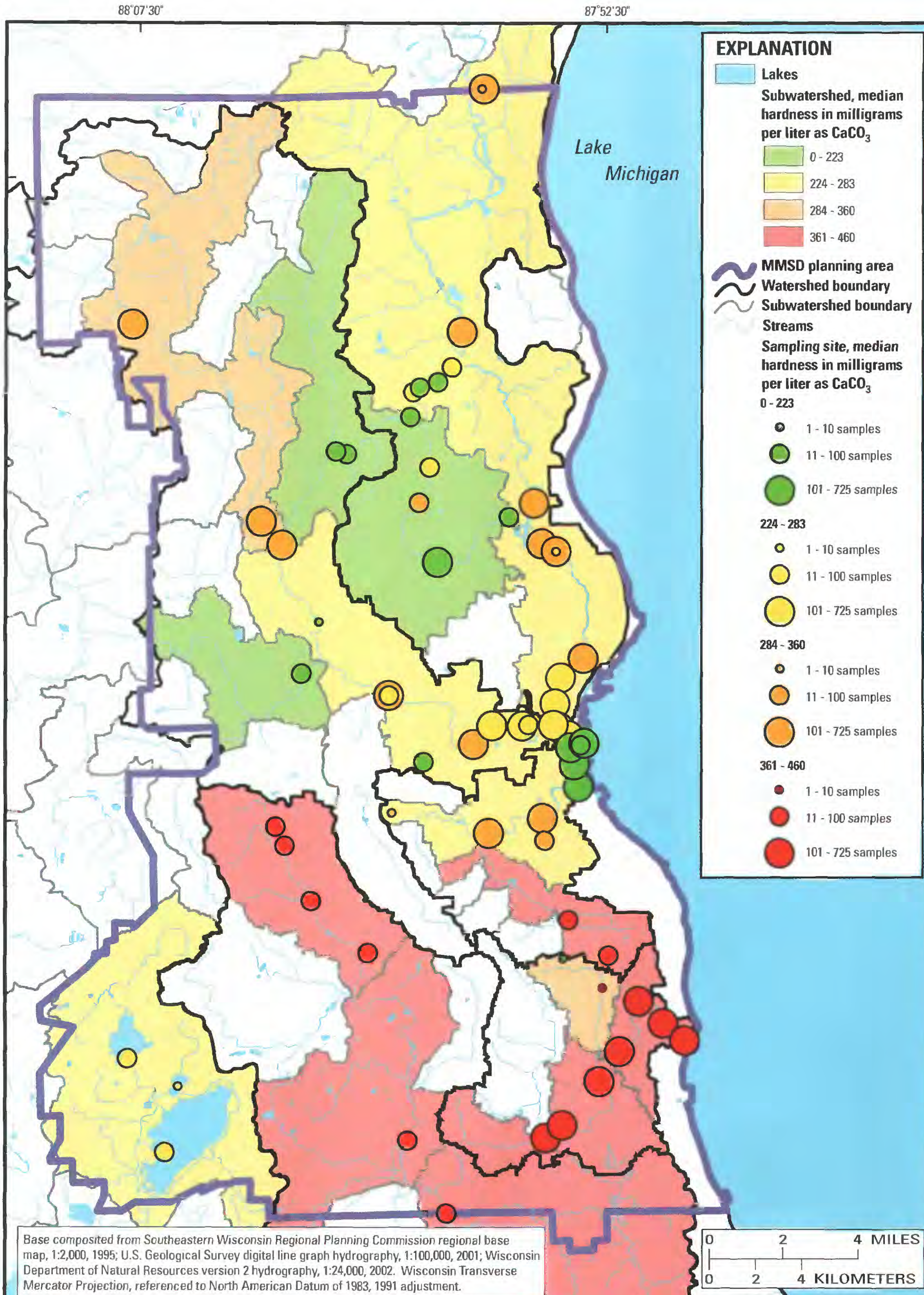

Figure 28. Sites sampled for hardness in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

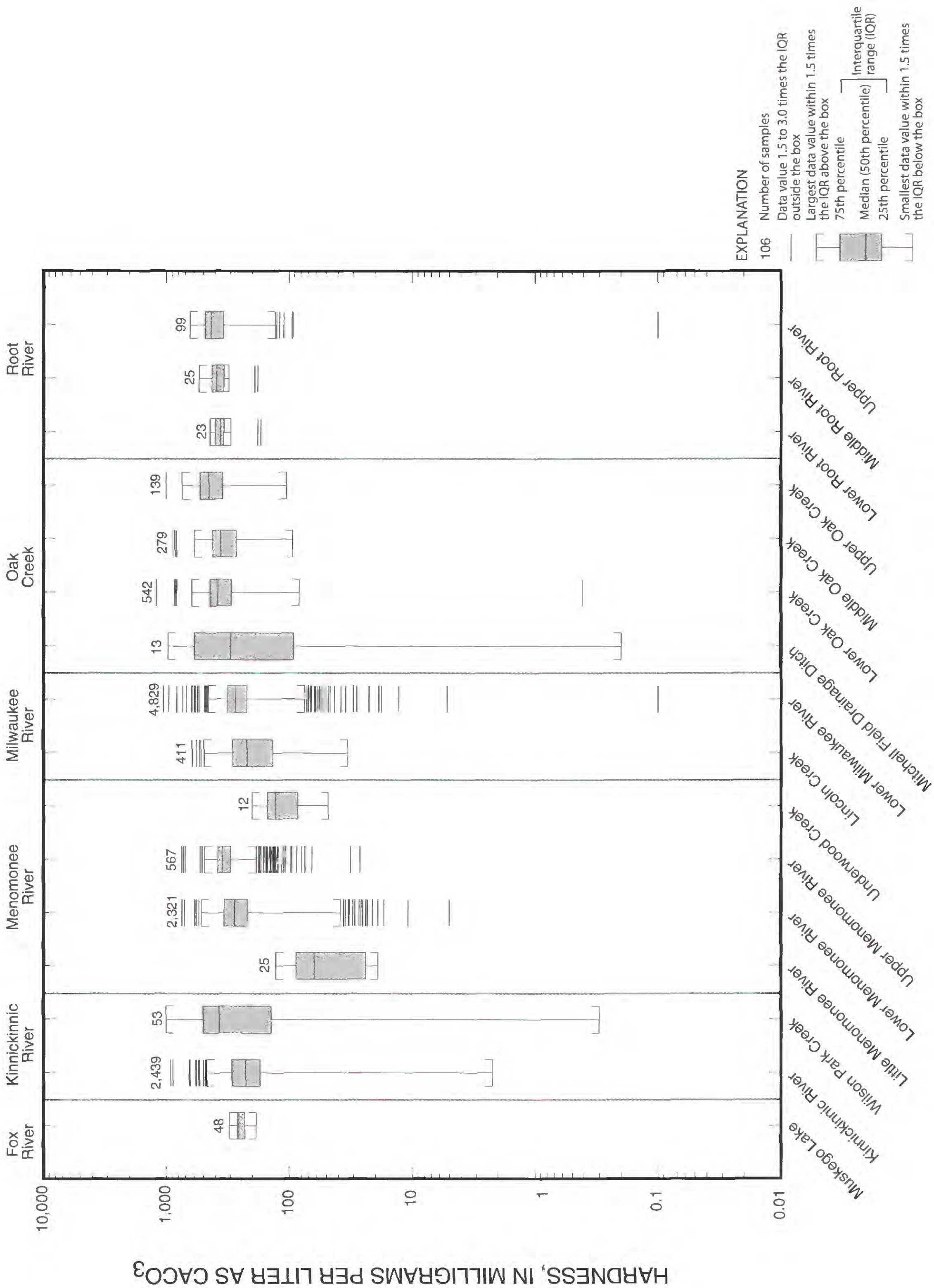

Figure 29. Statistical distribution of hardness concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

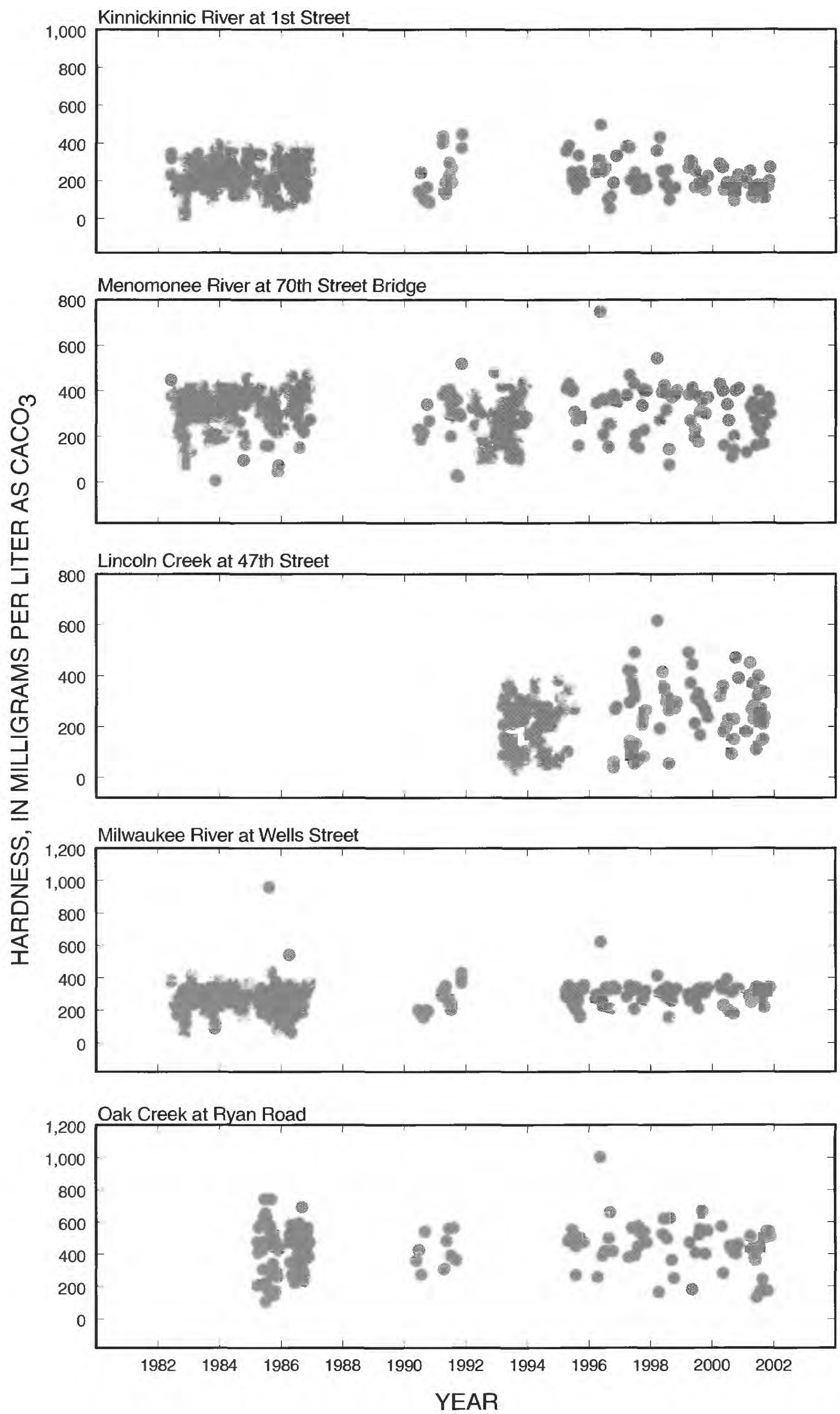

Figure 30. Trends of hardness for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 12. Summary statistics for hardness, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; values are expressed in milligrams per liter as calcium carbonate (mg/L as $CaCO_3$); values rounded to the nearest whole number]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	3	0	48	0	48	0	04/07/1987	04/19/2001	186	208	230	258	248	263	273	306
Kinnickinnic River	Kinnickinnic River	6	2,435	0	4	2,439	0	06/01/1982	11/14/2001	2	147	172	226	236	292	346	924
	Wilson Park Creek	3	0	0	53	53	0	01/11/1999	09/22/2000	0	1	140	370	362	500	708	1,000
Menomonee River	Little Menomonee River	2	0	25	0	25	0	02/01/1990	06/29/1990	19	20	24	63	59	89	110	129
	Lower Menomonee River	8	2,210	111	0	2,321	0	06/01/1982	11/14/2001	5	167	219	281	277	341	385	750
	Upper Menomonee River	3	567	0	0	567	0	08/23/1982	11/14/2001	27	212	300	349	330	381	404	750
	Underwood Creek	1	0	12	0	12	0	02/01/1990	06/29/1990	48	75	87	130	124	145	178	200
Milwaukee River	Lincoln Creek	5	266	145	0	411	0	03/11/1993	11/27/2001	34	81	136	221	224	290	370	618
	Lower Milwaukee River	16	4,541	286	2	4,829	0	01/25/1973	11/15/2001	0	172	221	274	268	318	345	1,058
Oak Creek	Mitchell Field Drainage Ditch	2	0	0	13	13	0	01/11/1999	09/22/2000	0	12	93	300	368	590	874	970
	Lower Oak Creek	4	542	0	0	542	0	03/21/1985	11/19/2001	0	210	296	381	369	440	481	1,208
	Middle Oak Creek	2	279	0	0	279	0	03/21/1985	11/19/2001	94	195	269	362	349	420	460	877
	Upper Oak Creek	1	139	0	0	139	0	03/21/1985	11/19/2001	105	239	353	450	436	530	577	1,002
Root River	Lower Root River	1	23	0	0	23	0	08/25/1999	10/10/2001	170	304	340	362	355	395	410	440
	Middle Root River	1	25	0	0	25	0	08/25/1999	10/10/2001	180	238	340	392	372	428	433	540
	Upper Root River	5	98	0	1	99	0	10/17/1996	10/10/2001	0	160	342	430	392	480	510	640

Dissolved Oxygen

Dissolved oxygen is perhaps the most biologically important dissolved gas in natural waters. With a few odd exceptions, all multicellular organisms (including plants) and many bacterial species rely on oxygen as an electron acceptor in respiration.

The two primary sources of dissolved oxygen to surface waters are the atmosphere and photosynthesis. The amount of dissolved oxygen in freshwater is controlled mainly by water temperature, but the actual ambient concentration represents a highly dynamic (on a time scale of seconds to minutes) balance between the atmospheric source and various biotic and abiotic sinks. These sinks include uptake by aquatic organisms and reaction with common reduced chemical species such as sulfide, methane, and ammonium that are formed when organic matter decomposes. In parts of the MMSD planning area, anthropogenic loading of decomposable organic matter and other nutrients can cause algal blooms, especially in the summer when high temperatures and abundant sunshine spur growth. When the algae die and decompose, the respiration of the organisms that consume the dead algae is a major oxygen-consuming process.

Various water-quality standards for minimum dissolved oxygen concentrations exist, sometimes tailored to the specific type of water (lake, stream, fresh, salt, and so forth). Of these, the Wisconsin Department of Natural Resources has selected a minimum of 5 mg/L as the minimum concentration to prevent fish kills and other deleterious effects on stream biotic communities.

Median dissolved oxygen concentrations below the minimum guideline concentration of 5 mg/L were observed at sites in the Upper Root River, the Lower Menomonee River, and the lower reaches of the Kinnickinnic River subwatersheds (fig. 31). Sites with the lowest median concentrations were clustered in several subwatersheds including the Lower Menomonee River, Kinnickinnic River, Upper Root River, and Lower Milwaukee River, with a scattering of sites in other subwatersheds (fig. 31). Sites with the highest median concentrations of dissolved oxygen were in the Lower Milwaukee River, Lincoln Creek, Lower Menomonee River, Kinnickinnic River, Honey Creek, Lower Oak Creek, and Muskego Lake subwatersheds (fig. 31).

Subwatersheds with dissolved oxygen concentrations in the lower quartile were the Lower Menomonee River, Kinnickinnic River, Upper Root River, Lower Root River, Upper Oak Creek, and Middle Oak Creek (fig. 31). There were no subwatersheds with median concentrations in the upper quartile (fig. 31). All subwatersheds except Honey Creek, Little Menomonee River, and Lower Root River had at least one sample with a dissolved oxygen concentration below the 5-mg/L guideline concentration (fig. 32, table 13). The Upper Root River (5.13 mg/L) and Lower Menomonee River (6.50 mg/L) subwatersheds had the lowest median concentrations (fig. 32, table 13). Willow Creek (9.81 mg/L) and Honey Creek (9.47 mg/L) subwatersheds had the highest median concentrations (fig. 32, table 13). Maximum observed concentrations of dissolved oxygen (over 20 mg/L) were in the Muskego Lake, Kinnickinnic River, Lower Menomonee River, and Lower Milwaukee River subwatersheds (fig. 32, table 13).

Dissolved oxygen concentrations varied with the season at all five highlighted sites, with the lowest concentrations generally observed in warm months (fig. 33). This pattern reflects the direct relation between oxygen use during organic matter decomposition and the inverse relation between solubility and water temperature.

There were no obvious trends in dissolved oxygen concentrations over time for the five sites (data not shown).

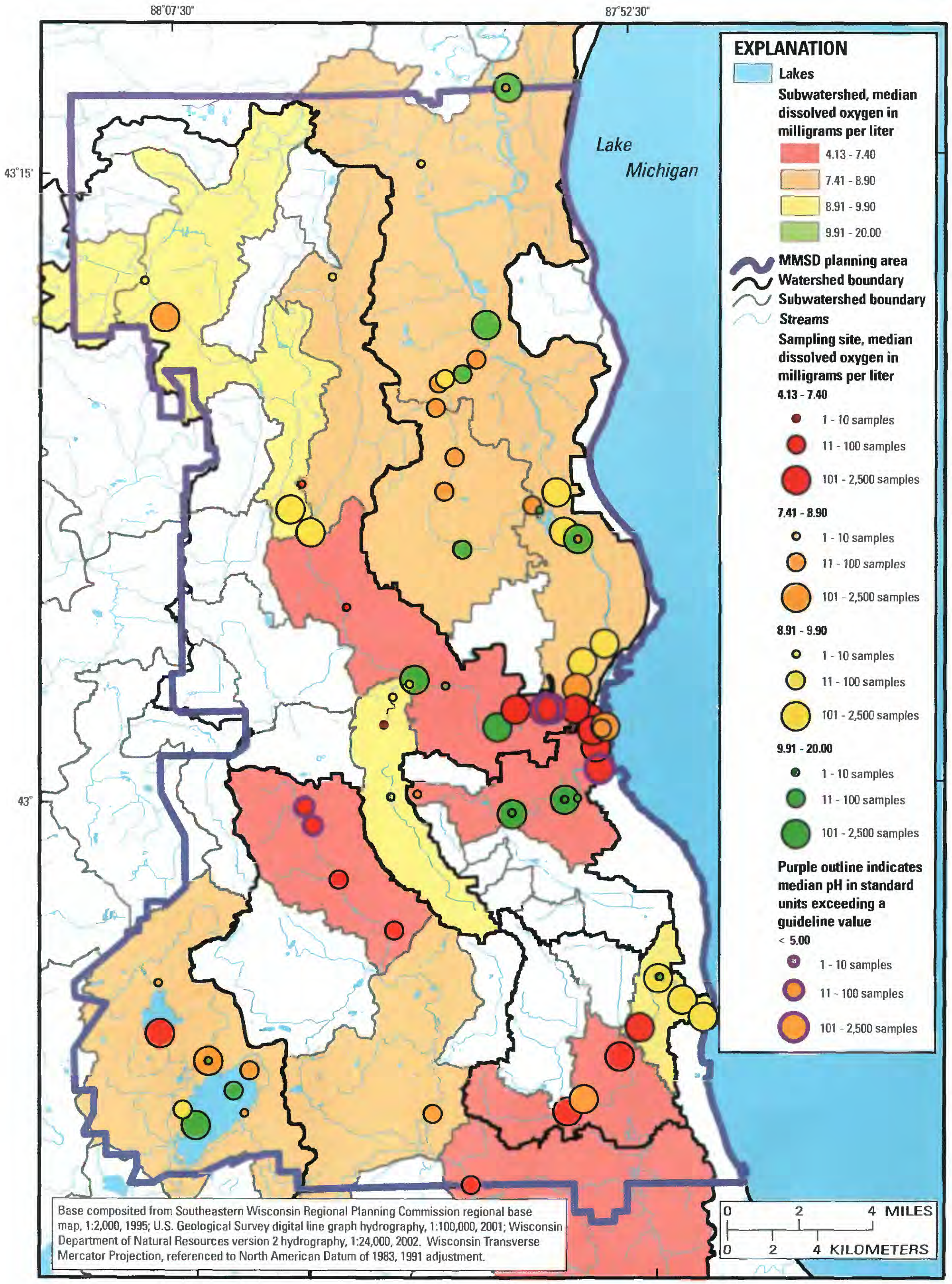

Figure 31. Sites sampled for dissolved oxygen in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

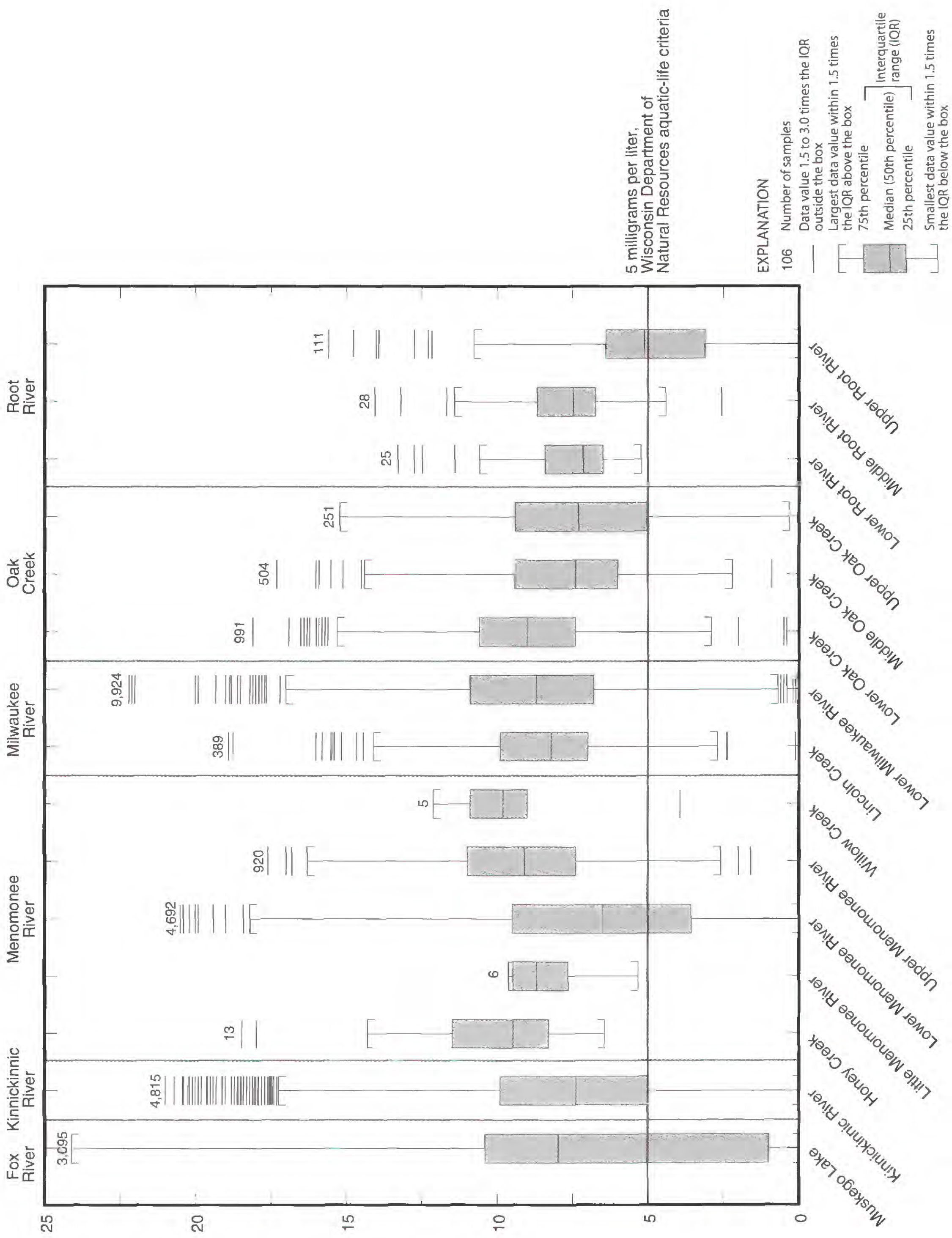

Figure 32. Statistical distribution of dissolved oxygen concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

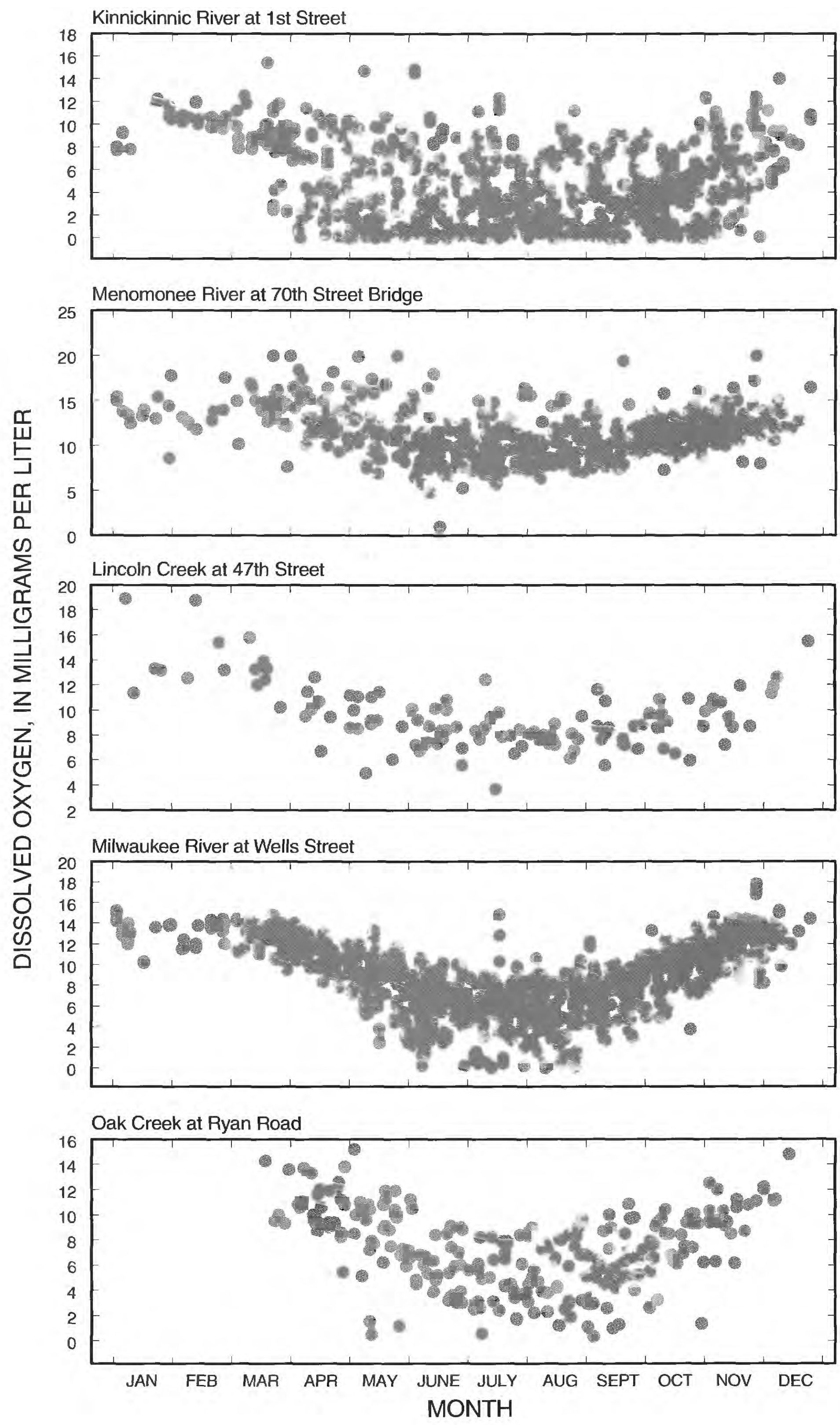

Figure 33. Seasonality of dissolved oxygen for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 13. Summary statistics for dissolved oxygen, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; values are expressed in milligrams per liter (mg/L); values rounded to the nearest hundredth]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90thpercentile	Maximum
Fox River	Muskego Lake	16	0	3,689	6	3,695	0	10/17/1986	08/29/2001	0.00	0.10	1.00	7.97	6.82	10.40	12.30	24.10
Kinnickinnic River	Kinnickinnic River	7	4,806	2	7	4,815	0	06/10/1975	11/27/2001	.00	2.20	5.00	7.38	7.75	9.90	14.00	21.00
Menomonee River	Honey Creek	4	12	1	0	13	0	07/10/1995	08/21/2001	6.44	7.05	8.30	9.47	10.64	11.49	17.23	18.45
	Little Menomonee River	2	0	6	0	6	0	07/10/1995	10/18/2001	5.33	6.49	7.74	8.70	8.25	9.46	9.55	9.62
	Lower Menomonee River	8	4,691	0	1	4,692	0	06/10/1975	11/27/2001	.00	1.20	3.58	6.50	6.63	9.50	11.80	20.50
	Upper Menomonee River	3	920	0	0	920	0	06/01/1982	11/27/2001	1.60	6.30	7.40	9.10	9.31	11.00	13.00	17.60
	Willow Creek	1	0	5	0	5	0	05/24/2001	10/18/2001	3.94	5.97	9.01	9.81	9.16	10.91	11.64	12.12
Milwaukee River	Lincoln Creek	6	338	51	0	389	0	08/31/1992	03/20/2002	.12	5.62	6.99	8.21	8.51	9.90	11.49	18.90
	Lower Milwaukee River	17	9,629	290	5	9,924	0	01/25/1973	03/20/2002	.00	5.00	6.80	8.70	8.79	10.90	12.80	22.20
Oak Creek	Lower Oak Creek	4	990	1	0	991	0	03/21/1985	11/19/2001	.40	5.80	7.43	9.00	9.04	10.59	12.30	18.10
	Middle Oak Creek	2	504	0	0	504	0	03/21/1985	11/19/2001	.90	4.60	6.00	7.40	7.80	9.40	11.80	17.30
	Upper Oak Creek	1	251	0	0	251	0	03/21/1985	11/19/2001	.32	3.00	5.00	7.30	7.19	9.40	11.06	15.20
Root River	Lower Root River	1	25	0	0	25	0	08/25/1999	10/10/2001	5.23	5.95	6.49	7.14	7.96	8.42	12.05	13.29
	Middle Root River	1	28	0	0	28	0	08/25/1999	10/10/2001	2.56	4.90	6.76	7.49	7.95	8.56	11.49	14.05
	Upper Root River	4	111	0	0	111	0	08/25/1999	10/10/2001	.00	1.76	3.13	5.13	5.28	6.39	8.02	15.59

Biochemical Oxygen Demand, 5 day

Five-day biochemical oxygen demand (BOD5) is an empirical measure of the oxygen-consuming material in a water sample. Because the analytical conditions are standardized at 20°C over 5 days, BOD5 measures the potential oxygen demand rather than the true oxygen demand in a stream, which may be limited by temperature or some other factor.

Sources of oxygen-consuming material include organic matter and detritus and reduced chemical species such as sulfide, methane, and ammonia.

There are no water-quality standards for BOD5 for the MMSD planning area, although effluents are sometimes monitored for BOD5 load. A high concentration of BOD5 (for example, greater than 60 mg/L) indicates a high potential for oxygen uptake and hypoxia or anoxia, therefore, effluents with high BOD5 concentrations have potential to cause deleterious effects in receiving waters.

Sites with median BOD5 concentrations in the upper quartile were clustered in four subwatersheds in the southeastern part of the planning area (fig. 34). Sites with median concentrations in the lower quartile were scattered throughout the planning area (fig. 34).

Subwatersheds with median BOD5 concentrations in the upper quartile were West Milwaukee Ditch, Wilson Park Creek, Mitchell Field Drainage Ditch, and Lake Michigan Direct subwatersheds (fig. 34). Subwatersheds with median concentrations in the lower quartile were the Upper Menomonee River, Muskego Lake, Upper Root River, Middle Root River, Lower Root River, Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek (fig. 34). The subwatersheds with some of the highest maximum and median concentrations were the Mitchell Field Drainage Ditch (38,600.0 mg/L; 1,865.0 mg/L) and Wilson Park Creek (5,790.0 mg/L; 100.0 mg/L) (fig. 35, table 14), both of which receive water draining from the General Mitchell International Airport. The only sample collected in the Lake Michigan Direct subwatershed, at a site that is near the airport, also had one of the highest concentrations (130.0 mg/L) (table 14). High BOD5 concentrations during winter may be caused by runoff of runway and airplane deicers (Corsi and others, 2001a). The Kinnickinnic River subwatershed, which is downstream from Wilson Park Creek, also had a relatively high maximum concentration (669.0 mg/L) but a relatively low median concentration (2.2 mg/L) (table 14). All other subwatersheds had median concentrations less than 3.0 mg/L (table 14).

There were no significant seasonal or temporal trends for the BOD5 data (data not shown).

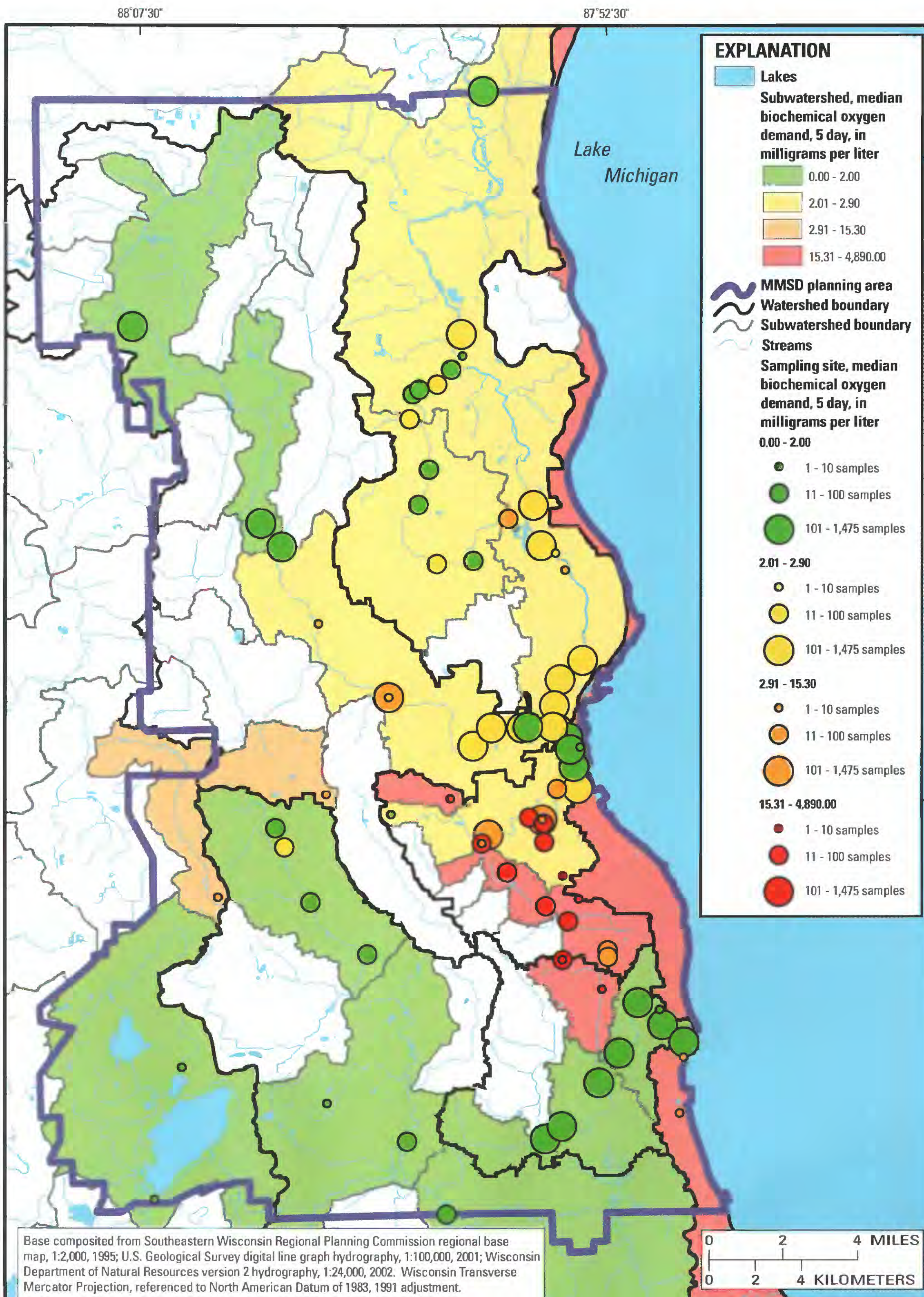

Figure 34. Sites sampled for 5-day biochemical oxygen demand in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 14. Summary statistics for biochemical oxygen demand, 5 day, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter (mg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Deer Creek	1	0	0	1	1	1	8	10/09/1979	10/09/1979	--	--	--	--	--	--	--	RL
	Muskego Lake	2	0	0	4	4	0	--	04/28/1994	09/22/1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kinnickinnic River	Kinnickinnic River	10	4,429	122	12	4,563	223	0.2, 2, 12, 24, 120	01/15/1975	11/27/2001	.0	1.2	2.0	2.2	4.7	3.5	6.3	669.0
	West Milwaukee Ditch	1	0	0	1	1	1	200	05/10/1977	05/10/1977	--	--	--	--	--	--	--	RL
	Wilson Park Creek	6	0	323	80	403	86	0, 0.2, 2, 3, 4, 6, 12, 15, 20, 24, 60, 120, 200, 300, 600	11/06/1996	01/16/2002	.0	3.0	9.9	100.0	376.1	372.5	959.2	5,790.0
Lake Michigan Direct	Lake Michigan Direct	1	0	0	1	1	0	--	11/23/1977	11/23/1977	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
Lake Michigan Tributary	Lake Michigan Tributary	2	0	0	6	6	6	3, 6, 8	03/10/1976	04/23/1981	--	--	--	--	--	--	--	RL
Menomonee River	Lower Menomonee River	7	4,362	103	5	4,470	225	0.2, 1, 2, 3	07/17/1975	11/27/2001	.0	1.4	2.0	2.4	3.0	3.6	5.5	26.0
	Upper Menomonee River	3	982	0	0	982	65	0.2, 2	10/04/1982	11/27/2001	.1	1.1	2.0	2.0	2.3	2.50	3.4	8.6
	South Branch Underwood Creek	1	0	0	1	1	1	10	07/21/1982	07/21/1982	--	--	--	--	--	--	--	RL
Milwaukee River	Lincoln Creek	7	340	82	29	451	60	0.2, 1, 2	03/11/1993	11/27/2001	.0	.7	1.2	2.5	4.0	4.5	7.4	73.0
	Lower Milwaukee River	16	7,450	0	11	7,461	411	0.2, 2, 20	01/15/1975	11/27/2001	.0	1.5	2.0	2.3	2.9	3.6	5.4	23.0

Table 14. Summary statistics for biochemical oxygen demand, 5 day, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002—Continued

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter (mg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Oak Creek	Mitchell Field Drainage Ditch	2	0	68	16	84	6	0, 120, 200, 600, 1200	11/06/1996	01/16/2002	.0	43.0	551.2	1,865.0	3,600.5	4,377.5	7,315.0	38,600.0
	Lower Oak Creek	5	994	0	1	995	90	0.2, 2, 3	10/26/1982	11/19/2001	.1	1.0	2.0	2.0	2.2	2.3	3.6	7.8
	Middle Oak Creek	2	502	0	0	502	45	0.2, 2	03/21/1985	11/19/2001	.1	1.0	2.0	2.0	2.2	2.3	3.4	8.4
	Upper Oak Creek	1	251	0	0	251	23	0.2, 2	03/21/1985	11/19/2001	.1	1.0	2.0	2.0	2.3	2.2	4.2	8.1
Root River	Lower Root River	1	25	0	0	25	11	0.2, 2	08/25/1999	10/10/2001	.1	.1	.1	1.1	1.5	2.2	3.1	6.2
	Middle Root River	2	28	0	2	30	18	0.2, 2, 4	09/03/1981	10/10/2001	.1	.1	.1	1.0	1.4	1.9	2.9	6.4
	Upper Root River	4	111	0	0	111	52	0.2, 2	08/25/1999	10/10/2001	.1	.1	.6	1.2	2.4	3.6	6.4	9.5

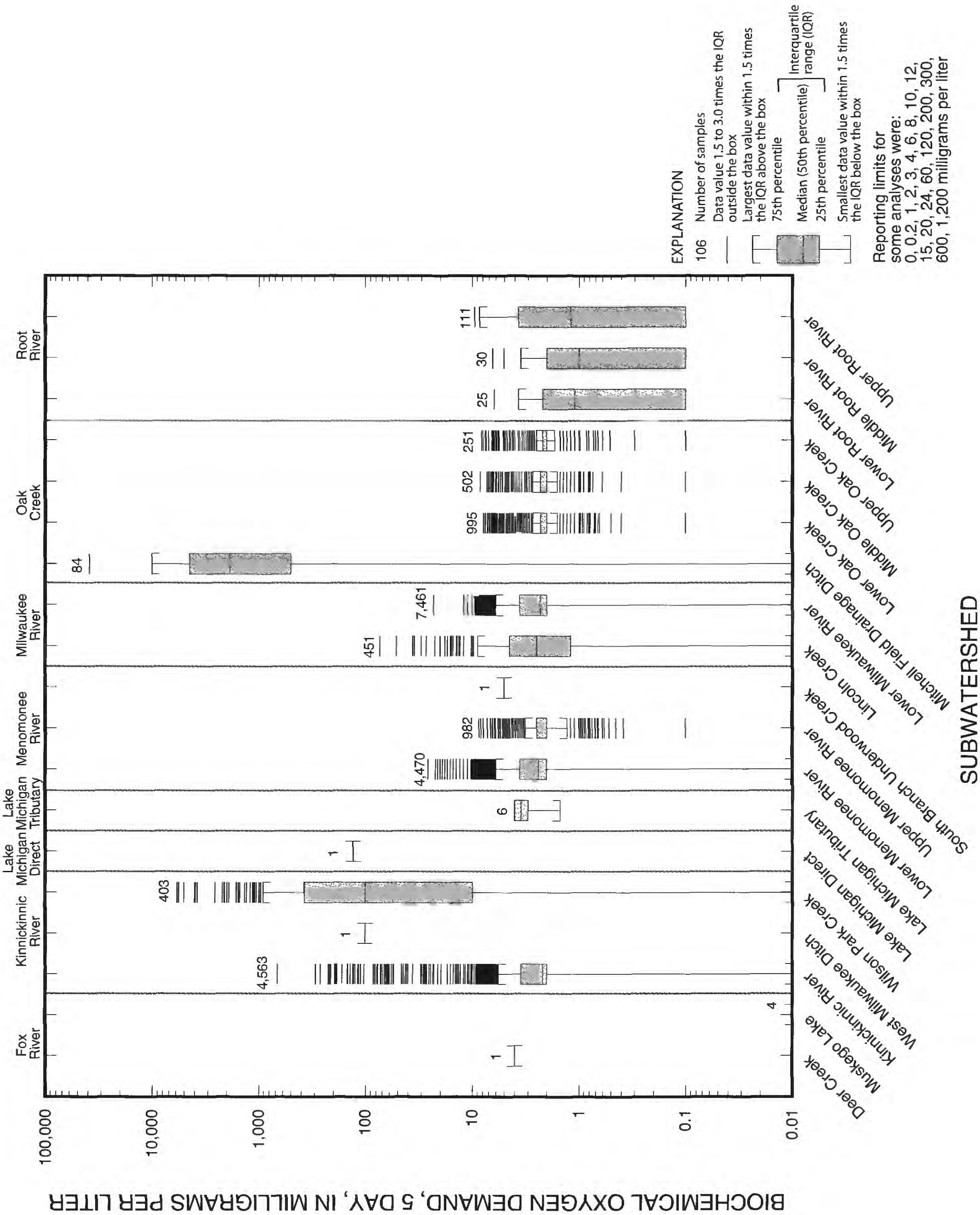

Figure 35. Statistical distribution of biochemical oxygen demand, 5 day, concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Chloride

Chlorine is the most abundant of the halogen elements. Although chlorine can occur in various oxidation states, the chloride form (Cl^-) is the only one of major significance in water exposed to the atmosphere (Hem, 1985). Chloride is widely distributed in nature, generally as sodium chloride (NaCl) and potassium chloride (KCl) and it constitutes approximately 0.05 percent of the lithosphere (National Research Council of Canada, 1977). Chloride is present in all natural waters, normally at low concentrations.

Sources of chloride are both natural and anthropogenic. Chloride is present in various rock types in lower concentrations than other major constituents. The major anthropogenic sources of chloride in surface water are road deicing salts, urban and agricultural runoff (including animal waste and potash fertilizer), and discharges from wastewater-treatment plants, septic systems, and industrial plants. Sodium chloride, and to a lesser extent, calcium chloride are used for snow and ice control in Canada and the United States. Chloride ions are conservative, moving with water without being retarded or lost. Accordingly, all chloride that enters the soil or ground water can ultimately be expected to reach surface water (Environment Canada, 2001).

There are no Federal regulatory standards for chloride with regard to the protection of aquatic species, nor are there U.S. or Canadian primary drinking-water standards for chloride. The USEPA has a Secondary Maximum Contaminant Level (SMCL) for chloride of 250 mg/L, related to salty taste. The Canadian guideline for drinking-water quality has an aesthetic objective of chloride concentrations less than/or equal to 250 mg/L. In the USEPA "National Recommended Water Quality Criteria", the non priority pollutants section, the recommended Criterion Maximum Concentration (CMC) for chloride is 860 mg/L and the Criterion Continuous Concentration (CCC) is 230 mg/L for freshwater species. The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in unacceptable effect. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in unacceptable effect (U.S. Environmental Protection Agency, 2002e). The WDNR in February 2000 adopted a rule to deal with the discharge of chlorides in wastewater effluents. All new dischargers must meet a chronic limit of 395 mg/L and an acute chloride limit of 757 mg/L (Wisconsin Department of Natural Resources, 2003a).

One site in the Upper Root River subwatershed had a median chloride concentration in exceedence of the 230 mg/L USEPA CCC, the highest concentration at which continued exposure does not cause undesirable effects in aquatic communities. Sites with median chloride concentrations in the upper quartile were clustered in the southern part of the planning area and scattered throughout the rest of the planning area (fig. 36). All the sites in the Upper Root River, Middle Root River, Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek had median concentrations in the upper quartile (fig. 36). Sites with median concentrations in the lower quartile were scattered throughout the planning area except for the southern part (fig. 36).

Subwatersheds with median chloride concentrations in the upper quartile were all located in the southern part of the planning area; specifically these were Upper Root River, Middle Root River, Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek subwatersheds (fig. 36). Subwatersheds with median concentrations in the lower quartile were Dousman Ditch, Lower Milwaukee River, Wilson Park Creek, and Lake Michigan Direct (fig. 36). At least one sample in all subwatersheds except Dousman Ditch, Lake Michigan Direct, Lower Root River, Willow Creek, and Wilson Park Creek, exceeded one or more drinking-water (250 mg/L USEPA SDWR and Canadian AO) or aquatic-life guideline concentrations (230 mg/L USEPA CCC; 860 mg/L USEPA CMC) or a future WDNR discharge limit for chloride (395 mg/L chronic discharge limit; 757 mg/L acute discharge limit) (fig. 37, table 15). One or more samples in the Kinnickinnic River, Lower Menomonee River, Lower Oak Creek, and Middle Oak Creek exceeded 860 mg/L, which is the USEPA maximum one-time concentration to which an aquatic community can be subject without experiencing an undesirable effect (fig. 37, table 15). Maximum concentrations in these subwatersheds, all greater than 900 mg/L, also accounted for the highest maximum concentrations (table 15). Of the subwatersheds with no exceedences, no more than 30 samples were collected in any subwatershed, and samples in Dousman Ditch, Wilson Park Creek, and Lake Michigan Direct were all below a reporting limit (table 15).

Data for chloride were available from all seasons from four of the five highlighted sites (Oak Creek being the exception). These data indicate higher concentrations during winter (fig. 38), likely related to the use of deicing salts on streets and highways. Lincoln Creek had a large increase in concentrations during the winter with lower concentrations in other seasons. Data from the Kinnickinnic, Menomonee, and Milwaukee Rivers indicated similar patterns but with smaller peaks in winter months than Lincoln Creek. The Oak Creek site did not have any samples before April and (or) May did have a gradual decrease in concentrations from the start to the end of the record in November.

Chloride concentrations at most sites demonstrated similar long-term temporal trends. Trends began with a slight upward trend in concentrations in the early 80s, changed to a very gradual downward trend until 1996, followed by a very gradual upward trend until 2000, and ended with a slight fall through the end of record (fig. 39).

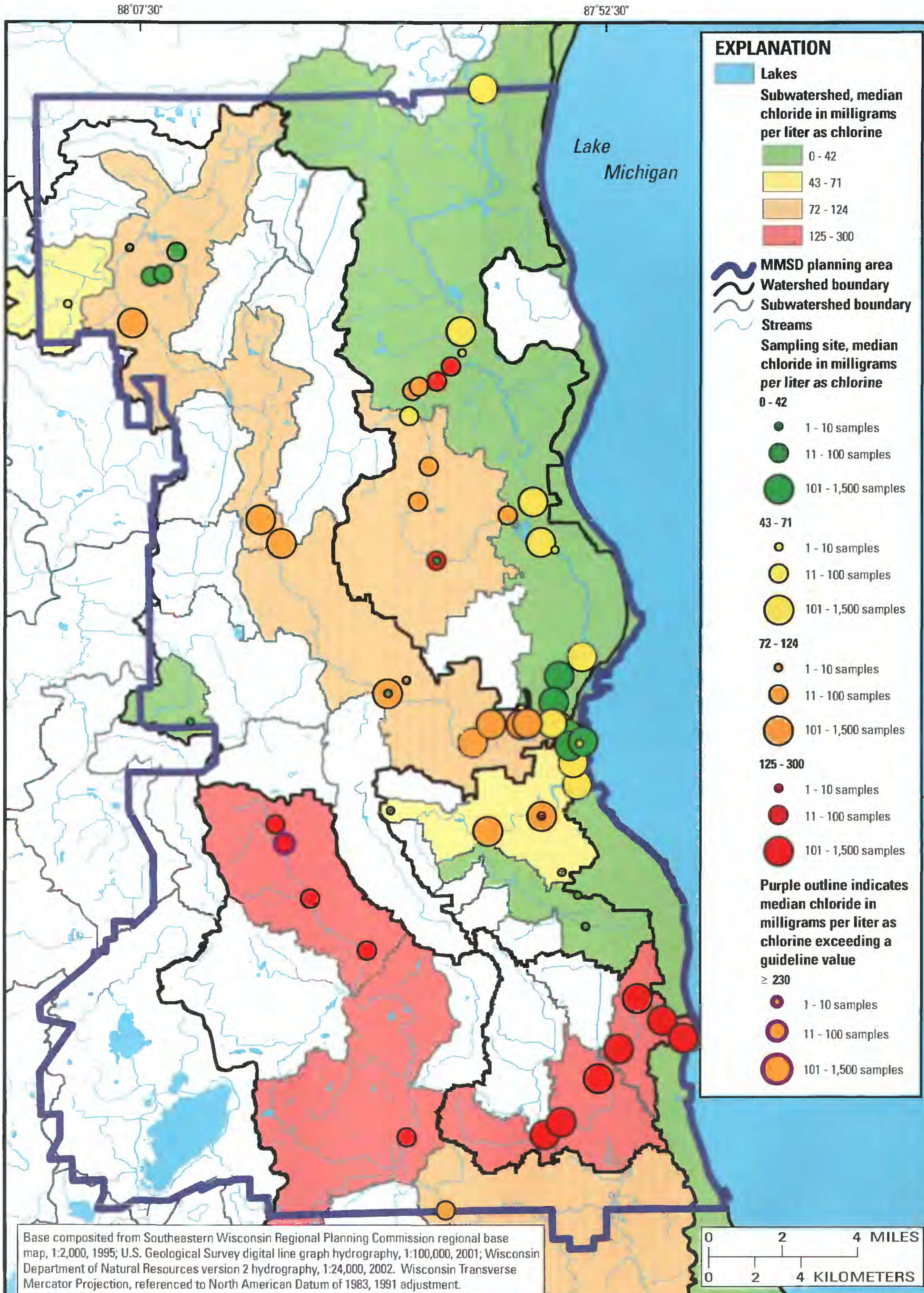

Figure 36. Sites sampled for chloride in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

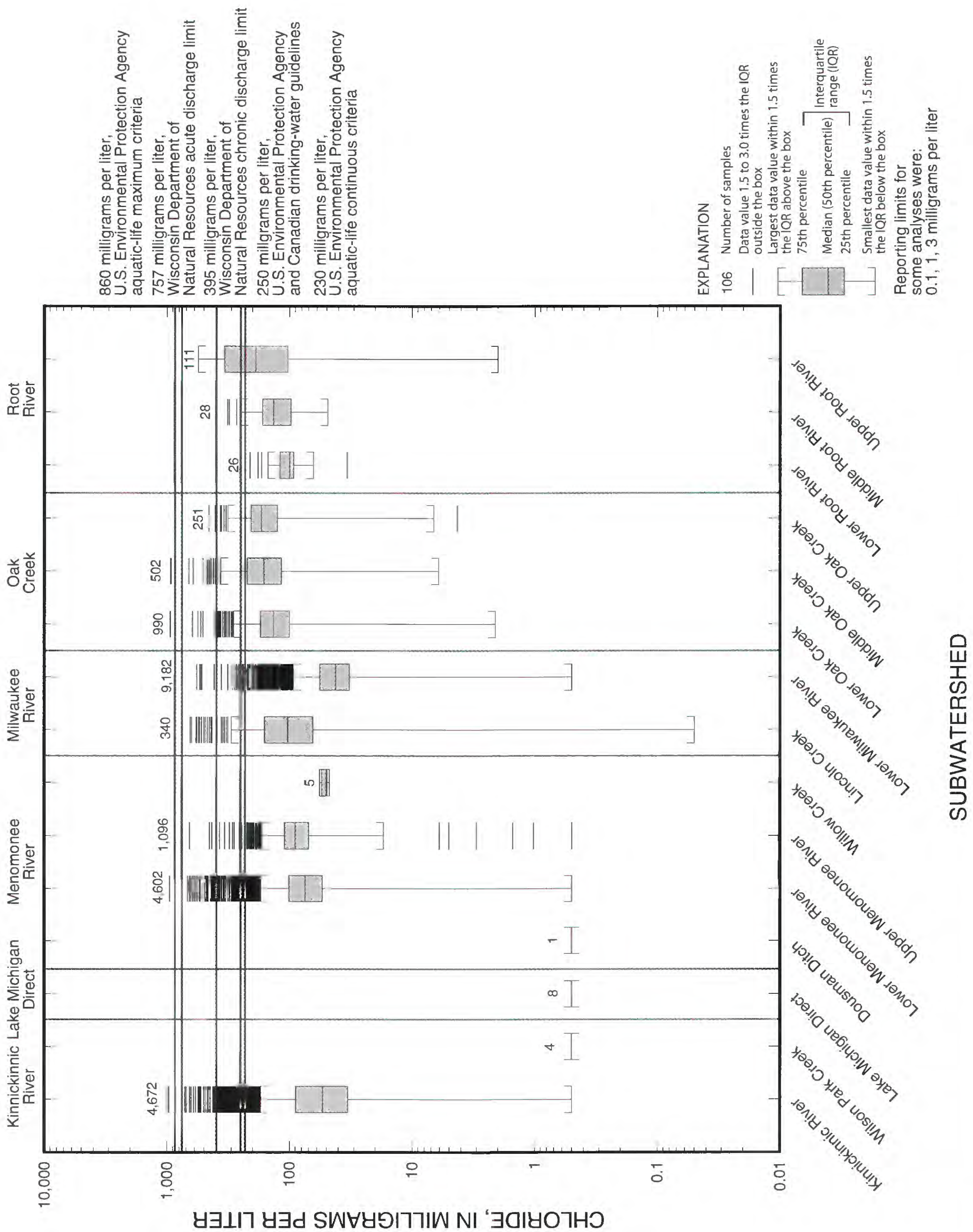

Figure 37. Statistical distribution of chloride concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

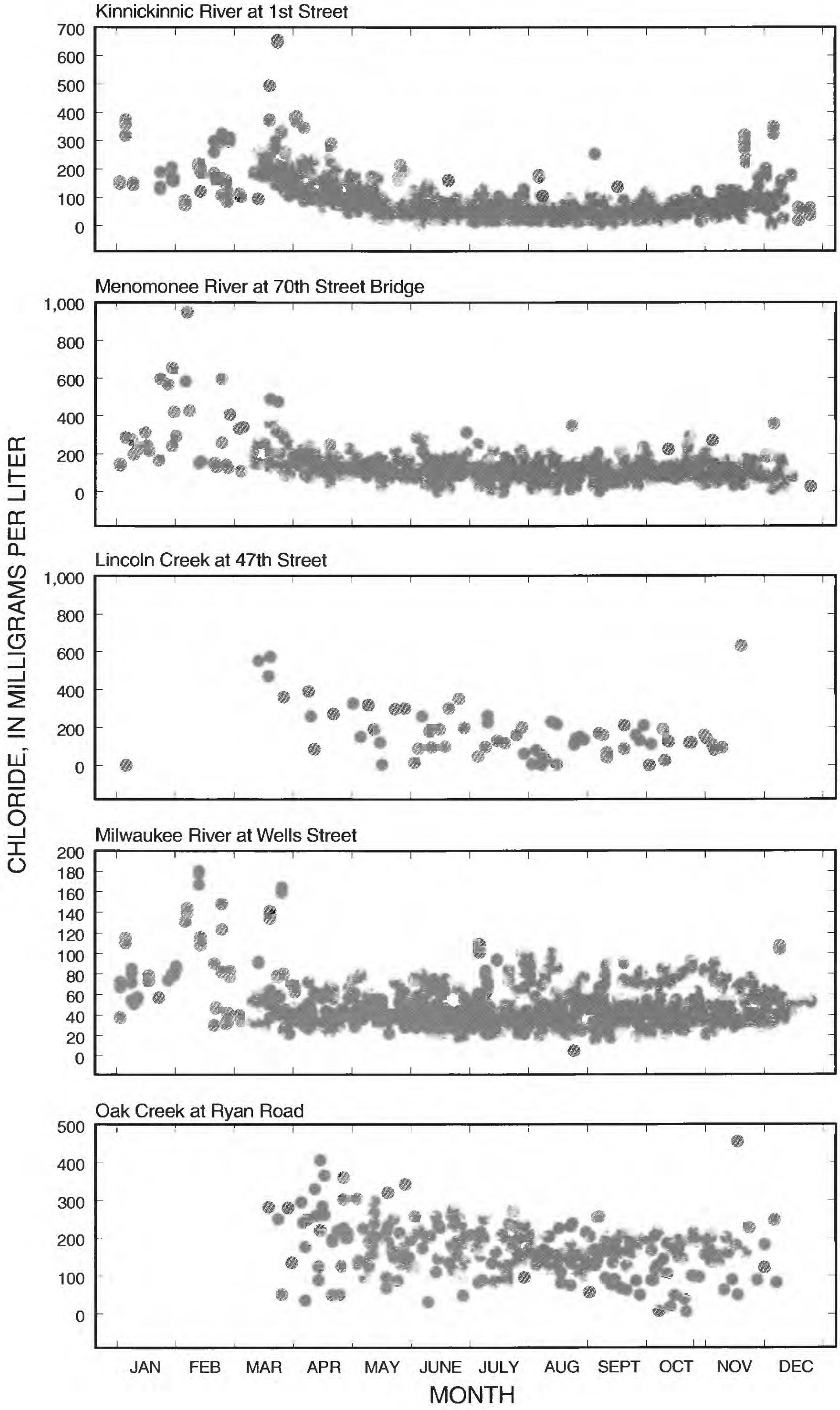

Figure 38. Seasonality of chloride for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

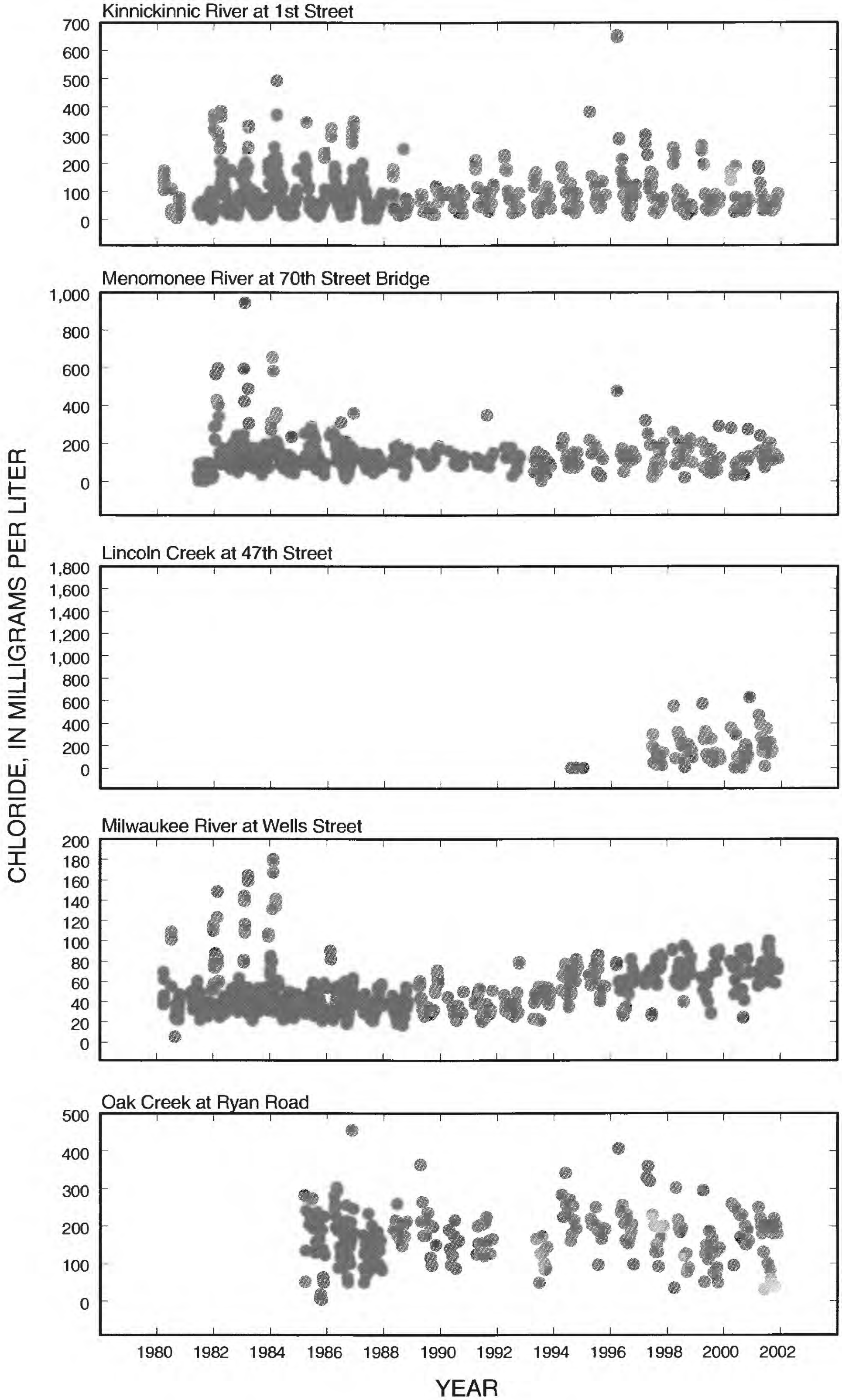

Figure 39. Trends of chloride for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 15. Summary statistics for chloride, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as chlorine (mg/L as Cl); values rounded to the nearest whole number; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	7	4,661	11	4,672	4	1	07/18/1977	11/27/2001	1	24	34	54	77	89	158	999
	Wilson Park Creek	1	0	4	4	4	1	08/13/1977	08/13/1977	--	--	--	--	--	--	--	RL
Lake Michigan Direct	Lake Michigan Direct	1	0	8	8	8	1	08/13/1977	11/23/1977	--	--	--	--	--	--	--	RL
Menomonee River	Dousman Ditch	1	0	1	1	1	1	09/19/1976	09/19/1976	--	--	--	--	--	--	--	RL
	Lower Menomonee River	7	4,598	4	4,602	4	1	08/20/1975	11/27/2001	1	40	54	75	90	101	148	946
	Upper Menomonee River	8	1,018	78	1,096	78	1, 3	06/06/1977	11/27/2001	1	37	70	90	93	110	143	653
	Willow Creek	1	0	5	5	0	--	06/12/2000	08/08/2000	48	48	50	50	52	55	56	57
Milwaukee River	Lincoln Creek	5	330	10	340	3	0.1	08/10/1994	11/27/2001	0	28	65	104	133	160	271	647
	Lower Milwaukee River	16	9,174	8	9,182	0	--	05/21/1979	11/27/2001	1	25	33	42	48	57	76	570
Oak Creek	Lower Oak Creek	4	990	0	990	0	--	03/21/1985	11/19/2001	2	78	100	135	145	174	216	943
	Middle Oak Creek	2	502	0	502	0	--	03/21/1985	11/19/2001	6	85	117	162	179	222	273	932
	Upper Oak Creek	1	251	0	251	0	--	03/21/1985	11/19/2001	4	86	126	170	170	206	250	455
Root River	Lower Root River	1	26	0	26	0	--	08/25/1999	10/10/2001	34	73	93	100	109	120	160	210
	Middle Root River	1	28	0	28	0	--	08/25/1999	10/10/2001	49	79	98	135	145	163	256	320
	Upper Root River	4	111	0	111	0	--	08/25/1999	10/10/2001	2	56	107	190	219	335	430	560

Sediment

Two types of suspended solid-phase material data, total suspended solids (TSS) and suspended sediment (SS), are in the MMSD Corridor Study database. Most TSS data were from MMSD and USEPA STORET, whereas all of the SS data were from USGS. Gray and others (2000) have shown conclusively that TSS and SS data are not comparable and that SS is a much more reliable and reproducible measure of suspended matter in natural waters, especially when sand-sized material is present. For this reason, these two data sets are discussed separately in this report.

Total Suspended Solids

Total suspended solids (TSS) is a measure of the all material, biotic and abiotic, that is retained on a filter. It is composed of suspended sediment mainly in the clay and silt size range, biomass (mainly live algae and zooplankton), and particulate detritus (dead organic matter). Soil and surficial deposit characteristics in the watershed generally control the amount and size range of sediment entering into and transported in a stream. Primary production, input of soil organic matter, and resuspension of fine-grained organic-rich sediments largely determine the amount of organic matter in total suspended solids.

Nonbiological suspended solids ultimately come from the watershed, although a significant amount at any particular site may be resuspended from the stream bottom. The main source of biological suspended solids is usually stream organisms, but detritus may be dominated by allochthonous sources such as soil organic matter and leaf fragments.

Total suspended solids in streams is usually dominated by nonbiological materials; therefore, its importance is mainly as an indicator of erosion and transport of sediments from watersheds. Construction sites are often regulated in an attempt to limit the sediment runoff into nearby surface waters. Also, buffer zones between agricultural sites and streams are increasingly used to decrease sediment inputs, and their associated nutrients, to surface waters. There is no TSS water-quality standard for the streams in MMSD planning area, although lower concentrations, indicative of clearer water, are usually more desirable.

Sites with median TSS concentrations in the upper quartile were primarily in the southern part of the planning area. All sites in the Upper Root River, Middle Root River, Lower Root River, Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek subwatersheds had median concentrations in the upper quartile (fig. 40). Sites with median concentrations in the lower quartile were in the Willow Creek, Butler Ditch, Lower Milwaukee River, Kinnickinnic River, Wilson Park Creek, and Mitchell Field Drainage Ditch subwatersheds (fig. 40).

Subwatersheds in the southern part of the planning area had median TSS concentrations in the upper quartile (fig. 40). Subwatersheds with median concentrations in the lower quartile were Willow Creek, Butler Ditch, Wilson Park Creek, and the Mitchell Field Drainage Ditch, although 10 or fewer samples were collected at most sites within the subwatersheds (fig. 40). The highest maximum concentrations were found in the Lower Milwaukee River (7,800 mg/L) and Kinnickinnic River (7,210 mg/L) subwatersheds (fig. 41, table 16). The Lower, Middle, and Upper Oak Creek and Root River subwatersheds had the highest median concentrations, with increasing median concentration in the downstream direction for each river (fig. 41, table 16). The lowest median concentrations were measured in the Willow Creek (7 mg/L), Wilson Park Creek (13 mg/L), and Mitchell Field Drainage Ditch (23 mg/L) subwatersheds (fig. 41, table 16).

There were some indications of higher TSS concentrations during the late winter through spring months at the Menomonee and Milwaukee River sites (fig. 42). The higher concentrations may be due to erosion during snowmelt on land with little cover. No obvious long-term trend in TSS concentration with sample year was evident at any of the five highlighted sites (data not shown).

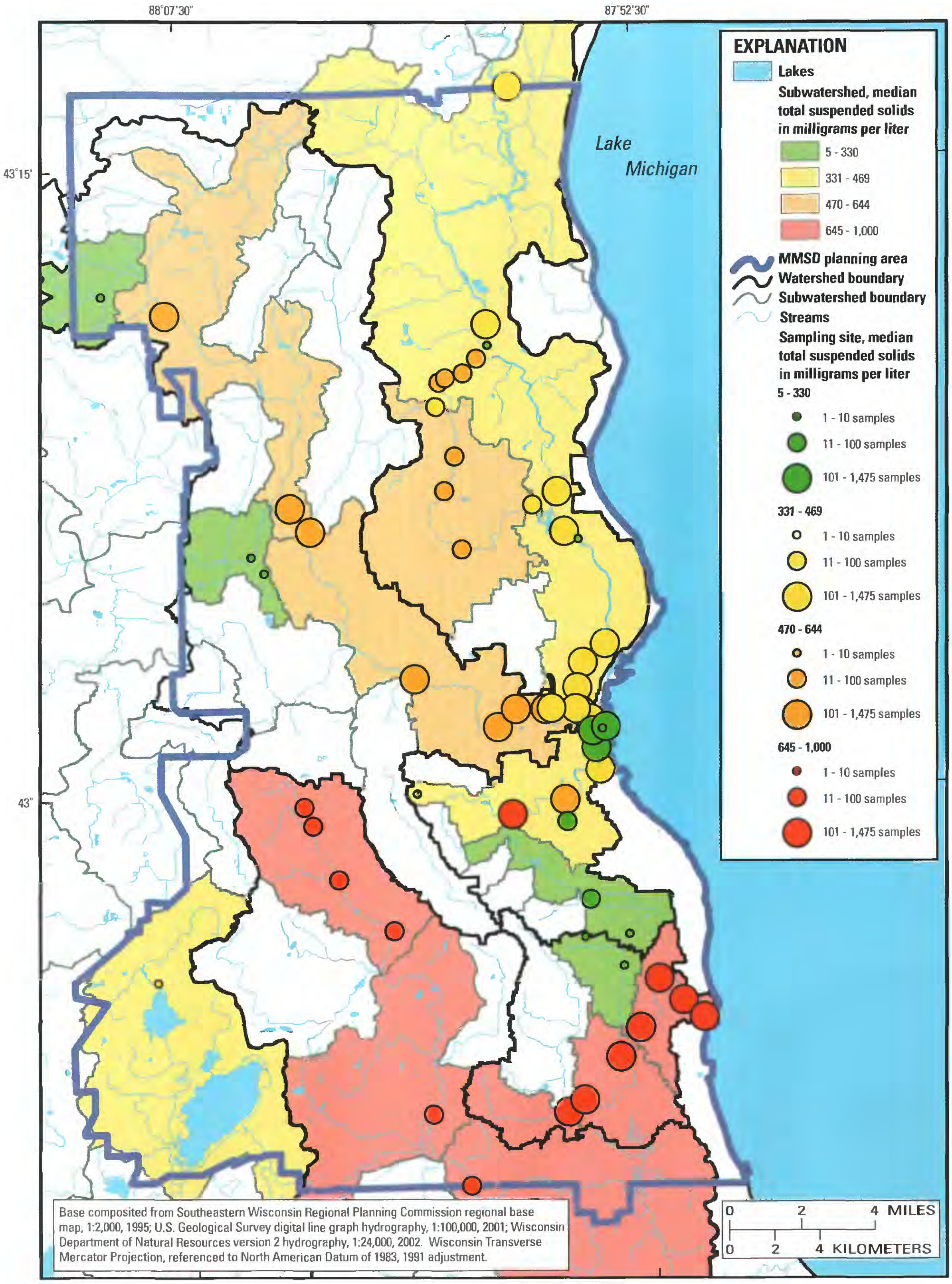

Figure 40. Sites sampled for total suspended solids in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

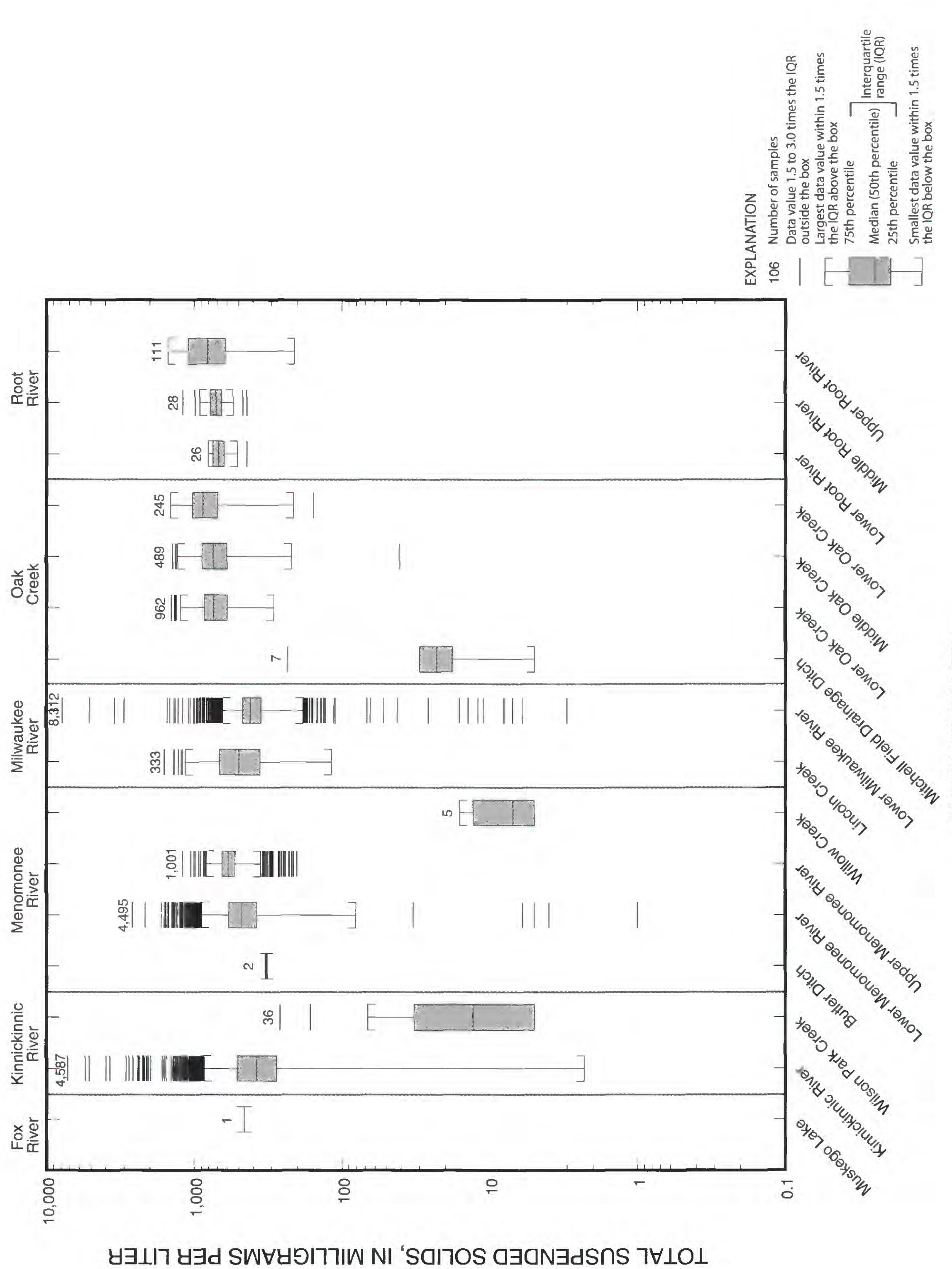

Figure 41. Statistical distribution of total suspended solids concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

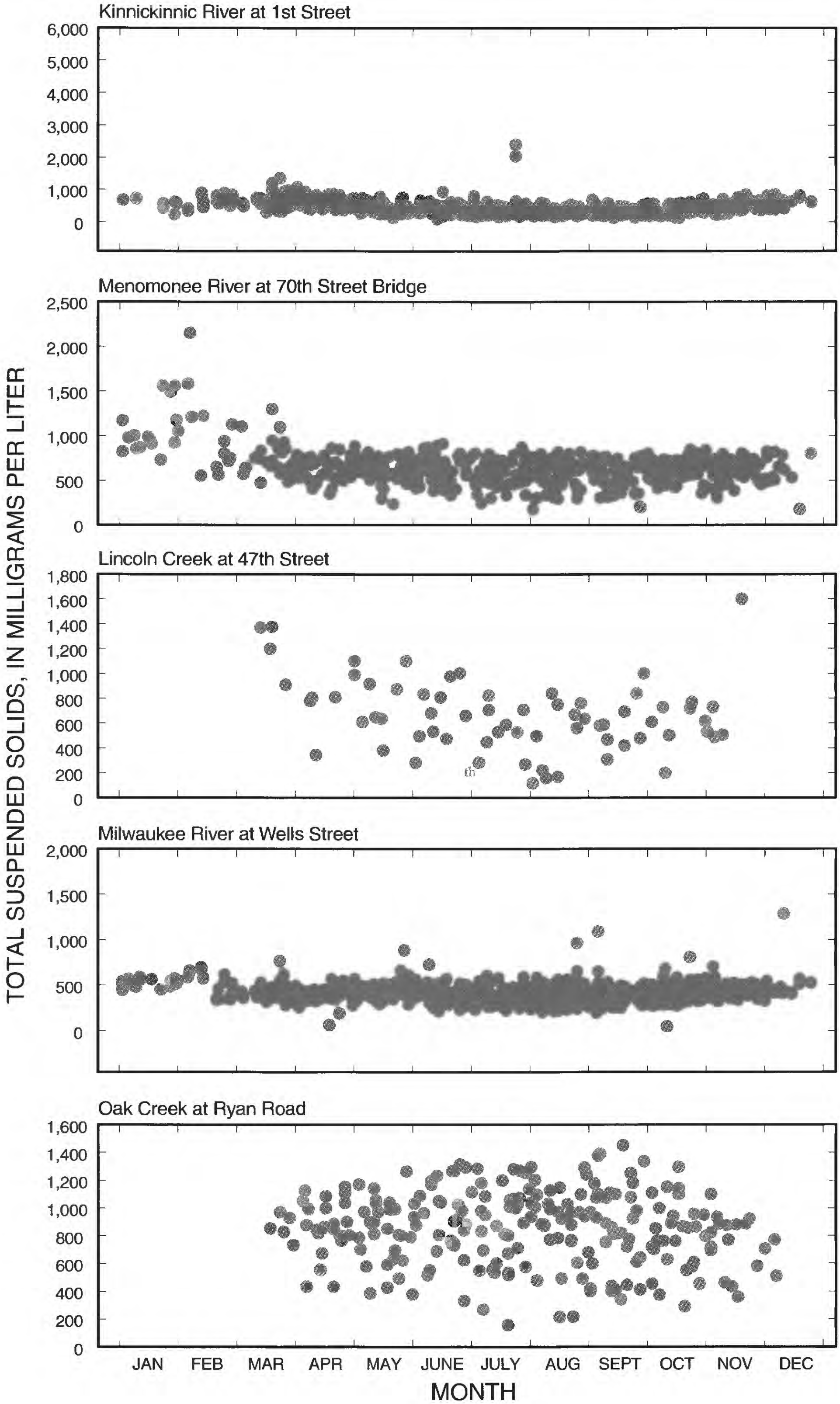

Figure 42. Seasonality of total suspended solids for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 16. Summary statistics for total suspended solids, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; STORET, STOrage and RETrieval System; --, no data available; values are expressed in milligrams per liter (mg/L); values rounded to the nearest whole number]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of STORET results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	1	0	1	1	0	04/18/2001	04/18/2001	458	458	458	458	458	458	458	458
Kinnickinnic River	Kinnickinnic River	6	4,583	4	4,587	0	03/31/1980	11/27/2001	2	231	278	380	434	510	690	7,210
	Wilson Park Creek	3	0	36	36	0	12/23/1999	09/22/2000	5	5	5	13	30	32	48	263
Menomonee River	Butler Ditch	2	0	2	2	0	04/19/2001	04/24/2001	320	321	323	325	325	328	329	330
	Lower Menomonee River	6	4,495	0	4,495	0	03/31/1980	11/27/2001	1	309	381	480	499	587	703	2,630
	Upper Menomonee River	3	1,001	0	1,001	0	05/24/1982	11/27/2001	202	439	530	590	583	650	708	1,200
	Willow Creek	1	0	5	5	0	06/12/2000	08/08/2000	5	5	5	7	9	13	15	16
Milwaukee River	Lincoln Creek	5	333	0	333	0	06/18/1997	11/27/2001	118	240	359	500	540	680	874	1,600
	Lower Milwaukee River	16	8,306	6	8,312	0	03/31/1980	11/27/2001	3	281	354	418	413	468	514	7,800
Oak Creek	Mitchell Field Drainage Ditch	2	0	7	7	0	01/03/2000	09/22/2000	5	13	21	23	51	27	112	234
	Lower Oak Creek	4	962	0	962	0	03/21/1985	11/19/2001	290	497	602	739	733	860	956	1,430
	Middle Oak Creek	2	489	0	489	0	03/21/1985	11/19/2001	41	470	602	745	745	887	1,000	1,402
	Upper Oak Creek	1	245	0	245	0	03/21/1985	11/19/2001	156	467	695	875	852	1,032	1,174	1,450
Root River	Lower Root River	1	26	0	26	0	08/25/1999	10/10/2001	440	564	635	685	676	743	767	800
	Middle Root River	1	28	0	28	0	08/25/1999	10/10/2001	440	549	665	716	726	780	885	1,200
	Upper Root River	4	111	0	111	0	08/25/1999	10/10/2001	210	410	620	810	835	1,100	1,200	1,500

Suspended Sediment

The general composition and sources of SS in streams and rivers are identical to those for TSS with the exception that SS will include any sand-sized (and larger) particles whereas TSS may or may not. Therefore, it is not unreasonable to presume that SS concentrations may be significantly higher than TSS in watersheds where surficial deposits contain large proportions of sand.

Sites with median SS concentrations in the upper quartile were scattered throughout the planning area and were in the Upper Menomonee River, Underwood Creek, Kinnickinnic River, and Upper Root River subwatersheds (fig. 43). Sites with median concentrations in the lower quartile were also scattered throughout the planning area in the Upper Menomonee River, Lower Milwaukee River, Lincoln Creek, Kinnickinnic River, and Muskego Lake subwatersheds (fig. 43).

The subwatersheds of Underwood Creek, Kinnickinnic River, and Upper Root River had median suspended-sediment concentrations in the upper quartile. Subwatersheds with median concentrations in the lower quartile were Lower Milwaukee River and Lincoln Creek, in the northeastern part of the planning area (fig. 43). The Upper Menomonee River subwatershed had the highest maximum concentration at 11,700 mg/L (fig. 44, table 17). The Kinnickinnic River (356 mg/L), Underwood Creek (234 mg/L), and Upper Root River (204 mg/L) subwatersheds had the highest median suspended-sediment concentrations (fig. 44, table 17). Median concentrations of the Lincoln Creek (25 mg/L) and the Lower Milwaukee River (28 mg/L) subwatersheds were the lowest compared to median concentrations in other subwatersheds (fig. 44, table 17).

Data were insufficient to indicate seasonal or long-term trends in suspended-sediment at the five highlighted sampling sites (data not shown).

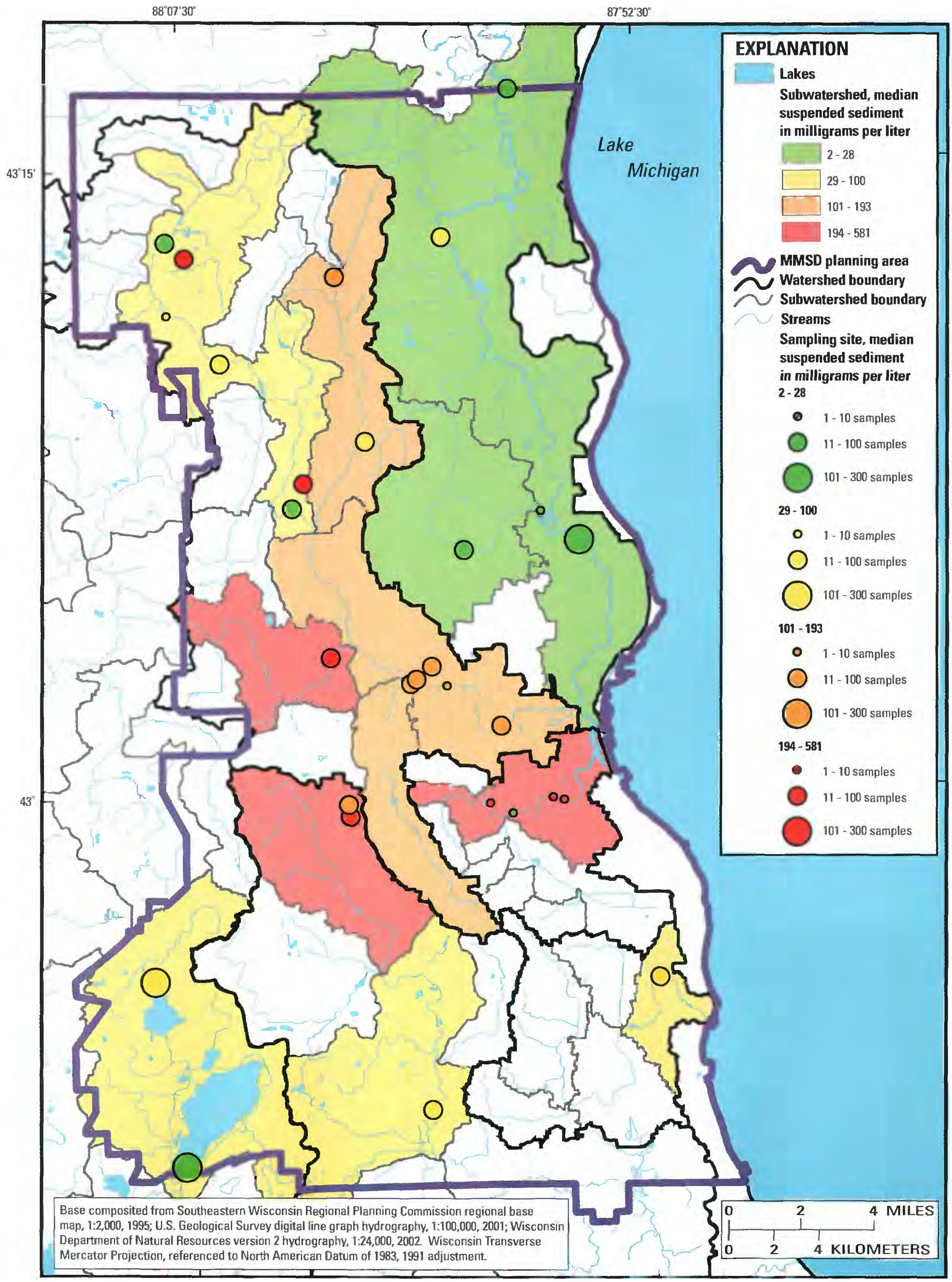

Figure 43. Sites sampled for suspended sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

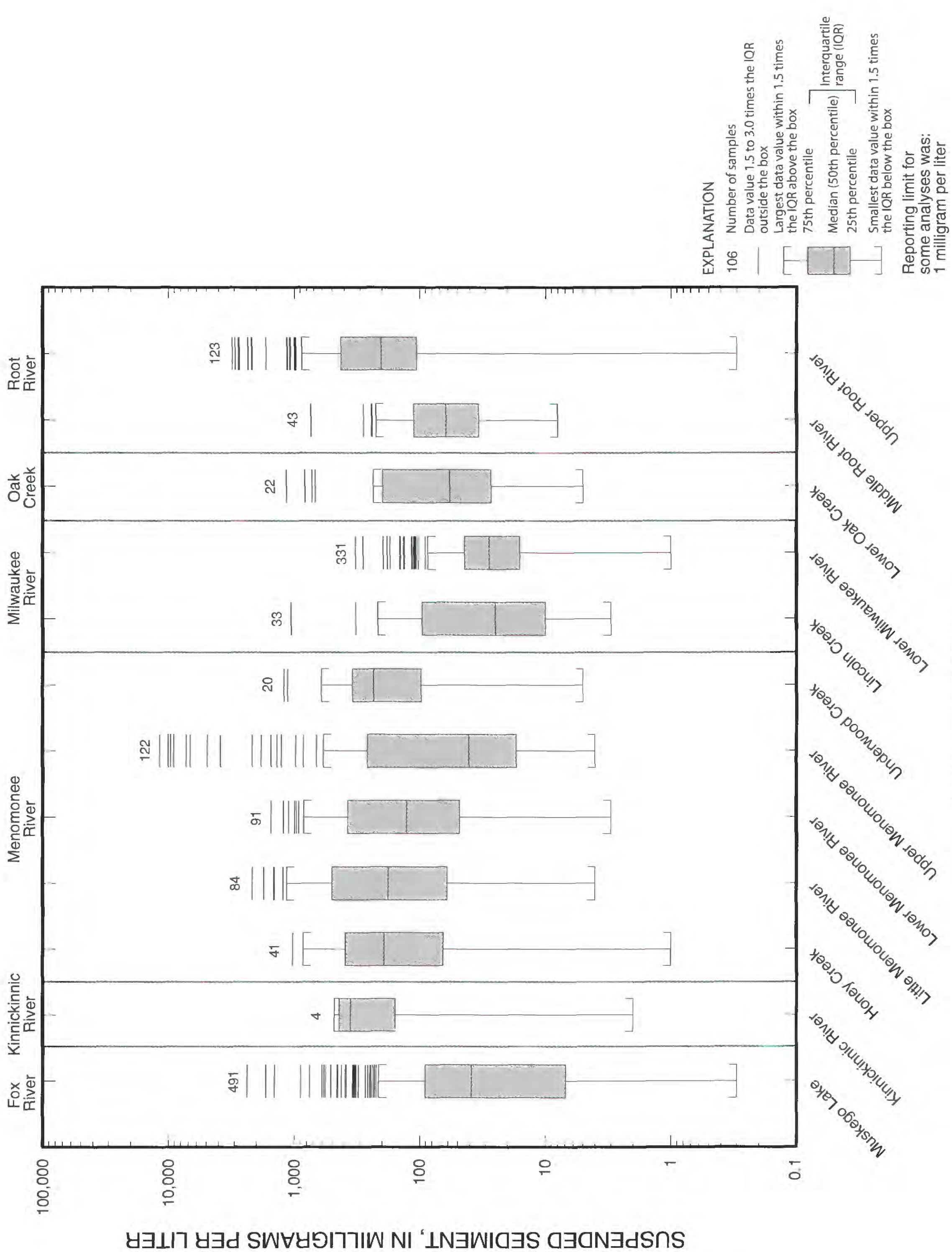

Figure 44. Statistical distribution of suspended-sediment concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 17. Summary statistics for suspended sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter (mg/L); values rounded to the nearest whole number; for the purpose of statistical calculations, values reported below reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	2	491	3	1	09/27/1995	11/06/2001	0	3	7	39	79	90	159	2,356
Kinnickinnic River	Kinnickinnic River	4	4	0	--	04/02/1977	07/10/1995	2	95	234	356	297	419	452	475
Menomonee River	Honey Creek	1	41	0	--	04/04/1973	07/10/1995	1	8	65	193	290	389	796	1,020
	Little Menomonee River	3	84	0	--	04/05/1973	07/10/1995	4	32	62	178	348	494	956	2,140
	Lower Menomonee River	4	91	0	--	04/04/1973	04/02/1983	3	10	48	127	252	366	592	1,520
	Upper Menomonee River	5	122	0	--	07/18/1973	04/02/1983	4	14	17	40	689	261	1,231	11,700
	Underwood Creek	1	20	0	--	04/04/1973	07/03/1977	5	70	98	234	308	324	655	1,200
Milwaukee River	Lincoln Creek	2	33	0	--	04/16/1993	08/16/2001	3	6	10	25	87	96	170	1,050
	Lower Milwaukee River	3	331	0	--	05/11/1971	08/16/2001	1	11	16	28	36	44	68	323
Oak Creek	Lower Oak Creek	1	22	0	--	09/21/1972	07/10/1995	5	12	28	58	210	194	716	1,150
Root River	Middle Root River	1	43	0	--	03/10/1971	03/15/1976	8	15	35	62	95	106	214	734
	Upper Root River	2	123	0	--	03/10/1999	09/14/2000	0	53	106	204	443	413	1,054	3,090

Nutrients

Nutrients are of concern in surface waters because high levels may cause excessive aquatic plant growth, which in turn may lead to lowered dissolved oxygen as the plants decompose. Excessive aquatic plant growth may cause other problems including large "mats" of weeds on the surface of waters that can be a nuisance to boaters and swimmers and aquatic life, and decomposing vegetation also may cause unpleasant odors.

Total Nitrogen

As a major element required for the synthesis of proteins, nucleic acids, and chlorophyll, nitrogen is a biologically essential element to stream communities. With no common nitrogen-containing minerals, virtually all nongaseous nitrogen in streams is associated with organic matter and detritus, with usually much lesser amounts of dissolved or sorbed inorganic species. The nitrogen cycle is particularly complex, having many forms of gaseous, truly dissolved, colloidal, and particulate forms. Particulate organic nitrogen is commonly the largest component of total nitrogen, with the remainder accounted for by dissolved and sorbed species--including ammonium, amino acids, peptides, proteins, amino sugars, and aliphatic amines--and dissolved nitrate (NO_3^-) and nitrite (NO_2^-).

Allochthonous sources of nitrogen include direct dissolution of nitrogen gas from the atmosphere, dissolved nitrogen associated with ground water, inputs of organic matter and detritus from watershed, and eroded sediments with sorbed nitrogen. Autochthonous sources are dominated by primary production and recycled nitrogen formed during organic matter decomposition in the water and stream sediments.

USEPA has proposed a criterion of 1.59 mg/L as N for total nitrogen in rivers for Level III Ecoregion 53 (U.S. Environmental Protection Agency, 2000a). The total nitrogen criterion for rivers is an attempt to limit the potential for nuisance algal blooms directly related to excessive nitrogen concentrations.

In most cases, concentrations of total nitrogen were derived from adding either dissolved nitrate plus dissolved Kjeldahl nitrogen concentrations or dissolved nitrate plus total organic nitrogen plus dissolved ammonia nitrogen concentrations. (For further discussion, see "Screening of data".) Because total nitrogen concentrations were calculated from several constituents, the number of samples with one or more components having concentrations below a reporting limit was not carried through the calculation.

At many sites scattered throughout the planning area, median total nitrogen concentrations exceeded the proposed USEPA nutrient-criterion concentration (for a calculated total nitrogen) of 1.59 mg/L as N (fig. 45). The sites with median concentrations in the upper quartile were generally found in the same subwatersheds with exceedences of the nutrient criterion (fig. 45). Sites with median concentrations in the lower quartile were also scattered throughout the planning area (fig. 45).

Subwatersheds with median concentrations in the upper quartile were Willow Creek, Little Menomonee River, Wilson Park Creek, Mitchell Field Drainage Ditch, and the Lower Root River (fig. 45). Subwatersheds with the lowest median concentrations were Honey Creek, North Branch Oak Creek, and Middle Oak Creek (fig. 45). All subwatersheds except Butler Ditch, Honey Creek and North Branch Oak Creek had multiple exceedences of the 1.59 mg/L as N nutrient criterion (fig. 46). All samples collected in the Mitchell Field Drainage Ditch exceeded the nutrient criterion (fig. 46, table 18). Those subwatersheds with no exceedences of the nutrient criterion each had fewer than 10 samples (fig. 46, table 18). The highest maximum concentrations were in the Wilson Park Creek (562.00 mg/L as N) and Mitchell Field Drainage Ditch (170.01 mg/L as N) subwatersheds (fig. 46, table 18). The highest median concentration, of 53.70 mg/L as N, was measured in the Mitchell Field Drainage Ditch subwatershed (table 18). Median concentrations in Wilson Park Creek, Little Menomonee River, Willow Creek, Lower Milwaukee River, and the Lower Root River also exceeded the nutrient criterion (fig. 46, table 18).

No general seasonal variations or long-term trends in total nitrogen were evident at the five highlighted sampling sites (data not shown).

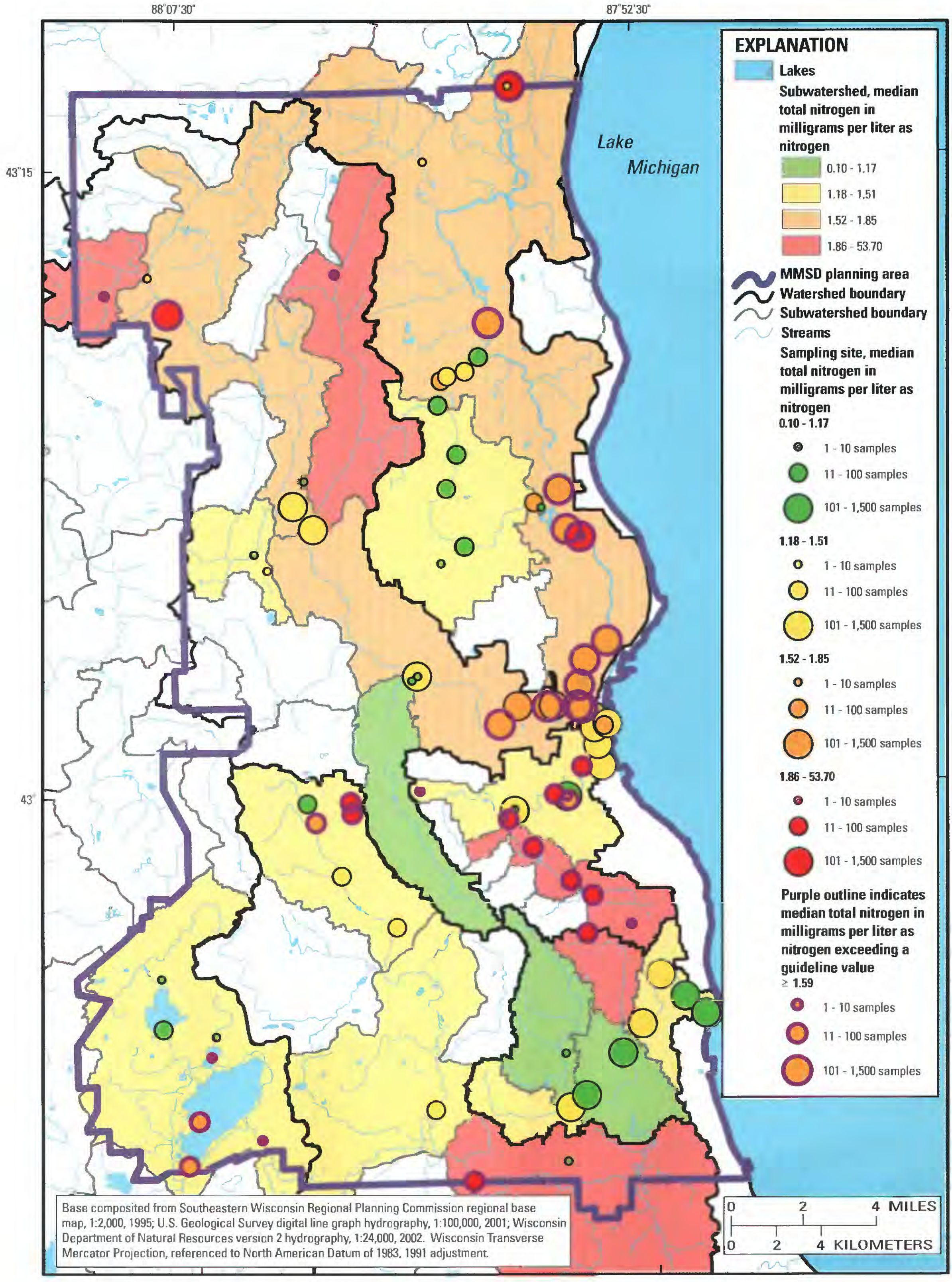

Figure 45. Sites sampled for total nitrogen in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

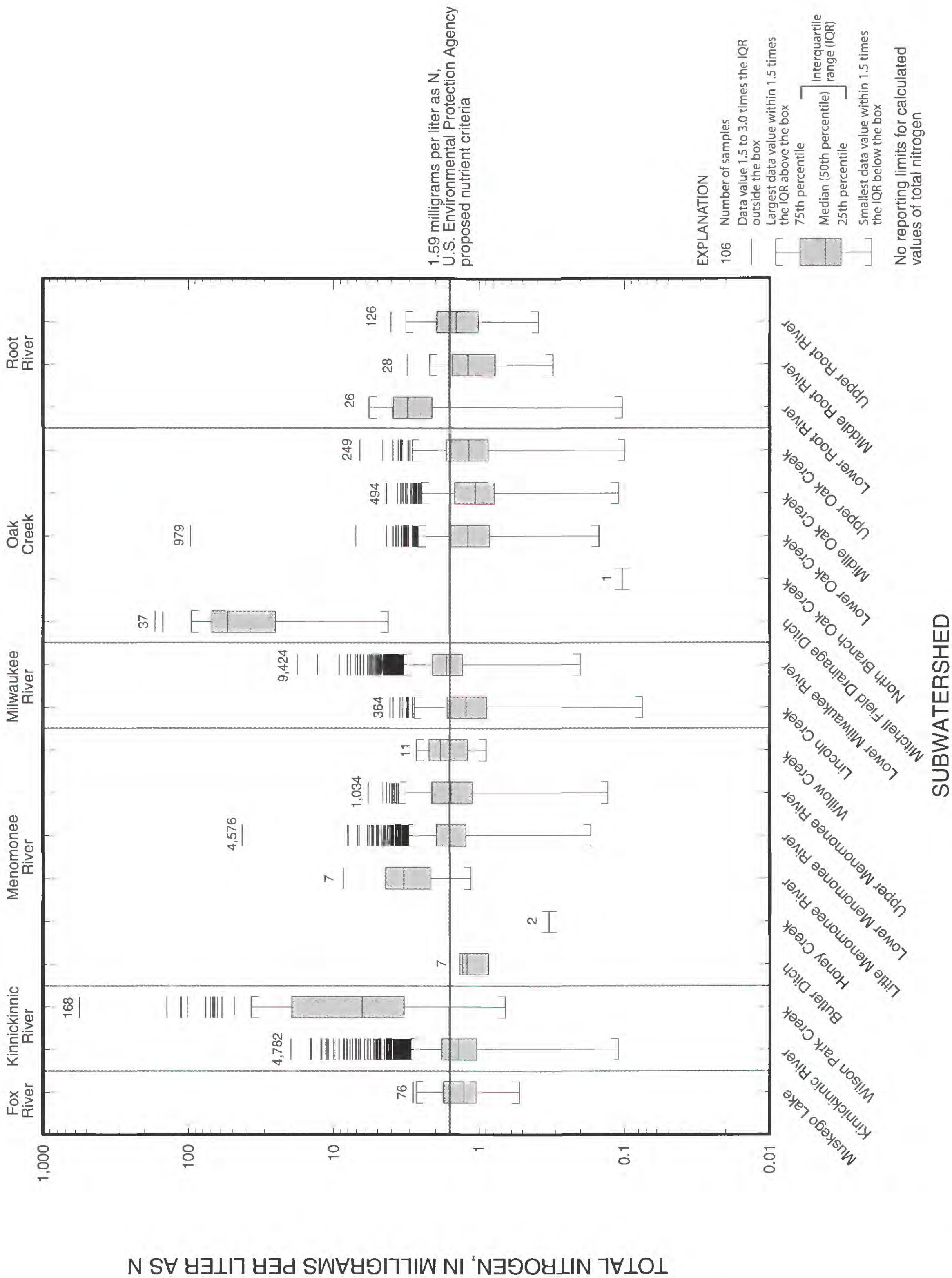

Figure 46. Statistical distribution of total nitrogen concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 18. Summary statistics for total nitrogen, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; values are expressed in milligrams per liter as nitrogen (mg/L as N); values are rounded to the nearest hundredth; total nitrogen values were available for some data, in most cases total nitrogen was derived by adding total nitrate plus Kjeldahl nitrogen, or total nitrate plus ammonia plus total organic nitrogen; for the purpose of statistical calculations, values of total nitrate, Kjeldahl nitrogen, ammonia, or total organic nitrogen reported below a reporting limit are set at one-half the reporting-limit value; some values below a reporting limit were reported as zero; due to the complexity of the total nitrogen calculations, indications of values that were used in the calculation of total nitrogen that were below a reporting limit have not been carried through to the total nitrogen values]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90thpercentile	Maximum
Fox River	Muskego Lake	8	0	12	64	76	10/17/1986	08/29/2001	0.53	0.91	1.06	1.27	1.43	1.73	2.32	2.84
Kinnickinnic River	Kinnickinnic River	12	4,681	1	100	4,782	06/11/1981	11/27/2001	.11	.80	1.04	1.39	1.55	1.80	2.33	19.70
	Wilson Park Creek	5	0	0	168	168	11/06/1996	01/04/1998	.66	2.30	3.30	6.37	20.11	19.45	58.99	562.00
Menomonee River	Butler Ditch	2	0	0	7	7	04/21/1999	04/24/2001	.86	.87	.88	1.21	1.11	1.28	1.32	1.35
	Honey Creek	1	0	0	2	2	07/10/1995	07/11/1995	.33	.33	.33	.33	.33	.33	.33	.33
	Little Menomonee River	2	0	0	7	7	07/10/1995	10/18/2001	1.14	1.76	2.31	3.32	3.63	3.87	6.09	8.62
	Lower Menomonee River	7	4,574	0	2	4,576	05/21/1979	11/27/2001	.17	.94	1.23	1.58	1.65	1.96	2.38	42.52
	Upper Menomonee River	3	1,034	0	0	1,034	05/24/1982	11/27/2001	.13	.78	1.11	1.56	1.66	2.11	2.66	5.78
	Willow Creek	2	0	0	11	11	06/12/2000	10/18/2001	.89	1.19	1.32	1.85	1.82	2.21	2.50	2.71
Milwaukee River	Lincoln Creek	8	316	0	48	364	08/07/1980	03/13/2002	.08	.68	.89	1.24	1.36	1.66	2.20	4.10
	Lower Milwaukee River	20	9,115	1	308	9,424	01/25/1973	03/13/2002	.20	.97	1.30	1.68	1.76	2.10	2.56	17.86
Oak Creek	Mitchell Field Drainage Ditch	1	0	0	37	37	11/06/1996	04/12/1997	4.24	7.36	25.30	53.70	53.31	69.20	83.70	170.01
	North Branch Oak Creek	1	0	1	0	1	08/05/1993	08/05/1993	.10	.10	.10	.10	.10	.10	.10	.10
	Lower Oak Creek	4	979	0	0	979	03/21/1985	11/19/2001	.15	.62	.85	1.20	1.41	1.57	2.21	97.15
	Middle Oak Creek	2	494	0	0	494	03/21/1985	11/19/2001	.11	.62	.79	1.07	1.22	1.48	2.01	4.38
	Upper Oak Creek	1	249	0	0	249	03/21/1985	11/19/2001	.10	.67	.87	1.18	1.39	1.69	2.33	6.60
Root River	Lower Root River	2	25	1	0	26	09/30/1993	10/10/2001	.10	1.43	2.12	3.10	3.07	3.90	5.05	5.70
	Middle Root River	1	28	0	0	28	08/25/1999	10/10/2001	.31	.64	.78	1.19	1.25	1.51	1.97	3.10
	Upper Root River	6	102	0	24	126	04/11/1999	10/10/2001	.39	.69	1.01	1.44	1.51	1.96	2.45	4.03

Nitrate

Dissolved nitrate (NO_3^-) is the dominant form of inorganic dissolved nitrogen in virtually all surface waters of the MMSD planning area. As a relatively bioavailable component of the nitrogen cycle, nitrate is readily taken up by algae, macrophytes, and other primary producer organisms.

Natural sources of nitrate to surface waters include atmospheric deposition and oxidation of reduced nitrogen species (including ammonia) in either influent ground water, surficial bed sediments, or the water column of streams and lakes. Nitrate is also applied as fertilizer in agricultural, urban, and suburban settings. In southeastern Wisconsin, elevated nitrate concentrations in ground water are often correlated with infiltration from excess fertilizer use in agricultural areas (Saad, 1997). Because of its relatively conservative nature in ground waters, nitrate tends to be physically transported rather than chemically altered or sorbed to aquifer matrices.

Nitrate is an important constituent in terms of human health in that concentrations in excess of 10 mg/L as N are correlated with "blue baby syndrome," a condition where the nitrate in ingested water competes with oxygen in infants. Nitrite (NO_2^-), another form of dissolved inorganic nitrogen in surface waters, also can cause or contribute to blue baby syndrome, but nitrite is usually present in much lower concentrations than nitrate. Hence, nitrate remains the focus of water-quality standards to safeguard against blue baby syndrome and is therefore sampled frequently in water-quality monitoring studies. The USEPA has set a Maximum Contaminant Level (MCL) for nitrate in drinking-water of 10 mg/L as N. The USEPA has also proposed a nutrient criterion concentration limit of 0.94 mg/L as N for total nitrate plus nitrite in rivers for Level III Ecoregion 53. Concentration limits of 10 mg/L as N have also been set by the WDNR for a water-quality MCL and by Canada as a Maximum Acceptable Concentration (MAC) in drinking water.

Sites with median nitrate concentrations in the upper quartile (including those with concentrations that exceeded the proposed USEPA nutrient criteria concentration of 0.94 mg/L as N) were scattered throughout the MMSD planning area but were generally found in subwatersheds with median concentrations in the upper two quartiles (fig. 47). Likewise, sites with median concentrations in the lower quartile were scattered throughout the planning area (fig. 47).

Subwatersheds with median nitrate concentrations in the upper quartile were Willow Creek, Upper Menomonee River, Wilson Park Creek, and the Lower Root River (fig. 47). Subwatersheds with median concentrations in the lower quartile were the Little Menomonee River, Underwood Creek, Milwaukee River Non-Contributing, and North Branch Oak Creek (fig. 47); however, of the four subwatersheds, only the Little Menomonee River subwatershed had samples with concentrations above a reporting limit (table 19). A few samples from the Wilson Park Creek subwatershed exceeded the USEPA drinking-water guideline concentration of 10 mg/L as N. Of the 24 subwatersheds with nitrate data, 17 had one or more samples with concentrations that exceeded the USEPA proposed nutrient-criterion concentration of 0.94 mg/L as N (fig. 48). The highest maximum concentrations were measured in Wilson Park Creek (10.70 mg/L as N), Little Menomonee River (7.94 mg/L as N), and Lower Menomonee River (7.11 mg/L as N) subwatersheds (fig. 48, table 19). The highest median concentrations were measured in the Lower Root River (1.90 mg/L as N) and Wilson Park Creek (0.98 mg/L as N) subwatersheds. These concentrations exceeded the proposed USEPA nutrient-criterion concentration of 0.94 mg/L as N (fig. 48, table 19).

There was distinct seasonality in the nitrate concentrations at the five highlighted sites, with concentrations being lower in the summer and higher in the winter (fig. 49). This pattern likely reflects both a strong input function to surface waters during spring in addition to biological uptake in the summer.

Nitrate concentrations were minimal in the period from the late 1980s to the early 1990s at four of the five highlighted sites (No data were available for Lincoln Creek during this time) (fig. 50). This pattern might be explained by relatively low rainfall and runoff during this period (the lowest streamflows were in 1987 and 1988) that decreased direct and ground-water inputs of nitrate to surface waters relative to periods before and after.

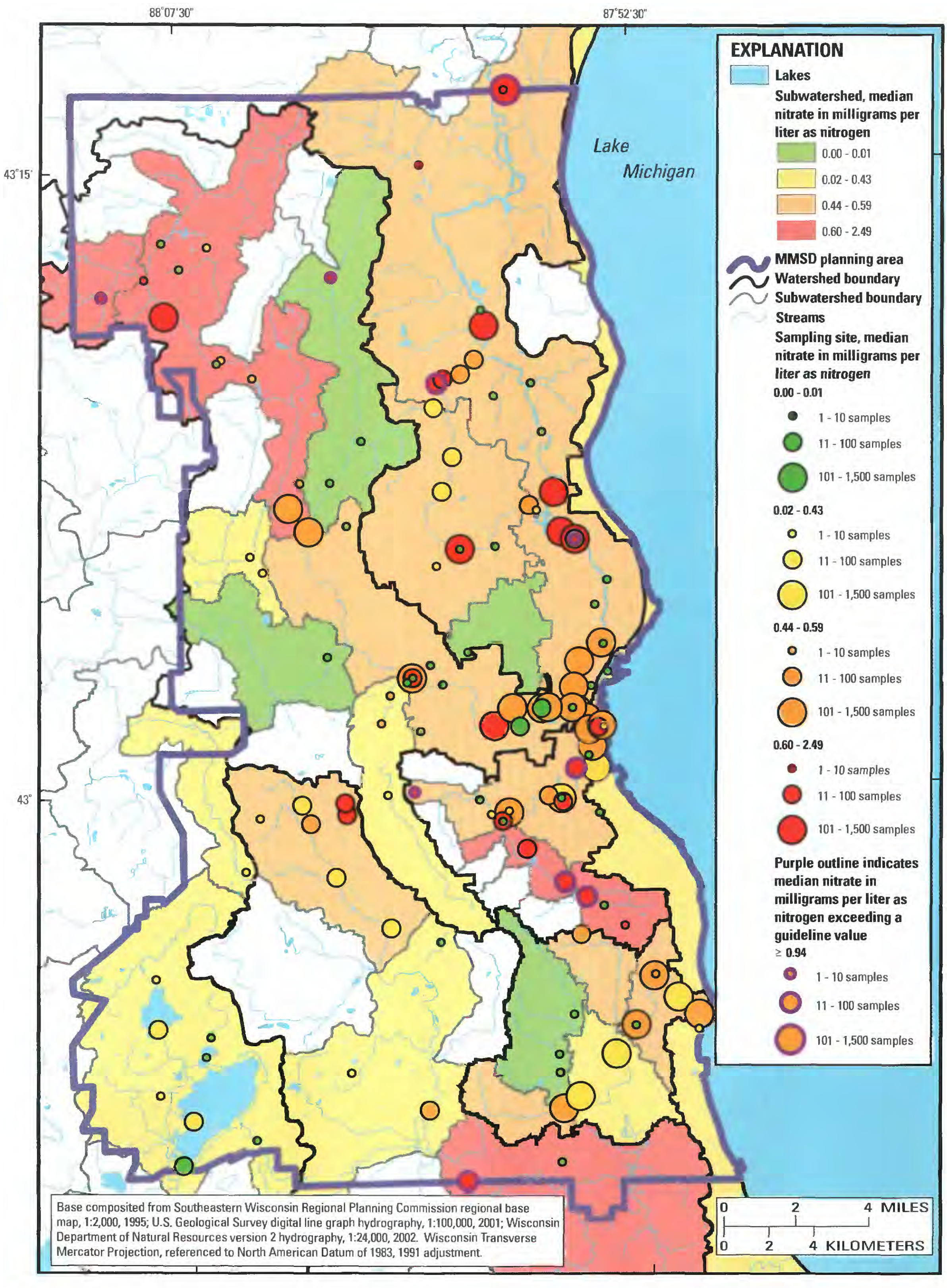

Figure 47. Sites sampled for nitrate in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

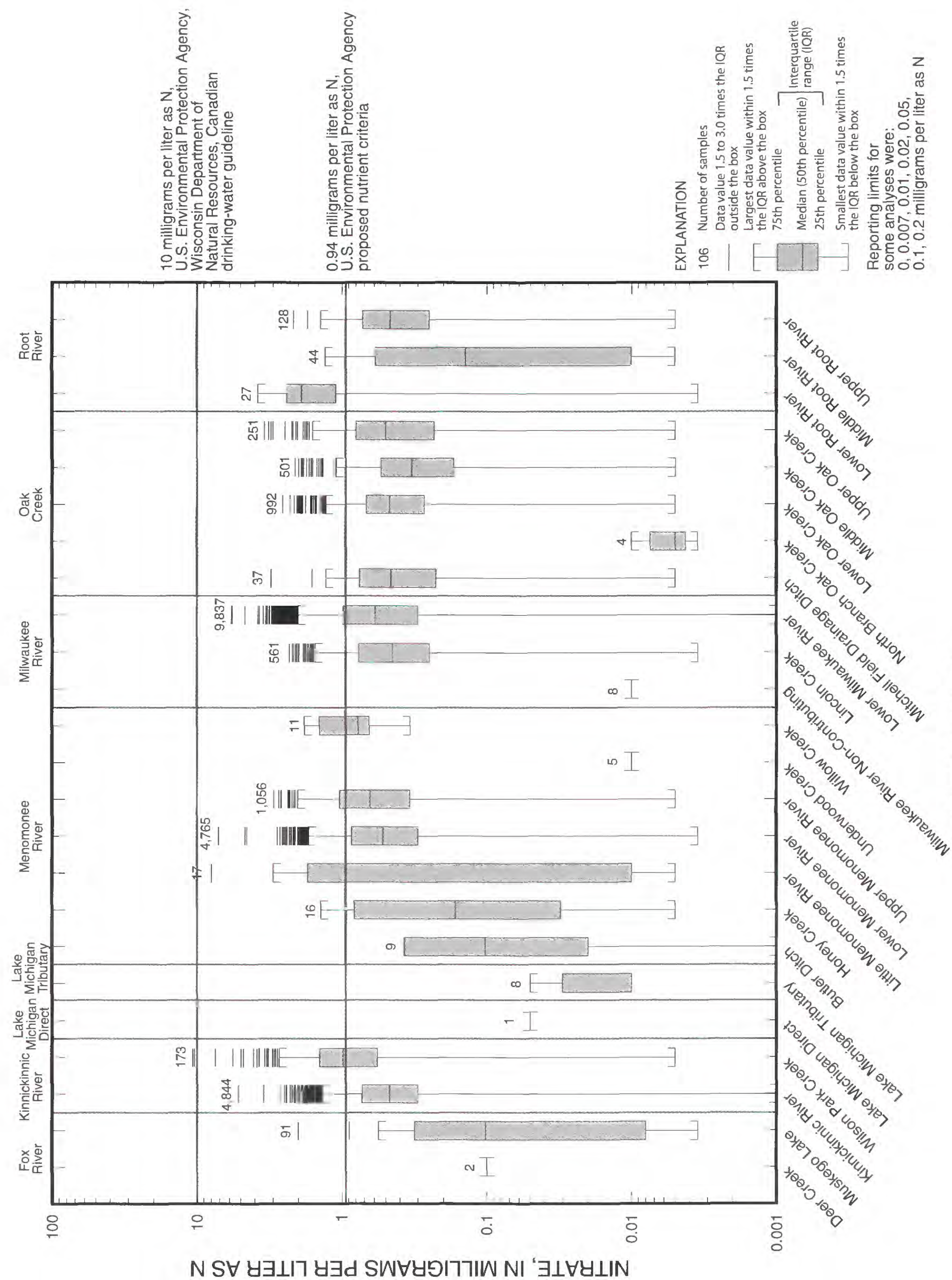

Figure 48. Statistical distribution of nitrate concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

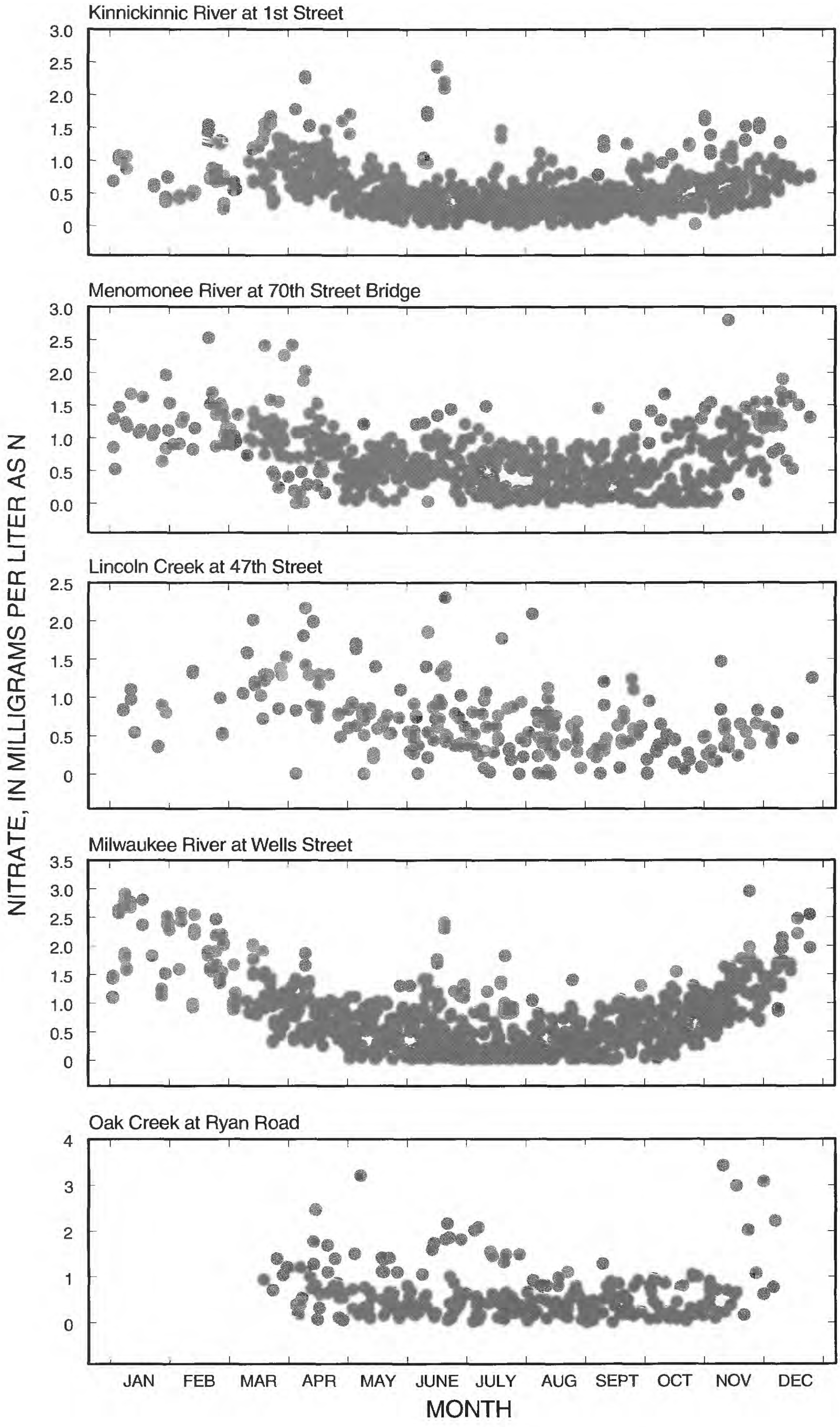

Figure 49. Seasonality of nitrate for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 19. Summary statistics for nitrate, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as nitrogen (mg/L as N); values rounded to the nearest hundredth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Deer Creek	1	0	0	2	2	2	0.2	08/16/1978	10/09/1979	--	--	--	--	--	--	--	RL
	Muskego Lake	8	0	65	26	91	28	0.007, 0.01, 0.02, 0.1	05/25/1977	08/29/2001	0.00	0.00	0.01	0.10	0.20	0.31	0.40	2.00
Kinnickinnic River	Kinnickinnic River	13	4,723	94	27	4,844	25	0, 0.01, 0.02, 0.2	09/15/1975	11/27/2001	.00	.20	.30	.47	.55	.73	1.03	5.17
	Wilson Park Creek	7	0	168	5	173	5	0.01, 0.02	09/15/1975	01/04/1998	.01	.34	.57	.98	1.36	1.43	2.97	10.70
Lake Michigan Direct	Lake Michigan Direct	1	0	0	1	1	1	0.1	05/08/1978	05/08/1978	--	--	--	--	--	--	--	RL
Lake Michigan Tributary	Lake Michigan Tributary	2	0	0	8	8	8	0.02, 0.1	05/25/1977	08/14/1981	--	--	--	--	--	--	--	RL
Menomonee River	Butler Ditch	2	0	0	9	9	2	0, 0.02	04/17/1989	08/21/2001	.00	.01	.02	.10	.16	.37	.37	.37
	Honey Creek	4	12	2	2	16	3	0.01, 0.02	10/13/1975	08/21/2001	.01	.01	.03	.17	.41	.78	1.05	1.40
	Little Menomonee River	4	0	7	10	17	10	0.01, 0.02	10/13/1975	10/18/2001	.01	.01	.01	.01	1.15	1.72	2.84	7.94
	Lower Menomonee River	11	4,617	94	54	4,765	53	0.007, 0.01, 0.02	09/02/1975	11/27/2001	.00	.14	.30	.52	.62	.86	1.21	7.11
	Upper Menomonee River	9	1,044	0	12	1,056	12	0.01, 0.02, 0.1	07/14/1975	11/27/2001	.01	.12	.34	.64	.72	1.03	1.40	2.95
	Underwood Creek	1	0	0	5	5	5	0.02	08/04/1976	06/27/1977	--	--	--	--	--	--	--	RL
	Willow Creek	2	0	6	5	11	0	--	06/12/2000	10/18/2001	.34	.63	.66	.78	.97	1.24	1.61	1.82
Milwaukee River	Milwaukee River Non-Contributing	1	0	0	8	8	8	0.02	05/07/1981	01/27/1982	--	--	--	--	--	--	--	RL
	Lincoln Creek	9	327	220	14	561	23	0.007, 0.01, 0.02, 0.05	08/07/1980	03/13/2002	.00	.07	.25	.45	.56	.77	1.20	2.30
	Lower Milwaukee River	23	9,225	564	48	9,837	75	0.007, 0.01, 0.02, 0.05, 0.1	01/25/1973	03/13/2002	.00	.13	.30	.59	.70	.98	1.40	5.76

Table 19. Summary statistics for nitrate, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002—Continued

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as nitrogen (mg/L as N); values rounded to the nearest hundredth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Oak Creek	Mitchell Field Drainage Ditch	1	0	37	0	37	1	0.01	11/06/1996	04/12/1997	.01	.16	.23	.46	.59	.76	1.16	3.08
	North Branch Oak Creek	3	0	0	4	4	4	0.007, 0.01, 0.02	09/15/1975	08/05/1993	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	990	1	1	992	5	0.01	09/15/1975	11/19/2001	.01	.15	.27	.47	.53	.68	.91	2.56
	Middle Oak Creek	2	501	0	0	501	3	0.01	03/21/1985	11/19/2001	.01	.07	.17	.33	.42	.54	.86	2.10
	Upper Oak Creek	1	251	0	0	251	2	0.01	03/21/1985	11/19/2001	.01	.12	.23	.50	.63	.80	1.39	3.42
Root River	Lower Root River	2	26	0	1	27	2	0.007, 0.01	09/30/1993	10/10/2001	.00	.49	1.19	1.90	1.88	2.40	3.48	3.80
	Middle Root River	3	28	0	16	44	17	0.01, 0.02, 0.1	06/11/1976	10/10/2001	.01	.01	.01	.14	.35	.57	.99	1.30
	Upper Root River	7	103	24	1	128	7	0.01, 0.02, 0.2	08/16/1978	10/10/2001	.01	.05	.25	.47	.51	.71	1.00	2.16

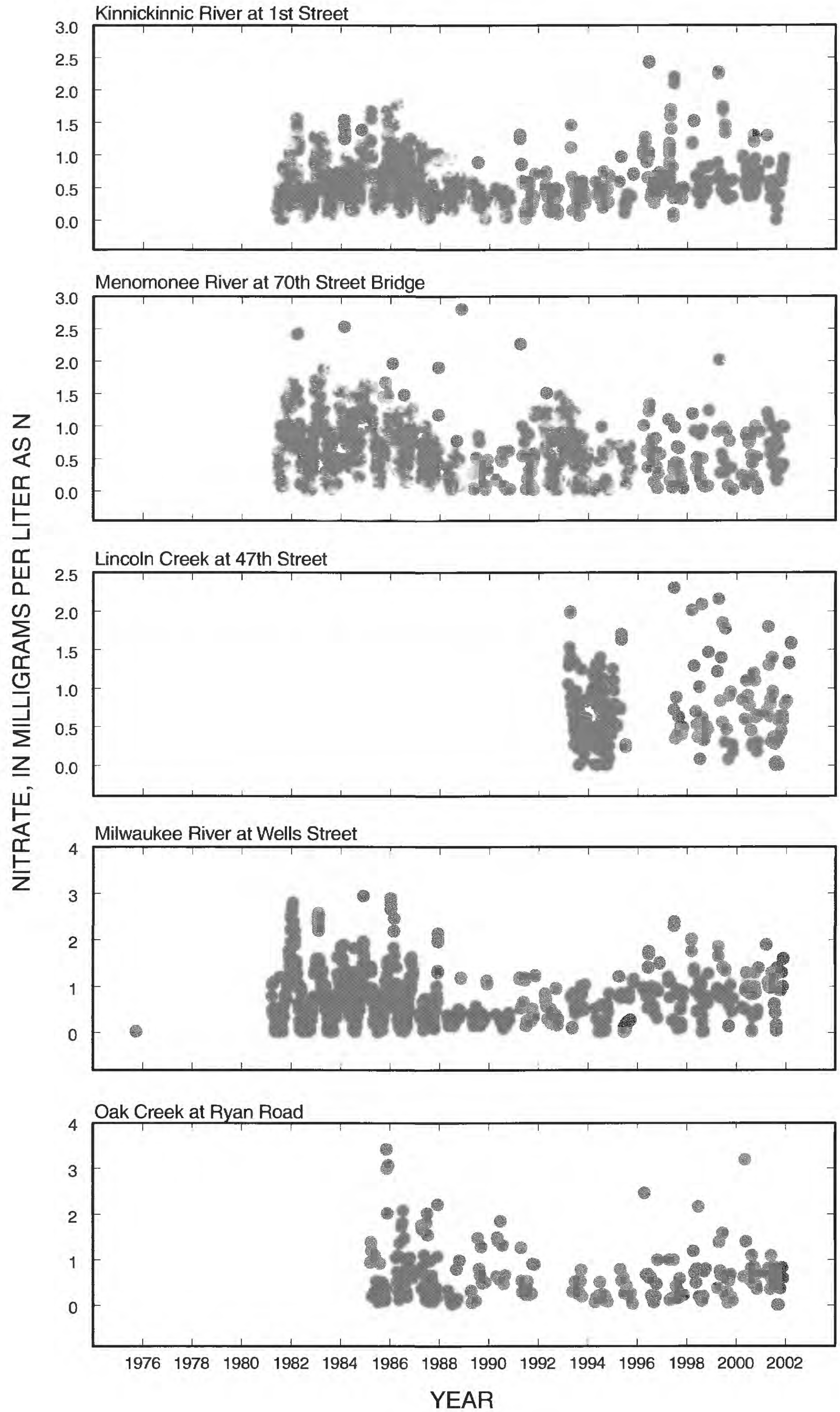

Figure 50. Trends of nitrate for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Kjeldahl Nitrogen

Kjeldahl nitrogen is an operationally defined fraction of total nitrogen that is composed of organic nitrogen compounds and ammonia. Even the particulate forms are decomposed by way of autolytic and microbial pathways on short time scales (minutes to hours). Therefore, Kjeldahl nitrogen represents a very bioavailable pool of nitrogen for primary production.

Allochthonous sources of Kjeldahl nitrogen in streams and rivers include direct wet and dry precipitation, inputs of organic matter and detritus from the watershed, and ground water (probably much smaller amounts). In agricultural and urban areas, anthropogenic sources such as manure and sewage-treatment-plant effluents may dominate. Autochthonous sources include primary production and recycled nitrogen formed during organic-matter decomposition in water and sediments.

Sites with median Kjeldahl nitrogen concentrations in the upper quartile were concentrated in the southern part of the planning area (fig. 51). Sites with median concentrations in the lower quartile were scattered throughout the planning area (fig. 51).

Subwatersheds with median Kjeldahl nitrogen concentrations in the upper quartile were Butler Ditch, Wilson Park Creek, Muskego Lake, Lower Root River, and Mitchell Field Drainage Ditch (fig. 51). Subwatersheds with the median concentrations in the lower quartile were Honey Creek, Middle Root River, Upper Oak Creek, and North Branch Oak Creek in the southern part of the planning area (fig. 51). The highest maximum concentrations were in Wilson Park Creek (560.00 mg/L as N) and Mitchell Field Drainage Ditch (170.00 mg/L as N) subwatersheds (fig. 52, table 20). Likewise, the highest median concentrations also were measured in the Mitchell Field Drainage Ditch (18.50 mg/L as N) and Wilson Park Creek (2.58 mg/L as N) subwatersheds (fig. 52, table 20).

There was no common trend or pattern in Kjeldahl nitrogen concentration with sample year or with season at the five highlighted sites (data not shown).

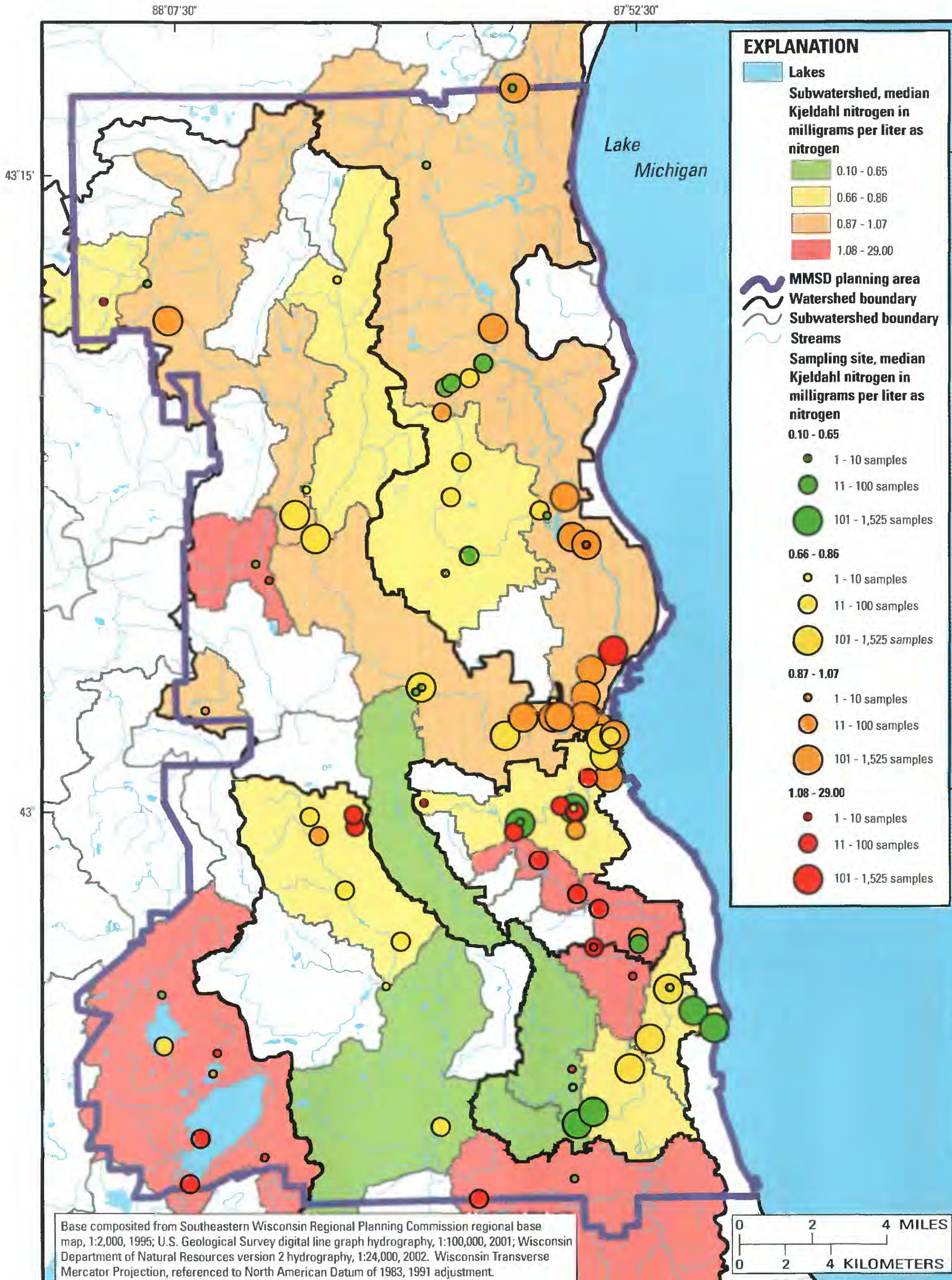

Figure 51. Sites sampled for Kjeldahl nitrogen in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

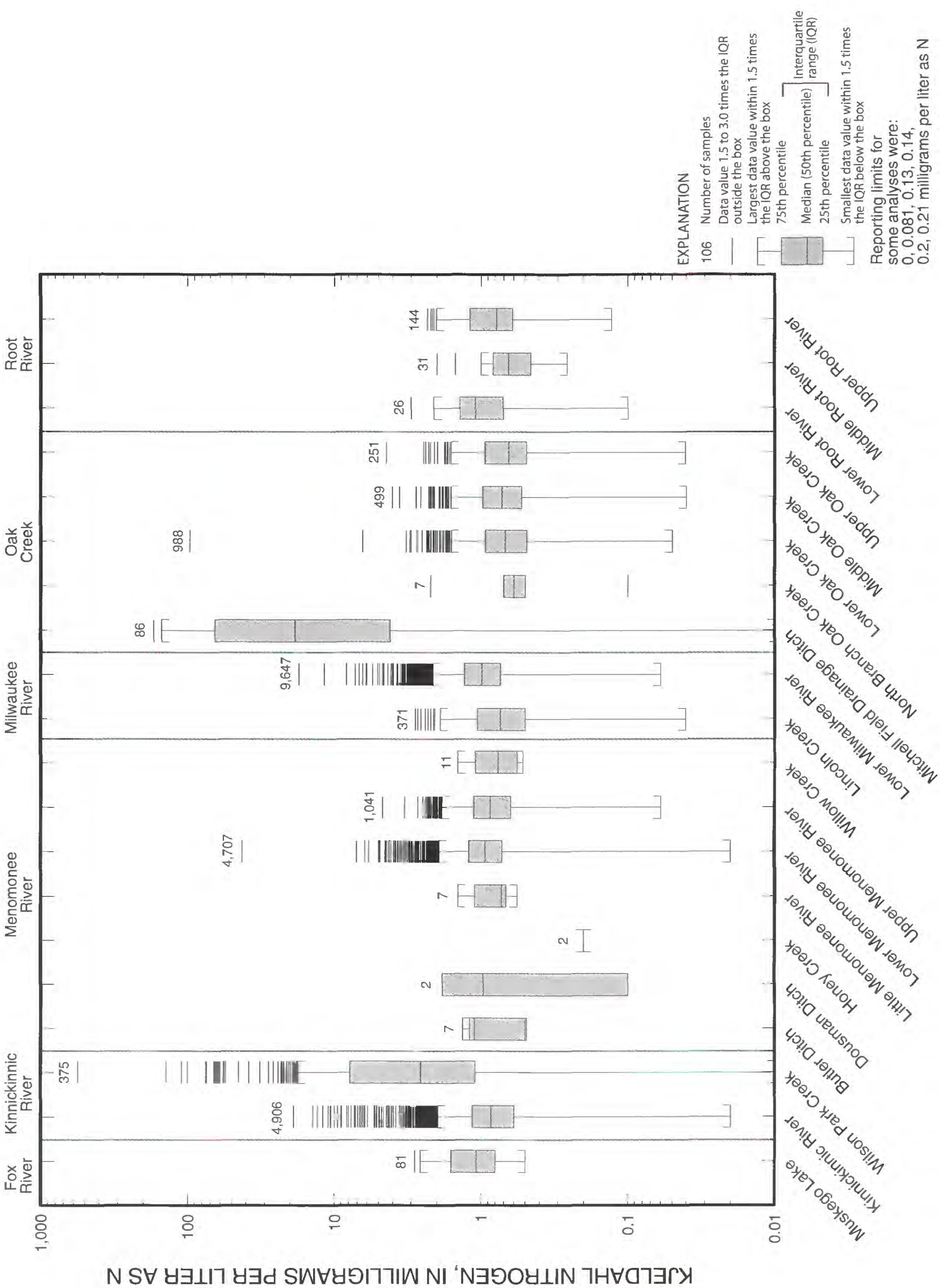

Figure 52. Statistical distribution of Kjeldahl nitrogen concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 20. Summary statistics for Kjeldahl nitrogen, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as nitrogen (mg/L as N); values rounded to the nearest hundredth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number or values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10thpercentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	7	0	61	20	81	0	--	10/17/1986	08/29/2001	0.50	0.70	0.80	1.08	1.25	1.60	2.16	2.84
Kinnickinnic River	Kinnickinnic River	9	4,800	94	12	4,906	3	0.081, 0.21	05/21/1979	11/27/2001	.02	.44	.60	.86	1.00	1.15	1.55	19.00
	Wilson Park Creek	6	0	298	77	375	8	0, 0.14	11/06/1996	01/16/2002	.00	.59	1.14	2.58	10.28	7.75	20.24	560.00
Menomonee River	Butler Ditch	2	0	0	7	7	0	--	04/21/1999	04/24/2001	.49	.50	.51	1.11	.90	1.18	1.25	1.33
	Dousman Ditch	1	0	0	2	2	1	0.2	10/13/1993	05/24/1994	.10	.27	.54	.97	.97	1.40	1.67	1.84
	Honey Creek	1	0	2	0	2	0	--	07/10/1995	07/11/1995	.20	.20	.20	.20	.20	.20	.20	.20
	Little Menomonee River	2	0	7	0	7	0	--	07/10/1995	10/18/2001	.57	.64	.69	.73	.86	.94	1.24	1.44
	Lower Menomonee River	6	4,706	1	0	4,707	0	--	05/21/1979	11/27/2001	.02	.52	.72	.94	1.03	1.21	1.60	42.50
	Upper Menomonee River	3	1,041	0	0	1,041	0	--	05/24/1982	11/27/2001	.06	.46	.63	.87	.93	1.12	1.50	4.68
	Willow Creek	2	0	6	5	11	0	--	06/12/2000	10/18/2001	.52	.55	.62	.77	.86	1.06	1.20	1.44
Milwaukee River	Lincoln Creek	7	323	48	0	371	8	0.081, 0.13	08/07/1980	03/13/2002	.04	.33	.50	.74	.83	1.06	1.39	2.80
	Lower Milwaukee River	17	9,326	308	13	9,647	1	0.13	01/25/1973	03/13/2002	.06	.53	.74	.99	1.06	1.30	1.63	17.50
Oak Creek	Mitchell Field Drainage Ditch	2	0	71	15	86	1	0	11/06/1996	01/16/2002	.00	2.12	4.19	18.50	33.78	64.02	75.00	170.00
	North Branch Oak Creek	2	0	0	7	7	1	0.2	08/05/1993	10/30/1996	.10	.34	.55	.60	.77	.70	1.30	2.21
	Lower Oak Creek	4	987	1	0	988	0	--	03/21/1985	11/19/2001	.05	.37	.49	.69	.88	.94	1.29	97.00
	Middle Oak Creek	2	499	0	0	499	0	--	03/21/1985	11/19/2001	.04	.40	.53	.72	.81	.96	1.29	4.01
	Upper Oak Creek	1	251	0	0	251	1	0.081	03/21/1985	11/19/2001	.04	.34	.49	.65	.77	.94	1.31	4.43
Root River	Lower Root River	2	25	0	1	26	1	0.2	09/30/1993	10/10/2001	.10	.63	.72	1.10	1.14	1.40	1.70	3.00
	Middle Root River	1	28	0	3	31	0	--	07/31/1996	10/10/2001	.26	.43	.48	.65	.70	.82	.88	2.00
	Upper Root River	8	110	24	10	144	0	--	07/31/1996	10/10/2001	.13	.48	.62	.79	.96	1.19	1.80	2.33

Total Phosphorus

When scarcity of a nutrient is found to be limiting the growth of plants in freshwater, the nutrient is usually phosphorus because of the relatively large biochemical requirement for this element compared to the available supply. Therefore, even small increases in phosphorus can lead to large increases in biomass (assuming no other limitation). Within the stream, phosphorus exists in several organic and inorganic forms, ranging in size from filterable particles to colloidal phases to truly dissolved monomeric molecules. Total phosphorus is usually dominated by particle-associated phosphorus that is assimilated in biomass and detritus or sorbed to various mineral phases (iron oxyhydroxides, clays, and so on).

Allochthonous sources of phosphorus in streams include wet and dry atmospheric deposition, eroded sediment, living organic matter, and detritus (dead organic matter). Autochthonous sources are probably dominated by streambed-sediment resuspension. Streambed sediments are also a temporary, albeit dynamic, sink for total phosphorus in streams.

Total phosphorus (along with nitrogen, chlorophyll *a*, and turbidity) has been selected by the USEPA as a key nutrient criterion indicator in streams. Its importance is mainly that it can limit algal and plant growth. For rivers in the Level III, Ecoregion 53, a concentration of 0.08 mg/L as P was proposed as a maximum allowable limit.

Exceedences of the proposed total phosphorus criterion concentration occurred at sites throughout the MMSD planning area (fig. 53). Also, sites with median concentrations in the upper quartile and in the lower quartile were scattered throughout the planning area (fig. 53).

Subwatersheds with median concentrations in the upper quartile were Whitnall Park Creeks, Mitchell Field Drainage Ditch, and Lower Root River (fig. 53). Subwatersheds with median concentrations in the lower quartile were the Little Menomonee River, Butler Ditch, Dousman Ditch, South Branch Underwood Creek, Milwaukee River Non-Contributing, and North Branch Oak Creek (fig. 53). Of those subwatersheds, only samples from Butler Ditch had more than half of its concentrations above a reporting limit (table 21). All subwatersheds other than those with median concentrations in the lower quartile had one or more samples with a concentration above the USEPA proposed nutrient-criterion concentration of 0.08 mg/L as P (fig. 54). The highest maximum concentrations were measured in the Middle Oak Creek (4.000 mg/L as P), Kinnickinnic River (3.600 mg/L as P), and Lower Menomonee River (3.500 mg/L as P) subwatersheds (fig. 54, table 21). The highest median concentration of 0.350 mg/L as P was measured in the Whitnall Park Creeks subwatershed (fig. 54, table 21).

There were no consistent trends or patterns in total phosphorus concentrations either by sample year or with season at the five highlighted sites (data not shown). The absence of higher concentrations during the typical algal bloom periods of spring and fall (data not shown), as can be seen for chlorophyll *a* (fig. 84), suggests that inorganic phosphorus sorbed to suspended sediment is a major component of total phosphorus at these sites.

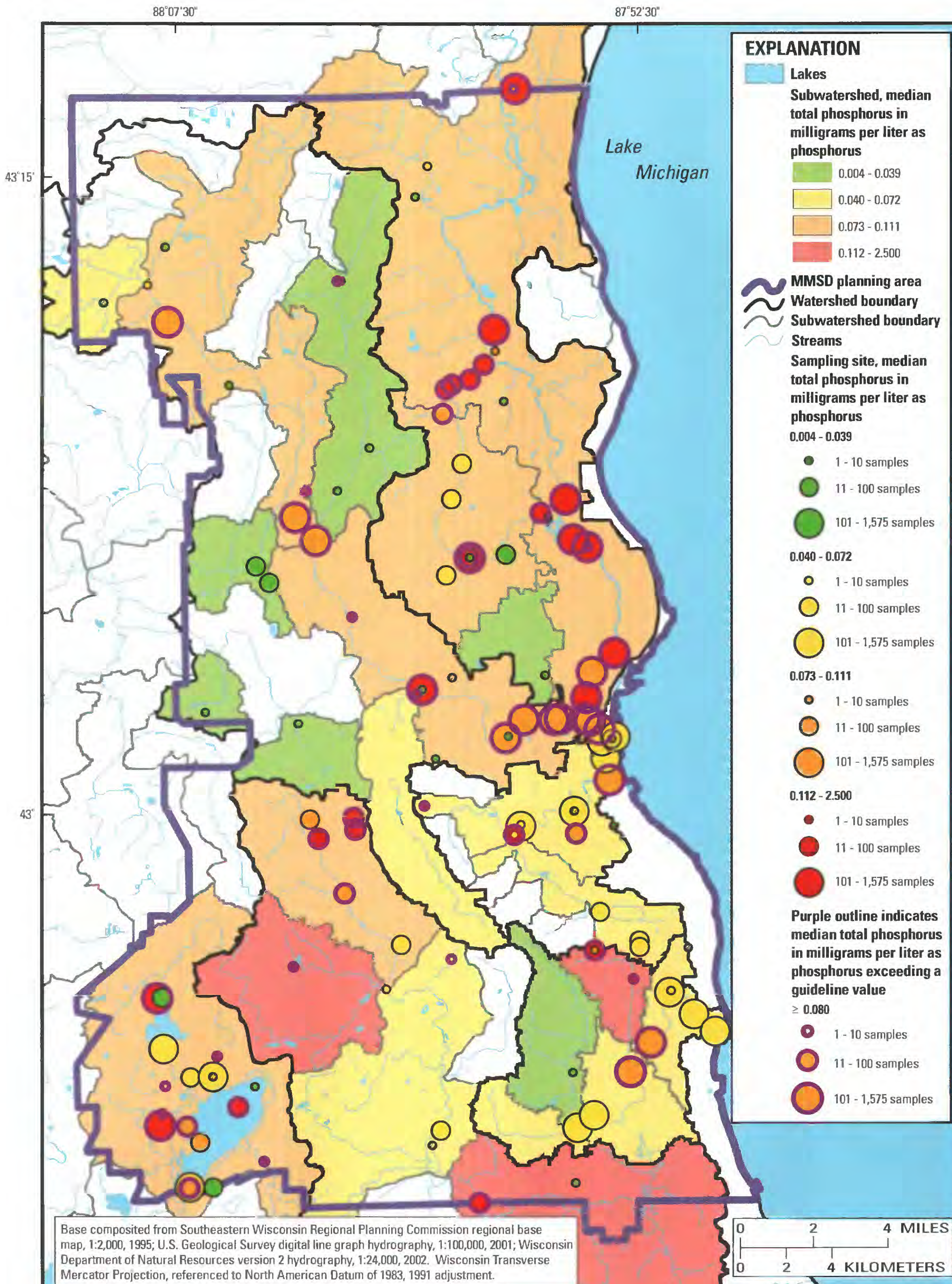

Figure 53. Sites sampled for total phosphorus in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 21. Summary statistics for total phosphorus, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as phosphorus (mg/L as P); values rounded to the nearest thousandth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	26	0	1,552	329	1,881	2	0.005	10/17/1986	11/28/2001	0.003	0.026	0.038	0.075	0.109	0.142	0.227	1.430
Kinnickinnic River	Kinnickinnic River	7	4,774	1	12	4,787	7	0.011, 0.02	01/15/1975	11/27/2001	.005	.030	.050	.070	.093	.110	.160	3.600
	Wilson Park Creek	4	0	76	60	136	6	0	10/16/1997	09/22/2000	.000	.028	.035	.066	.101	.136	.229	.450
Menomonee River	Butler Ditch	2	0	0	40	40	1	0.02	07/26/1989	08/21/2001	.009	.010	.012	.028	.031	.036	.046	.255
	Dousman Ditch	1	0	0	1	1	1	0.02	10/13/1993	10/13/1993	--	--	--	--	--	--	--	RL
	Honey Creek	1	0	2	1	3	1	5	06/05/1977	07/11/1995	.020	.024	.030	.040	.853	1.270	2.008	2.500
	Little Menomonee River	4	0	7	8	15	8	0.02	06/05/1977	10/18/2001	.010	.010	.010	.010	.047	.082	.104	.150
	Lower Menomonee River	10	4,740	128	11	4,879	14	0.01, 0.011, 0.02, 0.042	06/10/1975	11/27/2001	.002	.050	.070	.100	.120	.140	.200	3.500
	Upper Menomonee River	5	1,019	0	4	1,023	10	0.011, 0.02, 0.042	06/05/1977	11/27/2001	.006	.030	.050	.090	.111	.140	.210	1.120
	South Branch Underwood Creek	1	0	0	1	1	1	0.042	04/18/1985	04/18/1985	--	--	--	--	--	--	--	RL
	Willow Creek	2	0	6	5	11	0	--	06/12/2000	10/18/2001	.030	.035	.039	.067	.064	.070	.112	.115
Milwaukee River	Milwaukee River Non-Contributing	1	0	0	1	1	1	0.02	02/03/1975	02/03/1975	--	--	--	--	--	--	--	RL
	Lincoln Creek	9	334	165	26	525	18	0.008, 0.011, 0.02	08/07/1980	03/13/2002	.004	.030	.050	.100	.137	.170	.288	1.110
	Lower Milwaukee River	19	9,633	400	14	10,047	14	0.011, 0.02	01/25/1973	03/13/2002	.004	.050	.070	.100	.122	.150	.210	2.310

Table 21. Summary statistics for total phosphorus, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002—Continued

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in milligrams per liter as phosphorus (mg/L as P); values rounded to the nearest thousandth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Oak Creek	Mitchell Field Drainage Ditch	2	0	25	15	40	2	0, 0.005	11/06/1996	09/22/2000	.000	.037	.059	.112	.167	.244	.353	.629
	North Branch Oak Creek	1	0	0	1	1	1	0.02	08/05/1993	08/05/1993	--	--	--	--	--	--	--	RL
	Lower Oak Creek	7	994	1	3	998	4	0.02	04/20/1977	11/19/2001	.004	.020	.030	.060	.086	.100	.160	1.760
	Middle Oak Creek	2	503	0	0	503	0	--	03/21/1985	11/19/2001	.008	.030	.040	.070	.099	.110	.168	4.000
	Upper Oak Creek	1	253	0	0	253	0	--	03/21/1985	11/19/2001	.003	.020	.030	.050	.070	.080	.150	.460
Root River	Lower Root River	2	26	0	1	27	1	0.02	09/30/1993	10/10/2001	.010	.065	.099	.140	.143	.180	.210	.300
	Middle Root River	3	28	0	8	36	2	0.02, 0.042	06/24/1985	10/10/2001	.010	.030	.045	.061	.151	.103	.175	2.488
	Upper Root River	7	110	24	1	135	2	--	08/14/1996	10/10/2001	.010	.041	.060	.100	.132	.170	.258	.763
	Whitnall Park Creeks	1	0	0	4	4	0	--	07/25/1996	09/10/1996	.013	.013	.014	.350	.452	.788	.972	1.095

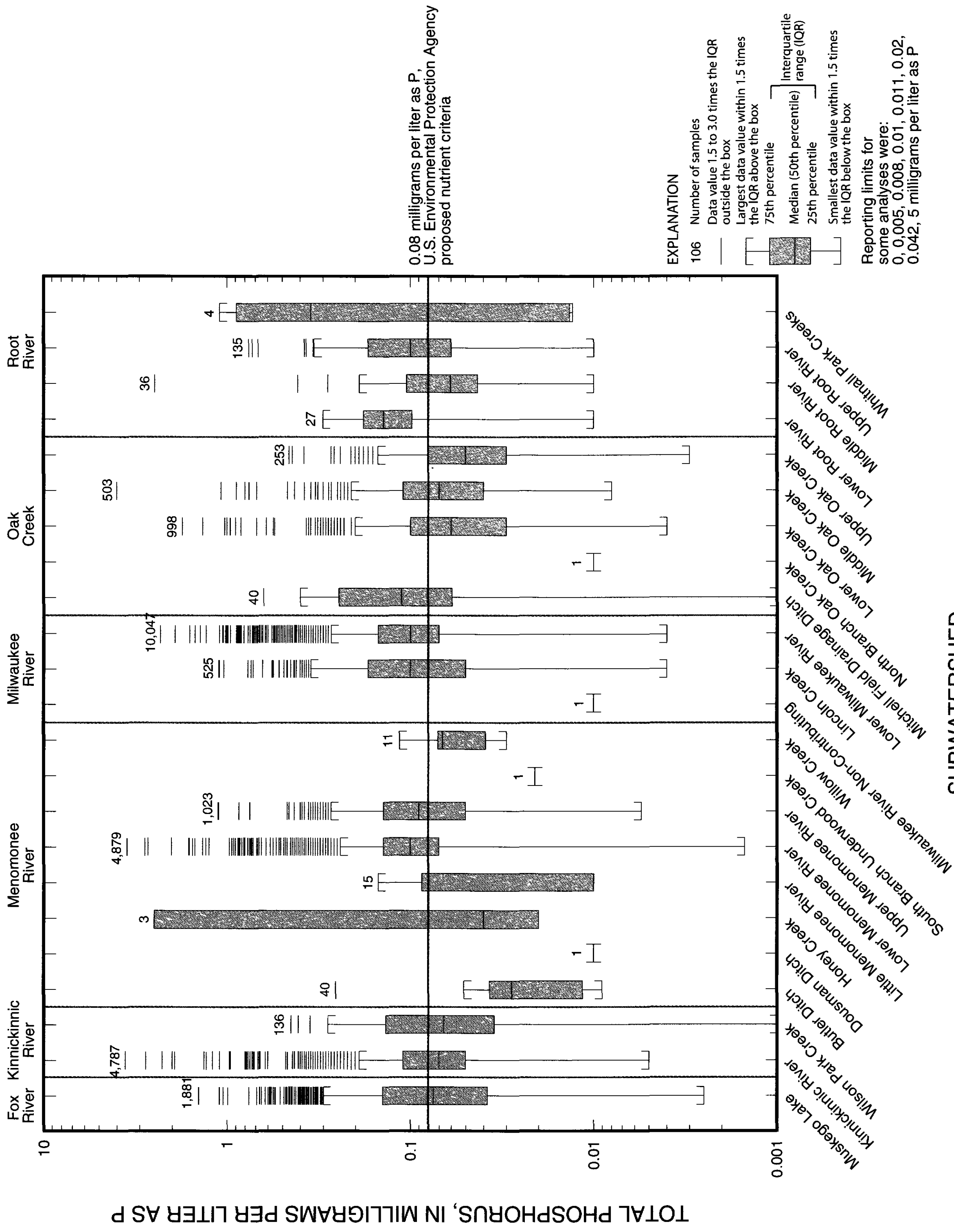

Figure 54. Statistical distribution of total phosphorus concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Dissolved Phosphorus

In fresh water, absent of a physical limitation (for example, light), phosphorus is usually the nutrient that limits primary production, owing to the relatively large biochemical requirement for this element coupled with its relatively low available supply. Therefore, large increases in primary production, often termed "blooms," can result from relatively small increases in phosphorus input (assuming no other limitation). Within the stream, dissolved phosphorus exists in several organic and inorganic forms and in a range of sizes from colloids to truly dissolved species. Algae can directly take up only the truly dissolved monomeric phosphate molecule (PO_4^{3-}).

Allochthonous sources of dissolved phosphorus to streams include wet deposition and influent ground water, in addition to that derived from sediment and organic-matter inputs. Autochthonous sources of dissolved phosphorus are dominated by desorption from suspended and bed sediment, excretion by organisms, and release during organic-matter decomposition. Sinks for dissolved phosphorus include uptake by organisms and sorption onto suspended and streambed sediments.

There are no ambient water-quality standards for dissolved phosphorus in the MMSD planning area. Low or high concentrations can exist under low or high primary productivity and so are not particularly instructive in that regard.

Many of the sites with median dissolved phosphorus concentrations in the upper quartile were in the Lower Milwaukee River subwatershed (fig. 55). Sites with median concentrations in the lower quartile were mainly in the southeastern part of the planning area (fig. 55).

Subwatersheds with median dissolved phosphorus concentrations in the upper quartile were Willow Creek, Little Menomonee River, and Lower Root River (fig. 55). The Honey Creek, Kinnickinnic River, Muskego Lake, Middle Root River, Upper Oak Creek, and Lower Oak Creek subwatersheds had median concentrations in the lower quartile (fig. 55). The highest maximum concentration of 3.000 mg/L as P was measured in the Upper Menomonee River subwatershed (fig. 56, table 22). The highest median concentrations were measured in the Little Menomonee River (0.059 mg/L as P), Willow Creek (0.057 mg/L as P), and Lower Root River (0.055 mg/L as P) subwatersheds (fig. 56, table 22).

There were no obvious seasonal patterns or long-term trends in dissolved phosphorus concentrations at the five highlighted sites (data not shown).

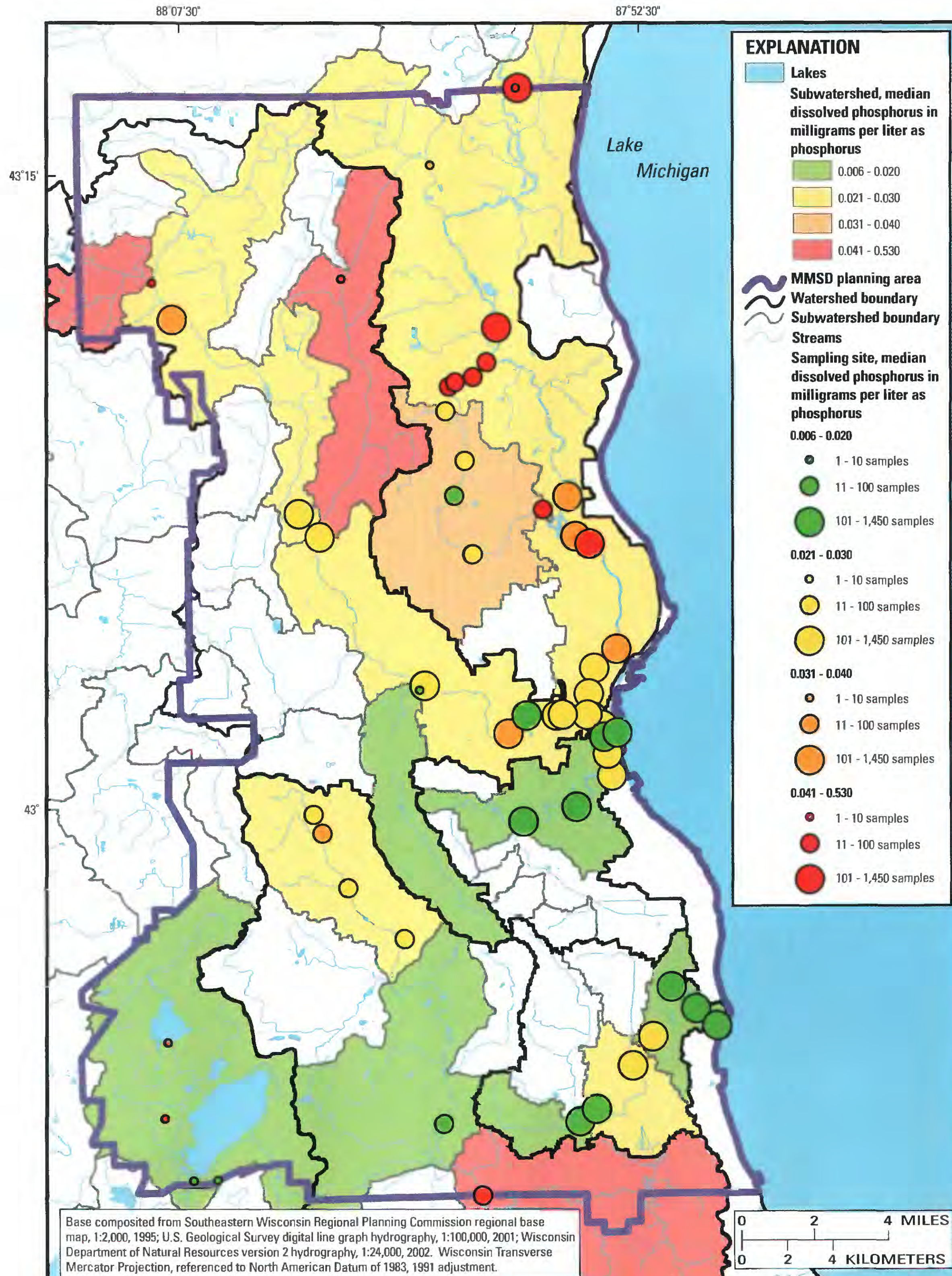

Figure 55. Sites sampled for dissolved phosphorus in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

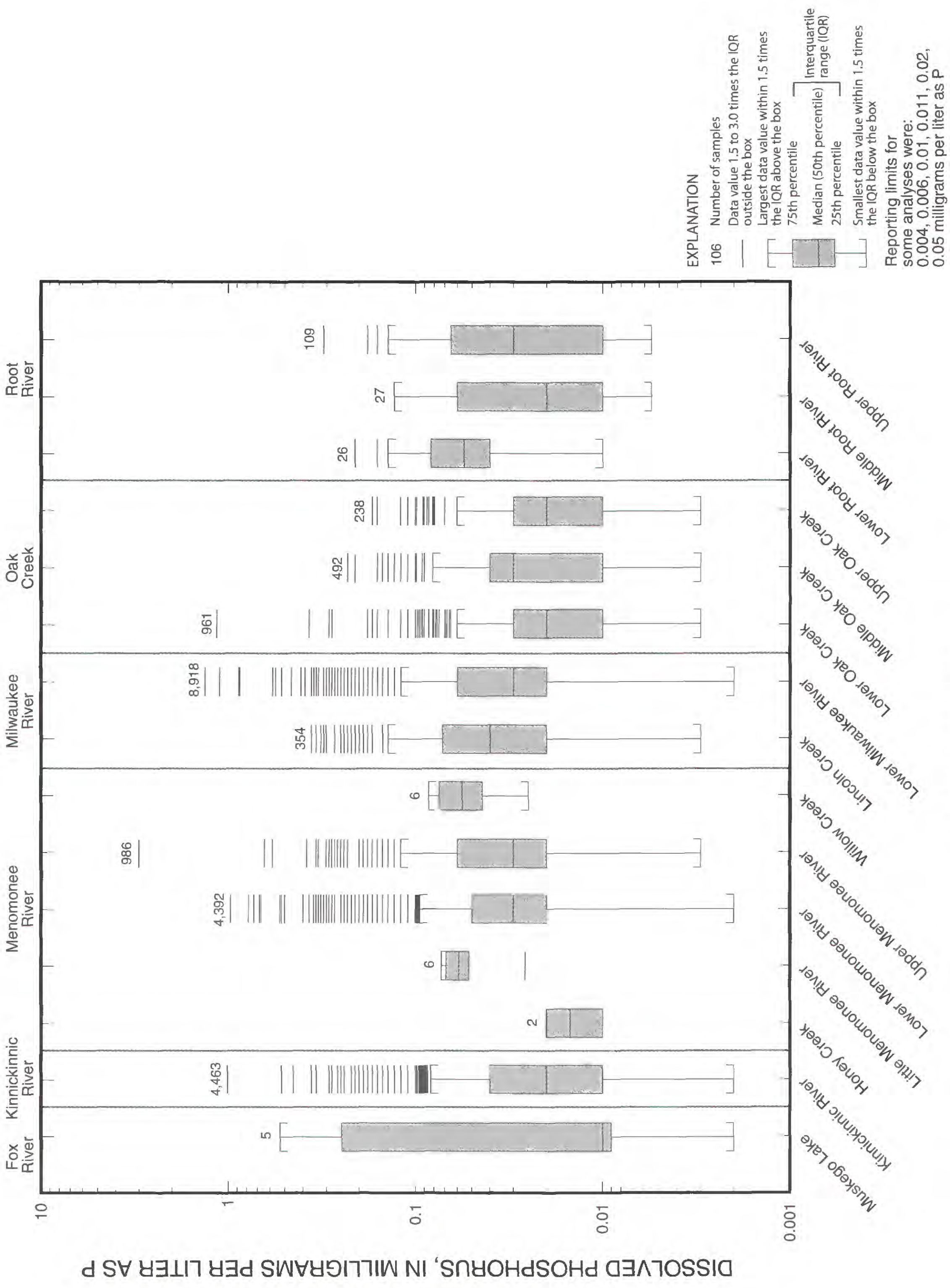

Figure 56. Statistical distribution of dissolved phosphorus concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 22. Summary statistics for dissolved phosphorus, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; values are expressed in milligrams per liter as phosphorus (mg/L as P); values rounded to the nearest thousandth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	4	0	3	2	5	1	0.004	12/17/1987	09/20/2000	0.002	0.005	0.009	0.010	0.160	0.248	0.417	0.530
Kinnickinnic River	Kinnickinnic River	5	4,463	0	0	4,463	46	0.011, 0.02	06/04/1980	11/27/2001	.002	.010	.010	.020	.033	.040	.070	1.010
Menomonee River	Honey Creek	1	0	2	0	2	0	--	07/10/1995	07/11/1995	.010	.011	.013	.015	.015	.018	.019	.020
	Little Menomonee River	1	0	6	0	6	0	--	05/24/2001	10/18/2001	.026	.039	.052	.059	.056	.068	.071	.073
	Lower Menomonee River	6	4,392	0	0	4,392	14	0.011, 0.02	06/04/1980	11/27/2001	.002	.010	.020	.030	.040	.050	.074	.970
	Upper Menomonee River	3	986	0	0	986	13	0.011, 0.02	05/24/1982	11/27/2001	.003	.010	.020	.030	.050	.060	.094	3.000
	Willow Creek	1	0	6	0	6	0	--	05/24/2001	10/18/2001	.025	.035	.044	.057	.057	.073	.080	.085
Milwaukee River	Lincoln Creek	5	319	35	0	354	30	0.01, 0.011, 0.02	04/16/1993	11/27/2001	.003	.010	.020	.040	.057	.072	.130	.360
	Lower Milwaukee River	16	8,706	212	0	8,918	65	0.006, 0.01, 0.011, 0.02, 0.05	09/20/1977	11/27/2001	.002	.010	.020	.030	.046	.060	.098	1.330
Oak Creek	Lower Oak Creek	4	961	0	0	961	41	0.011, 0.02	03/21/1985	11/19/2001	.003	.007	.010	.020	.028	.030	.055	1.150
	Middle Oak Creek	2	492	0	0	492	10	0.011, 0.02	03/21/1985	11/19/2001	.003	.010	.010	.030	.035	.040	.070	.230
	Upper Oak Creek	1	238	0	0	238	9	0.011, 0.02	03/21/1985	11/19/2001	.003	.008	.010	.020	.025	.030	.050	.170
Root River	Lower Root River	1	26	0	0	26	2	0.02	08/25/1999	10/10/2001	.010	.029	.040	.055	.074	.082	.150	.210
	Middle Root River	1	27	0	0	27	8	0.011, 0.02	08/25/1999	10/10/2001	.006	.010	.010	.020	.036	.059	.085	.130
	Upper Root River	4	109	0	0	109	25	0.011, 0.02	08/25/1999	10/10/2001	.006	.010	.010	.030	.049	.065	.112	.310

Trace Elements

Detection of trace elements in surface water, sediment, and tissues can be a result of not only inputs from the natural landscape but also from anthropogenic processes that contribute these elements to the streams.

Sediment provides habitat and a food source for a wide variety of benthic organisms. Exposure to certain substances in sediments, such as trace elements, can potentially be a significant hazard to the health of the benthic organisms and other species in the food chain above them. The Canadian Council of Ministers of the Environment (2002a) have established Sediment Quality Guidelines (SQGs) for the protection of aquatic life that provide a reference point for assessing the likelihood for observing adverse biological effects (Canadian Council of Ministers of the Environment, 2001). The formal protocol used to derive SQGs relies both on a modification of Canada's national status and trends program and spiked-sediment toxicity tests. Canada's Interim Sediment Quality Guidelines (ISQG) are recommended if information is available to support only one approach (Canadian Council of Ministers of the Environment, 2001). Concentrations below the ISQG are not expected to show any significant effects on aquatic life. The Canadian Probable Effect Level (PEL) is the concentration above which adverse biological effects are expected to appear frequently. The effects on aquatic life when concentrations fall between the ISQG and the PEL are unknown. Also referred to in this report is the MacDonald scale (MacDonald and others, 2000). MacDonald's thresholds are the Threshold Effect Concentration (TEC), below which adverse effects are not expected, and Probable Effect Concentration (PEC), at or above which adverse effects are expected. When concentrations fall between the MacDonald TEC and PEC the potential effects on aquatic life are unknown. The implications of the sediment guidelines for the Canadian and MacDonald scales are similar although they have different values for the "threshold" and "probable" effect levels. Concentrations below the "threshold" level are not expected to effect aquatic life, concentrations between the "threshold" and "probable" levels have unknown effects, and effects on aquatic life are expected at concentrations above the "probable" level.

Very few data points exist for trace elements in tissue (typically fish or macroinvertebrate) in the MMSD Corridor database, so tissue contamination will not be discussed in this report. Many concentrations for trace elements in water were below a specified reporting limit; however, for many trace elements, the reporting limit was relatively high. Because of the large amount of data below a reporting limit and high reporting limits, no maps of trace elements in water or statistical distribution figures were created, and summary-statistic tables contain only a subset of the usual information. Also, because of the small number of samples, no trends or seasonality analysis was done for trace elements in sediment or water.

Cadmium

Cadmium is found to some extent in all soils and rocks, including coal and mineral fertilizers. Common sources of cadmium input to water include dissolution of galvanized pipes, erosion of soils and rocks, and point and nonpoint sources. During 1987–93, Wisconsin ranked as one the top seven states in the release of cadmium to land (U.S. Environmental Protection Agency, 2002b).

Most cadmium used in the United States is extracted during the smelting of copper, zinc, and lead. Anthropogenic uses of cadmium include electroplating and coating, pigments in paint and plastics, batteries (nickel-cadmium and solar), machinery and baking enamels, and fluorescent light tubes. Cadmium binds tightly to soil particles and does not break down in the environment, but it may change form (Agency for Toxic Substances and Disease Registry, 1999b).

The Canadian drinking-water MAC guideline, WDNR MCL, and USEPA MCL for cadmium in drinking water are all the same, 5 µg/L. The USEPA MCL was based on the possibility of kidney, liver, bone, and blood damage from long-term exposure to cadmium concentrations above the MCL. The Canadian water-quality guideline for the protection of aquatic life is 0.017 µg/L.

Reporting limits for cadmium in water were well above the Canadian aquatic life guideline of 0.017 µg/L; therefore, all results reported above a reporting limit were also above the guideline concentration. Subwatersheds with maximum concentrations above the USEPA, WDNR, and Canadian drinking-water guideline concentration of 5 µg/L were the Lower Milwaukee River (942.00 µg/L), Kinnickinnic River (60.00 µg/L), and Lower Menomonee River (41.00 µg/L), Lower Oak Creek (14.00 µg/L), Mitchell Field Drainage Ditch (12.00 µg/L), Middle Oak Creek (11.00 µg/L), Upper Menomonee River (9.00 µg/L), Underwood Creek (9.00 µg/L), Upper Oak Creek (8.00 µg/L), and Wilson Park Creek (5.60 µg/L) (table 23). No subwatersheds had median concentrations above the drinking-water guideline (table 23).

The ISQG for cadmium in sediment was set at 0.6 µg/g, and the PEL was 3.5 µg/g. MacDonald recommends a TEC of 0.99 µg/g and PEC of 4.98 µg/g for cadmium in sediment.

Most sites with exceedences of the PEL for cadmium in sediment (3.5 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 57). Sites with median concentrations in the upper quartile were also clustered near the confluence of the three rivers (fig. 57). Sites with median concentrations in the lower quartile were scattered around the planning area (fig. 57).

No subwatersheds had median cadmium in sediment concentrations in the upper quartile (fig. 57). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, Muskego Lake, and Middle Root River subwatersheds had median concentrations in the lower quartile (fig. 57). One or more samples in the Little Menomonee River, Lower Menomonee River, Lower Milwaukee River, and Kinnickinnic River subwatersheds exceeded either the PEC or the PEL (4.98 µg/g, 3.5 µg/g) (fig. 58, table 24). The highest median concentrations, all above the PEL, were measured in the Kinnickinnic River (4.4 µg/g), Little Menomonee River (4.0 µg/g), Lower Menomonee River (3.9 µg/g) subwatersheds (fig. 58, table 24). At least one concentration in the Lower Menomonee River, Upper Menomonee River, Lower Milwaukee River, and Muskego Lake subwatersheds fell below the ISQG or the TEC (0.6 µg/g, 0.99 µg/g) (fig. 58, table 24).

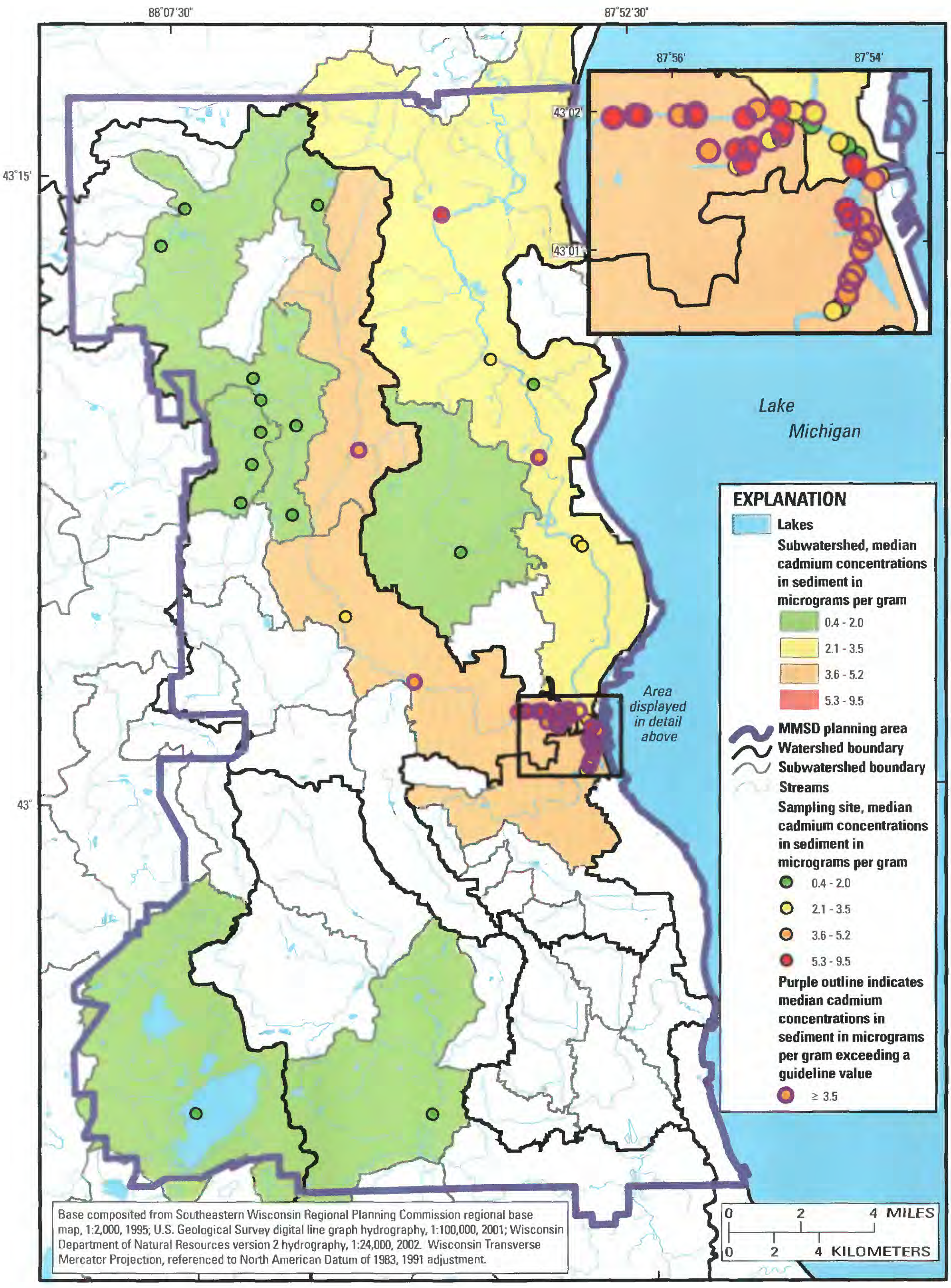

Figure 57. Sites sampled for cadmium in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 23. Summary statistics for cadmium in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to nearest hundredth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	10	1,382	0	144	1,526	233	0.1, 0.2, 0.7, 3, 10, 20	04/30/1975	11/14/2001	0.05	0.10	0.11	3.00	2.08	3.00	3.00	60.00
	West Milwaukee Ditch	2	0	0	2	2	2	0.2	09/30/1975	10/02/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	6	0	0	50	50	32	0, 0.2	05/27/1975	01/03/2000	.00	.05	.10	.10	.28	.10	.52	5.60
Lake Michigan Direct	Lake Michigan Direct	1	0	0	1	1	1	0.2	06/16/1977	06/16/1977	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	0	1	1	1	0.2	07/01/1977	07/01/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	4	0	22	18	40	36	0.2, 1	09/03/1975	06/29/1990	.10	.10	.10	.50	.42	.50	.55	2.00
	Lower Menomonee River	11	1,398	53	10	1,461	144	0.1, 0.2, 1	09/03/1975	11/14/2001	.05	.10	1.00	3.00	2.21	3.00	3.00	41.00
	Upper Menomonee River	5	408	0	7	415	70	0.1, 0.2	09/03/1975	11/14/2001	.05	.05	.11	1.00	1.43	3.00	3.00	9.00
	Underwood Creek	2	0	13	1	14	8	0.2, 1	09/03/1975	06/29/1990	.10	.50	.50	.50	1.47	1.00	3.10	9.00
Milwaukee River	Combined Sewer Service Area	1	0	0	1	1	1	0.2	02/03/1975	02/03/1975	--	--	--	--	--	--	--	RL
	Lincoln Creek	7	262	0	23	285	104	0.1, 0.2, 0.3	05/19/1975	11/27/2001	.05	.05	.05	.10	.15	.11	.20	2.50
	Lower Milwaukee River	23	2,813	21	205	3,039	491	0.1, 0.2, 0.3, 1, 2	07/18/1974	11/15/2001	.00	.10	.11	3.00	2.29	3.00	3.00	942.00

Table 23. Summary statistics for cadmium in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002—Continued

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to nearest hundredth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Oak Creek	Mitchell Field Drainage Ditch	2	0	0	8	8	1	0	01/11/1999	01/03/2000	.00	.07	.32	.46	2.34	1.58	6.96	12.00
	North Branch Oak Creek	2	0	0	24	24	24	0.2	04/17/1975	12/11/1990	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	364	0	11	375	84	0.1, 0.2, 0.7	05/27/1975	11/19/2001	.05	.05	.15	1.00	1.92	3.00	3.00	14.00
	Middle Oak Creek	2	186	0	0	186	38	0.1	03/21/1985	11/19/2001	.05	.05	1.00	3.00	1.94	3.00	3.00	11.00
	Upper Oak Creek	1	92	0	0	92	17	0.1	03/21/1985	11/19/2001	.05	.05	1.00	3.00	1.92	3.00	3.00	8.00
Root River	East Branch Root River	1	0	0	12	12	12	0.2	05/27/1975	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Root River	1	23	0	0	23	14	0.1	08/25/1999	10/10/2001	.05	.05	.05	.05	.08	.11	.12	.22
	Middle Root River	1	25	0	0	25	14	0.1	08/25/1999	10/10/2001	.05	.05	.05	.05	.09	.11	.16	.38
	Upper Root River	6	98	0	2	100	59	0.1	10/17/1996	10/10/2001	.05	.05	.05	.05	.08	.11	.11	.69

Table 24. Summary statistics for cadmium in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting-limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	1	0	2	0	2	1	0.4	07/07/1994	07/07/1994	0.2	0.2	0.3	0.4	0.4	0.6	0.6	0.7
Kinnickinnic River	Kinnickinnic River	14	0	0	14	14	0	--	04/26/1984	08/21/1993	1.8	2.1	3.2	4.4	4.4	5.2	5.4	9.5
Menomonee River	Lilly Creek	3	3	0	0	3	0	--	11/01/1989	11/01/1989	1.0	1.0	1.0	1.0	1.3	1.5	1.8	2.0
	Little Menomonee Creek	1	1	0	0	1	0	--	11/07/1989	11/07/1989	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Little Menomonee River	1	1	0	0	1	0	--	11/01/1989	11/01/1989	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	Lower Menomonee River	25	2	1	22	25	1	1	07/29/1980	08/20/1993	.5	2.7	3.1	3.9	4.6	5.6	8.0	9.4
	Upper Menomonee River	6	6	0	0	6	1	1	10/31/1989	11/08/1989	.5	.8	1.2	2.0	1.6	2.0	2.0	2.0
Milwaukee River	Lincoln Creek	1	1	0	0	1	0	--	11/01/1989	11/01/1989	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Lower Milwaukee River	17	6	1	10	17	1	1	08/15/1973	08/21/1993	.5	1.2	1.7	3.0	2.9	3.5	5.4	6.1
Root River	Middle Root River	1	1	0	0	1	0	--	10/03/1973	10/03/1973	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

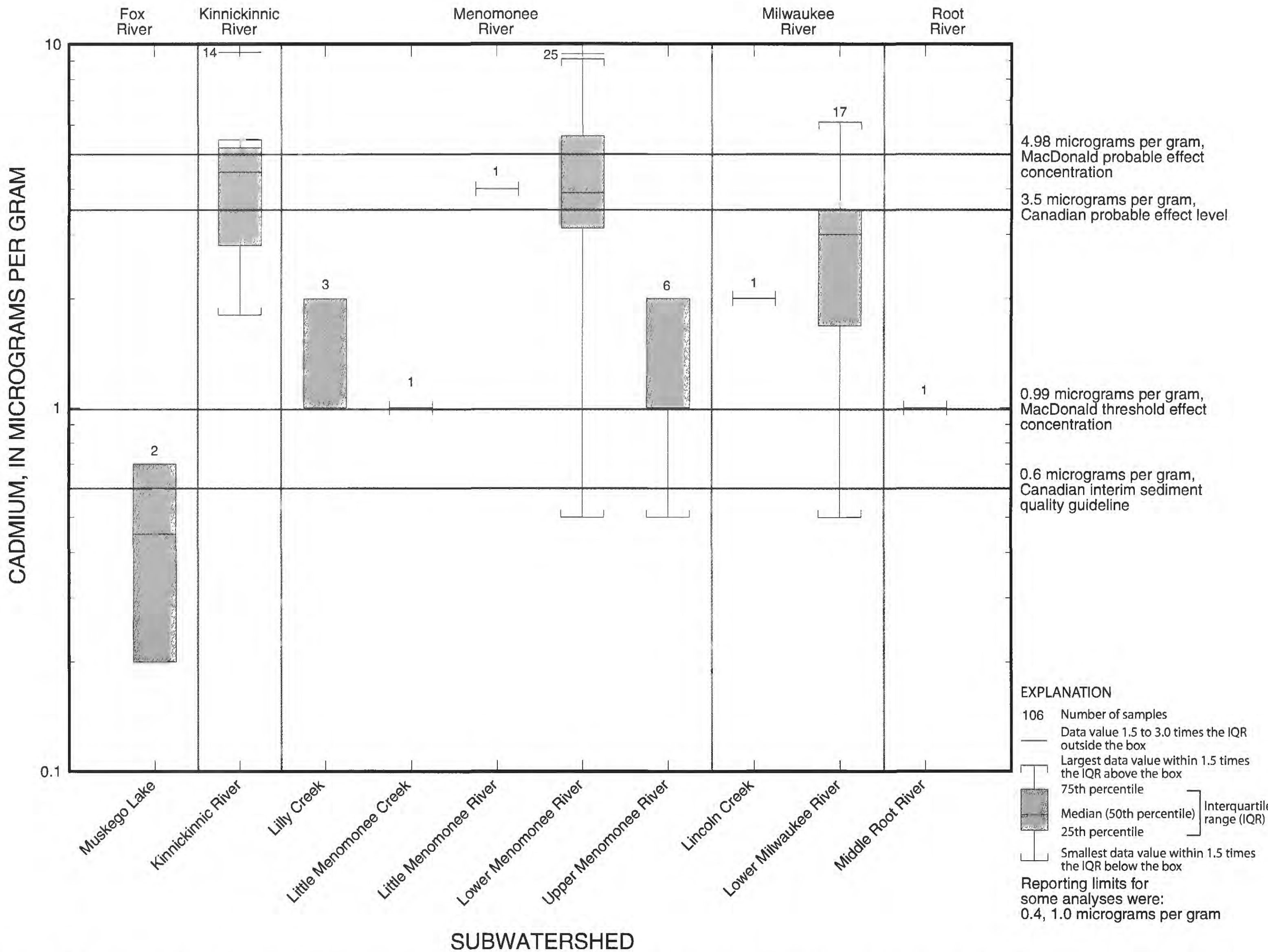

Figure 58. Statistical distribution of cadmium concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Mercury

There are 3 forms of mercury—elemental, methyl, and inorganic. Mercury released to the environment is usually in elemental, or inorganic forms. Biological processes change the chemical form of mercury to the organic form (methylmercury), which is the more toxic form found in aquatic species (U.S. Environmental Protection Agency, 2002d). Methyl-mercury bioaccumulates in (builds up in the tissues of) fish, birds, and mammals (Agency for Toxic Substances and Disease Registry, 2003), and is biomagnified up the food chain. Mercury is the leading contaminant-related human-health advisory in the United States, accounting for almost 80 percent of all fish-consumption advisories.

Mercury enters the environment from natural and anthropogenic sources. Natural sources include volcanoes, natural mercury deposits, and volatilization from the ocean. Anthropogenic sources include coal combustion, chlorine alkali processing, waste incineration, and metal processing. Best estimates to date suggest that human activities have doubled or tripled the amount of mercury in the atmosphere and that the atmospheric burden is increasing by about 1.5 percent per year. (U.S. Geological Survey Mercury Studies Team, 2003a). Analyses of sediment cores show that sediments deposited since the industrial revolution have mercury concentrations 3 to 5 times those of the pre-industrial sediments (U.S. Geological Survey Mercury Studies Team, 2003a). The highest atmospheric deposition rates in the United States occur in the southern Great Lakes, Ohio Valley, the Northeast, and parts of the Southeast. Globally, the United States contributes about 3 percent to the environment, but approximately two-thirds of this is transported outside our borders. Approximately 60 percent of the mercury deposition comes from domestic anthropogenic sources, with the remainder coming from foreign anthropogenic sources, re-emitted mercury from historic sources, and natural sources (U.S. Environmental Protection Agency, 2000b).

Many changes have taken place with mercury analysis and collection techniques since the late 1980s. Analysis now can accurately quantify aqueous mercury samples at the sub-parts-per-trillion range. Newer generation analytical instrumentation have allowed the development of analytical methods for environmentally relevant forms of mercury, including gaseous elemental mercury and methyl-mercury. New cleaning and field methodology have been developed to address sample contamination at these very low levels of detection. (U.S. Geological Survey Mercury Studies Team, 2003b).

The USEPA MCL for mercury is in response to potential kidney damage at concentrations above the MCL. WDNR and USEPA MCL are both 2 µg/L and the Canadian guideline for the protection of aquatic species is 0.1 µg/L.

Many reporting limits for mercury in water were above the Canadian aquatic life criterion of 0.1 µg/L, and therefore many concentrations above a reporting limit exceeded the guideline concentration (table 25). No samples exceeded the USEPA and WDNR drinking-water guideline of 2 µg/L (table 25). The Lower Milwaukee River subwatershed had the highest maximum concentration of 1.500 µg/L (table 25). The highest median concentrations of 0.100 µg/L were measured in the Lower Menomonee River and Upper Menomonee River subwatersheds; however, the majority of results for both subwatersheds were below a reporting limit (table 25).

Sediment-quality guidelines for mercury are ISQG, 0.17 µg/g; TEC, 0.18 µg/g; PEL, 0.486 µg/g; and PEC, 1.06 µg/g.

Most sites with exceedences of the PEL for mercury in sediment (0.486 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 59). Sites with median concentrations in the upper quartile were also clustered near the confluence of the three rivers (fig. 59). Sites with median concentrations in the lower quartile were scattered around the planning area (fig. 59).

No subwatersheds had median mercury concentrations in sediment in the upper quartile (fig. 59). The Little Menomonee Creek, Lilly Creek, Lincoln Creek, and Middle Root River subwatersheds had median concentrations in the lower quartile (fig. 59). The highest maximum concentrations, which were above either the PEC or PEL (1.06 µg/g, 0.486 µg/g), were measured in the Lower Menomonee River (3.550 µg/g), Lower Milwaukee River (3.350 µg/g), and Kinnickinnic River (3.150 µg/g) subwatersheds (fig. 60, table 26). The highest median concentration of 0.460 µg/g was measured in the Lower Menomonee River (fig. 60, table 26). Samples collected in the Lilly Creek, Little Menomonee Creek, Lincoln Creek, and Middle Root River subwatersheds all had concentrations below either the ISQG or TEC (0.17 µg/g, 0.18 µg/g) (fig. 60, table 26).

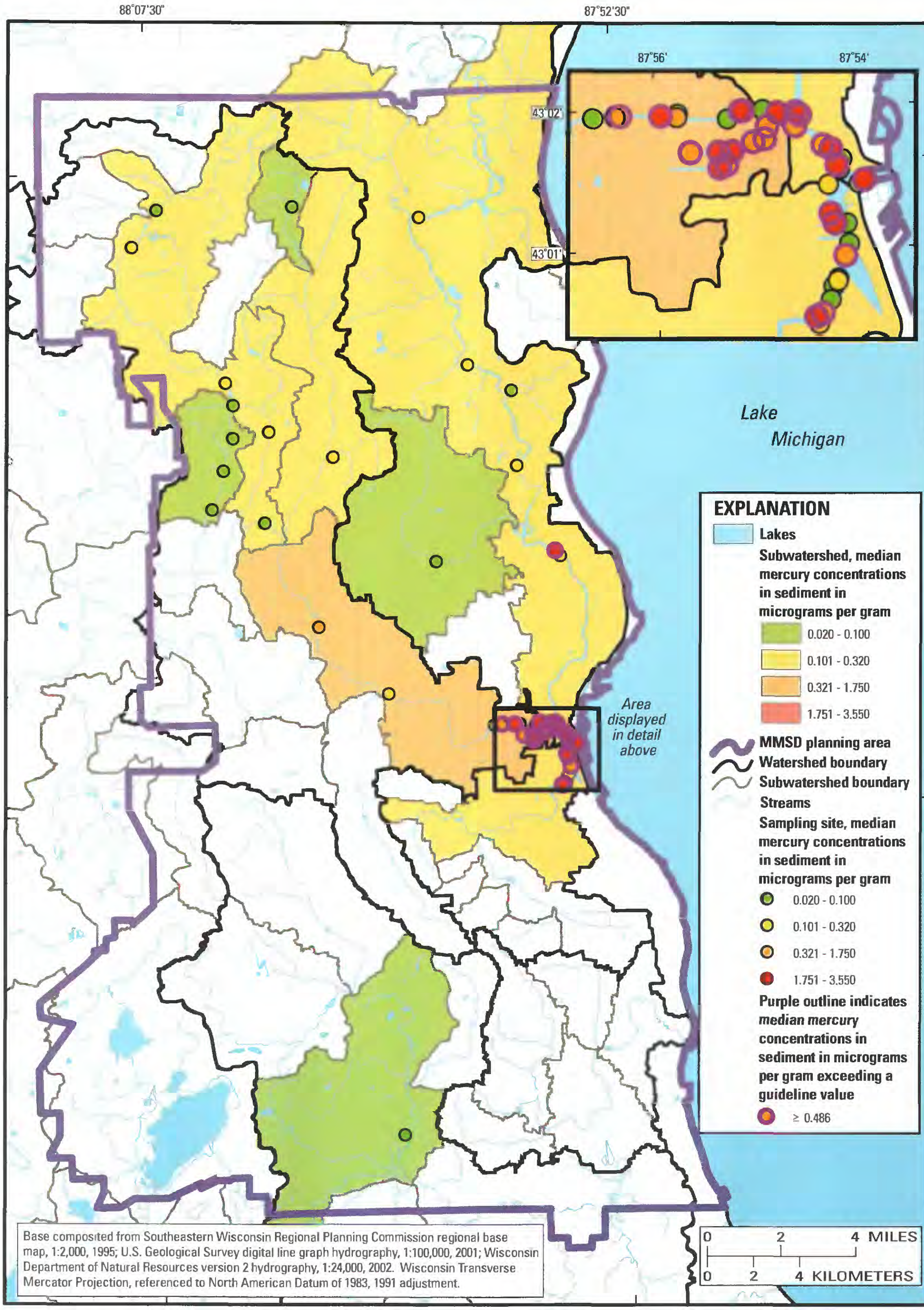

Figure 59. Sites sampled for mercury in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 25. Summary statistics for mercury in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (μg/L); values rounded to the nearest thousandth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	8	212	57	269	238	0.04, 0.045, 0.1, 0.2, 0.22	04/30/1975	11/14/2001	0.020	0.020	0.023	0.023	0.069	0.100	0.110	0.440
	West Milwaukee Ditch	3	0	3	3	3	0.2	09/30/1975	10/02/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	2	0	25	25	25	0.2	05/27/1975	04/12/1976	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	10	10	10	0.2	09/03/1975	06/05/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	3	0	23	23	23	0.002, 0.2	06/25/1975	06/05/1977	--	--	--	--	--	--	--	RL
	Lower Menomonee River	11	222	45	267	190	0.04, 0.045, 0.2, 0.22	06/25/1975	11/14/2001	.020	.023	.023	.100	.091	.100	.220	.780
	Upper Menomonee River	5	125	12	137	76	0.04, 0.045, 0.2, 0.22	06/25/1975	11/14/2001	.020	.023	.023	.100	.115	.150	.250	.530
	Underwood Creek	1	0	8	8	8	0.2	09/03/1975	06/05/1977	--	--	--	--	--	--	--	RL
Milwaukee River	Combined Sewer Service Area	1	0	1	1	1	0.1	02/03/1975	02/03/1975	--	--	--	--	--	--	--	RL
	Lincoln Creek	7	174	22	196	160	0.04, 0.045, 0.2, 0.22	05/19/1975	11/27/2001	.020	.020	.023	.023	.067	.100	.210	.500
	Lower Milwaukee River	20	495	86	581	406	0.04, 0.045, 0.2, 0.22, 2.2, 3	05/28/1975	11/15/2001	.020	.023	.023	.074	.102	.110	.220	1.500
Oak Creek	North Branch Oak Creek	2	0	23	23	23	0.03, 0.2	04/17/1975	10/30/1996	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	90	12	102	61	0.045, 0.2	05/27/1975	11/19/2001	.023	.023	.023	.050	.082	.100	.199	.610
	Middle Oak Creek	2	46	0	46	29	0.045	04/18/2000	11/19/2001	.023	.023	.023	.023	.075	.081	.150	.520
	Upper Oak Creek	1	22	0	22	13	0.045	04/18/2000	11/19/2001	.023	.023	.023	.023	.074	.069	.128	.600
Root River	East Branch Root River	1	0	12	12	12	0.2	05/27/1975	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Root River	1	20	0	20	10	0.04, 0.045	09/20/1999	10/10/2001	.020	.023	.023	.034	.077	.088	.205	.340
	Middle Root River	1	20	0	20	13	0.04, 0.045	09/20/1999	10/10/2001	.020	.022	.023	.023	.105	.101	.284	.660
	Upper Root River	6	80	3	83	43	0.03, 0.04, 0.045	10/17/1996	10/10/2001	.015	.020	.023	.023	.089	.092	.200	.890

Table 26. Summary statistics for mercury in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to the nearest thousandth; for the purpose of statistical calculations, values reported a below detection limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	15	0	3	13	16	9	0.1, 0.2, 0.4	06/21/1973	08/21/1993	0.050	0.100	0.100	0.200	0.689	0.888	2.095	3.150
Menomonee River	Lilly Creek	3	3	0	0	3	0	--	11/01/1989	11/01/1989	.040	.040	.040	.040	.040	.040	.040	.040
	Little Menomonee Creek	1	1	0	0	1	0	--	11/07/1989	11/07/1989	.060	.060	.060	.060	.060	.060	.060	.060
	Little Menomonee River	1	1	0	0	1	0	--	11/01/1989	11/01/1989	.200	.200	.200	.200	.200	.200	.200	.200
	Lower Menomonee River	26	2	3	22	27	10	0.09, 0.1, 0.2, 0.4	06/21/1973	08/20/1993	.045	.100	.100	.460	.971	1.710	2.788	3.550
	Upper Menomonee River	6	6	0	0	6	0	--	10/31/1989	11/08/1989	.060	.060	.065	.120	.125	.183	.195	.200
Milwaukee River	Lincoln Creek	1	1	0	0	1	0	--	11/01/1989	11/01/1989	.070	.070	.070	.070	.070	.070	.070	.070
	Lower Milwaukee River	18	6	2	10	18	5	0.1, 0.2, 0.4	06/21/1973	08/21/1993	.050	.088	.115	.270	.957	1.610	2.944	3.350
Root River	Middle Root River	1	1	0	0	1	0	--	10/03/1973	10/03/1973	.020	.020	.020	.020	.020	.020	.020	.020

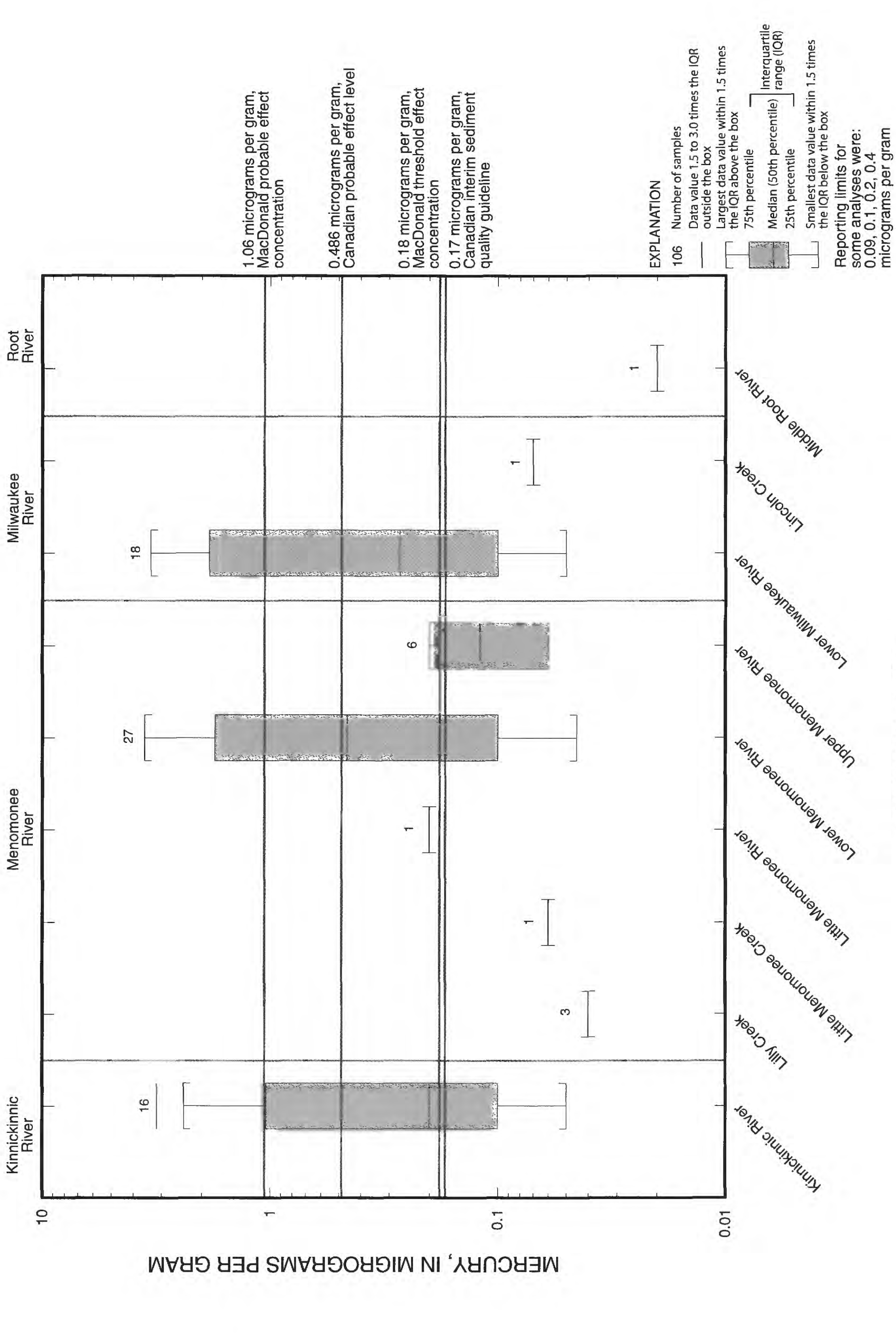

Figure 60. Statistical distribution of mercury concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Copper

Copper is an essential element in plant and animal metabolism. Metallic copper is used for money, electrical wiring, and plumbing. Copper is mixed with other metals to make brass and bronze. Copper occurs in the Earth's crust as a metal. Copper does not break down in the environment. Copper salts are used in small amounts in water-supply reservoirs to discourage the excessive growth of algae. Other anthropological sources from copper are pesticide sprays, combustion of fossil fuels, and as preservatives for wood, leather, and fabrics. Because of its widespread use, copper is more likely to be in ground and surface water than its low average abundance in rocks might imply (Hem, 1985). Concentrations of copper in bed sediment is well correlated with population density (Rice, 1999).

The USEPA established an MCL for copper in water because of stomach distress (short-term exposure) and possible damage to liver and kidneys from long-term exposure. The USEPA MCL and WDNR MCL are both 1,300 µg/L, and the Canadian drinking water AO is 1,000 µg/L. The Canadian standard for the protection of aquatic life is 2–4 µg/L.

Most reporting limits for copper in water were above the Canadian aquatic life guideline of 2–4 µg/L, and therefore most concentrations with data above a reporting limit exceeded the guideline concentration (table 27). No maximum concentrations of copper in water exceeded any drinking-water standard (table 27). The highest maximum concentrations were measured in the Lower Menomonee River (600.0 µg/L) and Lower Milwaukee River (478.0 µg/L) subwatersheds (table 27). The highest median concentrations were in the Underwood Creek (19.0 µg/L) and Lincoln Creek (10.0 µg/L) subwatersheds (table 27). Median concentrations in all other subwatersheds were below 10.0 µg/L (table 27).

Sediment quality guidelines for copper are TEC, 31.6 µg/g; ISQG, 35.7 µg/g; PEC, 149 µg/g; and PEL, 197 µg/g.

Most sites with exceedences of the PEC for copper in sediment (149 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 61). Sites with median concentrations in the upper quartile also were clustered near the confluence of the three rivers (fig. 61). Sites with median concentrations in the lower quartile were in the northern part of the planning area (fig. 61).

The Lower Menomonee River and Little Menomonee River subwatersheds had median copper concentrations in sediment in the upper quartile (fig. 61). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, and Lincoln Creek subwatersheds had median concentrations in the lower quartile (fig. 61). The highest maximum concentration of 254.0 µg/g in the Lower Menomonee River subwatershed exceeded both the PEL and the PEC (197 µg/g, 149 µg/g) (fig. 62, table 28). The highest median concentration of 140.0 µg/g was measured in the Lower Menomonee River and Little Menomonee River subwatersheds (fig. 62, table 28). The only sample collected in the Little Menomonee Creek subwatershed had a concentration of 29.0 µg/g, which was below the ISQG and the TEC (35.7 µg/g, 31.6 µg/g) (fig. 62, table 28).

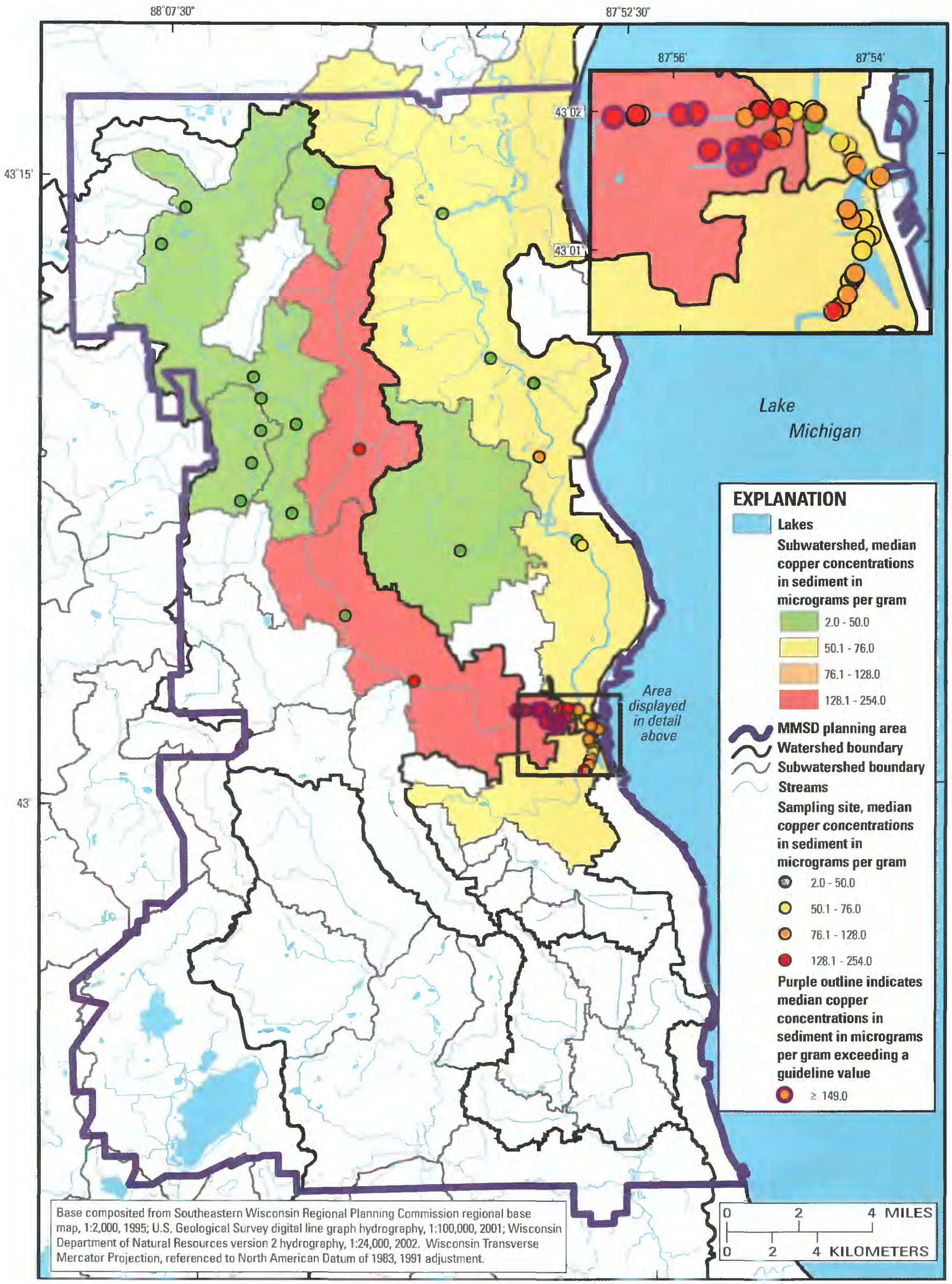

Figure 61. Sites sampled for copper in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 27. Summary statistics for copper in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting level	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Deer Creek	1	0	0	1	1	1	3	03/11/1981	03/11/1981	--	--	--	--	--	--	--	RL
Kinnickinnic River	Kinnickinnic River	11	1,375	6	32	1,413	73	3, 10, 15	04/30/1975	11/14/2001	1.5	3.0	3.0	7.0	10.7	12.0	21.0	275.0
	Wilson Park Creek	7	0	0	61	61	14	0, 3	10/13/1975	09/22/2000	.0	.0	1.5	3.0	6.4	9.0	14.0	59.0
Lake Michigan Direct	Lake Michigan Direct	1	0	0	2	2	2	3	08/13/1977	08/13/1977	--	--	--	--	--	--	--	RL
Lake Michigan Tributary	Lake Michigan Tributary	1	0	0	1	1	1	3	09/28/1981	09/28/1981	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	0	4	4	4	3	06/30/1977	07/18/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	3	0	22	4	26	4	3	09/03/1975	06/29/1990	1.5	1.5	6.0	8.0	14.5	15.8	26.0	99.0
	Lower Menomonee River	18	1,365	63	11	1,439	27	3, 10, 20, 50	09/03/1975	11/14/2001	1.5	3.0	4.0	9.1	14.3	14.0	25.0	600.0
	Upper Menomonee River	6	419	0	5	424	55	3, 10	06/25/1975	11/14/2001	1.5	3.0	3.8	7.0	9.5	10.0	15.7	321.0
	Underwood Creek	1	0	13	0	13	0	--	02/01/1990	06/29/1990	12.0	15.4	18.0	19.0	30.6	24.0	40.4	140.0
Milwaukee River	Combined Sewer Service Area	2	0	0	2	2	2	3, 5	02/03/1975	02/24/1982	--	--	--	--	--	--	--	RL
	Lincoln Creek	7	267	0	21	288	59	0.7, 10	10/05/1994	11/27/2001	.4	5.0	5.0	10.0	9.1	10.0	14.0	32.0
	Lower Milwaukee River	23	2,759	44	81	2,884	266	2, 3, 10, 20	01/25/1973	11/15/2001	1.0	3.0	3.0	6.0	9.6	10.0	18.0	478.0
Oak Creek	Mitchell Field Drainage Ditch	2	0	0	13	13	1	0	01/11/1999	09/22/2000	.0	1.0	3.0	5.0	8.5	12.0	23.4	27.0
	North Branch Oak Creek	2	0	0	11	11	11	3, 4	04/17/1975	09/05/1990	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	477	0	7	484	64	3, 10	05/27/1975	11/19/2001	1.5	3.0	3.0	5.4	8.3	10.0	16.7	97.0
	Middle Oak Creek	2	245	0	0	245	29	10	03/21/1985	11/19/2001	2.0	3.0	3.0	6.0	7.8	10.0	13.6	37.0
	Upper Oak Creek	1	122	0	0	122	16	10	03/21/1985	11/19/2001	2.0	3.0	3.0	5.8	8.9	10.0	16.0	111.0
Root River	East Branch Root River	1	0	0	3	3	3	3	06/16/1975	08/05/1975	--	--	--	--	--	--	--	RL
	Lower Root River	1	23	0	0	23	8	10	08/25/1999	10/10/2001	5.0	5.0	5.0	7.0	7.9	10.0	11.6	16.0
	Middle Root River	1	25	0	0	25	14	10	08/25/1999	10/10/2001	5.0	5.0	5.0	5.0	7.4	10.0	11.0	16.0
	Upper Root River	5	98	0	1	99	50	10	10/17/1996	10/10/2001	4.0	5.0	5.0	5.0	8.2	10.0	13.0	55.0

Table 28. Summary statistics for copper in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to the nearest tenth]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	14	0	14	14	0	04/26/1984	08/21/1993	60.0	63.6	65.8	74.5	87.4	107.0	124.9	143.0
Menomonee River	Lilly Creek	3	3	0	3	0	11/01/1989	11/01/1989	23.0	26.4	31.5	40.0	34.7	40.5	40.8	41.0
	Little Menomonee Creek	1	1	0	1	0	11/07/1989	11/07/1989	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0
	Little Menomonee River	1	1	0	1	0	11/01/1989	11/01/1989	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0
	Lower Menomonee River	24	2	22	24	0	04/25/1984	08/20/1993	49.0	71.1	84.5	140.0	134.2	164.8	207.0	254.0
	Upper Menomonee River	6	6	0	6	0	10/31/1989	11/08/1989	2.0	14.0	27.8	37.0	33.3	46.2	49.0	50.0
Milwaukee River	Lincoln Creek	1	1	0	1	0	11/01/1989	11/01/1989	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0
	Lower Milwaukee River	16	6	10	16	0	08/15/1973	08/21/1993	23.0	37.5	44.2	69.0	64.3	80.5	90.4	110.0

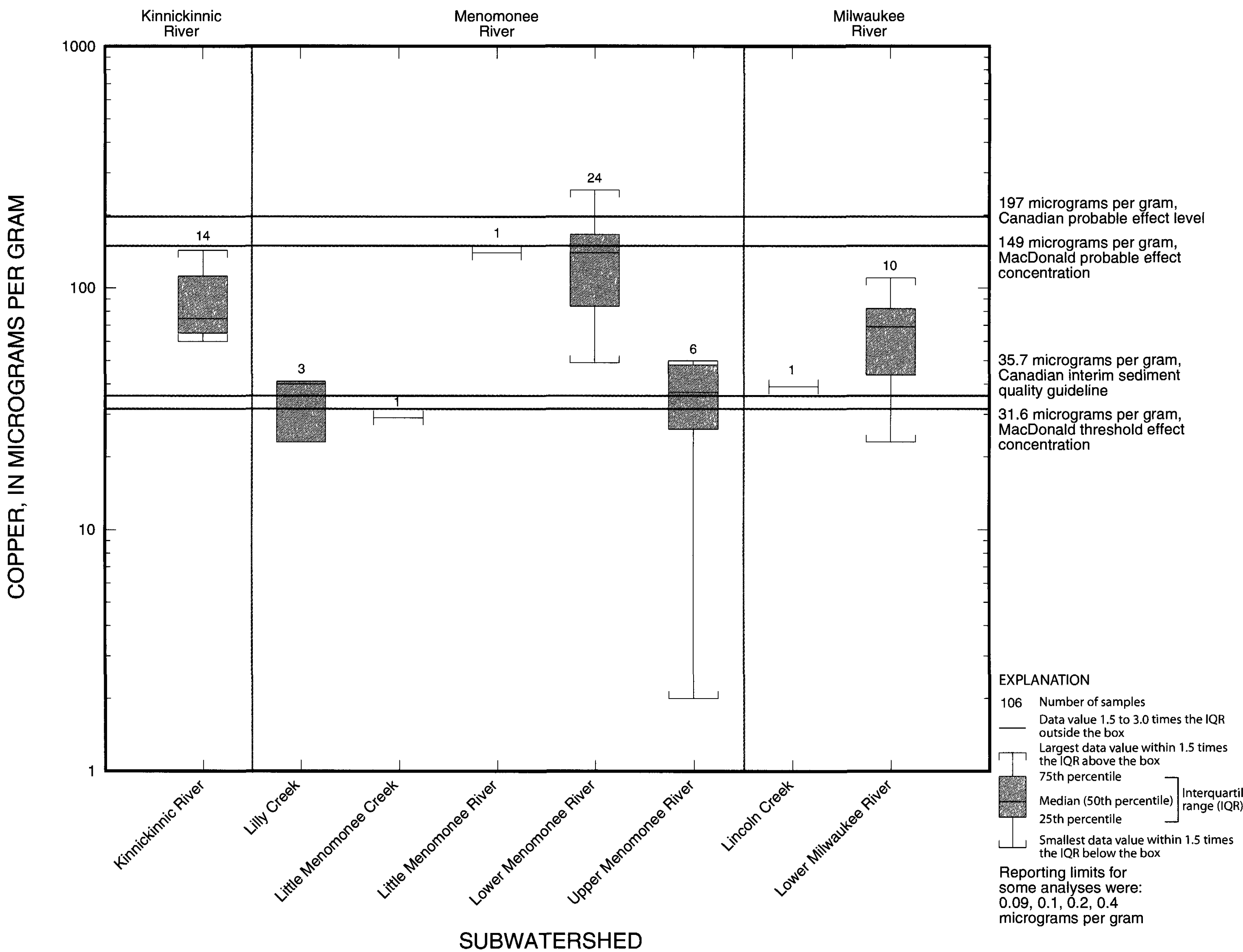

Figure 62. Statistical distribution of copper concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Lead

Lead is a naturally occurring metal, but most lead found in aquatic systems is from anthropogenic sources. Lead was historically used in household plumbing and service lines to the home and is still present in many older homes. Another plumbing source is in some solder used for copper pipes. Today, most of the new anthropogenic lead additions to the environment are derived from material sources such as paper, plastics, and ceramics. Point sources of lead to aquatic systems include industrial effluents, municipal wastewater effluent, stack emissions, and fossil-fuel combustion. Lead concentrations have declined with the removal of leaded gasoline (Callendar and Rice, 2000). Concentrations of lead are well correlated with population density (Rice, 1999). From 1987 to 1993, Wisconsin was in the top 10 states in release of lead to land and water (U.S. Environmental Protection Agency, 2002c).

The Treatment Techniques Action Level (TTAL) for the WDNR and the USEPA MCL are both 15 µg/L for lead in water. If the TTAL concentration is exceeded, water treatments are required (Wisconsin Department of Natural Resources, 2003b). The USEPA MCL was established because of potential health concerns related to physical and mental development in infants and potential kidney problems and high blood pressure in adults. The Canadian drinking-water guideline is 10 µg/L, and the Canadian guideline for the protection of aquatic health is 1–7 µg/L.

Many reporting limits were above the Canadian aquatic life guideline concentration of 1–7 µg/L for lead in water, and therefore most concentrations above a reporting limit exceeded the guideline (table 29). All maximum concentrations exceeded the USEPA and WDNR drinking-water guideline of 15 µg/L and the Canadian drinking-water guideline concentration of 10 µg/L, with the highest maximums measured in the Lower Menomonee River (2,200.0 µg/L) and Kinnickinnic River (1,400.0 µg/L) subwatersheds (table 29). Median concentrations in the Underwood Creek (24.5 µg/L), Lower Menomonee River (19.0 µg/L), Kinnickinnic River (17.0 µg/L), Middle Oak Creek (16.0 µg/L), Upper Oak Creek (16.0 µg/L), Lower Oak Creek (15.0 µg/L), and Lower Milwaukee River (15.0 µg/L) subwatersheds met or exceeded water-quality guideline concentrations (table 29).

Sediment-quality guidelines for lead are the ISQG, 35.0 µg/g; TEC, 35.8 µg/g; PEL, 91.3 µg/g; and PEC, 128 µg/g.

Most sites with exceedences of the PEL for lead in sediment (91.3 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 63). Sites with median concentrations in the upper quartile were also clustered near the confluence of the three rivers (fig. 63). Sites with median concentrations in the lower quartile were scattered around the planning area (fig. 63).

The Honey Creek subwatershed had a median lead concentration in the upper quartile (fig. 63). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, Muskego Lake, and Middle Root River subwatersheds had median concentrations in the lower quartile (fig. 63). The highest maximum concentrations, all above the PEC of 128 mg/g, were measured in the Honey Creek (4,100.0 mg/g), Lower Menomonee River (610.0 mg/g), Kinnickinnic River (530.0 mg/g), Lower Milwaukee River (350.0 mg/g), and Little Menomonee River (260.0 mg/g) subwatersheds (fig. 64, table 30). The highest median concentrations were found in these subwatersheds as well (fig. 64, table 30). Concentrations for all samples collected in the Muskego Lake, Little Menomonee Creek, and Middle Root River subwatersheds were below either the ISQG or TEC (35.0 mg/g, 35.8 mg/g) (fig. 64, table 30).

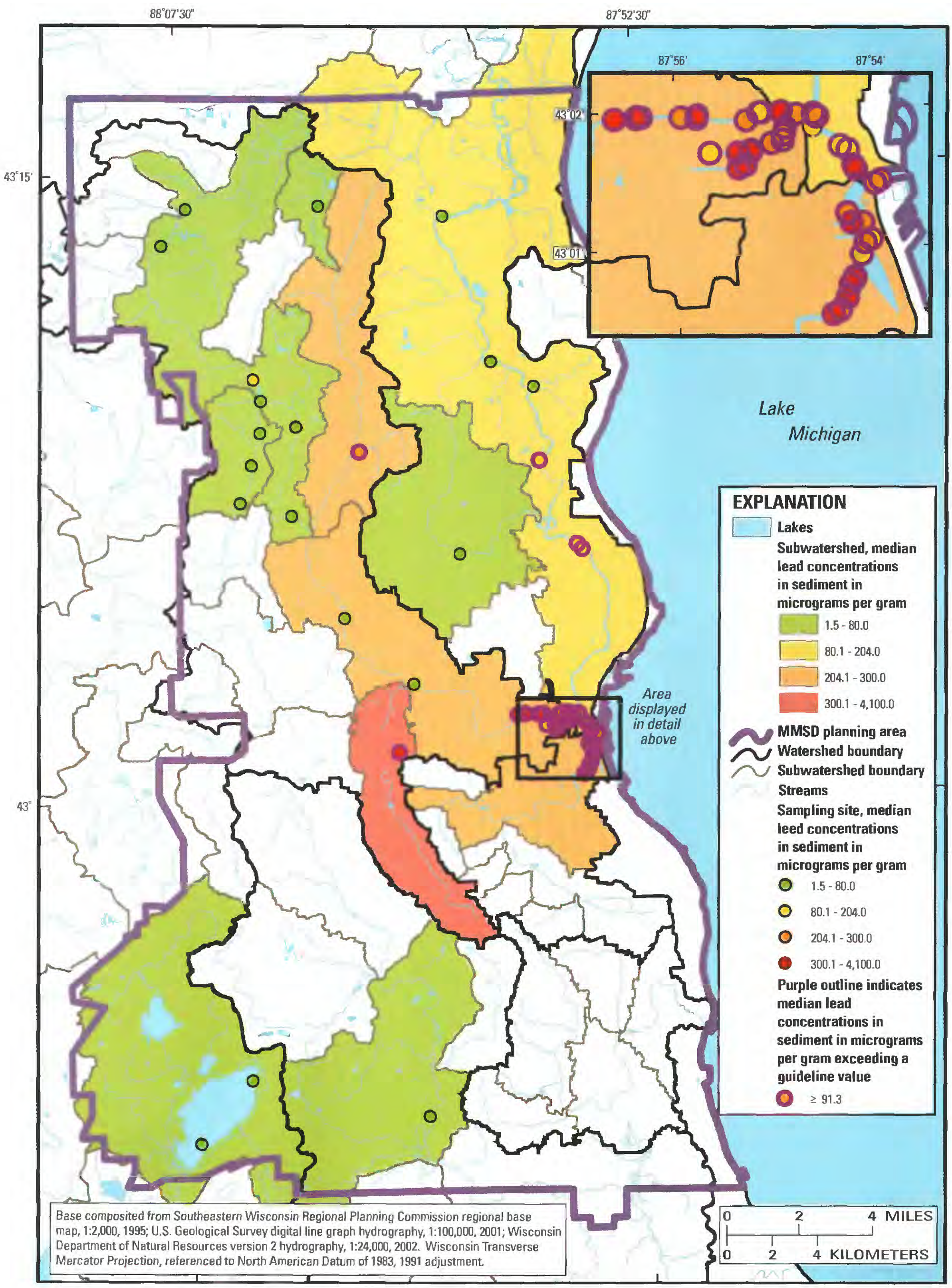

Figure 63. Sites sampled for lead in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 29. Summary statistics for lead in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below a reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	11	1,380	6	106	1,492	130	1.9, 3, 40, 78	04/30/1975	11/14/2001	1.0	1.5	3.0	17.0	45.4	44.2	105.0	1,400.0
	West Milwaukee Ditch	1	0	0	2	2	2	50	04/29/1975	04/29/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	7	0	0	63	63	19	0, 3	05/27/1975	09/22/2000	.0	.0	.0	1.5	5.6	3.6	12.0	67.0
Lake Michigan Direct	Lake Michigan Direct	1	0	0	2	2	2	3	08/13/1977	08/13/1977	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	0	1	1	1	3	07/01/1977	07/01/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	4	0	22	32	54	32	3	06/25/1975	06/29/1990	1.5	1.5	1.5	1.5	11.5	12.8	27.2	150.0
	Lower Menomonee River	17	1,401	60	7	1,468	13	1.9, 3	06/05/1977	11/14/2001	1.0	2.0	5.0	19.0	52.0	50.0	120.0	2,200.0
	Upper Menomonee River	5	407	0	7	414	17	1.9, 3	06/25/1975	11/14/2001	1.0	1.4	2.1	5.8	28.6	23.0	66.0	550.0
	Underwood Creek	2	0	13	1	14	1	3	04/26/1976	06/29/1990	1.5	12.3	14.2	24.5	51.1	45.5	65.9	340.0
Milwaukee River	Combined Sewer Service Area	1	0	0	1	1	1	3	02/24/1982	02/24/1982	--	--	--	--	--	--	--	RL
	Lincoln Creek	9	261	6	48	315	52	0.4, 1.9, 3	05/20/1975	11/27/2001	.2	.9	1.4	2.2	5.4	5.0	12.1	100.0
	Lower Milwaukee River	24	2,831	74	116	3,021	181	0.2, 1.9, 2, 3, 20	01/25/1973	11/15/2001	.0	1.5	3.2	15.0	35.0	36.0	88.0	700.0
Oak Creek	Mitchell Field Drainage Ditch	2	0	0	13	13	1	0	01/11/1999	09/22/2000	.0	.0	1.6	2.4	8.6	9.5	26.2	41.0
	North Branch Oak Creek	2	0	0	7	7	7	3, 6	05/27/1975	09/05/1990	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	365	0	6	371	22	1.9, 3	07/08/1975	11/19/2001	1.0	1.0	2.2	15.0	42.4	41.5	124.0	464.0
	Middle Oak Creek	2	185	0	0	185	14	1.9	03/21/1985	11/19/2001	1.0	1.0	1.8	16.0	40.1	39.0	133.2	394.0
	Upper Oak Creek	1	92	0	0	92	5	1.9	03/21/1985	11/19/2001	1.0	1.0	3.3	16.0	43.0	41.2	92.0	415.0
Root River	East Branch Root River	1	0	0	5	5	5	3	05/27/1975	01/27/1976	--	--	--	--	--	--	--	RL
	Lower Root River	1	23	0	0	23	5	1.9	08/25/1999	10/10/2001	1.0	1.0	1.2	2.5	5.8	4.8	11.8	43.0
	Lower Root River	2	25	0	1	26	5	1.9, 3	02/24/1982	10/10/2001	1.0	1.0	1.5	2.8	5.1	7.2	11.5	23.4
	Upper Root River	4	98	0	0	98	20	1.9	08/25/1999	10/10/2001	1.0	1.0	1.0	2.4	4.2	6.2	9.0	22.0

Table 30. Summary statistics for lead in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	2	0	2	0	2	0	--	07/07/1994	07/07/1994	6.0	6.1	6.2	6.5	6.5	6.8	6.9	7.0
Kinnickinnic River	Kinnickinnic River	14	0	0	14	14	0	--	04/26/1984	08/21/1993	170.0	193.0	220.0	271.0	298.3	372.5	420.4	530.0
Menomonee River	Honey Creek	1	1	0	0	1	0	--	05/28/1980	05/28/1980	4,100.0	4,100.0	4,100.0	4,100.0	4,100.0	4,100.0	4,100.0	4,100.0
	Lilly Creek	3	3	0	0	3	0	--	11/01/1989	11/01/1989	20.0	22.0	25.0	30.0	33.3	40.0	46.0	50.0
	Little Menomonee Creek	1	1	0	0	1	0	--	11/07/1989	11/07/1989	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Little Menomonee River	1	1	0	0	1	0	--	11/01/1989	11/01/1989	260.0	260.0	260.0	260.0	260.0	260.0	260.0	260.0
	Lower Menomonee River	24	2	0	22	24	0	--	04/25/1984	08/20/1993	40.0	122.3	203.0	225.0	277.2	345.0	452.0	610.0
	Upper Menomonee River	6	6	0	0	6	1	10	10/31/1989	11/08/1989	5.0	17.5	32.5	45.0	45.8	57.5	75.0	90.0
Milwaukee River	Lincoln Creek	1	1	0	0	1	0	--	11/01/1989	11/01/1989	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
	Lower Milwaukee River	16	6	1	10	17	1	3	08/15/1973	08/21/1993	1.5	60.0	85.0	150.0	151.3	180.0	256.2	350.0
Root River	Middle Root River	1	1	0	0	1	0	--	10/03/1973	10/03/1973	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

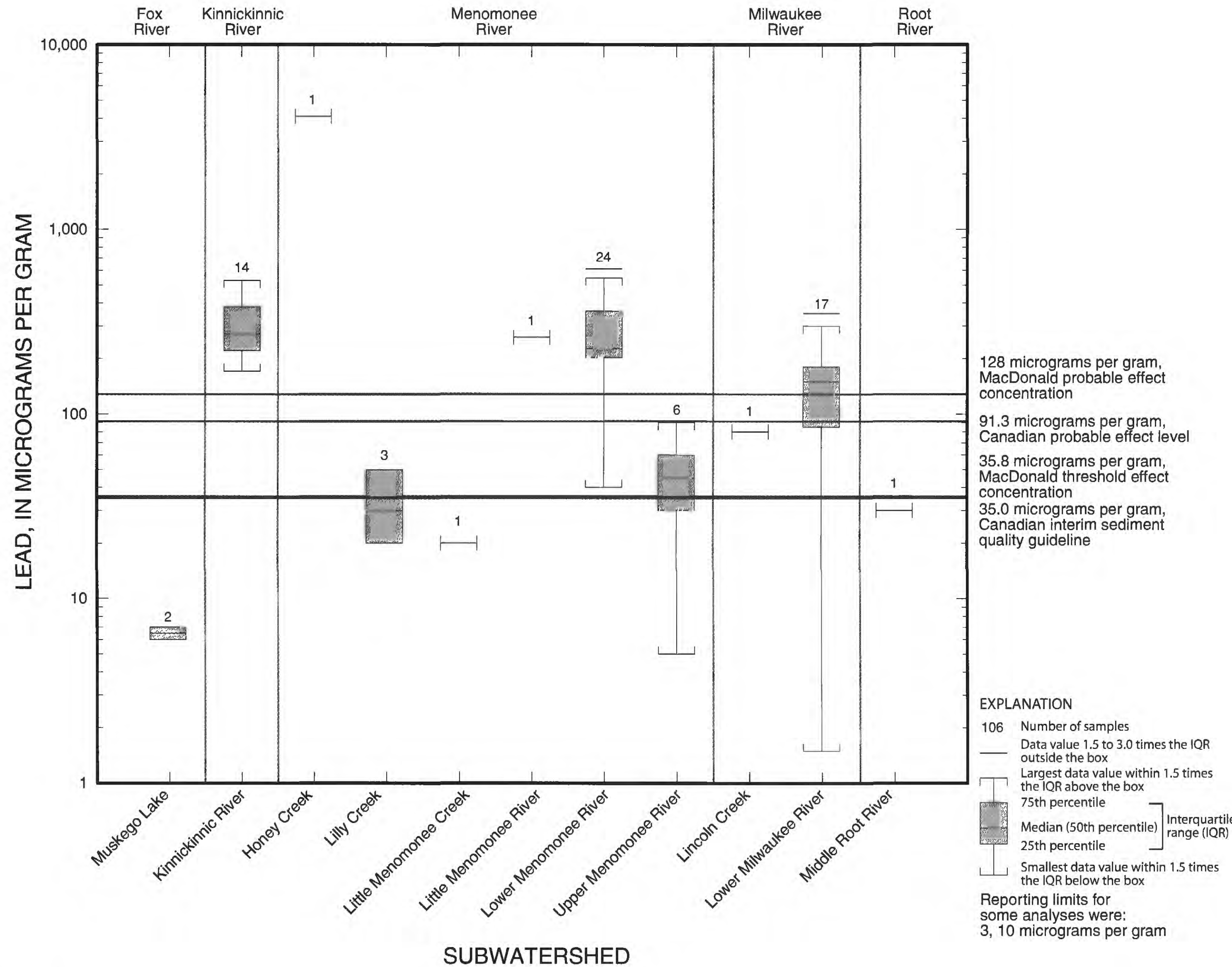

Figure 64. Statistical distribution of lead concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Arsenic

Sources of arsenic in surface water and sediments can be both natural and anthropogenic. Geologic sources of arsenic include sorbed arsenic in iron oxide coatings on minerals and impurities in pyrite and other metal sulfides, especially rock that contains iron and copper. Anthropogenic sources of arsenic include wood preservatives, glass production, poultry and swine feed production, semiconductor manufacturing and petroleum refining (U.S. Environmental Protection Agency, 2003b; Welch and others, 2000). Presently about 90 percent of all arsenic produced is used for wood preservative as chromated copper arsenate (Agency for Toxic Substances and Disease Registry, 1999a). Prior to being banned in the 1990s, pesticide application of lead arsenate (primarily) on fruit orchards was the dominant use of inorganic arsenic.

Arsenic is considered a highly undesirable impurity in water supplies because in small amounts it can be toxic to humans (Hem, 1985). The USEPA MCL for arsenic was established because of the possible health effects related to exposure above the MCL. These health effects include skin damage, circulatory system problems, and an increased risk of cancer. The USEPA revised its MCL for arsenic in drinking water from 50 µg/L to 10 µg/L in January 2001. Public water supplies must comply with the new standard beginning January 2006 (U.S. Environmental Protection Agency, 2003a). The WDNR maintains a MCL of 50 µg/L. Canada has an Interim Maximum Acceptable Concentration (IMAC) of 25 µg/L and an aquatic life criterion of 5 µg/L.

Some reporting limits were above the Canadian aquatic life guideline concentration of 5 µg/L for arsenic in water, and therefore any data above a reporting limit may have exceeded the guideline concentration (table 31). Subwatersheds with maximum concentrations that exceeded the aquatic guideline of 5 µg/L were the Upper Menomonee River (52.0 µg/L), Lincoln Creek (15.2 µg/L), Lower Milwaukee River (14.0 µg/L), Kinnickinnic River (9.5 µg/L), Lower Oak Creek (9.1 µg/L), Upper Root River (5.5 µg/L), and Lower Menomonee River (5.4 µg/L) (table 31). Of these subwatersheds, the Upper Menomonee River maximum concentration exceeded the Canadian interim drinking-water guideline concentration of 25 µg/L and the current USEPA and WDNR drinking water-quality guideline of 50 µg/L (table 31). Also, the maximum concentrations measured in Upper Menomonee River, Lincoln Creek, and Lower Milwaukee River exceeded the new USEPA drinking-water standard of 10 µg/L that will take affect in January 2006 (table 31). Median concentrations were comparatively low and affected by reporting-limit concentrations in most cases (table 31).

Canada has an ISQG of 5.9 µg/g and a PEL of 17.0 µg/g. A TEC of 9.79 µg/g and a PEC of 33.0 µg/g were recommended by MacDonald for arsenic in sediment.

Almost all sites with exceedences of the PEL for arsenic in sediment (17.0 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 65). Sites with median concentrations in the upper quartile were also clustered near the confluence of the three rivers and also located in the Little Menomonee Creek and Lilly Creek subwatersheds (fig. 65). Sites with median concentrations in the lower quartile were scattered around the planning area (fig. 65).

The Little Menomonee Creek and Lilly Creek subwatersheds had median arsenic concentrations in sediment in the upper quartile (fig. 65). The Upper Menomonee River, Lincoln Creek, and Middle Root River subwatersheds had median concentrations in the lower quartile (fig. 65). The concentration of arsenic of 38.0 mg/g measured in the Little Menomonee Creek subwatershed (the only sample collected in the subwatershed) was the highest recorded, exceeding both the PEC and the PEL (33.0 mg/g, 17.0 mg/g) (fig. 66, table 32). The maximum concentration measured in the Lower Menomonee River subwatershed, 25.0 mg/g, exceeded the PEL of 17.0 mg/g (fig. 66, table 32). The concentrations of all samples collected in the Lincoln Creek, Upper Menomonee River, and Middle Root River subwatersheds were below the ISQG and the TEC (5.9 mg/g, 9.79 mg/g) (fig. 66, table 32).

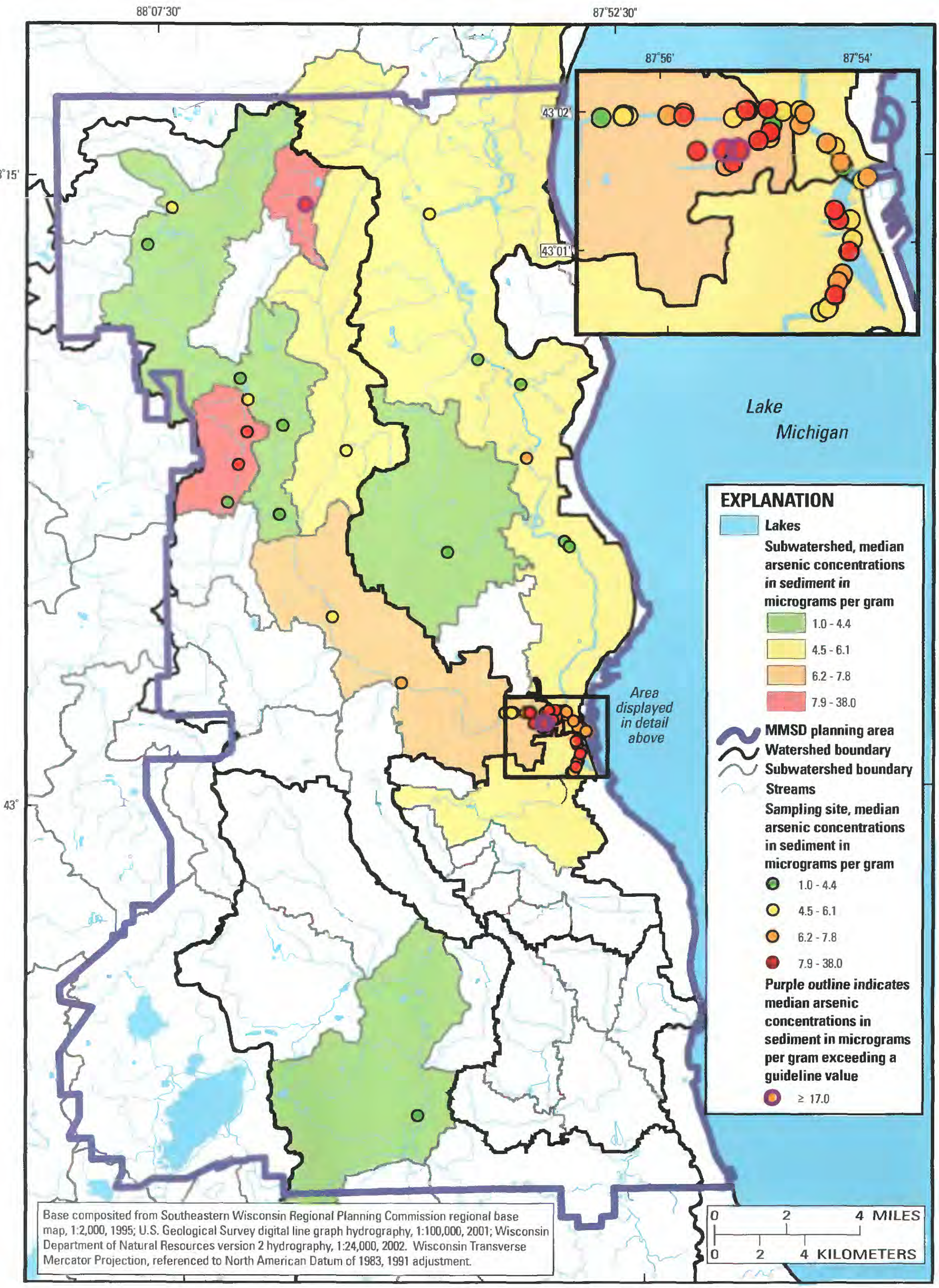

Figure 65. Sites sampled for arsenic in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 31. Summary statistics for arsenic in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the value of the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	7	335	0	26	361	123	1.9, 10	01/25/1977	11/14/2001	1.0	1.0	1.0	1.9	1.9	1.9	3.0	9.5
Lake Michigan Tributary	Lake Michigan Tributary	1	0	0	3	3	3	10	06/24/1981	02/24/1982	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	0	20	20	20	10, 20	09/03/1975	07/19/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	4	0	22	128	150	134	1, 10	06/25/1975	06/29/1990	.5	1.0	5.0	5.0	4.4	5.0	5.0	5.0
	Lower Menomonee River	15	347	19	125	491	218	1, 1.9, 10	06/25/1975	11/14/2001	.5	1.0	1.0	1.9	2.5	5.0	5.0	5.4
	Upper Menomonee River	5	194	0	32	226	85	0, 1.9, 10	06/25/1975	11/14/2001	.0	1.0	1.0	1.9	2.4	2.3	5.0	52.0
	Underwood Creek	2	0	13	10	23	11	1, 10	06/25/1975	06/29/1990	.5	1.0	1.0	3.0	3.0	5.0	5.0	5.0
Milwaukee River	Combined Sewer Service Area	1	0	0	1	1	1	1	02/03/1975	02/03/1975	--	--	--	--	--	--	--	RL
	Lincoln Creek	5	262	0	0	262	87	1.9	06/18/1997	11/27/2001	1.0	1.0	1.0	1.9	1.8	1.9	2.3	15.2
	Lower Milwaukee River	18	804	39	69	912	290	1, 1.9, 10	01/25/1973	11/15/2001	0.5	1.0	1.0	1.9	2.0	2.0	4.0	14.0
Oak Creek	Lower Oak Creek	4	98	0	0	98	59	1.9	05/14/1991	11/19/2001	1.0	1.0	1.0	1.0	1.7	1.9	3.0	9.1
	Middle Oak Creek	2	50	0	0	50	32	1.9	05/14/1991	11/19/2001	1.0	1.0	1.0	1.0	1.4	1.2	2.2	4.1
	Upper Oak Creek	1	24	0	0	24	18	1.9	05/14/1991	11/19/2001	1.0	1.0	1.0	1.0	1.4	1.0	2.8	4.9
Root River	Lower Root River	1	23	0	0	23	11	1.9	08/25/1999	10/10/2001	1.0	1.0	1.0	1.2	1.4	1.9	2.0	2.2
	Middle Root River	2	25	0	1	26	15	1.9, 10	02/24/1982	10/10/2001	1.0	1.0	1.0	1.0	1.5	1.9	2.2	5.0
	Upper Root River	6	98	0	2	100	42	1, 1.9	10/17/1996	10/10/2001	.0	1.0	1.0	1.2	1.6	1.9	3.1	5.5

Table 32. Summary statistics for arsenic in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to the nearest tenth]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of WDNR results	Count of all results	Number of values belowa reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	13	0	13	13	0	04/26/1984	08/21/1993	3.5	4.2	5.5	6.1	7.0	8.4	10.2	14.0
Menomonee River	Lilly Creek	3	3	0	3	0	11/01/1989	11/01/1989	2.0	3.6	6.0	10.0	8.0	11.0	11.6	12.0
	Little Menomonee Creek	1	1	0	1	0	11/07/1989	11/07/1989	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
	Little Menomonee River	1	1	0	1	0	11/01/1989	11/01/1989	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Lower Menomonee River	24	2	22	24	0	04/25/1984	08/20/1993	3.4	5.1	5.9	7.0	8.2	8.9	10.5	25.0
	Upper Menomonee River	6	6	0	6	0	10/31/1989	11/08/1989	1.0	2.0	3.2	4.0	3.7	4.8	5.0	5.0
Milwaukee River	Lincoln Creek	1	1	0	1	0	11/01/1989	11/01/1989	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	Lower Milwaukee River	16	6	10	16	0	08/15/1973	08/21/1993	2.0	3.4	4.0	5.1	5.3	6.8	7.4	7.8
Root River	Middle Root River	1	1	0	1	0	10/03/1973	10/03/1973	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

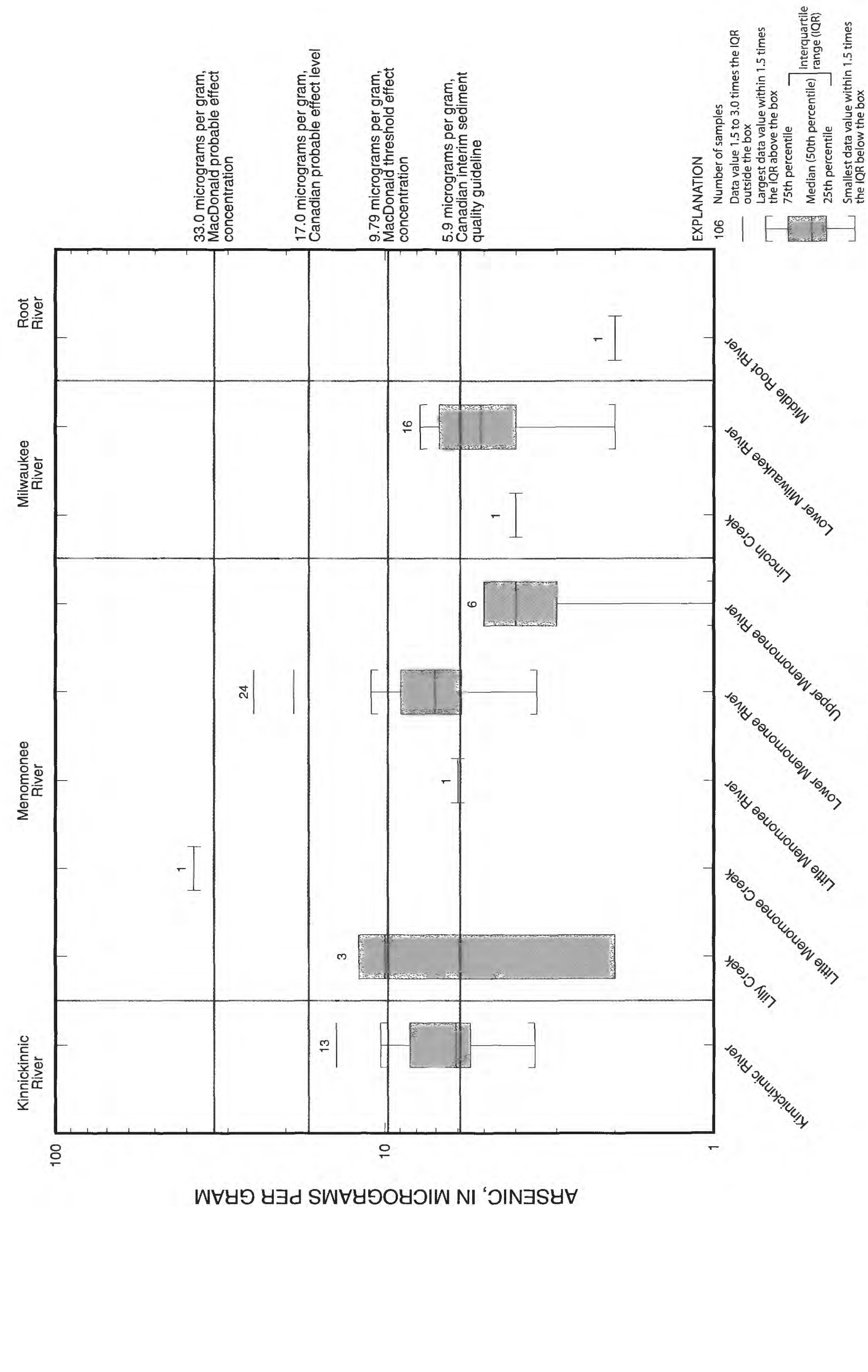

Figure 66. Statistical distribution of arsenic concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Chromium

Chromium is present in the environment in several forms. The most common forms are chromium 0, chromium III (trivalent), and chromium VI (hexavalent) (Agency for Toxic Substances and Disease Registry, 1999c). Chromium occurs mostly as chrome iron ore and is widely distributed in soils and plants, but it is rare in natural waters. Concentrations of chromium in natural waters not affected by waste disposal are commonly less than 10 µg/L (Hem, 1985). Anthropogenic sources of chromium include stainless steel, protective coatings on metals as a rust inhibitor, wearing down of asbestos brake lining on automobiles, pigments for paints, cement, paper, rubber, composition flooring, chemical synthesis, industrial water treatment (electroplating, leather tanning, and textile industries), astringents and antiseptics, and emissions from cooling towers (treated with rust inhibitors). Most chromium in surface water is particulate, very persistent, and ultimately deposited into sediments.

Because of potential for skin irritation, the USEPA and WDNR have a MCL of 100 µg/L for drinking water. The Canadian drinking-water guidelines has a lower MCL of 50 µg/L, and the Canadian water-quality guidelines for the protection of aquatic life has two standards: trivalent chromium, 8.9 µg/L; and hexavalent chromium, 1.0 µg/L.

Many reporting limits for chromium in water were above the Canadian aquatic life criterion of 1.0 µg/L hexavalent chromium and 8.9 µg/L trivalent chromium, and therefore concentrations above a reporting limit likely exceeded the guideline concentrations (table 33). Maximum concentrations in the Lower Milwaukee River (8,866.4 µg/L), Lower Menomonee River (600.0 µg/L), and Kinnickinnic River (581.0 µg/L) exceeded the USEPA and WDNR drinking-water guideline of 100 µg/L (table 33). In addition to these sites, maximum concentrations in the Upper Menomonee River (90.0 µg/L), Upper Root River (84.0 µg/L), Middle Root River (72.0 µg/L), Lower Root River (69.0 µg/L), Underwood Creek (60.0 µg/L), and Lincoln Creek (51.0 µg/L) subwatersheds exceeded the Canadian drinking-water guideline of 50 µg/L (table 33). No median concentrations exceeded a drinking-water guideline (table 33).

Sediment-quality guidelines for chromium are ISQG, 37.3 µg/g; TEC, 43.4 µg/g; PEL, 90 µg/g; and PEC, 111 µg/g.

All sites with exceedences of the PEL for chromium in sediment (90.0 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 67). Sites with median concentrations in the upper quartile were also clustered near the confluence of the three rivers (fig. 67). Sites with median concentrations in the lower quartile were scattered around the planning area but not located near the confluence of the three rivers (fig. 67).

The Kinnickinnic River subwatershed had a median chromium in sediment concentration in the upper quartile (fig. 67). Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, and Middle Root River subwatersheds had median concentrations in the lower quartile (fig. 67). Maximum exceedences above either the PEC or PEL (111 µg/g, 90.0 µg/g) were measured in the Lower Menomonee River, Lower Milwaukee River, and Kinnickinnic River subwatersheds (fig. 68, table 34). Concentrations for all samples in the Lilly Creek, Little Menomonee Creek, Lincoln Creek, and Middle Root River subwatersheds were below the ISQG and the TEC (37.3 µg/g, 43.4 µg/g) (fig. 68, table 34).

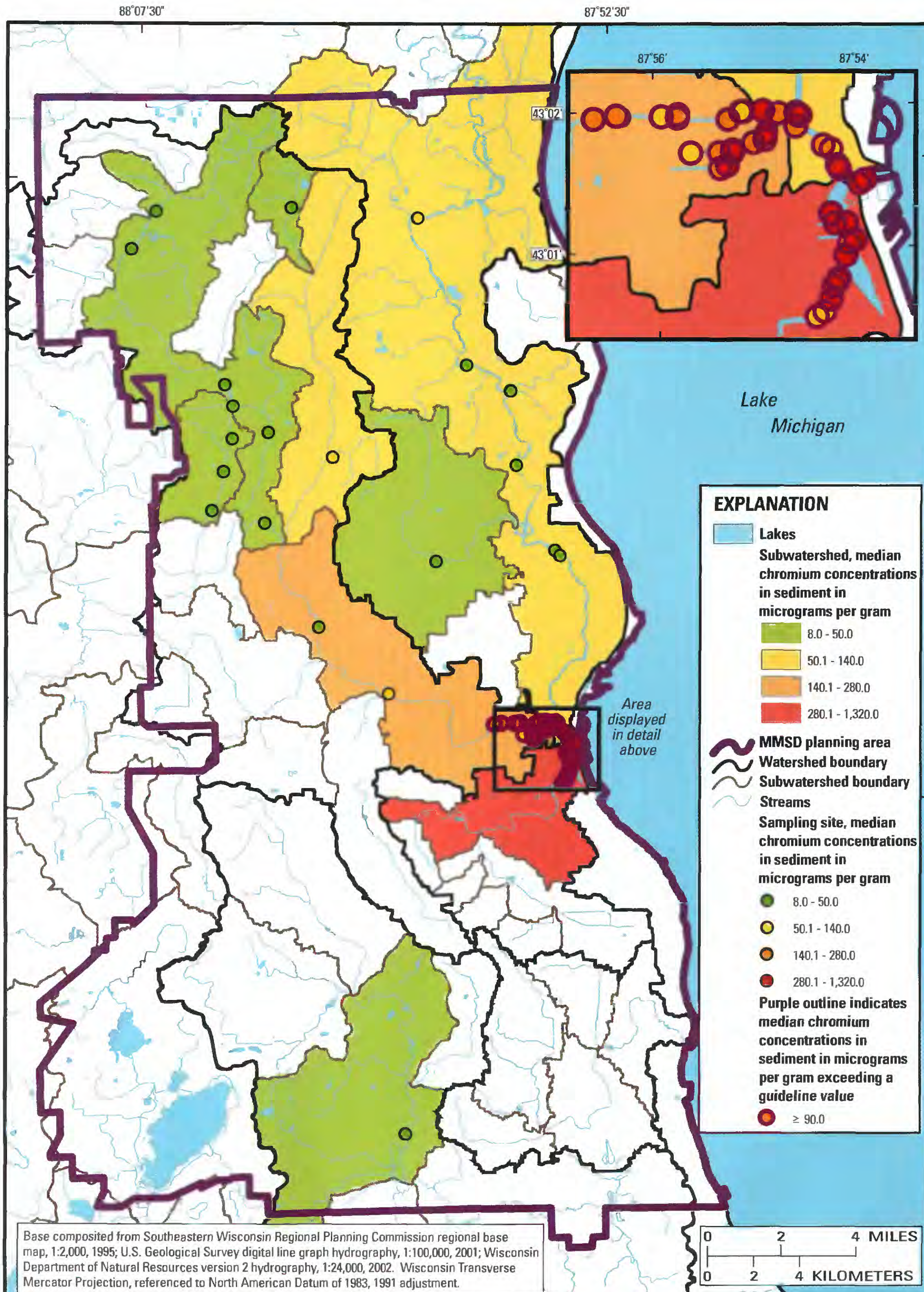

Figure 67. Sites sampled for chromium in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 33. Summary statistics for chromium in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	14	1,420	6	128	1,554	234	0.2, 3, 9.4, 20, 100	04/30/1975	11/14/2001	0.1	2.0	5.0	5.0	11.1	9.4	18.0	581.0
	West Milwaukee Ditch	3	0	0	3	3	3	0.2, 3	09/30/1975	10/02/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	4	0	0	51	51	51	3	05/27/1975	11/23/1977	--	--	--	--	--	--	--	RL
Lake Michigan Direct	Lake Michigan Direct	1	0	0	4	4	4	3	06/16/1977	08/13/1977	--	--	--	--	--	--	--	RL
Lake Michigan Tributary	Lake Michigan Tributary	2	0	0	3	3	3	3	09/12/1977	02/24/1982	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	0	1	1	1	3	06/30/1977	06/30/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	4	0	22	72	94	73	1, 3, 30	06/25/1975	06/29/1990	.5	1.5	1.5	1.5	2.8	1.5	4.7	28.0
	Lower Menomonee River	17	1,447	58	13	1,518	138	1, 3, 9.4	09/03/1975	11/14/2001	.5	4.7	5.0	6.0	14.5	10.0	28.0	600.0
	Upper Menomonee River	5	420	0	14	434	82	3, 9.4	06/25/1975	11/14/2001	1.5	4.7	4.7	5.0	8.1	9.4	12.0	90.0
	Underwood Creek	2	0	13	3	16	3	3	04/26/1976	06/29/1990	1.5	1.5	4.8	7.0	11.2	12.8	17.5	60.0
Milwaukee River	Combined Sewer Service Area	2	0	0	2	2	2	3, 5	02/03/1975	02/24/1982	--	--	--	--	--	--	--	RL
	Lincoln Creek	10	267	0	47	314	125	0.5, 3, 9.4	05/20/1975	11/27/2001	.2	1.4	4.7	5.8	6.6	9.4	9.4	51.0
	Lower Milwaukee River	26	2,888	34	179	3,101	512	3, 9.4, 10, 20	01/25/1973	11/15/2001	1.5	4.7	5.0	5.0	15.4	9.4	22.0	8,866.4
Oak Creek	North Branch Oak Creek	2	0	0	22	22	22	3	04/17/1975	12/11/1990	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	477	0	4	481	79	3, 9.4	10/13/1975	11/19/2001	1.5	4.7	5.0	5.0	7.7	9.4	12.0	40.0
	Middle Oak Creek	2	245	0	0	245	42	9.4	03/21/1985	11/19/2001	2.0	4.7	5.0	5.0	7.4	9.4	11.0	39.0
	Upper Oak Creek	1	122	0	0	122	20	9.4	03/21/1985	11/19/2001	2.0	4.7	5.0	6.0	7.9	9.4	12.9	34.0
Root River	East Branch Root River	1	0	0	6	6	6	3	10/13/1975	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Root River	1	23	0	0	23	15	9.4	08/25/1999	10/10/2001	4.7	4.7	4.7	4.7	12.6	9.4	20.8	69.0
	Middle Root River	2	25	0	1	26	15	3, 9.4	02/24/1982	10/10/2001	1.5	4.7	4.7	4.7	9.9	9.4	16.0	72.0
	Upper Root River	6	98	0	2	100	59	2, 9.4	10/17/1996	10/10/2001	1.0	4.7	4.7	4.7	10.5	9.4	17.0	84.0

Table 34. Summary statistics for chromium in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/L); values rounded to the nearest tenth]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	14	0	14	14	0	04/26/1984	08/21/1993	69.3	99.6	197.5	330.0	392.0	462.5	625.6	1,320.0
Menomonee River	Lilly Creek	3	3	0	3	0	11/01/1989	11/01/1989	20.0	20.0	20.0	20.0	23.3	25.0	28.0	30.0
	Little Menomonee Creek	1	1	0	1	0	11/07/1989	11/07/1989	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Little Menomonee River	1	1	0	1	0	11/01/1989	11/01/1989	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
	Lower Menomonee River	24	2	22	24	0	04/25/1984	08/20/1993	30.0	66.2	110.2	162.0	190.3	225.0	328.0	570.0
	Upper Menomonee River	6	6	0	6	0	10/31/1989	11/08/1989	20.0	20.0	22.5	30.0	28.3	30.0	35.0	40.0
Milwaukee River	Lincoln Creek	1	1	0	1	0	11/01/1989	11/01/1989	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Lower Milwaukee River	16	6	10	16	0	08/15/1973	08/21/1993	20.0	31.0	50.0	117.0	177.3	269.8	380.0	540.0
Root River	Middle Root River	1	1	0	1	0	10/03/1973	10/03/1973	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0

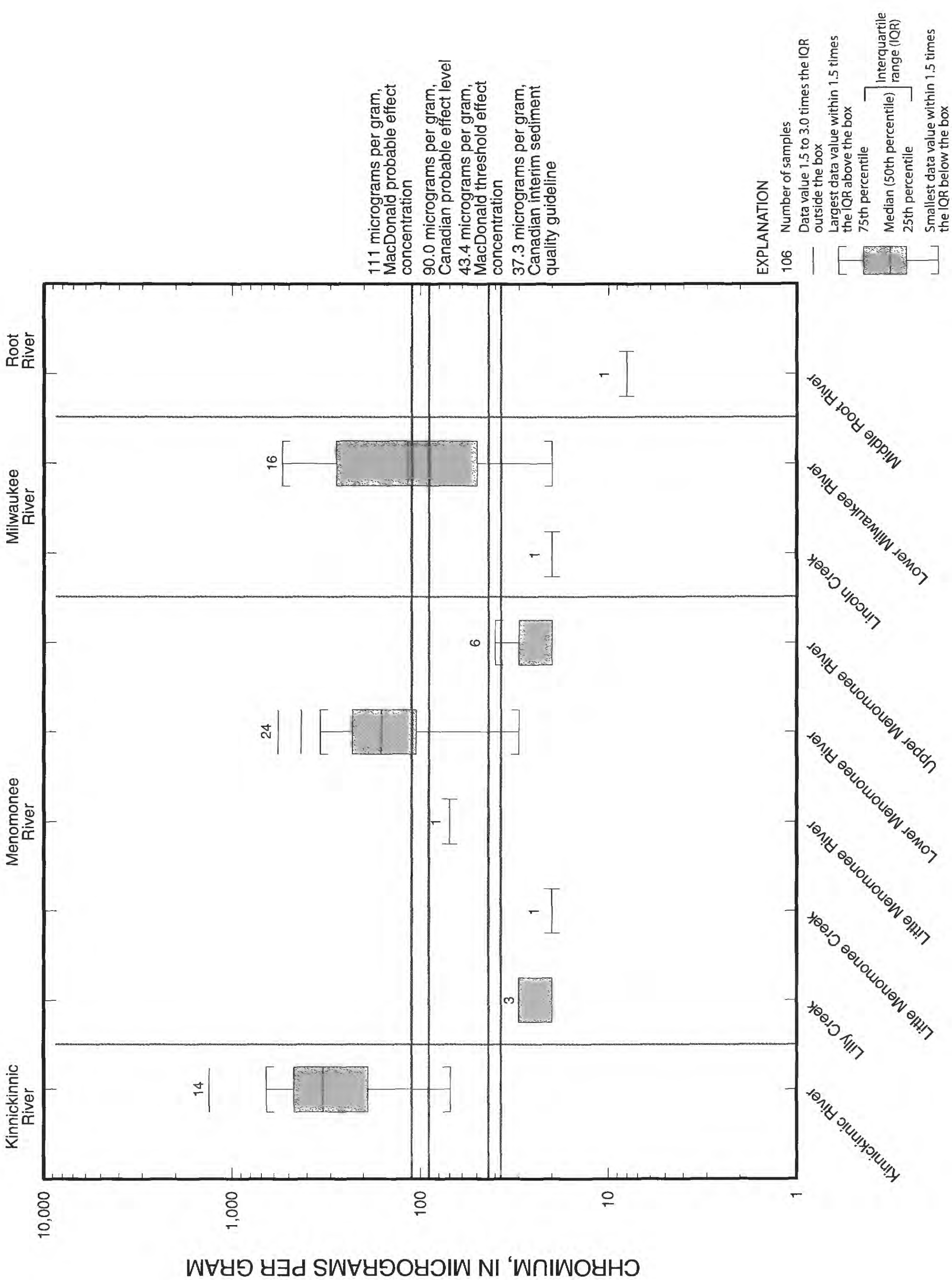

Figure 68. Statistical distribution of chromium concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Nickel

Nickel is a naturally abundant element that is found mainly in soils and sediments. Nickel attaches to particles that contain iron or manganese, which are commonly present in soil (Agency for Toxic Substances and Disease Registry, 1999d). Nickel is used in the production of stainless steel and other corrosive-resistant metal, batteries, and color ceramics, and as a catalyst in organic chemical manufacturing and petroleum refining. Because of its widespread use, nickel can be contributed to the environment in significant amounts by waste disposal (Hem, 1985). Nickel is one of the most mobile of heavy metals in the aquatic system. This mobility is controlled by the ability of various sorbents to scavenge it from solution. Nickel does not appear to accumulate in the tissues of fish, plants, or animals used as food (Agency for Toxic Substances and Disease Registry, 1999d).

The USEPA remanded its MCL and Maximum Contaminant Level Goal (MCLG) for nickel in February 1995. There currently is no federal legal limit on the amount of nickel in drinking water. The USEPA is reconsidering the limit on nickel at this time (U.S. Environmental Protection Agency, 2002f). There are currently no Canadian drinking-water guidelines. The WDNR MCL standard for nickel is 100 µg/L. The Canadian guideline for the protection of aquatic health lists a standard of 25–150 µg/L.

Maximum concentrations of nickel in water exceeded the WDNR drinking-water guideline of 100 µg/L and in most cases the upper limit of the Canadian aquatic life guideline of 25–150 µg/L in the Lower Milwaukee River (3,810.8 µg/L), Kinnickinnic River (710.0 µg/L), Upper Oak Creek (270.0 µg/L), Lower Menomonee River (150.0 µg/L), Upper Menomonee River (116.0 µg/L), and Lincoln Creek (110.0 µg/L) subwatersheds (table 35). Nearly all median concentrations appeared to be concentrations below a reporting limit (table 35).

Currently, there are no Canadian sediment-quality guidelines for nickel. The MacDonald sediment-quality guidelines for freshwater ecosystems have set a TEC of 22.7 µg/g and a PEC of 48.6 µg/g for nickel.

Only one site in the Lower Menomonee River subwatershed had an exceedence of the PEC for nickel in sediment (48.6 µg/g) (fig. 69). Sites with median concentrations in the upper quartile were mainly clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers but were also scattered throughout several other subwatersheds to a lesser extent (fig. 69). Sites with median concentrations in the lower quartile were scattered among subwatersheds in the northern part of the planning area (fig. 69).

The Little Menomonee River subwatershed had a median nickel in sediment concentration in the upper quartile (fig. 69). Median concentrations in the lowest quartile were in the Upper Menomonee River, Little Menomonee Creek, and Lilly Creek subwatersheds (fig. 69). One sample in the Lower Menomonee River subwatershed with a concentration of 49.0 µg/g exceeded the PEC of 48.6 µg/g (fig. 70, table 36). The concentration of the only sample collected in the Little Menomonee Creek subwatershed (20.0 µg/g) fell below the TEC of 22.7 µg/g (fig. 70, table 36).

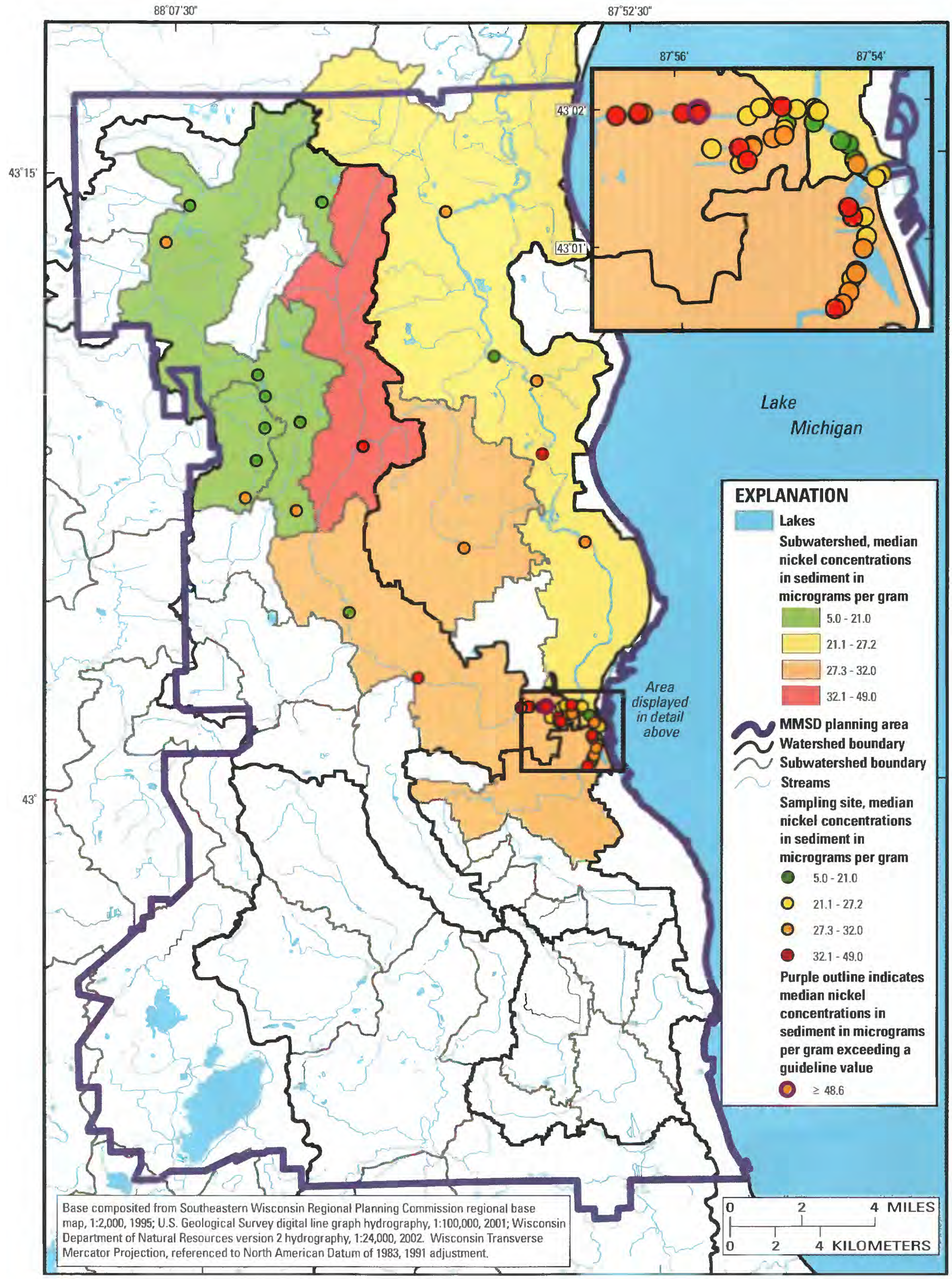

Figure 69. Sites sampled for nickel in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 35. Summary statistics for nickel in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (µg/L); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75thpercentile	90th percentile	Maximum
Fox River	Deer Creek	1	0	0	4	4	4	20, 100	04/24/1985	05/08/1985	--	--	--	--	--	--	--	RL
Kinnickinnic River	Kinnickinnic River	13	701	0	86	787	209	14.3, 20, 30	04/30/1975	11/14/2001	5.0	7.2	10.0	10.0	12.2	14.0	14.3	710.0
	West Milwaukee Ditch	4	0	0	5	5	5	20, 30	04/29/1975	12/22/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	4	0	0	74	74	74	20	05/27/1975	11/23/1977	--	--	--	--	--	--	--	RL
Lake Michigan Direct	Lake Michigan Direct	1	0	0	8	8	8	10, 20	06/16/1977	11/23/1977	--	--	--	--	--	--	--	RL
Lake Michigan Tributary	Lake Michigan Tributary	1	0	0	2	2	2	20, 40	09/28/1981	02/24/1982	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	1	0	0	17	17	17	20	06/25/1975	07/19/1977	--	--	--	--	--	--	--	RL
	Little Menomonee River	4	0	22	113	135	113	20	06/25/1975	06/29/1990	2.0	5.4	10.0	10.0	9.4	10.0	10.0	25.0
	Lower Menomonee River	14	758	19	97	874	224	1, 14.3, 20	06/25/1975	11/14/2001	.5	7.2	10.0	10.0	11.2	13.0	14.3	150.0
	Upper Menomonee River	5	307	0	25	332	99	14.3, 20	06/25/1975	11/14/2001	5.0	7.2	7.2	10.0	11.0	14.0	14.3	116.0
	Underwood Creek	2	0	13	7	20	7	20	06/25/1975	06/29/1990	3.0	5.0	5.8	10.0	9.7	10.0	11.2	36.0
Milwaukee River	Combined Sewer Service Area	1	0	0	1	1	1	20	02/24/1982	02/24/1982	--	--	--	--	--	--	--	RL
	Lincoln Creek	7	267	0	24	291	138	14.3, 20	05/19/1975	11/27/2001	7.2	7.2	7.2	14.0	11.5	14.3	14.3	110.0
	Lower Milwaukee River	23	1,476	21	193	1,690	529	10, 14.3, 20	05/28/1975	11/15/2001	1.0	7.2	7.2	10.0	13.0	11.0	14.3	3,810.8
Oak Creek	North Branch Oak Creek	2	0	0	24	24	24	20	04/17/1975	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	319	0	12	331	91	14.3, 20	05/27/1975	11/19/2001	5.0	7.2	7.2	10.0	10.6	14.0	14.3	32.6
	Middle Oak Creek	2	165	0	0	165	44	14.3	05/21/1990	11/19/2001	5.0	7.2	7.2	10.0	11.0	14.0	14.3	81.0
	Upper Oak Creek	1	82	0	0	82	22	14.3	05/21/1990	11/19/2001	7.0	7.2	7.2	10.0	13.7	14.0	14.3	270.0
Root River	East Branch Root River	1	0	0	12	12	12	20	05/27/1975	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Root River	1	23	0	0	23	15	14.3	08/25/1999	10/10/2001	72	7.2	7.2	7.2	10.9	14.3	21.0	24.0
	Middle Root River	2	25	0	1	26	17	14.3, 20	02/24/1982	10/10/2001	72	7.2	7.2	7.2	10.7	14.3	18.2	24.0
	Upper Root River	6	98	0	2	100	61	14.3	10/17/1996	10/10/2001	0	7.2	7.2	7.2	10.6	14.3	17.4	27.0
	Whitnall Park Creeks	1	0	0	1	1	1	20	05/24/1976	05/24/1976	--	--	--	--	--	--	--	RL

Table 36. Summary statistics for nickel in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to the nearest tenth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	13	0	13	13	0	--	04/26/1984	08/21/1993	22.0	24.4	27.0	30.0	29.9	32.0	36.5	41.5
Menomonee River	Lilly Creek	3	3	0	3	0	--	11/01/1989	11/01/1989	20.0	20.0	20.0	20.0	23.3	25.0	28.0	30.0
	Little Menomonee Creek	1	1	0	1	0	--	11/07/1989	11/07/1989	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Little Menomonee River	1	1	0	1	0	--	11/01/1989	11/01/1989	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	Lower Menomonee River	24	2	22	24	0	--	04/25/1984	08/20/1993	14.5	22.4	26.2	29.0	30.8	34.2	42.1	49.0
	Upper Menomonee River	6	6	0	6	1	10	10/31/1989	11/08/1989	5.0	12.5	20.0	20.0	20.8	27.5	30.0	30.0
Milwaukee River	Lincoln Creek	1	1	0	1	0	--	11/01/1989	11/01/1989	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	Lower Milwaukee River	15	5	10	15	0	--	04/26/1984	08/21/1993	16.0	18.7	20.1	23.0	24.2	29.5	30.0	40.0

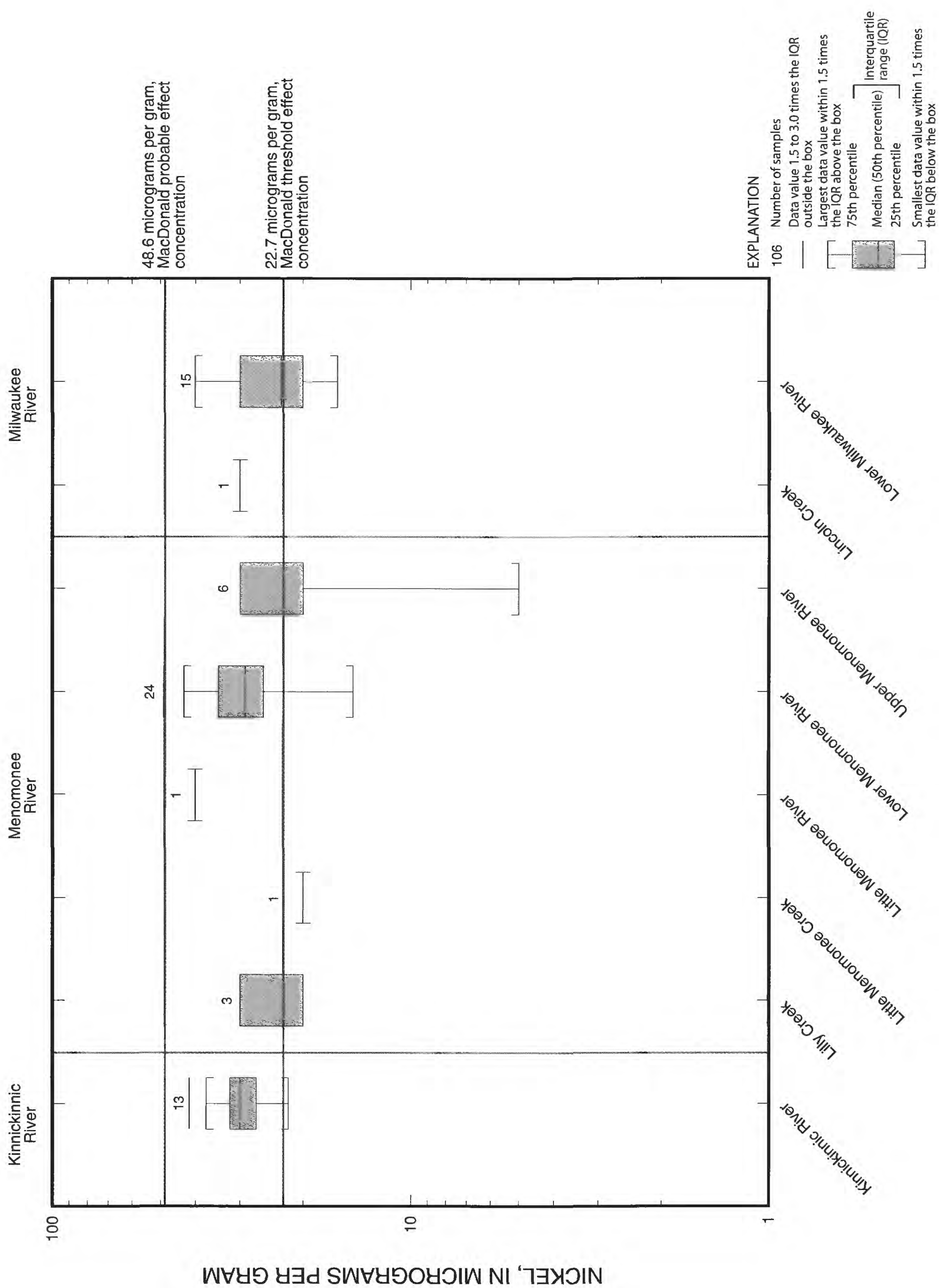

Figure 70. Statistical distribution of nickel concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Zinc

Zinc is a common element in rock (about the same abundance as copper or nickel), but it is substantially more soluble in water than the other two metals. Zinc naturally occurs in the air, soils, and water. Zinc is an essential mineral to plant and animal metabolism and is found in most foods (Hem, 1985). Most zinc in soils stays bound to the soil particles. Zinc accumulates in fish and other aquatic organisms but not plants (Agency for Toxic Substances and Disease Registry, 1999e). Zinc is a component of brass, bronze, and galvanized metals and is used to make paint, rubber, dye, and wood preservatives (Callendar and Rice, 2000). Fossil-fuel combustion is the main contributor to worldwide anthropogenic emissions of zinc (Callendar, and Rice, 2000). Concentration of zinc in bed sediment is well correlated with population density in the United States (Rice, 1999).

The USEPA has established SMCLs for fifteen contaminants that are goals but are not enforceable. These SMCLs are established for aesthetic considerations (taste and odor, and color) and are not considered to present a risk to human health. The USEPA does not have a MCL for zinc but does have an SCML of 5,000 µg/L related to odor and taste. The Canadian drinking-water guideline also is 5,000 µg/L and is an AO. The WDNR does not have a drinking-water standard for zinc. The Canadian water-quality guideline for the protection of aquatic life is 30 µg/L.

Maximum concentrations of zinc in water at all subwatersheds exceeded the Canadian aquatic life criterion of 30 µg/L (table 37). The highest maximum concentration was in the Lower Menomonee River subwatershed (1,500 µg/L) (table 37). Median concentrations in the Underwood Creek (90 µg/L), Mitchell Field Drainage Ditch (80 µg/L) and Little Menomonee River (30 µg/L) matched or exceeded the Canadian aquatic life guideline (table 37). No exceedences of the USEPA or Canadian drinking-water guideline concentrations of 5,000 µg/L were found in any subwatershed (table 37).

The Canadian sediment-quality guidelines for the protection of aquatic life for zinc are an ISQG of 123 µg/g and a PEL of 315 µg/g; MacDonald's consensus-based sediment-quality guidelines are a TEC of 121 µg/g and a PEC of 459 µg/g.

Almost all sites with exceedences of the PEL for zinc in sediment (315 µg/g) were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 71). Sites with median concentrations in the upper quartile were also mostly clustered near the confluence of the three rivers (fig. 71). Sites with median concentrations in the lower quartile were scattered around the planning area but typically not located near the confluence of the three rivers (fig. 71).

No subwatersheds had median zinc concentrations in the upper quartile (fig. 71). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, and Middle Root River subwatersheds had median concentrations in the lower quartile (fig. 71). The maximum concentrations, above either the PEC or PEL (459 µg/g, 315 µg/g), were measured in the Lower Menomonee River, Little Menomonee River, Lower Milwaukee River, and the Kinnickinnic River subwatersheds (fig. 72, table 38). The concentrations collected for the only samples in the Little Menomonee Creek (93 µg/g) and Middle Root River (52 µg/g) subwatersheds were below the TEC and the ISQG (121 µg/g, 123 µg/g) (fig. 72, table 38).

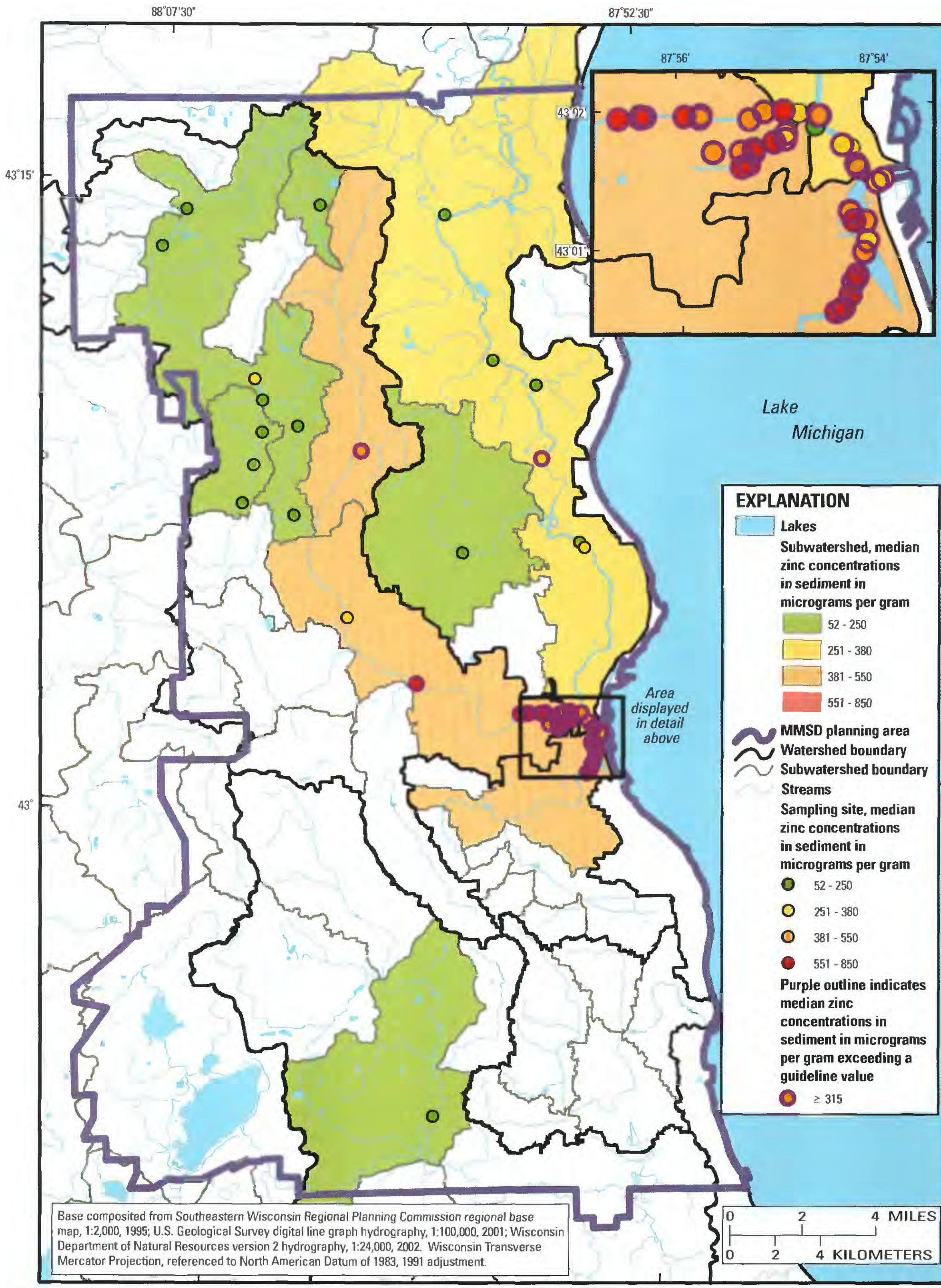

Figure 71. Sites sampled for zinc in sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 37. Summary statistics for zinc in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in micrograms per liter (mg/L); values rounded to the nearest whole number; for the purpose of statistical calculations, values reported below a reporting-limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	7	1,382	0	2	1,384	2	20	07/08/1975	11/14/2001	4	5	11	19	31	36	63	710
	West Milwaukee Ditch	1	0	0	1	1	1	20	10/02/1975	10/02/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	6	0	0	54	54	16	0, 20	05/27/1975	04/07/2000	0	0	0	23	51	66	137	440
Lake Michigan Tributary	Lake Michigan Tributary	2	0	0	3	3	3	20	03/10/1976	09/28/1981	--	--	--	--	--	--	--	RL
Menomonee River	Little Menomonee River	4	0	22	19	41	19	20	06/25/1975	06/29/1990	10	10	10	30	57	70	130	450
	Lower Menomonee River	9	1,429	53	4	1,486	9	10, 20	06/25/1975	11/14/2001	5	6	10	18	31	30	56	1,500
	Upper Menomonee River	5	416	0	5	421	5	20	06/25/1975	11/14/2001	3	5	6	11	20	21	36	350
	Underwood Creek	1	0	13	0	13	0	--	02/01/1990	06/29/1990	60	62	80	90	155	170	242	670
Milwaukee River	Combined Sewer Service Area	1	0	0	1	1	1	5	02/03/1975	02/03/1975	--	--	--	--	--	--	--	RL
	Lincoln Creek	10	267	6	58	331	42	8, 20	06/18/1975	11/27/2001	4	6	13	22	32	40	75	200
	Lower Milwaukee River	22	2,838	50	147	3,035	157	10, 20, 30	01/25/1973	11/15/2001	2	5	7	12	19	21	40	330
Oak Creek	Mitchell Field Drainage Ditch	2	0	0	12	12	1	0	01/11/1999	02/23/2000	0	21	42	80	75	112	129	140
	North Branch Oak Creek	2	0	0	8	8	8	10, 20	04/17/1975	12/11/1990	--	--	--	--	--	--	--	RL
	Lower Oak Creek	4	477	0	4	481	9	4.3, 20	07/08/1975	11/19/2001	2	5	7	13	21	23	49	212
	Middle Oak Creek	2	245	0	0	245	2	4.3	03/21/1985	11/19/2001	2	5	9	15	21	26	43	122
	Upper Oak Creek	1	121	0	0	121	1	4.3	03/21/1985	11/19/2001	2	5	8	14	20	27	41	110
Root River	East Branch Root River	1	0	0	8	8	8	20	05/27/1975	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Root River	1	23	0	0	23	0	--	08/25/1999	10/10/2001	8	9	12	17	20	24	31	60
	Middle Root River	1	25	0	0	25	0	--	08/25/1999	10/10/2001	7	8	10	15	18	21	27	50
	Upper Root River	4	98	0	0	98	1	4.3	08/25/1999	10/10/2001	2	9	12	18	22	28	44	70

Table 38. Summary statistics for zinc in sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; --, no data available; values are expressed in micrograms per gram (µg/g); values rounded to the nearest whole number]

Watershed	Subwatershed	Sites per subwatershed	Count of USGS results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	13	0	13	13	0	04/26/1984	08/21/1993	340	384	490	540	528	600	628	677
Menomonee River	Lilly Creek	3	3	0	3	0	11/01/1989	11/01/1989	77	88	104	130	132	160	178	190
	Little Menomonee Creek	1	1	0	1	0	11/07/1989	11/07/1989	93	93	93	93	93	93	93	93
	Little Menomonee River	1	1	0	1	0	11/01/1989	11/01/1989	540	540	540	540	540	540	540	540
	Lower Menomonee River	24	2	22	24	0	04/25/1984	08/20/1993	212	281	392	503	486	580	620	850
	Upper Menomonee River	6	6	0	6	0	10/31/1989	11/08/1989	93	106	125	140	167	222	255	260
Milwaukee River	Lincoln Creek	1	1	0	1	0	11/01/1989	11/01/1989	160	160	160	160	160	160	160	160
	Lower Milwaukee River	16	6	10	16	0	08/15/1973	08/21/1993	87	138	235	318	294	350	400	500
Root River	Middle Root River	1	1	0	1	0	10/03/1973	10/03/1973	52	52	52	52	52	52	52	52

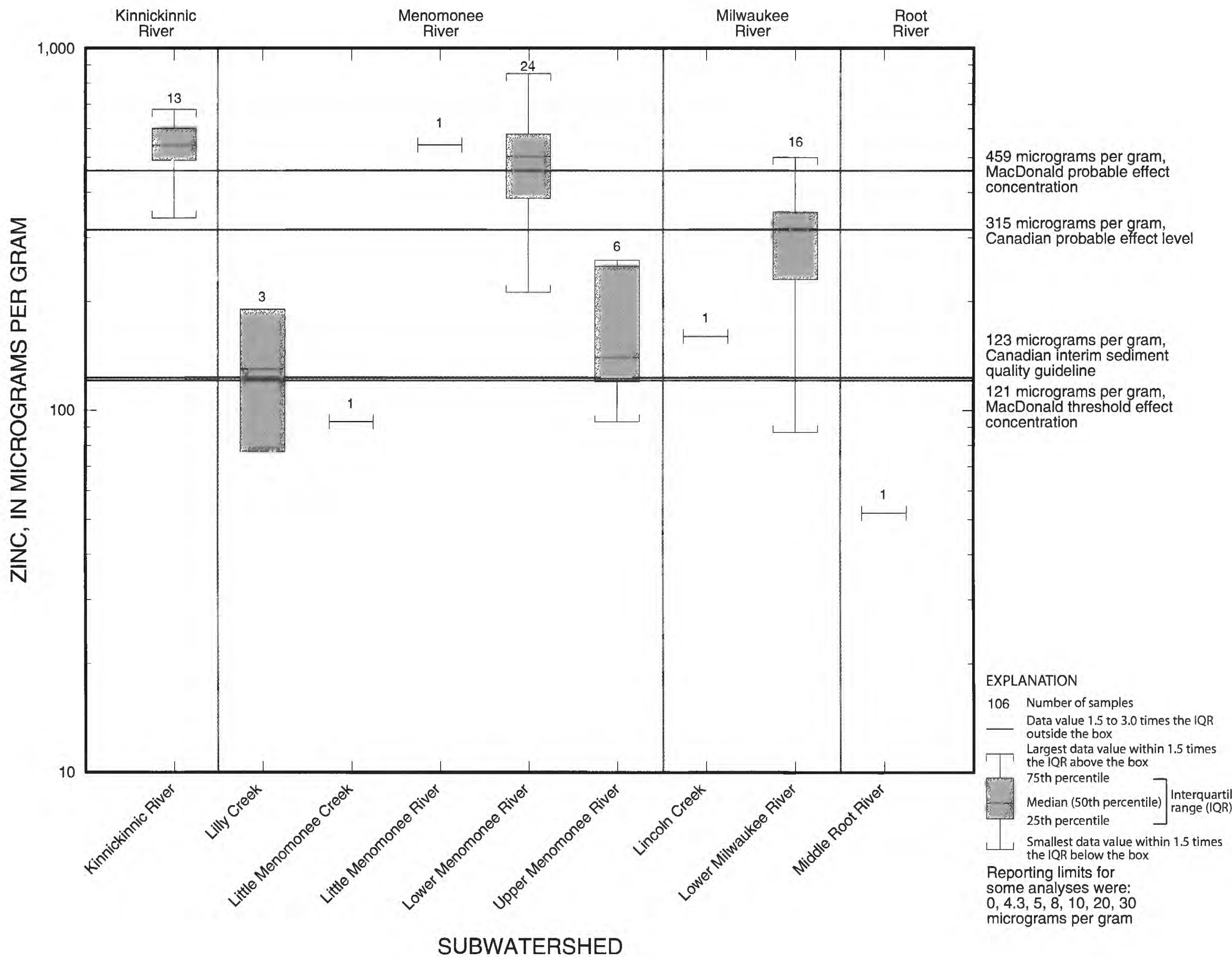

Figure 72. Statistical distribution of zinc concentrations in sediment in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Pesticides

For the purposes of this report, discussion of pesticides has been broken into sections describing (1) historically used and now banned pesticides and (2) pesticides still in use.

Historically used pesticides are low-solubility, hydrophobic compounds that, when transported to aquatic systems, partition into sediment and bioaccumulate in aquatic organisms. Because they can cause unintended effects on nontarget organisms, they are a long-lived threat to the health of streams and the organisms (including humans) that utilize the streams. Chlordane, dieldrin, DDT, and DDD are insecticides formerly used on crops. All crop uses of these compounds were banned between 1972 (DDT) and 1983 (chlordane). Limited use of dieldrin and chlordane was allowed after that time for termite control, but all uses were banned in 1987 and 1988, respectively. However, these compounds and others are frequently detected in sediment and the tissues of animals exposed to contaminated sediments. (The others are breakdown products and (or) related chemicals whose source is from pesticide mixtures containing the main compound.) Although the concentrations are usually low, these compounds bioaccumulate in fish, birds, and mammals (Agency for Toxic Substances and Disease Registry, 2003).

Consensus-based TECs have been developed for each of the historically used pesticides selected for this report (MacDonald and others, 2000); however these values are not listed herein.

Pesticides currently in use are generally highly soluble, hydrophilic compounds and thus are primarily found dissolved in the water compartment of aquatic systems. These modern pesticides have short half-lives and a seasonal periodicity related to application. Agricultural herbicides are generally applied in conjunction with planting. Urban use of pesticides is generally on an as-needed basis anytime during the growing season. Concentrations in surface waters are highest during and after rainstorms that occur after planting and before significant crop growth slows runoff. In southern Wisconsin, this period generally is mid-May through mid-June (Sullivan and Richards, 1996).

Historically Used Pesticides

The following pesticides were selected from the MMSD Corridor Study database for description in this report: chlordane, dieldrin, DDT, DDE, DDD, *p,p'*-DDT, *p,p'*-DDE, and *p,p'*-DDD in sediment; and dieldrin, chlordane (*cis* and *trans* isomers), nonachlor (*cis* and *trans* isomers), *p,p'*-DDT, *p,p'*-DDE, and *p,p'*-DDD in tissue. These pesticides were chosen for description because data are relatively plentiful (generally more than 10 samples) and are commonly analyzed for in urban areas and areas adjacent to agricultural lands. Pesticide data in sediment came from both the USGS and USEPA STORET databases. Data on pesticides in tissue was only from the USEPA STORET database, although a small amount of additional USGS data is in the MMSD Corridor study database. Locations of pesticide sampling sites are shown in figure 73.

Of the selected pesticides in sediment, only dieldrin was not found at a concentration above the reporting limit (data not shown). Of the selected pesticides in tissue, the following were found only at concentrations below the reporting limit: chlordane (*cis* and *trans* isomers), nonachlor (*cis* isomer), *p,p'*-DDT, and *p,p'*-DDD (data not shown).

Most sites with data for pesticides in sediment were clustered around the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers, although other such sites were scattered around the planning area (fig. 73). Data for pesticides in tissue were available for several sites in the Milwaukee and Kinnickinnic watersheds but not for most other watersheds (fig. 73, table 39).

Almost all data for pesticides in sediment were collected in the early 1990s or before (table 39). Results were below the reporting limit in at least half the samples in the Kinnickinnic River, Lower Menomonee River, Lincoln Creek, Lower Milwaukee River, and North Branch Oak Creek subwatersheds (table 39). All data for pesticides in tissue also were collected in the early 1990s or before (table 39). Of the 11 subwatersheds with data, concentrations were below a reporting limit except for a few samples in the Lower Milwaukee River subwatershed (table 39).

Pesticides Still in Use

Pesticides in current use are most likely found in surface water. Atrazine, deethyl atrazine, diazinon, metolachlor, prometon, simazine, and 2,4-D can be found in urban areas or streams draining agricultural lands; consequently, a significant amount of data was available. Pesticide data in water came from the USGS, although data for a few samples were also available in the MMSD Corridor Study database from USEPA STORET. Locations where surface water was analyzed for pesticides are shown in figure 73.

All of the selected pesticides were observed at concentrations above the reporting limit in at least one sample; however, no maximum concentration of any of the selected pesticides was above an MCL or other health advisory level (data not shown).

Data selected for analysis in this report were collected at two sites: the Milwaukee River at Estabrook Park in Milwaukee (91 samples) and Lincoln Creek at 47th Street in Milwaukee (10 samples) during 1993–2002 and 2001–2002, respectively (fig. 73, table 39).

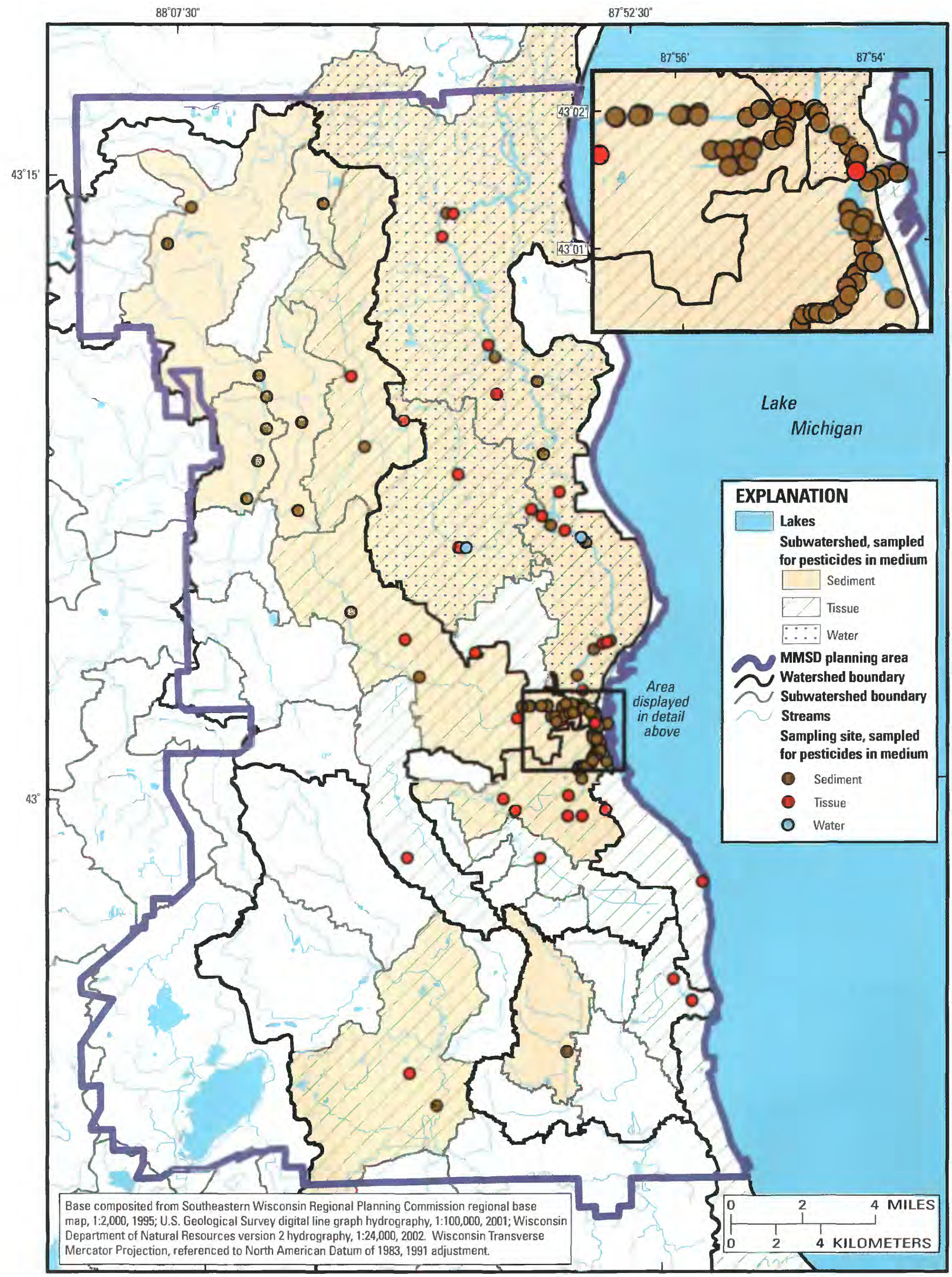

Figure 73. Sites sampled for pesticides in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 39. Summary statistics for pesticides in sediment, tissue, and water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; refer to text for list of selected pesticides included in this summary]

		Sediment								Tissue							Water						
Watershed	Subwatershed	Sites per subwatershed	Count of samples	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Sites per subwatershed	Count of samples	Count of STORET results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Sites per subwatershed	Count of samples	Count of USGS results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date
Kinnickinnic River	Kinnickinnic River	32	33	0	0	190	189	04/1984	06/1994	6	29	111	111	111	08/1978	05/1988	--	--	--	--	--	--	--
	Wilson Park Creek	--	--	--	--	--	--	--	--	1	3	16	16	16	05/1988	05/1988	--	--	--	--	--	--	--
Lake Michigan Direct	Lake Michigan Direct	--	--	--	--	--	--	--	--	1	1	5	5	5	10/1986	10/1986	--	--	--	--	--	--	--
Menomonee River	Honey Creek	--	--	--	--	--	--	--	--	1	1	8	8	8	08/1992	08/1992	--	--	--	--	--	--	--
	Lilly Creek	3	3	15	0	15	5	11/1989	11/1989	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Little Menomonee Creek	1	1	5	0	5	1	11/1989	11/1989	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Little Menomonee River	1	1	5	0	5	0	11/1989	11/1989	1	3	7	7	7	03/1987	03/1987	--	--	--	--	--	--	--
	Lower Menomonee River	28	34	10	7	126	113	04/1984	08/1993	2	9	32	32	32	07/1979	05/1993	--	--	--	--	--	--	--
	Upper Menomonee River	6	6	30	0	30	4	10/1989	11/1989	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Milwaukee River	Combined Sewer Service Area	--	--	--	--	--	--	--	--	1	2	8	8	8	05/1988	05/1988	--	--	--	--	--	--	--
	Lincoln Creek	2	13	5	14	19	14	11/1989	06/1994	4	14	63	63	63	08/1992	05/1993	1	10	63	63	23	05/2001	02/2002
	Lower Milwaukee River	24	25	35	0	201	174	05/1982	08/1993	11	64	296	296	292	08/1978	08/1993	1	91	583	583	130	04/1993	02/2002
Oak Creek	North Branch Oak Creek	1	4	0	5	5	5	08/1993	11/1993	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Lower Oak Creek	--	--	--	--	--	--	--	--	3	5	28	28	28	03/1987	05/1993	--	--	--	--	--	--	--
Root River	Middle Root River	1	1	5	0	5	0	10/1973	10/1973	1	1	6	6	6	10/1992	10/1992	--	--	--	--	--	--	--

Polychlorinated Biphenyls

Despite being banned since the 1970s, polychlorinated biphenyls (PCBs) are ubiquitous contaminants, present not only in industrial areas where they were manufactured and used (in cutting oils, sealants, hydraulic fluids and pesticides) but also in remote locales such as the polar regions, owing to atmospheric transport and deposition. PCBs are a set of 209 related chlorinated organic compounds, some of which have demonstrated toxicity (McFarland and Clarke, 1989). Major present-day sources include streambed sediments and, in some cases, the atmosphere. Being relatively hydrophobic and lipophilic, these compounds tend to adsorb onto clay surfaces or be associated with lipids and other subcellular components in aquatic organisms. Therefore, major loss mechanisms for truly dissolved PCBs in water include partitioning to suspended and bottom sediments and passive uptake by algae. In addition, because PCBs tend to be refractory in most aquatic environments, it is often possible to determine the particular commercial mixtures of PCBs, termed Aroclors, that were released to the stream. Under certain conditions, Aroclor mixtures undergo weathering wherein selective solubilization, volatilization, and (or) microbially mediated decomposition of some congeners (compounds belonging to the same chemical family) can significantly change the Aroclor mixture, sometimes beyond recognition.

Total PCB concentrations are most often determined by summing all measurable congeners from a congener-specific analysis of a sample. Aroclors are quantified either from older methods that do not include analysis of individual congeners or by matching the suite of measured individual congeners with that of known Aroclor mixtures using computer programs.

Sites with PCB data in water were scattered throughout the planning area. Sites sampled for PCBs in sediment were lightly scattered throughout the northern part of the planning area, with a concentration of sites at the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers (fig. 74). Sites with PCB data in tissue were very lightly scattered throughout the planning area (fig. 74).

Data collection for PCBs in water in most subwatersheds began in 1975 (table 40). In half of the subwatersheds, data collected for PCBs in water were collected through 2001 (table 40). At least half the results for PCBs in water were below reporting limit in all subwatersheds (table 40). All results for PCBs in water were below a reporting limit in half the subwatersheds (table 40). Data for PCBs in sediment in about half of the subwatersheds were collected once in 1989 (table 41). In most other subwatersheds, data collection for PCBs in sediment began in 1980 and ended in the mid-1990s (table 41). In about half the subwatersheds, concentrations in sediment were below a reporting limit in more than half of the results (table 41). PCB data in tissue were collected primarily in the mid to late 1980s, with a few additional samples in the mid-1990s. Fewer than 20 results are available for each subwatershed (table 41). Concentrations for most subwatersheds were below a reporting limit for PCB data in tissues (table 41).

So-called toxic PCB congeners can be defined as a subset of total PCB congeners that are ranked on a scale that considers both intrinsic toxicity and prevalence in environmental samples (McFarland and Clarke, 1989). In terms of toxicity, they include PCB congeners that are directly toxic, including some of the co-planar congeners, and congeners that are indirectly toxic, including those that induce bioactivating enzyme systems. For the purposes of this report, we include PCB congener Groups 1A, 1B, or 2 as defined in MacFarland and Clarke (1989) as toxic congeners. Among the most toxic, Group 1A congeners, so-called pure 3-methylcholanthrene-type inducers, were congeners 77, 126, and 169, non-ortho-substituted coplanar congeners. These congeners are similar in structure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD or simply "Dioxin"), a standard of toxicity against which all organic compounds are measured. Group 1B congeners are mixed-type inducers that have been observed frequently in environmental samples. These include 105, 118, 128, 138, 156, and 170. Group 2 congeners are phenobarbital-type inducers prevalent in the environment and include 87, 99, 101, 153, 180, 183, and 194.

Data collection of the toxic PCBs took place at a subset of the sampling events where sampling for a larger suite of PCBs was done. Sampling for toxic PCBs in water occurred throughout the planning area but was concentrated in the east-central part (fig. 75). Sites where samples were analyzed for toxic PCBs in sediment were clustered near the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers, just downstream from the confluence of Lincoln Creek with the Milwaukee River, and in a few spots on the Milwaukee River toward the northern extent of the planning area (fig. 75). There were no samples for toxic PCBs in tissues.

Sampling for toxic PCBs in water began as early as 1990 and continued through 2001 (table 42). At least half of the concentrations for PCBs in water in most subwatersheds were below a reporting limit (table 42). Sampling for toxic PCBs in sediment also began in 1990 and generally ended in the mid-1990s (table 42). Results for almost all samples were above reporting limits (table 42).

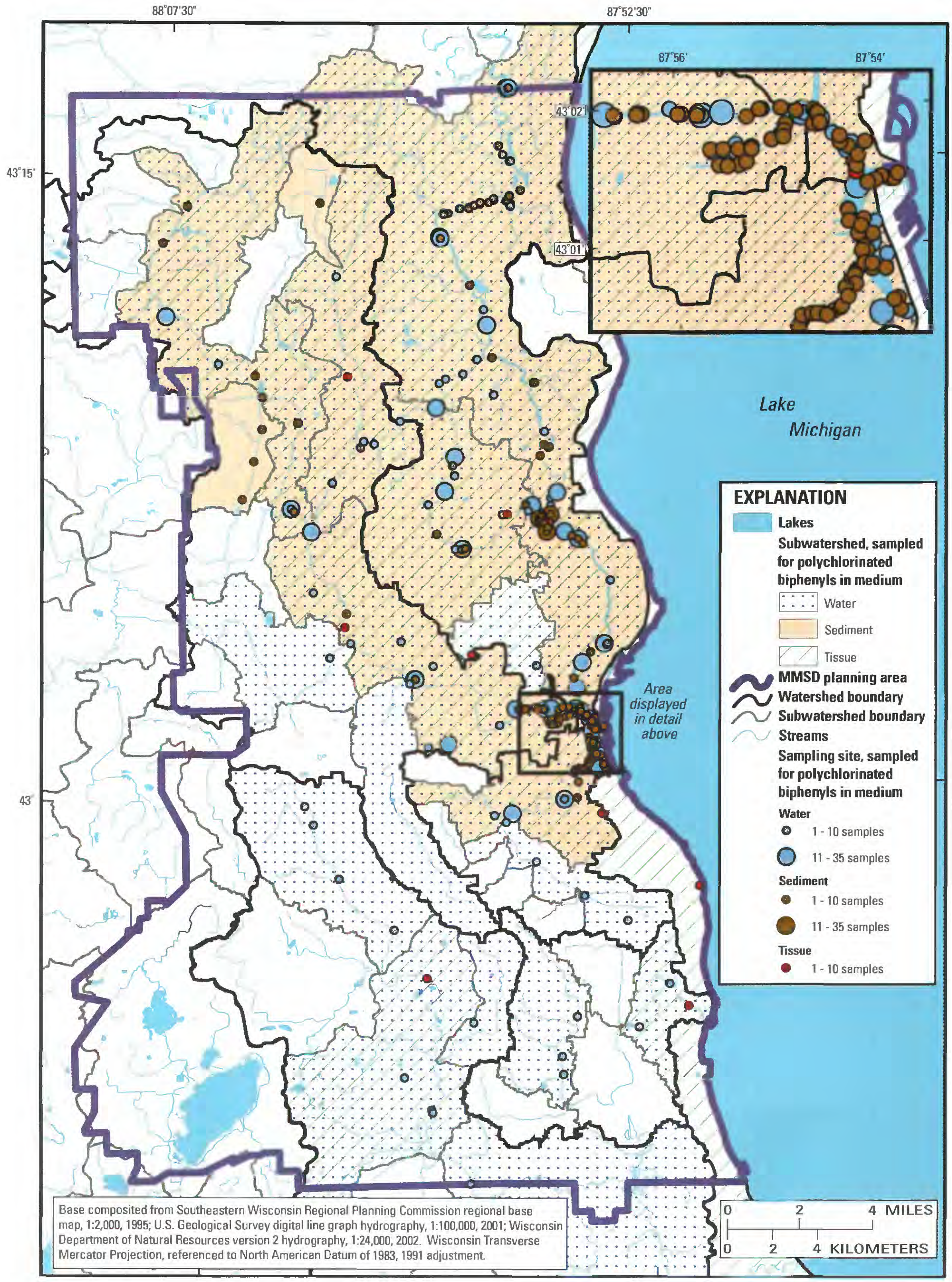

Figure 74. Sites sampled for all polychlorinated biphenyls in water, sediment, and tissue in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 40. Summary statistics for all polychlorinated biphenyls in water, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; WDNR, Wisconsin Department of Natural Resources; --, no data available]

Watershed	Subwatershed	Sites per subwatershed	Count of samples	Count of MMSD results	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date
Kinnickinnic River	Kinnickinnic River	28	140	1,498	6	7	1,313	2,824	1,498	05/27/1975	07/18/2001
	Wilson Park Creek	4	9	0	0	9	0	9	9	05/27/1975	05/17/1988
Menomonee River	Honey Creek	1	2	0	0	2	0	2	2	06/11/1975	09/09/1975
	Little Menomonee River	4	27	0	14	13	0	27	26	06/11/1975	06/29/1990
	Lower Menomonee River	20	174	1,540	24	36	21	1,621	1,569	06/11/1975	07/18/2001
	Upper Menomonee River	4	69	923	0	3	0	926	919	06/11/1975	07/18/2001
	Underwood Creek	2	12	0	10	2	0	12	10	06/11/1975	06/29/1990
Milwaukee River	Combined Sewer Service Area	1	1	0	0	5	0	5	5	02/03/1975	02/03/1975
	Lincoln Creek	10	83	1,050	0	8	0	1,058	1,050	05/29/1975	07/18/2001
	Lower Milwaukee River	41	390	2,982	8,396	5,160	383	16,921	8,987	05/28/1975	07/18/2001
Oak Creek	North Branch Oak Creek	3	11	0	0	11	0	11	11	05/27/1975	11/12/1993
	Lower Oak Creek	2	3	0	0	3	0	3	3	05/27/1975	05/17/1993
Root River	East Branch Root River	1	2	0	0	2	0	2	2	05/27/1975	06/16/1975
	Lower Root River	1	6	84	0	0	0	84	84	09/20/1999	07/11/2001
	Middle Root River	3	8	84	1	1	0	86	85	10/03/1973	07/11/2001
	Upper Root River	4	24	336	0	0	0	336	336	09/20/1999	07/11/2001

Table 41. Summary statistics for all polychlorinated biphenyls in sediment and tissue, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; WDNR, Wisconsin Department of Natural Resources; --, no data available]

		Sediment									Tissue								
Watershed	Subwatershed	Sites per subwatershed	Count of samples	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Sites per subwatershed	Count of samples	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date
Kinnickinnic River	Kinnickinnic River	39	40	1	13	1,691	1,705	77	07/29/1980	06/08/1994	1	1	0	1	0	1	1	10/08/1986	10/08/1986
Lake Michigan Direct	Lake Michigan Direct	--	--	--	--	--	--	--	--	--	1	1	0	1	0	1	1	10/08/1986	10/08/1986
Menomonee River	Lilly Creek	3	3	3	0	0	3	2	11/01/1989	11/01/1989	--	--	--	--	--	--	--	--	--
	Little Menomonee Creek	1	1	1	0	0	1	1	11/07/1989	11/07/1989	--	--	--	--	--	--	--	--	--
	Little Menomonee River	1	1	1	0	0	1	0	11/01/1989	11/01/1989	1	2	0	7	0	7	7	03/24/1987	11/01/1991
	Lower Menomonee River	29	30	2	2	175	179	104	07/29/1980	08/20/1993	1	1	0	5	0	5	5	06/29/1988	06/29/1988
	Upper Menomonee River	6	6	6	0	0	6	4	10/31/1989	11/08/1989	1	1	0	2	0	2	2	04/11/1988	04/11/1988
Milwaukee River	Combined Sewer Service Area	--	--	--	--	--	--	--	--	--	1	1	0	1	0	1	1	05/11/1988	05/11/1988
	Lincoln Creek	6	12	2	0	10	12	6	11/01/1989	10/09/1995	2	4	1	0	3	4	0	09/06/1995	10/09/1995
	Lower Milwaukee River	79	162	8	284	2,676	2,968	204	07/29/1980	08/12/1997	9	10	2	1	12	15	1	06/20/1985	08/19/1997
Oak Creek	Lower Oak Creek	--	--	--	--	--	--	--	--	--	1	1	0	1	0	1	1	05/19/1988	05/19/1988
Root River	Middle Root River	--	--	--	--	--	--	--	--	--	1	1	0	1	0	1	1	06/03/1986	06/03/1986

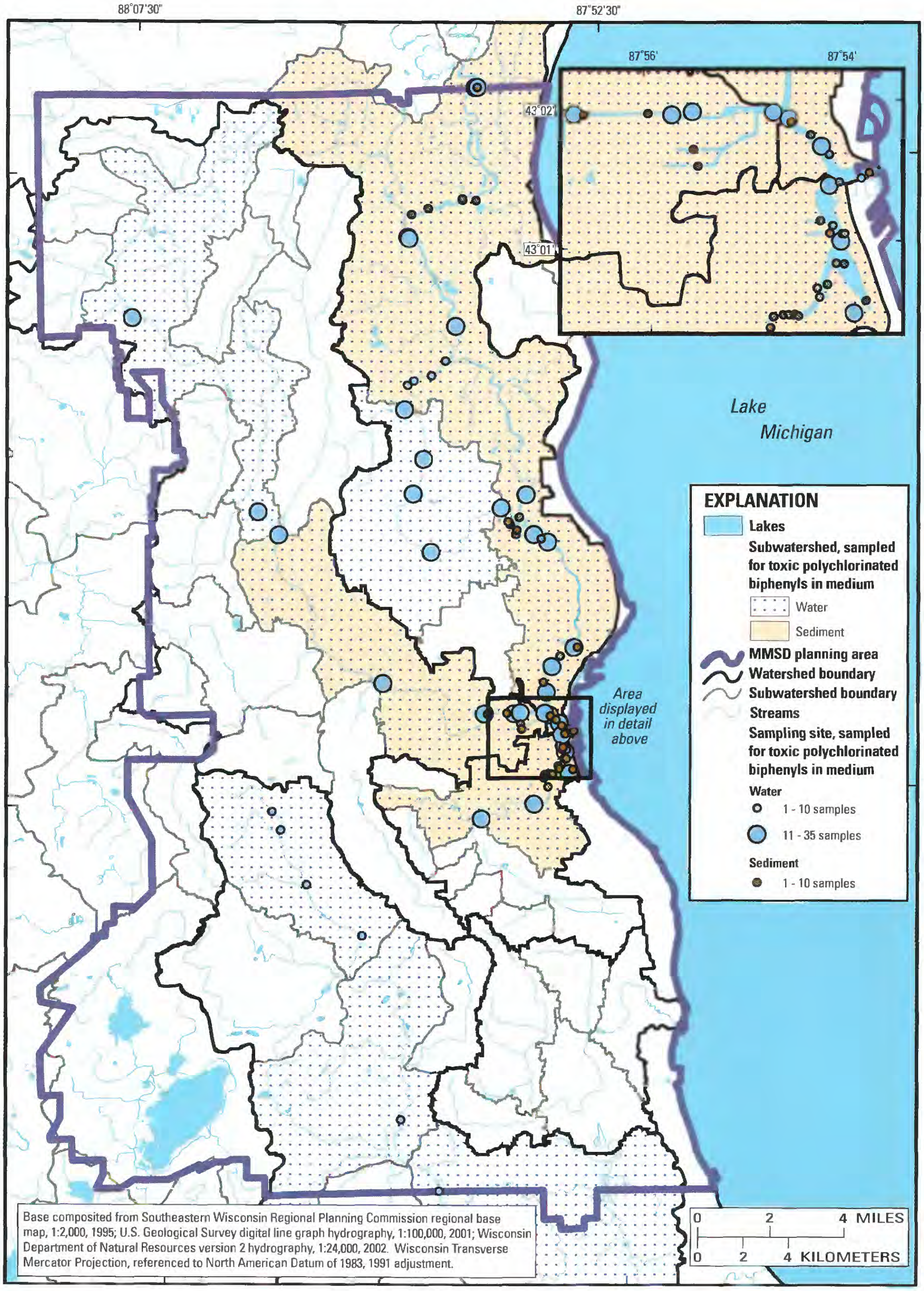

Figure 75. Sites sampled for toxic polychlorinated biphenyls in water and sediment in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 42. Summary statistics for toxic polychlorinated biphenyls in water and sediment, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; WDNR, Wisconsin Department of Natural Resources; --, no data available]

Watershed	Subwatershed	Water										Sediment							
		Sites per subwatershed	Count of samples	Count of MMSD results	Count of USGS results	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date	Sites per subwatershed	Count of samples	Count of STORET results	Count of WDNR results	Count of all results	Number of values below a reporting limit	Earliest sample date	Latest sample date
Kinnickinnic River	Kinnickinnic River	23	127	214	0	0	431	645	214	09/25/1990	07/18/2001	19	20	0	723	723	9	09/25/1990	06/08/1994
Menomonee River	Lower Menomonee River	9	114	220	0	0	12	232	220	10/02/1990	07/18/2001	4	4	0	18	18	0	10/02/1990	10/23/1990
	Upper Menomonee River	3	66	132	0	0	0	132	132	06/19/1995	07/18/2001	--	--	--	--	--	--	--	--
Milwaukee River	Lincoln Creek	5	75	150	0	0	0	150	150	06/23/1997	07/18/2001	--	--	--	--	--	--	--	--
	Lower Milwaukee River	25	358	426	1,540	680	211	2,857	1,035	09/25/1990	07/18/2001	24	41	11	672	683	0	09/25/1990	09/28/1995
Root River	Lower Root River	1	6	12	0	0	0	12	12	09/20/1999	07/11/2001	--	--	--	--	--	--	--	--
	Middle Root River	1	6	12	0	0	0	12	12	09/20/1999	07/11/2001	--	--	--	--	--	--	--	--
	Upper Root River	4	24	48	0	0	0	48	48	09/20/1999	07/11/2001	--	--	--	--	--	--	--	--

Ecological Indicators of Water Quality

Aquatic organisms of a stream corridor are affected by the water and sediment chemistry as well as the flow regime of the river. The makeup of the aquatic community can provide indicators as to the chemical quality of streamwater.

Macroinvertebrates

Macroinvertebrates can be used to assess stream-water quality through a numerical index that allows quantification and evaluation of water quality (Shepard, 2003). Macroinvertebrates are common in most streams, relatively easy to collect and identify, and fairly stationary; many have life cycles of up to a year or greater and therefore are well suited for use in assessing stream-water quality (Shepard, 2003; Hilsenhoff 1977). Macroinvertebrates can indicate environmental change because they are subject to instream extremes during their life cycles (Shepard, 2003).

Two basic metrics that are based on the invertebrate population and can describe water-quality conditions of a stream are the percentage of invertebrates in the insect orders Ephemeroptera-Plecoptera-Trichoptera (EPT) and the Hilsenhoff Biotic Index (HBI). EPT taxa are generally considered to be relatively intolerant of water-quality degradation (Lenat, 1988; Hilsenhoff, 1988 and 1998), so the proportion of EPT individuals and taxa tend to decrease with decreasing water quality. The HBI is a rapid screening method designed to assess oxygen depletion in streams resulting from organic-matter pollution; however, the index may also be sensitive to other types of pollution, such as from some chemicals. The HBI represents the number of arthropod invertebrates in certain species multiplied by their pollution-tolerance value, divided by the number of arthropods in the sample. The HBI scale ranges from 0.00 (Excellent) to 10.00 (Very Poor).

Invertebrate data were collected from 1979 through 1999 for 27 of the 37 subwatersheds in the MMSD planning area. Data for macroinvertebrates in the MMSD Corridor study database came from a database maintained for the WDNR by Stan Szczytko at the University of Wisconsin - Stevens Point. The majority of the data was collected by the WDNR, but other agencies, universities, and groups also contributed samples. Scores for the HBI and percent EPT, community-level data, and counts of species were available for most samples.

Sites with percent EPT falling in the lower quartile (indicating poorer water quality than sites with higher percent EPT) were scattered throughout the planning area but dominated certain subwatersheds, such as Lincoln Creek and the Little Menomonee River (fig. 76). Sites with percent EPT in the upper quartile (indicating better water quality) were also scattered throughout the planning area but were absent in some of the subwatersheds such as Lincoln Creek, Muskego Lake, and Kinnickinnic River (fig. 76).

Subwatersheds with percent EPT in the lower quartile were the Little Menomonee River, Nor-X-Way Channel, Lincoln Creek, Kinnickinnic River, Wilson Park Creek, Deer Creek, East Branch Root River, and North Branch Oak Creek (fig. 76). These low percentages may be due to inadequate habitat for these taxa in low-gradient streams with predominantly clayey surficial deposits; however, they also may indicate degraded water quality. Subwatersheds with percent EPT in the upper quartile were the Middle Root River and Lower Root River (fig. 76). Maximum percent EPT values were calculated for the Lower Root River (92 percent), Lower Milwaukee River (82 percent), Lower Oak Creek (74 percent), and Middle Oak Creek (71 percent) subwatersheds (fig. 77, table 43). The highest median concentrations for subwatersheds were calculated for Lower Root River (51 percent), Middle Root River (50 percent), Middle Oak Creek (40 percent), and Cedar Creek (40 percent) (fig. 77, table 43). Half of the subwatersheds had median percent EPT below 10 percent (fig. 77, table 43).

Sites with HBI scores indicating "poor" or "very poor" water quality were scattered throughout the planning area (fig. 78). Only one site, in the Whitnall Park Creeks subwatershed had an HBI score indicating "very good" water quality (fig. 78). Sites in seven subwatersheds had a "good" HBI water-quality rating (fig. 78).

The Little Menomonee River, East Branch Root River, North Branch Oak Creek, and Upper Oak Creek subwatersheds had HBI scores indicating "very poor" water quality (fig. 78). The Deer Creek, Upper Root River, Lower Root River, Middle Oak Creek, and Lower Oak Creek subwatersheds had HBI scores indicating "poor" water quality (fig. 78). The Little Menomonee Creek and Willow Creek subwatersheds were the only ones to have a "good" HBI water-quality rating (fig. 78). Nearly all subwatersheds had at least one HBI score that indicated "poor" or "very poor" water quality (fig. 79). Subwatersheds with median HBI scores indicating "poor" or "very poor" water quality were the Little Menomonee River, Deer Creek, North Branch Oak Creek, Upper Oak Creek, Middle Oak Creek, Lower Oak Creek, Upper Root River, Lower Root River, and East Branch Root River. Only the Whitnall Park Creeks subwatershed had an HBI score indicating "very good" water quality (fig. 79, table 44). The Little Menomonee River, Little Menomonee Creek, Lower Menomonee River, Upper Menomonee River, West Branch Menomonee River, Willow Creek, Cedar Creek, Lower Milwaukee River, Whitnall Park Creeks, and Mitchell Field Drainage Ditch subwatersheds had at least one sample for which an HBI score indicating a "good" water-quality rating was calculated (fig. 79, table 44). Only the Little Menomonee Creek and Willow Creek subwatersheds had a median HBI score indicating a "good" water-quality rating (fig. 79, table 44).

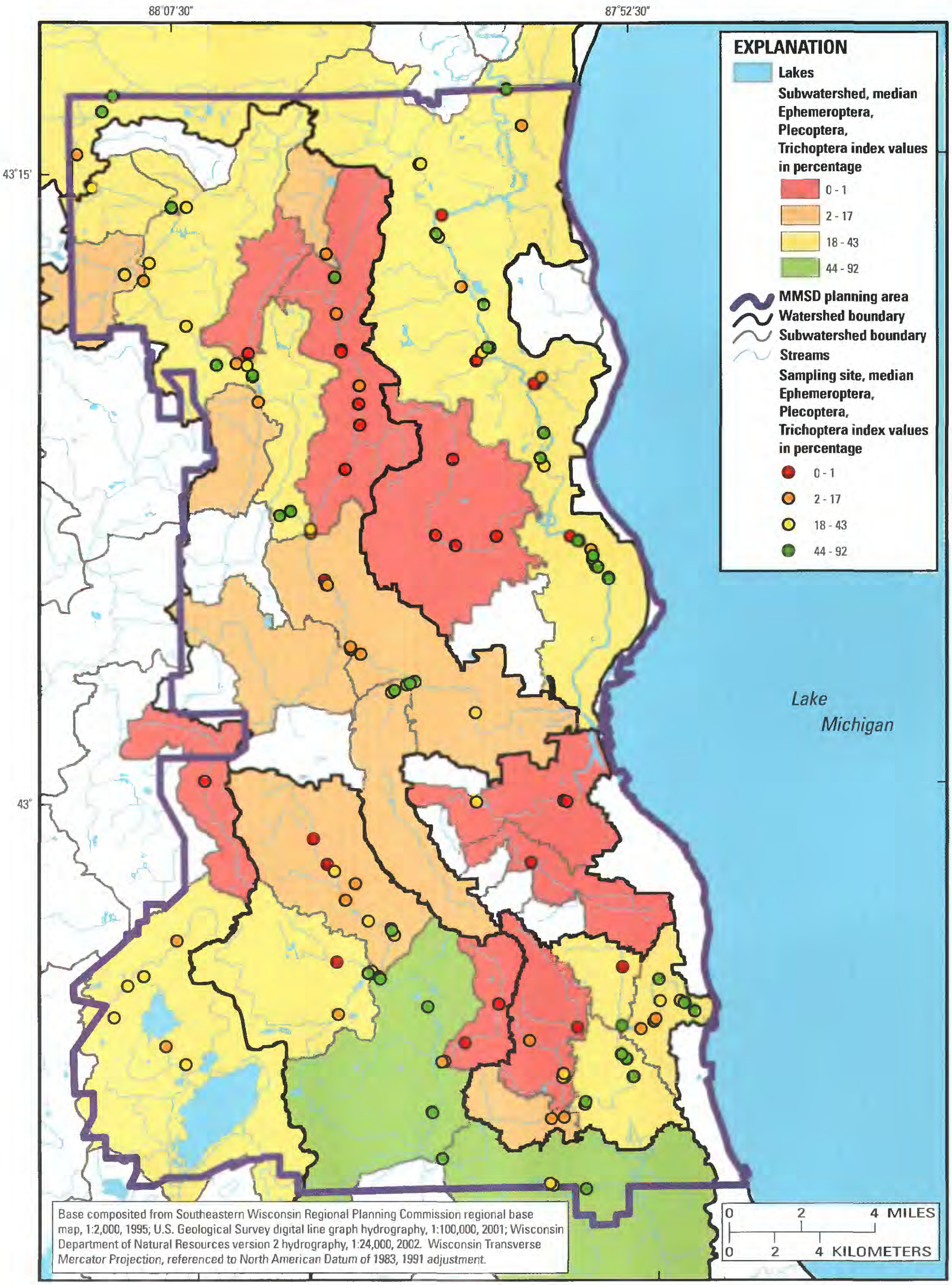

Figure 76. Sites sampled for macroinvertebrates with percent Ephemeroptera, Plecoptera, and Trichoptera in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

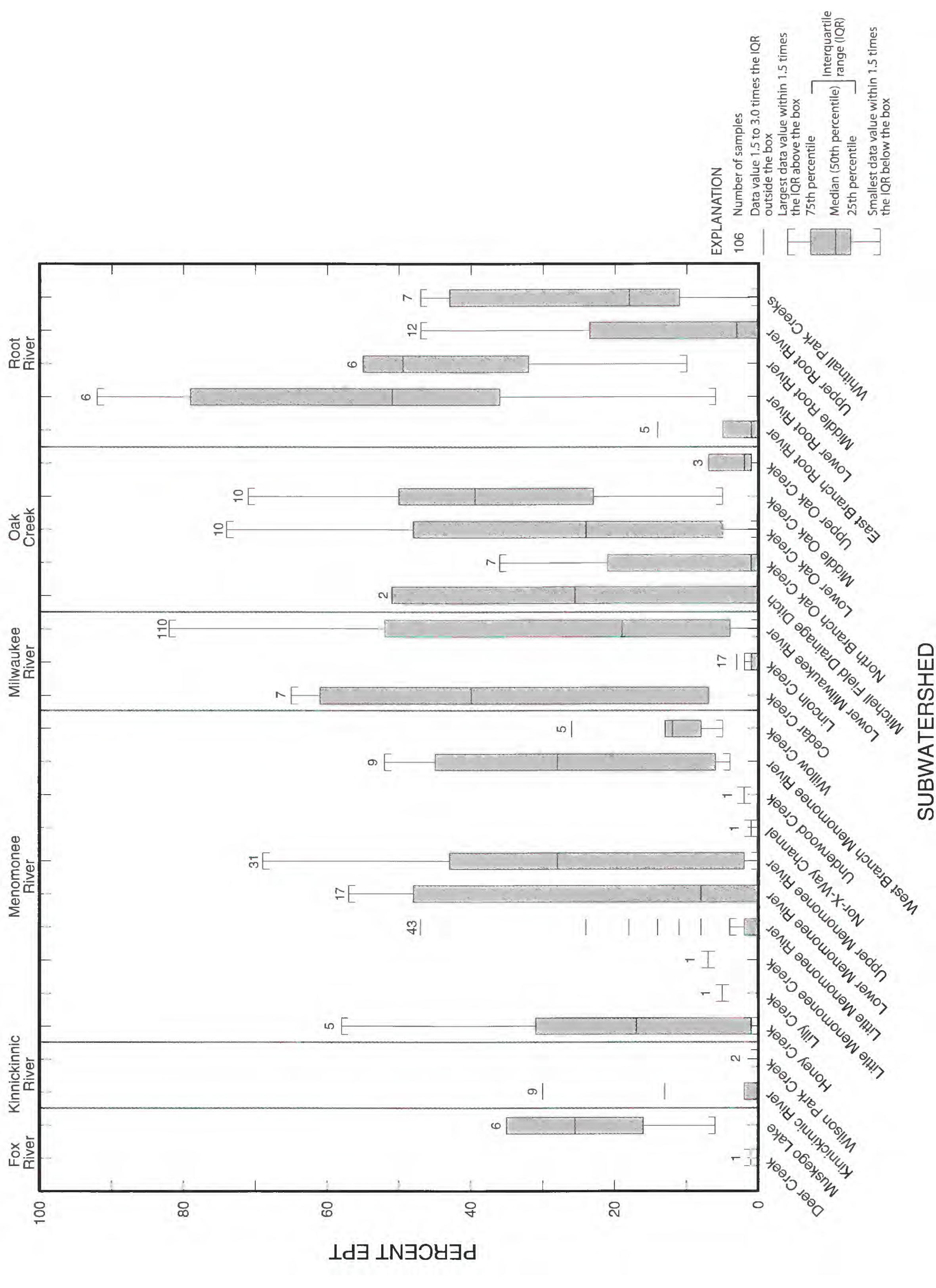

Figure 77. Statistical distribution of percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 43. Summary statistics for percent Ephemeroptera, Plecoptera, Trichoptera, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[Values are expressed as a percentage; values rounded to the nearest whole number]

Watershed	Subwatershed	Count of samples	Sites per subwatershed	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Deer Creek	1	1	05/01/1990	05/01/1990	1	1	1	1	1	1	1	1
	Muskego Lake	6	6	10/06/1992	10/06/1992	6	11	18	26	24	33	35	35
Kinnickinnic River	Kinnickinnic River	9	3	09/29/1987	10/08/1997	0	0	0	0	5	2	16	30
	Wilson Park Creek	2	2	10/09/1997	10/09/1997	0	0	0	0	0	0	0	0
Menomonee River	Honey Creek	5	5	05/18/1979	10/08/1997	0	0	1	17	21	31	47	58
	Lilly Creek	1	1	05/01/1997	05/01/1997	5	5	5	5	5	5	5	5
	Little Menomonee Creek	1	1	05/01/1997	05/01/1997	7	7	7	7	7	7	7	7
	Little Menomonee River	43	11	05/18/1979	05/01/1997	0	0	0	0	3	2	10	47
	Lower Menomonee River	17	11	05/18/1979	05/16/1997	0	0	0	8	20	48	52	57
	Upper Menomonee River	31	15	05/18/1979	10/08/1997	0	0	2	28	24	43	49	69
	Nor-X-Way Channel	1	1	05/29/1997	05/29/1997	1	1	1	1	1	1	1	1
	Underwood Creek	1	1	05/16/1997	05/16/1997	2	2	2	2	2	2	2	2
	West Branch Menomonee River	9	5	05/12/1979	09/29/1999	4	5	6	28	27	45	47	52
	Willow Creek	5	3	05/13/1997	09/29/1999	5	6	8	12	13	13	21	26
Milwaukee River	Cedar Creek	7	5	04/21/1986	09/24/1998	7	7	20	40	37	55	63	65
	Lincoln Creek	17	5	05/11/1992	10/08/1997	0	0	0	0	1	1	1	3
	Lower Milwaukee River	110	46	05/13/1980	12/01/1999	0	0	4	19	28	52	64	82
Oak Creek	Mitchell Field Drainage Ditch	2	2	11/25/1985	10/08/1996	0	5	13	26	26	38	46	51
	North Branch Oak Creek	7	7	05/17/1979	10/09/1997	0	0	1	1	9	12	27	36
	Lower Oak Creek	10	10	05/17/1979	10/08/1996	0	4	6	24	29	46	60	74
	Middle Oak Creek	10	9	05/17/1979	10/09/1997	5	7	23	40	37	50	67	71
	Upper Oak Creek	3	3	05/17/1979	10/08/1996	1	1	2	2	3	4	6	7
Root River	East Branch Root River	5	5	05/21/1979	10/16/1996	0	0	0	1	4	5	10	14
	Lower Root River	6	6	05/31/1979	10/22/1996	6	21	38	51	52	74	86	92
	Middle Root River	6	6	05/31/1979	10/16/1996	10	21	36	50	42	54	55	55
	Upper Root River	12	12	05/31/1979	10/08/1997	0	0	0	3	12	23	28	47
	Whitnall Park Creeks	7	7	05/31/1979	10/11/1996	0	7	13	18	23	36	45	47

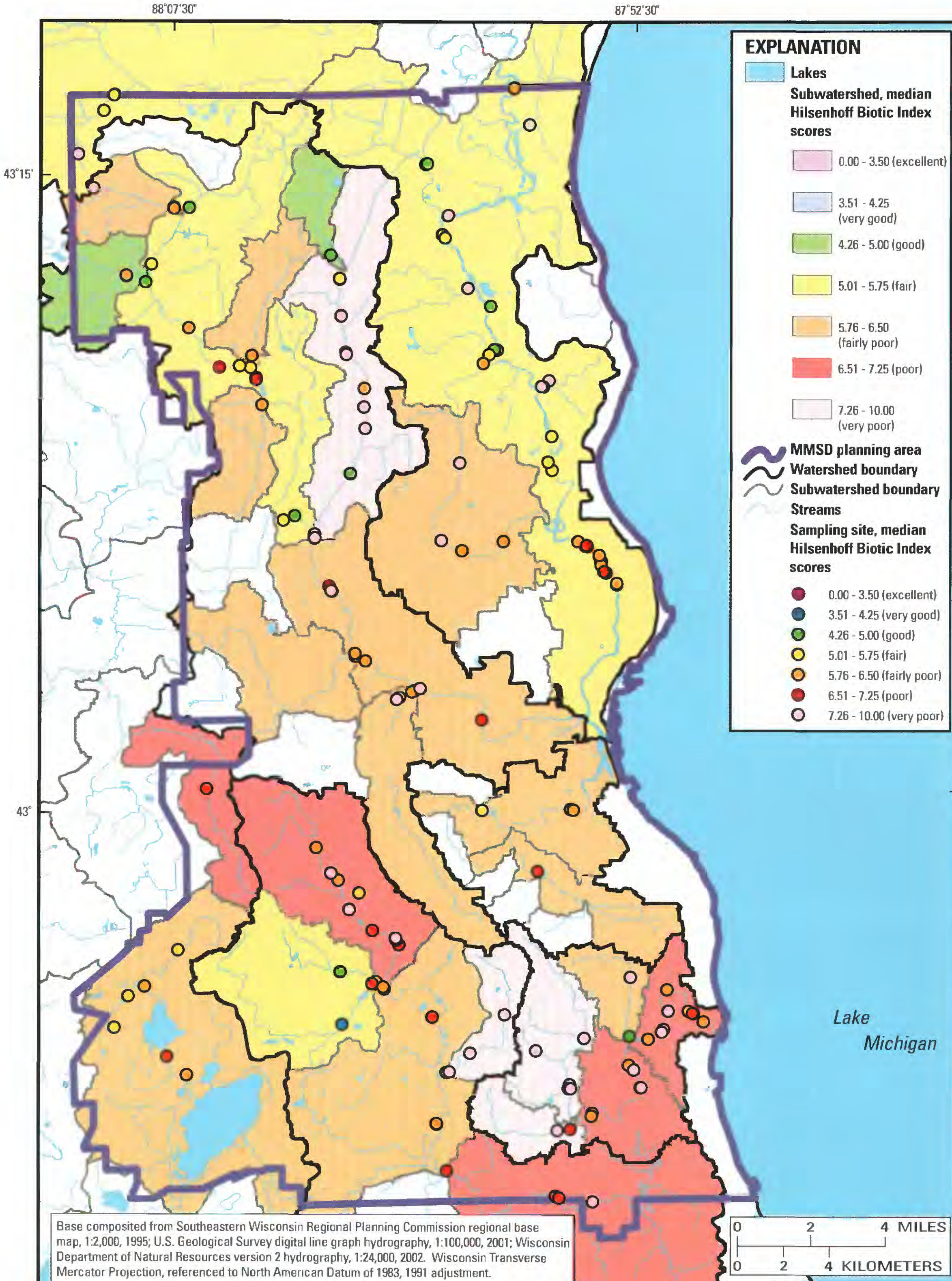

Figure 78. Sites sampled for macroinvertebrates with Hilsenhoff Biotic Index scores in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

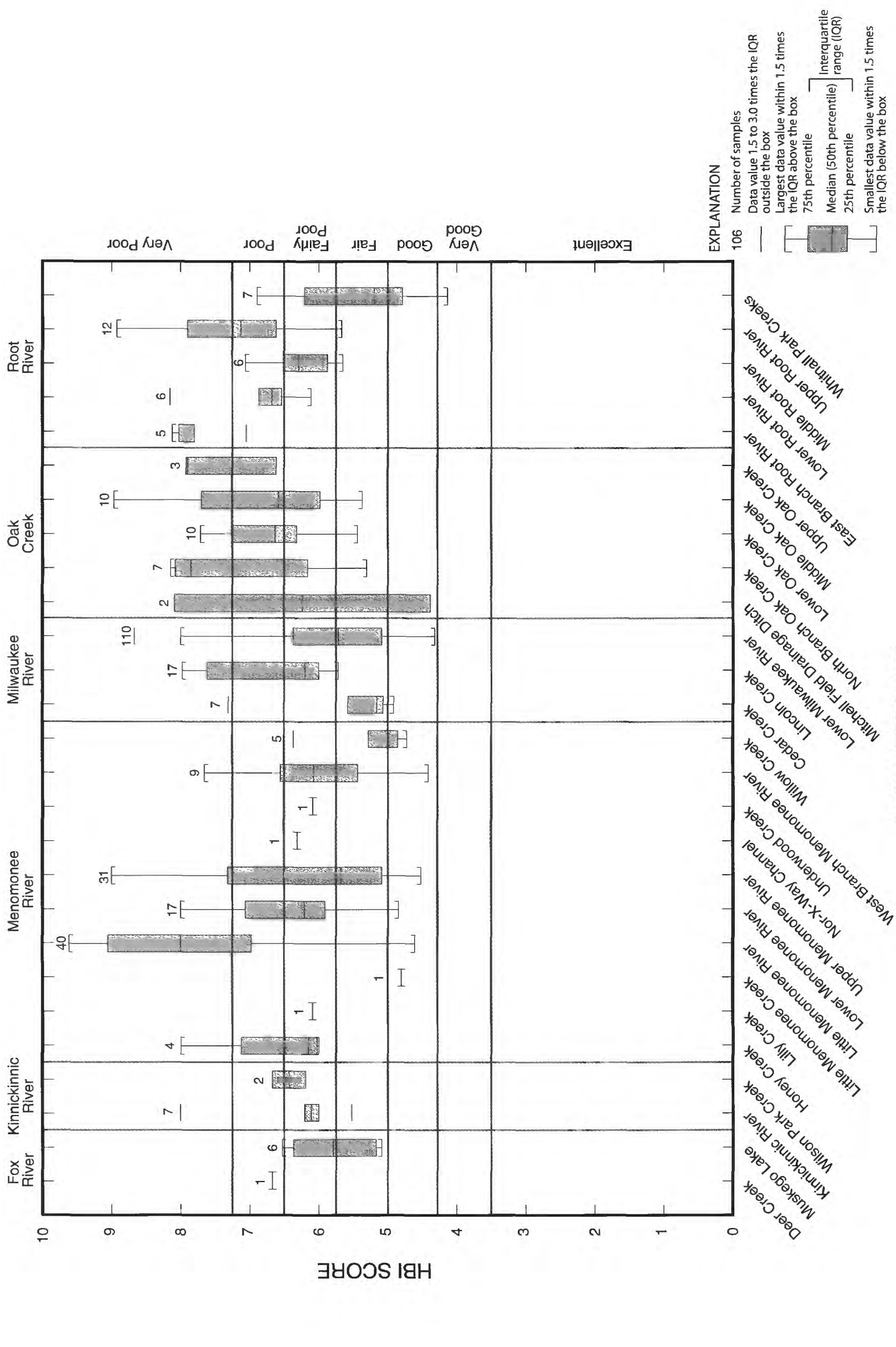

Figure 79. Statistical distribution of Hilsenhoff Biotic Index (HBI) scores in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 44. Summary statistics for Hilsenhoff Biotic Index scores, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[--, no data available; HBI, Hilsenhoff Biotic Index; values rounded to the nearest hundredth; HBI scores and rating: 0.00–3.50, excellent, no apparent organic pollution; 3.51–4.25, very good, possible slight organic pollution; 4.26–5.00, good, some organic pollution probable; 5.01-5.75, fair, fairly substantial pollution likely; 5.76–6.50, fairly poor, substantial pollution likely; 6.51–7.25, poor, very substantial pollution likely; 7.26–10.0, very poor, severe organic pollution likely]

Watershed	Subwatershed	Count of samples	Sites per subwatershed	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Deer Creek	1	1	05/01/1990	05/01/1990	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67
	Muskego Lake	6	6	10/06/1992	10/06/1992	5.09	5.13	5.27	5.80	5.79	6.28	6.45	6.53
Kinnickinnic River	Kinnickinnic River	7	3	09/29/1987	10/08/1997	5.52	5.81	6.00	6.11	6.28	6.17	6.92	8.00
	Wilson Park Creek	2	2	10/09/1997	10/09/1997	6.20	6.25	6.32	6.45	6.45	6.57	6.64	6.69
Menomonee River	Honey Creek	4	4	11/09/1979	10/08/1997	6.00	6.02	6.04	6.15	6.58	6.69	7.48	8.00
	Lilly Creek	1	1	05/01/1997	05/01/1997	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09
	Little Menomonee Creek	1	1	05/01/1997	05/01/1997	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80
	Little Menomonee River	40	11	05/18/1979	05/01/1997	4.61	5.57	6.99	8.00	7.86	9.05	9.44	9.61
	Lower Menomonee River	17	11	05/18/1979	05/16/1997	4.85	5.41	5.91	6.21	6.43	7.07	7.80	8.00
	Upper Menomonee River	31	15	05/18/1979	10/08/1997	4.52	4.91	5.15	5.68	6.26	7.19	8.66	9.00
	Nor-X-Way Channel	1	1	05/29/1997	05/29/1997	6.31	6.31	6.31	6.31	6.31	6.31	6.31	6.31
	Underwood Creek	1	1	05/16/1997	05/16/1997	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10
	West Branch Menomonee River	9	5	05/12/1979	09/29/1999	4.43	4.57	5.45	6.09	6.04	6.57	7.61	7.67
	Willow Creek	5	3	05/13/1997	09/29/1999	4.74	4.79	4.87	4.87	5.23	5.30	5.95	6.38
Milwaukee River	Cedar Creek	7	5	04/21/1986	09/24/1998	4.92	5.01	5.08	5.16	5.48	5.40	6.27	7.31
	Lincoln Creek	17	5	05/11/1992	10/08/1997	5.72	5.87	6.00	6.20	6.67	7.62	7.83	7.98
	Lower Milwaukee River	110	46	05/13/1980	12/01/1999	4.32	4.66	5.09	5.72	5.88	6.35	7.65	8.67
Oak Creek	Mitchell Field Drainage Ditch	2	2	11/25/1985	10/08/1996	4.38	4.75	5.31	6.24	6.24	7.16	7.72	8.09
	North Branch Oak Creek	7	7	05/17/1979	10/09/1997	5.31	5.82	6.68	7.85	7.26	8.07	8.11	8.15
	Lower Oak Creek	10	10	05/17/1979	10/08/1996	5.44	5.73	6.33	6.64	6.67	7.18	7.64	7.71
	Middle Oak Creek	10	9	05/17/1979	10/09/1997	5.37	5.72	6.06	6.58	6.80	7.50	7.98	8.96
	Upper Oak Creek	3	3	05/17/1979	10/08/1996	6.62	6.88	7.26	7.90	7.48	7.91	7.92	7.92
Root River	East Branch Root River	5	5	05/21/1979	10/16/1996	7.05	7.35	7.80	7.80	7.76	8.03	8.08	8.12
	Lower Root River	6	6	05/31/1979	10/22/1996	6.11	6.33	6.57	6.68	6.84	6.83	7.51	8.15
	Middle Root River	6	6	05/31/1979	10/16/1996	5.65	5.76	5.97	6.29	6.28	6.46	6.79	7.06
	Upper Root River	12	12	05/31/1979	10/08/1997	5.67	6.43	6.71	7.13	7.24	7.85	8.25	8.92
	Whitnall Park Creeks	7	7	05/31/1979	10/11/1996	4.15	4.54	4.98	5.21	5.39	5.76	6.50	6.91

Fish

Fish data are often used to assess and monitor environmental quality in an approach generally termed "bioassessment" or "biomonitoring" (Plafkin and others, 1989). These bioassessment and biomonitoring techniques have been shown to be a useful way to detect and quantify environmental degradation in aquatic systems (Lyons, 1992b). Of all types of biota, fish, along with macroinvertebrates, have been shown to be particularly effective for use in bioassessments. Wisconsin began development of an Index of Biotic Integrity (IBI) for fish in warmwater streams of the State in the mid-1980s and published the resulting "how to" guide in 1992 (Lyons, 1992b). The IBI was originally developed during the late 1970s and early 1980s to assess biotic integrity and environmental quality in small streams in Indiana and Illinois (Karr, 1981; Karr and others, 1986). This original IBI was modified to fit the physical and biological characteristics of streams throughout North America (Lyons, 1992b). Biotic integrity has been defined as "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and natural habitat of the region" (Karr and Dudley, 1981).

Fish data in the MMSD Corridor Study database came from the WDNR Biology database (as maintained by the WDNR Bureau of Fisheries Management and Habitat Protection) and a series of fish surveys completed by the WDNR in and around the Milwaukee River. Counts of species, and in some cases length, weight, and sex, were available for fish samples. Locations of WDNR Biology database and WDNR Milwaukee fish survey sampling sites are shown in figure 80.

Fish collection has taken place in all but the smallest headwater streams in the MMSD planning area at one time or another (fig. 80). The Milwaukee River watershed has had the most samples collected since 1990 (table 45). Of the three decades for which data exist, the 1970s had the most extensive fish sampling, with fewer sites sampled in each succeeding decade (2000–2002 samples have been grouped with samples collected through the 1990s). Twenty-six subwatersheds were sampled in the 1970s, 21 subwatersheds in the 1980s, and 12 subwatersheds in the 1990s through 2001 (table 45). On the basis of data in the MMSD Corridor Study database, a total of 73 species of fish have been found in water bodies in the MMSD planning area. In addition, various hybrid sunfishes, minnows, and bullheads have been documented.

IBI scores indicating "poor" or "very poor" water quality were assigned to sites in all subwatersheds with data collected during 1990–2002 (fig. 81). At several sites in the Lower Milwaukee River subwatershed, IBI scores indicated "good" or "excellent" water quality (fig 81). There was little IBI data for the southern part of the planning area (fig. 81).

The Lincoln Creek subwatershed (10, "very poor") had the lowest median IBI score for data collected since 1990 (table 45). The Lower Milwaukee River subwatershed had the highest median IBI score of 62, indicating "good" conditions (table 45).

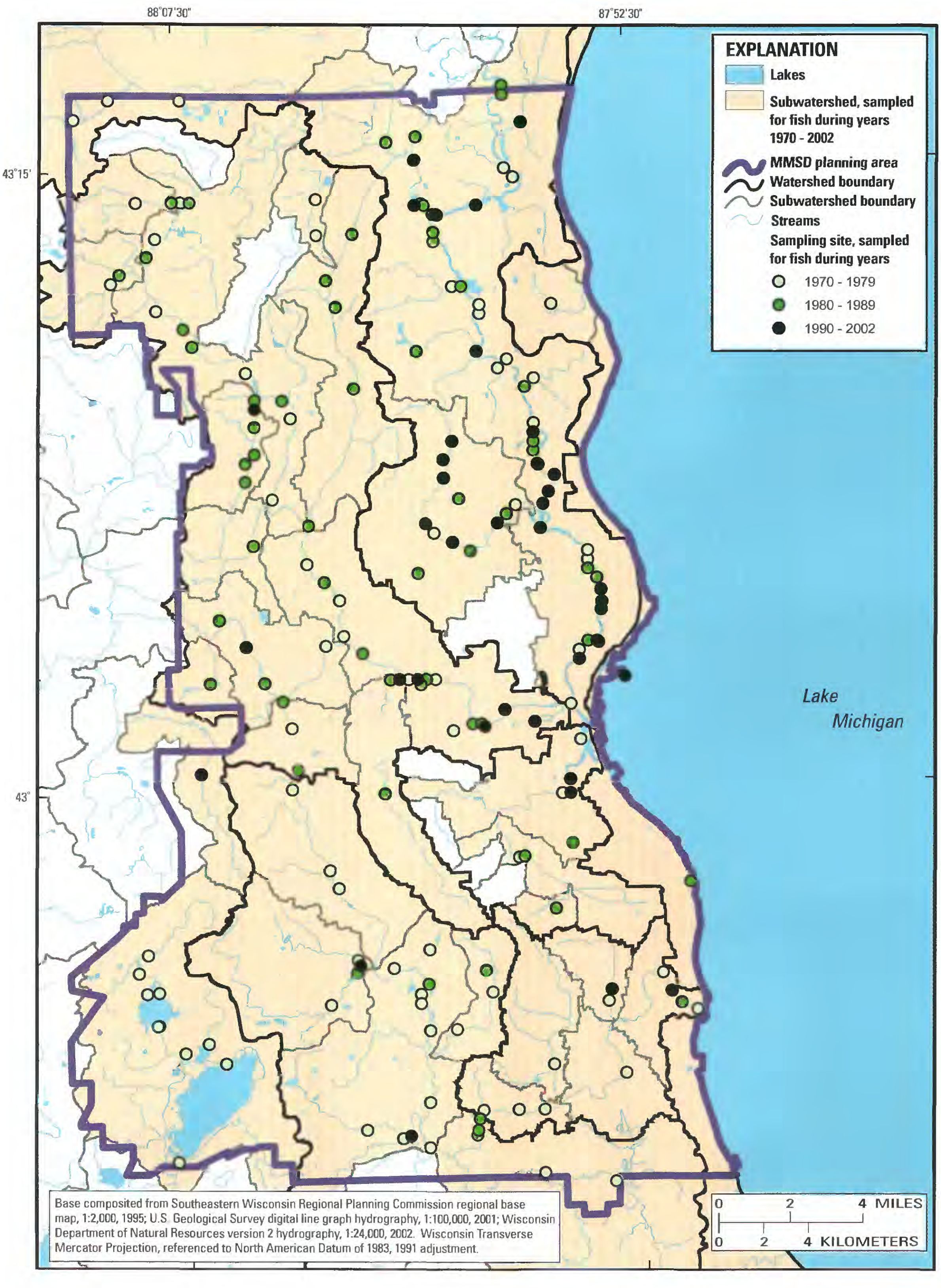

Figure 80. Sites sampled for fish in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 45. Summary statistics for fish, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[--, no data available; IBI, Warmwater Index of Biotic Integrity: IBI scores and rating: 0–19, very poor: 20–29 poor: 30–49, fair, 50–64, good: 65–100 excellent]

Watershed	Subwatershed	1970-79					1980-89					1990-02					
		Count of sites	Count of samples	Count of distinct taxon	Earliest sample date	Latest sample date	Count of sites	Count of samples	Count of distinct taxon	Earliest sample date	Latest sample date	Count of sites	Count of samples	Count of distinct taxon	Earliest sample date	Latest sample date	Median IBI scores
Fox River	Deer Creek	--	--	--	--	--	--	--	--	--	--	1	1	5	08/23/1990	08/23/1990	--
	Muskego Lake	10	15	37	10/16/1972	07/13/1978	--	--	--	--	--	--	--	--	--	--	--
Kinnickinnic River	Holmes Avenue Creek	--	--	--	--	--	1	1	5	08/18/1981	08/18/1981	--	--	--	--	--	--
	Kinnickinnic River	2	2	12	11/10/1977	10/09/1979	1	1	6	08/20/1981	08/20/1981	2	4	13	07/16/1997	08/04/1997	20
	Wilson Park Creek	1	1	1	09/08/1975	09/08/1975	1	2	10	08/19/1981	08/31/1981	--	--	--	--	--	--
Lake Michigan Direct	Lake Michigan Direct	--	--	--	--	--	1	2	6	08/18/1981	08/31/1981	--	--	--	--	--	--
Lake Michigan Tributary	Fish Creek	1	1	4	09/09/1975	09/09/1975	--	--	--	--	--	--	--	--	--	--	--
Menomonee River	Butler Ditch	--	--	--	--	--	1	1	2	05/24/1984	05/24/1984	--	--	--	--	--	--
	Dousman Ditch	--	--	--	--	--	1	1	4	10/04/1984	10/04/1984	--	--	--	--	--	--
	Honey Creek	2	2	5	08/07/1973	09/10/1973	2	3	14	08/19/1981	07/27/1984	2	5	13	06/05/1991	06/17/1993	20
	Lilly Creek	--	--	--	--	--	6	10	20	05/10/1984	09/13/1985	1	3	12	06/20/1991	06/02/1993	19
	Little Menomonee Creek	2	2	7	08/07/1973	08/07/1973	--	--	--	--	--	--	--	--	--	--	--
	Little Menomonee River	2	2	8	08/07/1973	08/07/1973	4	4	12	05/16/1984	07/25/1984	--	--	--	--	--	--
	Lower Menomonee River	7	7	13	08/07/1973	09/10/1973	6	6	18	08/18/1981	08/26/1988	4	6	26	06/11/1991	03/28/2000	15
	Upper Menomonee River	8	8	19	08/07/1973	08/07/1973	7	7	26	05/17/1984	07/27/1984	--	--	--	--	--	--
	South Branch Underwood Creek	1	1	8	09/10/1973	09/10/1973	2	3	12	08/17/1981	10/04/1984	--	--	--	--	--	--
	Underwood Creek	1	1	4	08/07/1973	08/07/1973	3	4	12	05/23/1984	10/04/1984	1	4	11	06/19/1991	06/09/1994	15
	West Branch Menomonee River	1	1	10	08/07/1973	08/07/1973	--	--	--	--	--	--	--	--	--	--	--
	Willow Creek	1	1	12	08/07/1973	08/07/1973	1	1	12	05/17/1984	05/17/1984	--	--	--	--	--	--
Milwaukee River	Cedar Creek	3	5	23	06/24/1975	08/15/1978	--	--	--	--	--	--	--	--	--	--	--
	Lincoln Creek	2	2	13	09/09/1975	09/09/1975	4	5	23	08/17/1981	07/27/1984	7	8	8	06/03/1992	06/03/1994	10
	Lower Milwaukee River	17	17	40	10/10/1970	10/09/1979	20	22	49	09/16/1981	05/05/1986	20	35	54	06/08/1994	09/05/2001	62

Table 45. Summary statistics for fish, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002—Continued

[--, no data available; IBI, Warmwater Index of Biotic Integrity; IBI scores and rating: 0–19, very poor; 20–29 poor; 30–49, fair, 50–64, good; 65–100 excellent]

		1970-79					1980-89					1990-02					
Watershed	Subwatershed	Count of sites	Count of samples	Count of distinct taxon	Earliest sample date	Latest sample date	Count of sites	Count of samples	Count of distinct taxon	Earliest sample date	Latest sample date	Count of sites	Count of samples	Count of distinct taxon	Earliest sample date	Latest sample date	Median IBI scores
Oak Creek	Mitchell Field Drainage Ditch	1	1	6	09/08/1975	09/08/1975	--	--	--	--	--	1	1	3	08/02/2001	08/02/2001	--
	North Branch Oak Creek	1	1	6	09/08/1975	09/08/1975	--	--	--	--	--	--	--	--	--	--	--
	Lower Oak Creek	2	2	7	03/22/1973	09/08/1975	1	2	9	08/18/1981	08/31/1981	1	3	10	06/12/1991	06/03/1993	17
	Middle Oak Creek	1	1	7	09/08/1975	09/08/1975	--	--	--	--	--	--	--	--	--	--	--
	Upper Oak Creek	3	3	6	03/22/1973	09/05/1975	--	--	--	--	--	--	--	--	--	--	--
Root River	East Branch Root River	2	2	5	09/08/1975	08/04/1976	1	2	8	08/19/1981	08/26/1981	--	--	--	--	--	--
	Lower Root River	2	2	19	09/05/1975	06/06/1979	3	5	8	08/20/1981	08/31/1981	--	--	--	--	--	--
	Middle Root River	9	10	24	09/25/1971	05/10/1979	1	2	13	08/19/1981	08/26/1981	1	1	5	09/04/2001	09/04/2001	--
	Upper Root River	3	3	6	07/27/1976	05/10/1979	--	--	--	--	--	--	--	--	--	--	--
	Whitnall Park Creeks	2	3	19	07/27/1976	05/10/1979	1	2	10	08/20/1981	08/27/1981	1	1	6	07/31/2001	07/31/2001	--

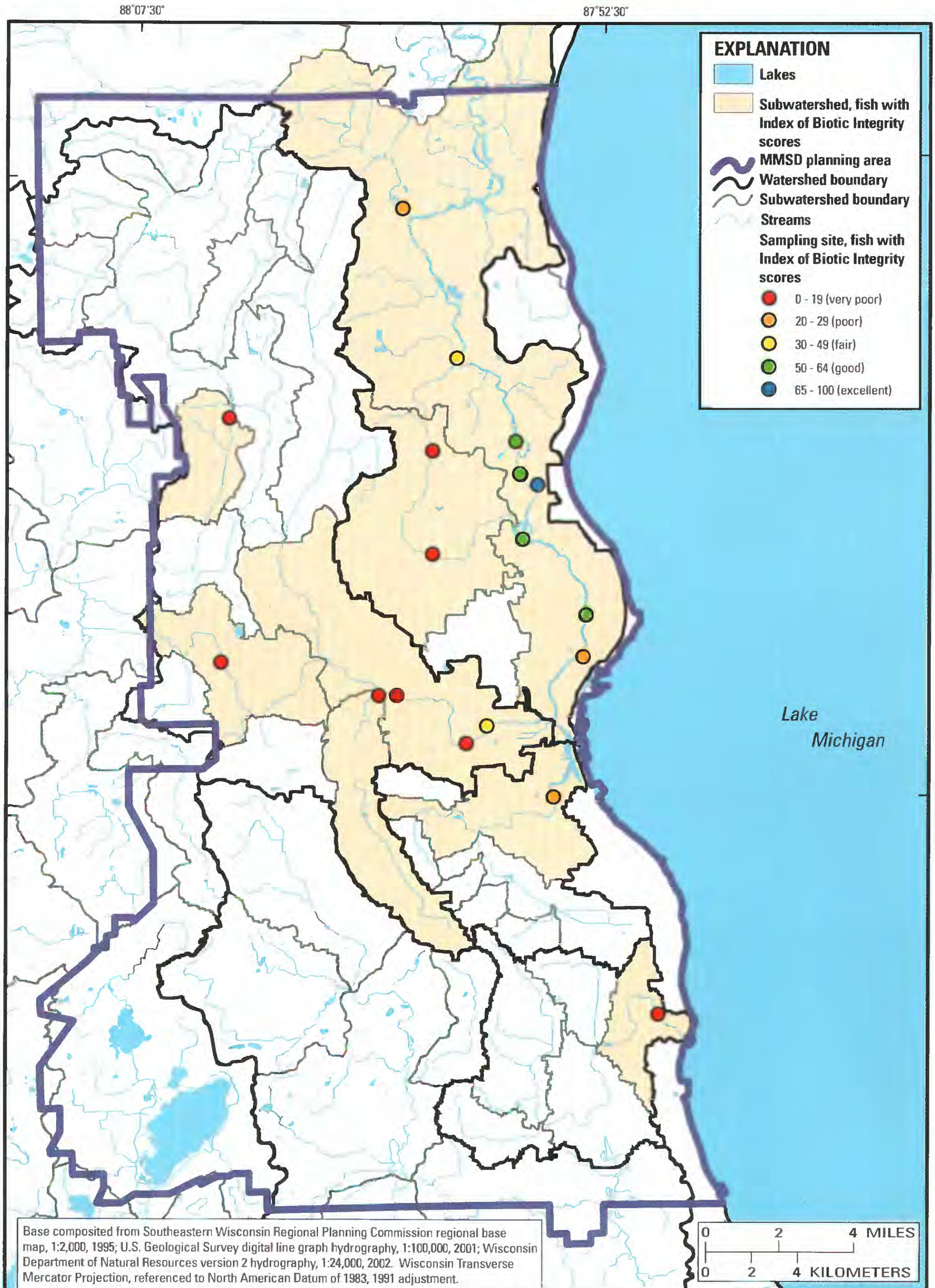

Figure 81. Sites sampled for fish with Index of Biotic Integrity scores for data since 1990 in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Chlorophyll *a*

Chlorophyll *a* is perhaps the most common algal pigment found in most natural freshwaters. Algae synthesize chlorophyll *a* as a means to harvest energy for sunlight during photosynthesis. Chlorophyll *a* is generally assumed to be a good proxy for algal biomass, although cellular quotas can vary with the amount of photosynthetically available radiation at a given time. Chlorophyll *a* is degraded abiotically or microbially either in dead algal cells or in zooplankton guts, producing pigment degradates including pheophytin and pheophorbide. These compounds are sometimes summed with chlorophyll *a* to get total pigments, a measure that better reflects the total amount of algal biomass as opposed to live algae, which only is indicated by chlorophyll *a*.

Chlorophyll *a* (along with nitrogen, phosphorus, and turbidity) has been selected by the USEPA as a key nutrient criterion indicator in streams. Its importance is its biological response to the presence of limiting nutrients (mainly phosphorus) in surface waters and as an indicator of potential oxygen-consuming material. For the MMSD planning area, a concentration of 0.55 mg/m^3 is proposed as a maximum allowable limit (U.S. Environmental Protection Agency, 2000a).

Median concentrations of chlorophyll *a* at all sites exceeded the 0.55 mg/m^3 USEPA proposed nutrient criterion (fig. 82). Sites with median concentrations in the upper quartile were mainly clustered in the Lower Milwaukee River subwatershed (fig. 82). Sites with median concentrations in the lower quartile were found primarily in the Upper Root River, Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek subwatersheds (fig. 82).

The median concentration of chlorophyll *a* in the Lower Milwaukee River subwatershed fell in the upper quartile (fig. 82). The Upper Root River, Upper Oak Creek, and Middle Oak Creek had median concentrations in the lower quartile (fig. 82). The majority of samples had concentrations above the 0.55 mg/m^3 USEPA proposed nutrient criteria (fig. 83, table 46). The highest maximum concentrations were measured in the Lower Milwaukee River (628.41 mg/m^3), Kinnickinnic River (358.52 mg/m^3), and Upper Menomonee River (318.23 mg/m^3) subwatersheds (fig. 83, table 46). The highest median concentration of 11.70 mg/m^3 was measured in the Lower Milwaukee River subwatershed (fig. 83, table 46). The lowest median concentration of 1.46 mg/m^3 was measured in the Upper Root River subwatershed (fig. 83, table 46).

There was some indication of higher chlorophyll *a* concentrations during the spring and fall, corresponding to classical algal bloom periods, at the Kinnickinnic River, Menomonee River, and Milwaukee River sites, although the pattern was not particularly pronounced (fig. 84). Trends in chlorophyll *a* by sample year indicated an absence of relatively high concentrations at three of the five highlighted sites (Kinnickinnic, Menomonee, and Milwaukee Rivers) during the period between the late 1980s and early 1990s (fig. 85). This might be related to low rainfall and concomitantly low nutrient inputs during this time period.

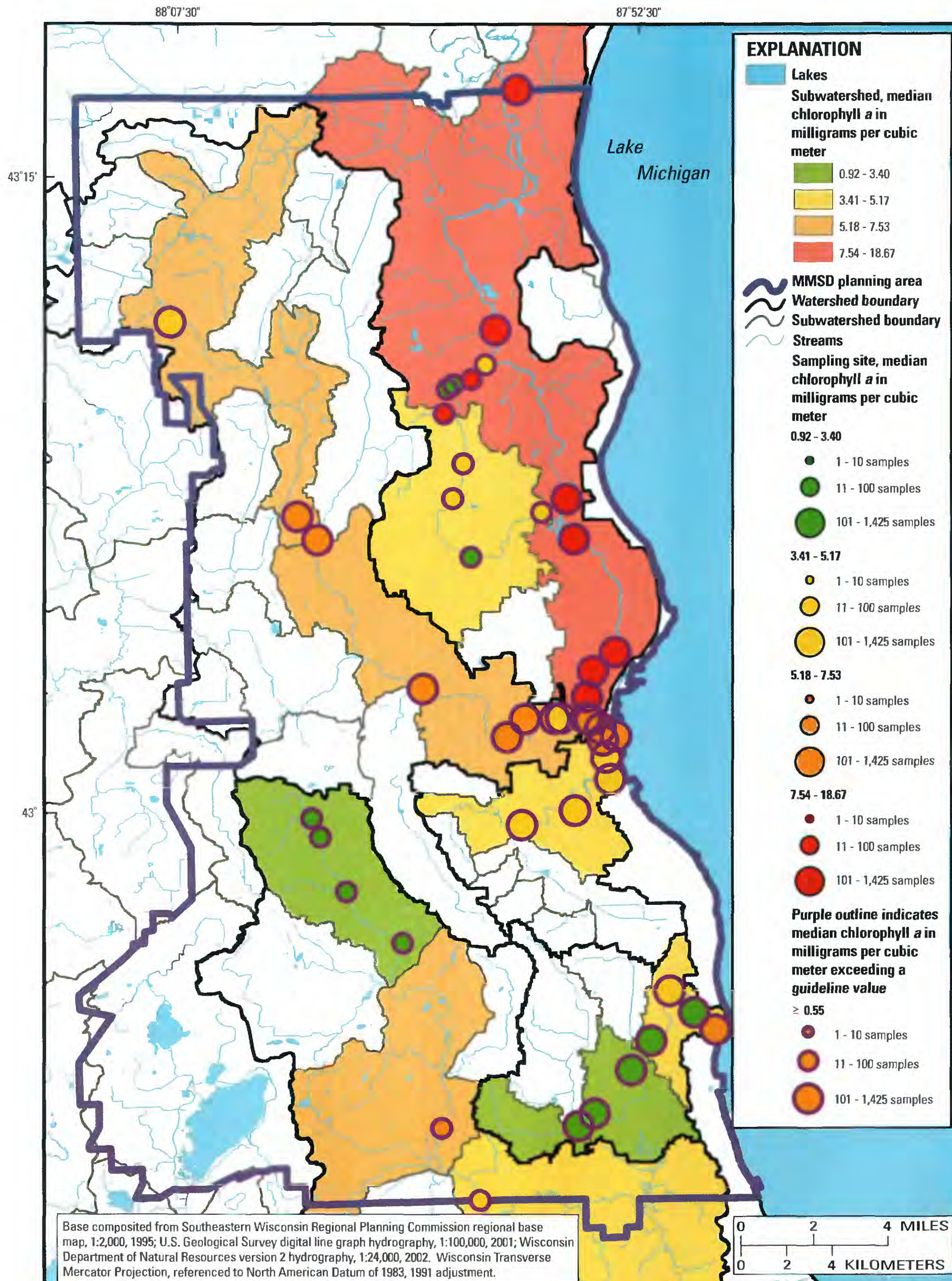

Figure 82. Sites sampled for chlorophyll *a* in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

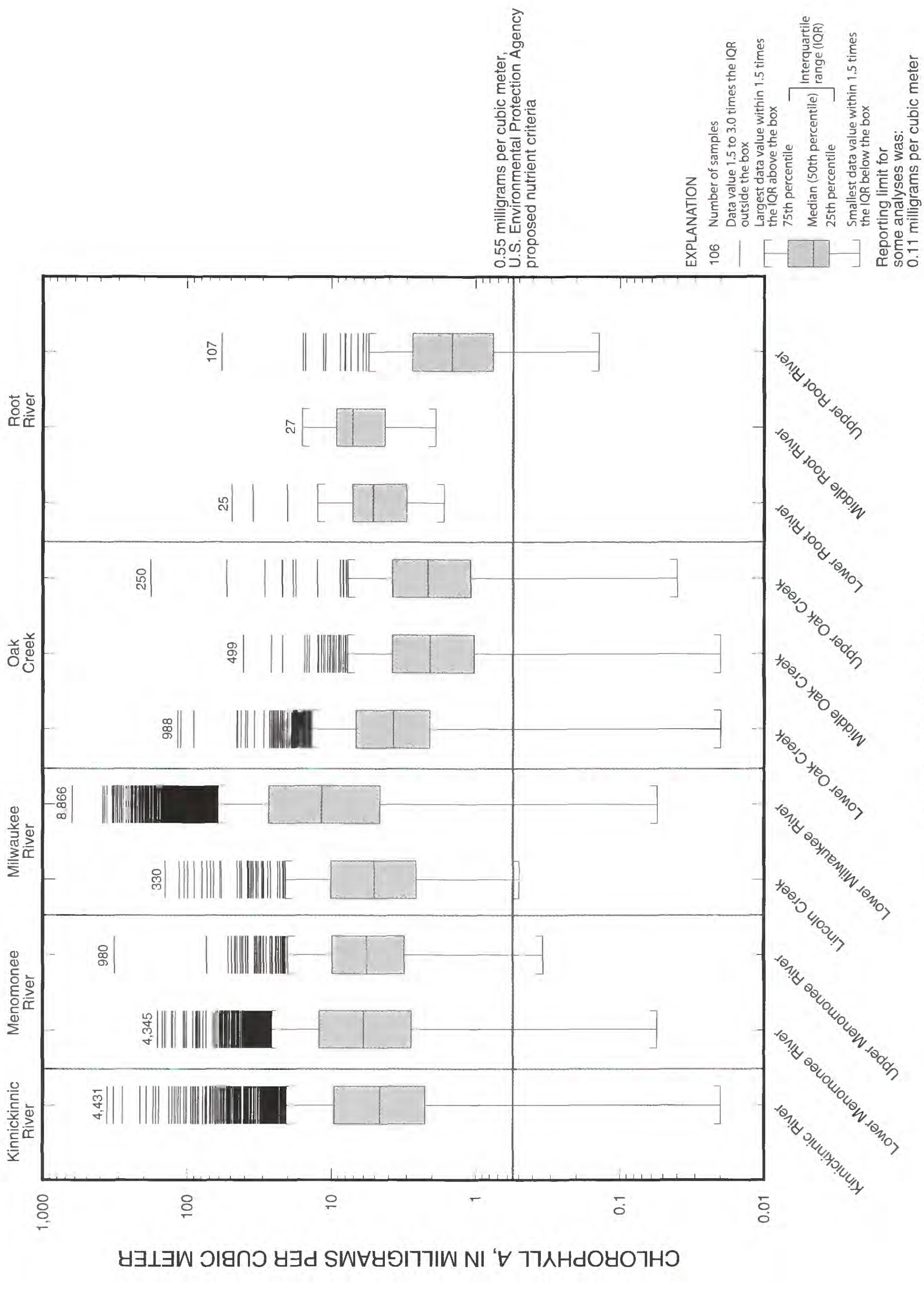

Figure 83. Statistical distribution of chlorophyll *a* concentrations in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

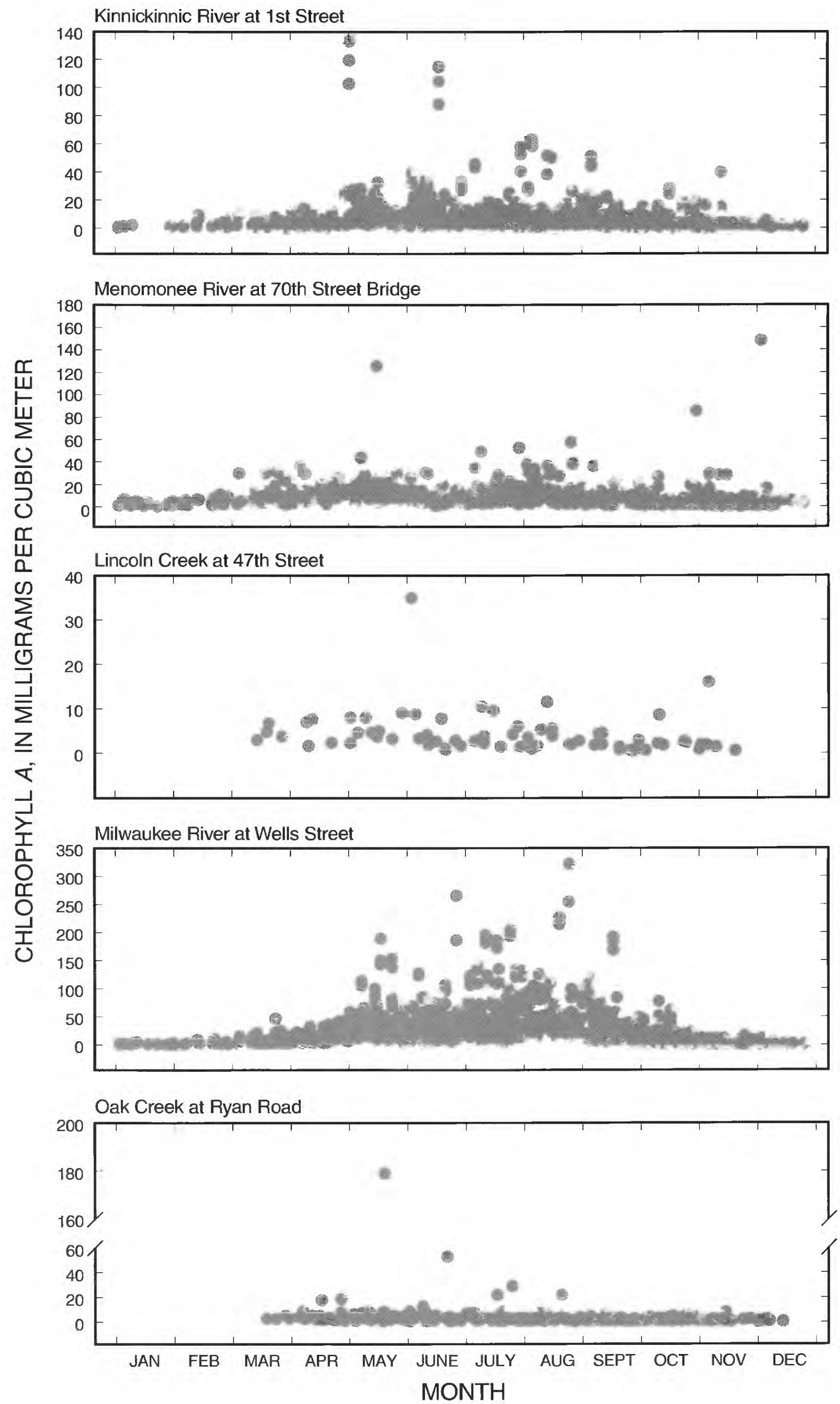

Figure 84. Seasonality of chlorophyll *a* for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

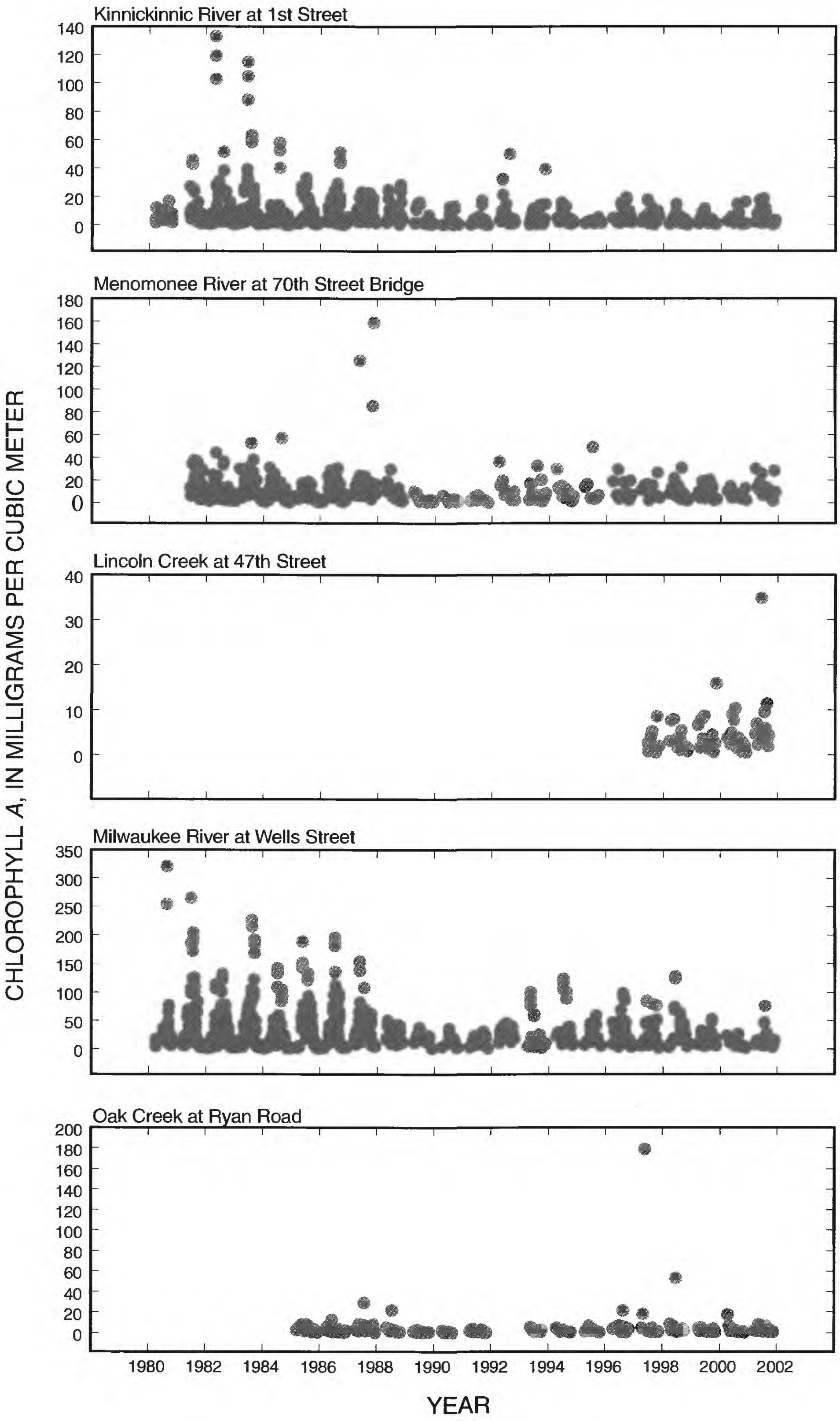

Figure 85. Trends of chlorophyll *a* for selected sites in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 46. Summary statistics for chlorophyll *a*, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; --, no data available; values are expressed in milligrams per cubic meter (mg/m^3); values rounded to the nearest hundredth; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Number of values below reporting limit	Detection limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	5	4,431	0	--	05/21/1979	11/27/2001	0.02	1.17	2.24	4.62	8.40	9.53	17.69	358.52
Menomonee River	Lower Menomonee River	6	4,345	1	0.11	05/21/1979	11/27/2001	.06	1.56	2.79	5.99	9.71	12.12	21.34	159.41
	Upper Menomonee River	3	980	0	--	05/24/1982	11/27/2001	.34	1.75	3.12	5.67	8.13	9.88	16.23	318.23
Milwaukee River	Lincoln Creek	5	330	0	--	06/18/1997	11/27/2001	.50	1.42	2.59	5.07	10.73	10.04	23.84	141.64
	Lower Milwaukee River	14	8,866	2	0.11	04/18/1979	11/27/2001	.06	2.20	4.61	11.70	23.48	27.22	59.30	628.41
Oak Creek	Lower Oak Creek	4	988	0	--	03/21/1985	11/19/2001	.02	.98	2.08	3.74	5.71	6.74	12.40	116.00
	Middle Oak Creek	2	499	0	--	03/21/1985	11/19/2001	.02	.62	1.03	2.07	2.96	3.74	6.06	40.70
	Upper Oak Creek	1	250	0	--	03/21/1985	11/19/2001	.04	.65	1.08	2.14	3.95	3.78	6.45	178.90
Root River	Lower Root River	1	25	0	--	09/07/1999	10/10/2001	1.66	2.23	3.02	5.15	8.69	7.15	17.12	48.90
	Middle Root River	1	27	0	--	09/07/1999	10/10/2001	1.90	2.88	4.58	7.17	7.33	9.24	13.01	16.00
	Upper Root River	4	107	0	--	09/07/1999	10/10/2001	.14	.31	.78	1.46	2.95	2.74	5.90	57.61

Habitat and Geomorphic Data

Habitat and geomorphic data in the MMSD Corridor Study database were collected by WDNR and MMSD (through a contract with Inter-Fluve, Inc.) (fig. 86, table 47).

Habitat data in the MMSD Corridor Study database were collected by the WDNR starting in 1991 and are derived from the WDNR Biology database. The types of information collected in WDNR habitat surveys include the percentage of canopy/shading of the stream channel, type of fish cover, stream-bottom cover, percentage macrophyte cover, and many other channel characteristics. These data can be used to analyze the change in habitat over time, determine aspects of the habitat characteristics that could be limiting aquatic life, and suggest management options designed to rehabilitate habitat (Wisconsin Department of Natural Resources, 2002).

Sites where habitat assessments were done were lightly scattered throughout the MMSD planning area and included locations in many subwatersheds except the Fox River and Lake Michigan Direct watersheds (fig. 86). Data for habitat assessments was available beginning in 1991 and extended through the late 1990s or 2001 in most subwatersheds (table 47). The most assessments were done in the Lincoln Creek subwatershed (40) and Underwood Creek subwatershed (20) (table 47). Habitat assessments were done in 20 of the subwatersheds with one to nine sites in each subwatershed (table 47). Seventeen of the 44 total sites were surveyed more than once, some up to eight times. The Lincoln Creek subwatershed had a relatively large number of sites (nine) where habitat assessments were done, with an average of four assessments at each site. However, only one or two assessments were done in most other subwatersheds. No habitat index scores were available for the data in the MMSD planning area, and summarizing the extensive amount of habitat data was not within the scope of this report.

Additional stream channel morphology and streambed measurements were recorded during the MMSD Menomonee River Sediment Transport study. The purpose of the MMSD Menomonee River Sediment Transport study was to provide a planning tool for the Menomonee River watershed that would allow MMSD to plan flood-management and channel-stabilization and rehabilitation projects that would improve flood conveyance and aquatic habitat (Inter-Fluve, Inc, 2001). A subset of the data collected for the study that has been compiled in the MMSD Corridor Study database includes channel cross-section information, pebble counts, and streambed sediment and grain-size analysis.

Sites examined as part of the Menomonee River sediment transport study (Inter-Fluve, Inc., 2001) were exclusively in the subwatersheds of the Menomonee River watershed (fig. 86). Sites were located in 8 of the 14 subwatersheds of the Menomonee River watershed, with 1 to 59 sites in each subwatershed. One-time channel measurements made as part of the Menomonee River sediment transport study took place from 2000 through 2001 at many sites in subwatersheds of the Menomonee River watershed (table 47).

Figure 86. Sites sampled for habitat and geomorphic data in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

Table 47. Summary statistics for habitat assessment and geomorphic data, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[WDNR, Wisconsin Department of Natural Resources; MMSD, Milwaukee Metropolitan Sewerage District; --, no data available]

Watershed	Subwatershed	WDNR habitat assessments				MMSD channel measurements			
		Count of assess-ments	Sites per subwater-shed	Earliest assess-ment date	Latest assess-ment date	Count of site visits	Sites per subwater-shed	Earliest measure-ment date	Latest measure-ment date
Kinnickinnic River	Kinnickinnic River	1	1	06/15/1997	06/15/1997	--	--	--	--
	Wilson Park Creek	1	1	06/17/1997	06/17/1997	--	--	--	--
Menomonee River	Butler Ditch	1	1	06/10/1997	06/10/1997	1	14	05/07/2000	07/01/2000
	Dousman Ditch	--	--	--	--	1	4	05/06/2000	09/01/2000
	Honey Creek	6	4	06/04/1991	07/29/1997	1	22	05/10/2000	07/01/2000
	Lilly Creek	4	2	06/19/1991	06/02/1993	--	--	--	--
	Little Menomonee River	8	2	06/01/1995	05/28/1998	1	36	03/25/2000	05/08/2001
	Lower Menomonee River	3	1	06/03/1991	06/04/1993	1	43	05/08/2000	09/06/2000
	Upper Menomonee River	1	1	06/16/1997	06/16/1997	1	59	03/29/2000	08/09/2000
	South Branch Underwood Creek	--	--	--	--	1	1	08/15/2000	08/15/2000
	Underwood Creek	20	4	06/19/1991	06/02/1998	1	30	05/03/2000	08/30/2000
Milwaukee River	Cedar Creek	1	1	09/12/2001	09/12/2001	--	--	--	--
	Lincoln Creek	40	9	06/03/1992	05/30/1998	--	--	--	--
	Lower Milwaukee River	5	5	06/03/1994	06/17/1997	--	--	--	--
Oak Creek	Mitchell Field Drainage Ditch	2	2	06/17/1997	08/02/2001	--	--	--	--
	North Branch Oak Creek	1	1	07/29/1997	07/29/1997	--	--	--	--
	Lower Oak Creek	4	2	06/11/1991	06/02/1993	--	--	--	--
	Middle Oak Creek	1	1	07/29/1997	07/29/1997	--	--	--	--
Root River	East Branch Root River	1	1	06/17/1997	06/17/1997	--	--	--	--
	Middle Root River	3	3	06/11/1997	09/04/2001	--	--	--	--
	Upper Root River	1	1	06/11/1997	06/11/1997	--	--	--	--
	Whitnall Park Creeks	1	1	07/31/2001	07/31/2001	--	--	--	--

Bacteria

Most of human pathogens transmitted by water originate from contamination of those waters by fecal material. It is generally assumed that human-pathogen-laden waters stem from human wastewater effluent. However, the relative contributions that animal and livestock wastes have on human pathogen loads is unknown and is a topic of current investigation (Madigan and others, 1997).

Although the dangers associated with waters contaminated with fecal material are greatly magnified when such water is used for drinking, the recreational use of sufficiently contaminated waters also constitutes a human health risk. In response to this danger, the USEPA recommends the testing of recreational waters for the presence of fecal contamination by means of fecal indicator organisms. These organisms provide an indirect indication of the presence of potential pathogens in the water. The two fecal indicators commonly used in the Milwaukee area are fecal coliforms and *Escherichia coli*. Elevated concentrations of microorganisms in surface water can indicate contamination by agricultural or human sources.

Fecal Coliforms

Fecal coliforms were recommended for the testing of recreational waters by the USEPA in 1976. Accompanying this recommendation was an acceptable limit guideline of 200 colonies per 100 mL (U.S. Environmental Protection Agency, 1976). Fecal coliform data for the planning area have been collected primarily by MMSD; however, smaller data sets have been supplied by the USGS and the USEPA.

Sites with median fecal coliform concentrations that exceeded the USEPA recreational water guideline concentration of 200 colonies per 100 mL were scattered throughout the planning area (fig. 87). Sites with median concentrations in the upper quartile were clustered in the central part of the planning area (fig. 87). Only one site, in the Kinnickinnic River subwatershed, was in the lower quartile (fig. 87).

Subwatersheds with median fecal coliform concentrations in the upper quartile were the Lower Menomonee River, Underwood Creek, Honey Creek, and Lincoln Creek (fig. 87). However, data collected in the Honey Creek subwatershed were part of a targeted survey, and are likely not indicative of typical fecal coliform levels. There were no subwatersheds with median concentrations in the lower quartile (fig. 87). Most samples exceeded the USEPA recreational water fecal coliform guideline of 200 colonies per 100 mL (fig. 88). The highest maximum concentrations were measured in the Lower Menomonee River (2,400,000 colonies per 100 mL), Lower Milwaukee River (1,350,000 colonies per 100 mL), Kinnickinnic River (1,100,000 colonies per 100 mL), and Lincoln Creek (1,100,000 colonies per 100 mL) subwatersheds (fig. 88, table 48). The highest median concentrations were measured in the Underwood Creek (20,000 colonies per 100 mL) and Honey Creek (16,650 colonies per 100 mL) subwatersheds (table 48). The lowest median concentration of 230 colonies per 100 mL, still above the USEPA recreational limit of 200 colonies per 100 mL, was measured in the Middle Root River subwatershed (table 48).

The fecal coliform data did not show significant trends or seasonality (data not shown).

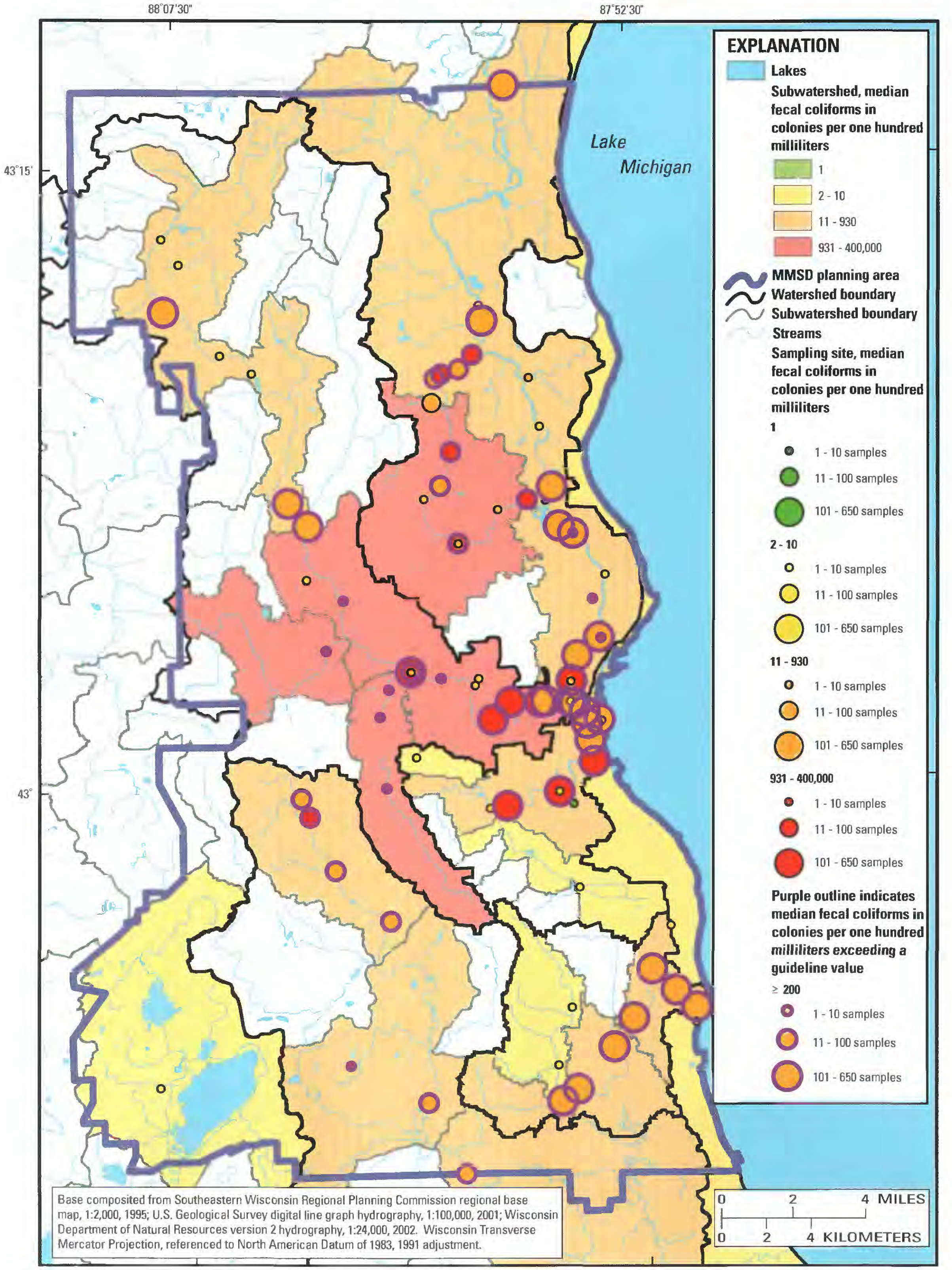

Figure 87. Sites sampled for fecal coliforms in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

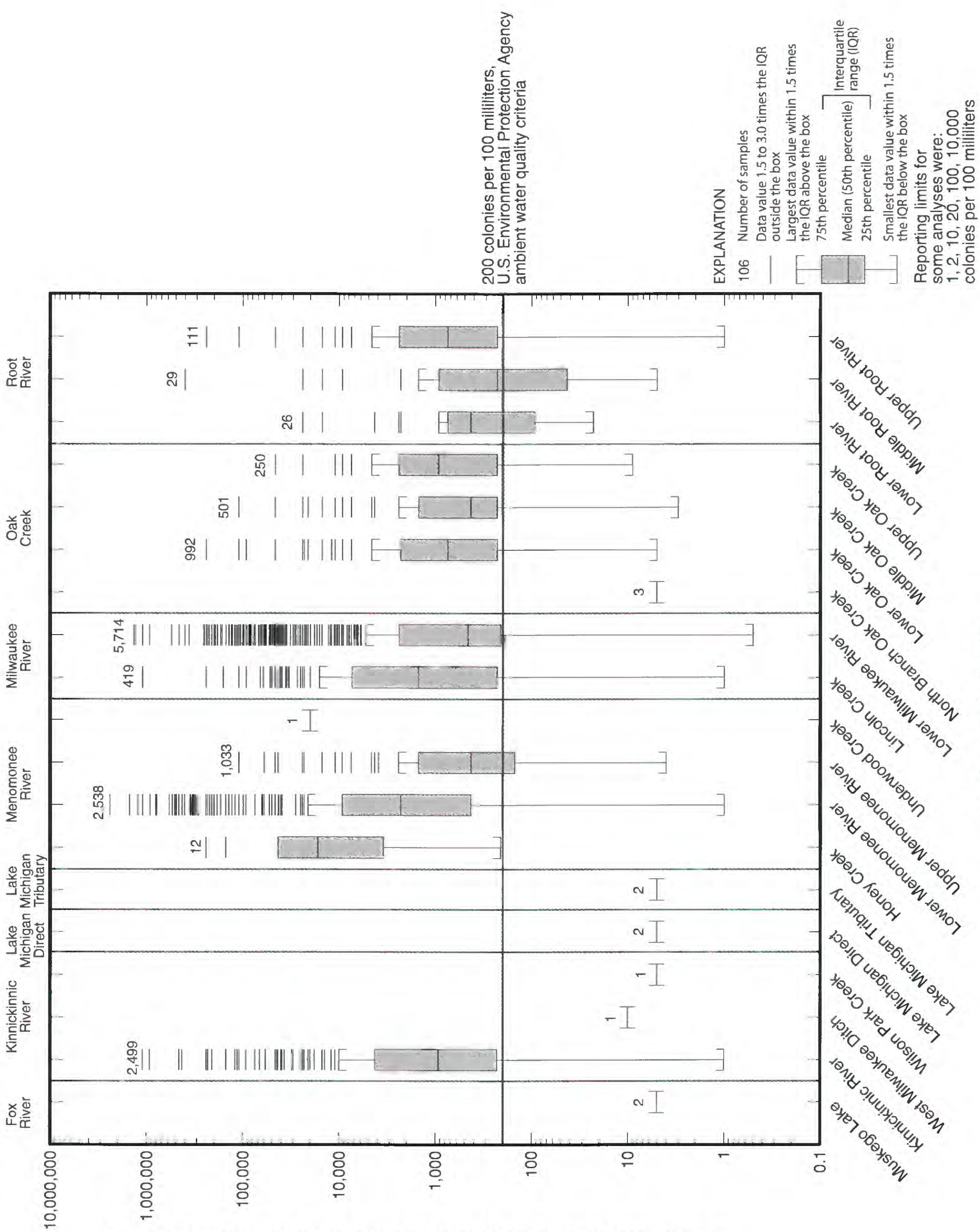

Figure 88. Statistical distribution of fecal coliform counts in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 48. Summary statistics for fecal coliforms, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

f[MMSD, Milwaukee Metropolitan Sewerage District; USGS, U.S. Geological Survey; STORET, STOrage and RETrieval System; --, no data available; RL, reporting-limit value; values are expressed in colony-forming units per 100 milliliters (CFU/100ml); values rounded to nearest whole number; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Count of USGS results	Count of STORET results	Count of all results	Number of values below a reporting limit	Reporting limit(s)	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Fox River	Muskego Lake	1	0	0	2	2	2	10	03/29/1977	05/23/1979	--	--	--	--	--	--	--	RL
Kinnickinnic River	Kinnickinnic River	7	2,496	0	3	2,499	9	2, 3, 10	01/15/1975	11/27/2001	1	43	230	930	10,888	4,300	23,000	1,100,000
	West Milwaukee Ditch	1	0	0	1	1	1	20	04/29/1975	04/29/1975	--	--	--	--	--	--	--	RL
	Wilson Park Creek	1	0	0	1	1	1	10	02/16/1976	02/16/1976	--	--	--	--	--	--	--	RL
Lake Michigan Direct	Lake Michigan Direct	1	0	0	2	2	2	10	04/25/1979	11/18/1981	--	--	--	--	--	--	--	RL
Lake Michigan Tributary	Lake Michigan Tributary	1	0	0	2	2	2	10	10/21/1976	05/02/1978	--	--	--	--	--	--	--	RL
Menomonee River	Honey Creek	3	12	0	0	12	0	--	08/09/2001	08/21/2001	210	1,580	4,025	16,650	45,542	43,000	139,300	240,000
	Lower Menomonee River	12	2,487	36	15	2,538	16	2, 3, 10, 10,000	06/10/1975	11/27/2001	1	90	430	2,300	28,998	9,300	46,000	2,400,000
	Upper Menomonee River	7	1,027	0	6	1,033	5	10	09/01/1976	11/27/2001	4	43	150	430	2,324	1,500	4,600	110,000
	Underwood Creek	1	0	0	1	1	0	--	06/24/1975	06/24/1975	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Milwaukee River	Lincoln Creek	7	339	69	11	419	15	2, 10	09/17/1975	11/27/2001	1	40	230	1,500	12,837	6,900	25,000	1,100,000
	Lower Milwaukee River	22	5,546	154	14	5,714	13	1, 2, 10, 100	01/26/1973	11/27/2001	1	50	210	460	8,574	2,400	15,000	1,350,000
Oak Creek	North Branch Oak Creek	2	0	0	3	3	3	10	03/22/1976	04/12/1976	--	--	--	--	--	--	--	RL
	Lower Oak Creek	6	990	0	2	992	2	10	04/20/1977	11/19/2001	5	93	230	750	4,038	2,300	4,600	240,000
	Middle Oak Creek	2	501	0	0	501	0	--	03/21/1985	11/19/2001	3	70	230	430	2,401	1,500	4,600	110,000
	Upper Oak Creek	1	250	0	0	250	0	--	03/21/1985	11/19/2001	9	90	230	930	3,017	2,400	7,680	46,000
Root River	Lower Root River	1	26	0	0	26	0	--	08/25/1999	10/10/2001	23	59	93	430	2,078	670	3,350	24,000
	Middle Root River	2	27	0	2	29	1	10	06/10/1977	10/10/2001	5	30	43	230	15,883	930	10,440	400,000
	Upper Root River	4	111	0	0	111	1	2	08/25/1999	10/10/2001	1	93	230	750	15,027	2,400	24,000	240,000

Escherichia coli

Epidemiological studies indicate that, when compared to fecal coliforms, counts of *Escherichia coli* (*E. coli*) correlate more strongly with illnesses attributable to swimming in fecal-contaminated water (Dufour and Cabelli, 1984). In response, the USEPA has modified its guidance to recommend the use of *E. coli* as a fecal indicator in freshwater, setting the single sample maximum allowable density for a designated beach area to 235 colonies per 100 mL (Dufour and Ballentine, 1986).

MMSD is the only agency that has collected *E. coli* data in the planning area. Samples have been recorded for six subwatersheds in the planning area (fig. 89). This was a relatively recent data set, with the range in collection dates spanning only from October 2000 to November 2001. The depiction in figure 89 for the Honey Creek subwatershed is not likely representative of typical *E. coli* counts because samples were collected as part of a targeted survey.

The median *E. coli* concentration of the Honey Creek subwatershed was in the upper quartile, whereas the median concentration of the Lower Milwaukee River subwatershed was in the lower quartile (fig. 89). Many concentrations exceeded the maximum single-sample USEPA recreational-water guideline of 235 colonies per 100 mL (fig. 90). The highest maximum concentrations were measured in the Upper Menomonee River (160,000 colonies per 100 mL), Kinnickinnic River (160,000 colonies per 100 mL), and Honey Creek (140,000 colonies per 100 mL) subwatersheds (fig. 90, table 49). The highest median concentrations were measured in the Honey Creek (2,400 colonies per 100 mL) and Lincoln Creek (1,300 colonies per 100 mL) subwatersheds (fig. 90, table 49). The Lower Milwaukee River (220 colonies per 100 mL) and Upper Menomonee River (300 colonies per 100 mL) subwatersheds had the lowest median concentrations (fig. 90, table 49).

Given the small number of samples and the short timespan of the data set, not enough data were available to indicate any trends or seasonality (data not shown).

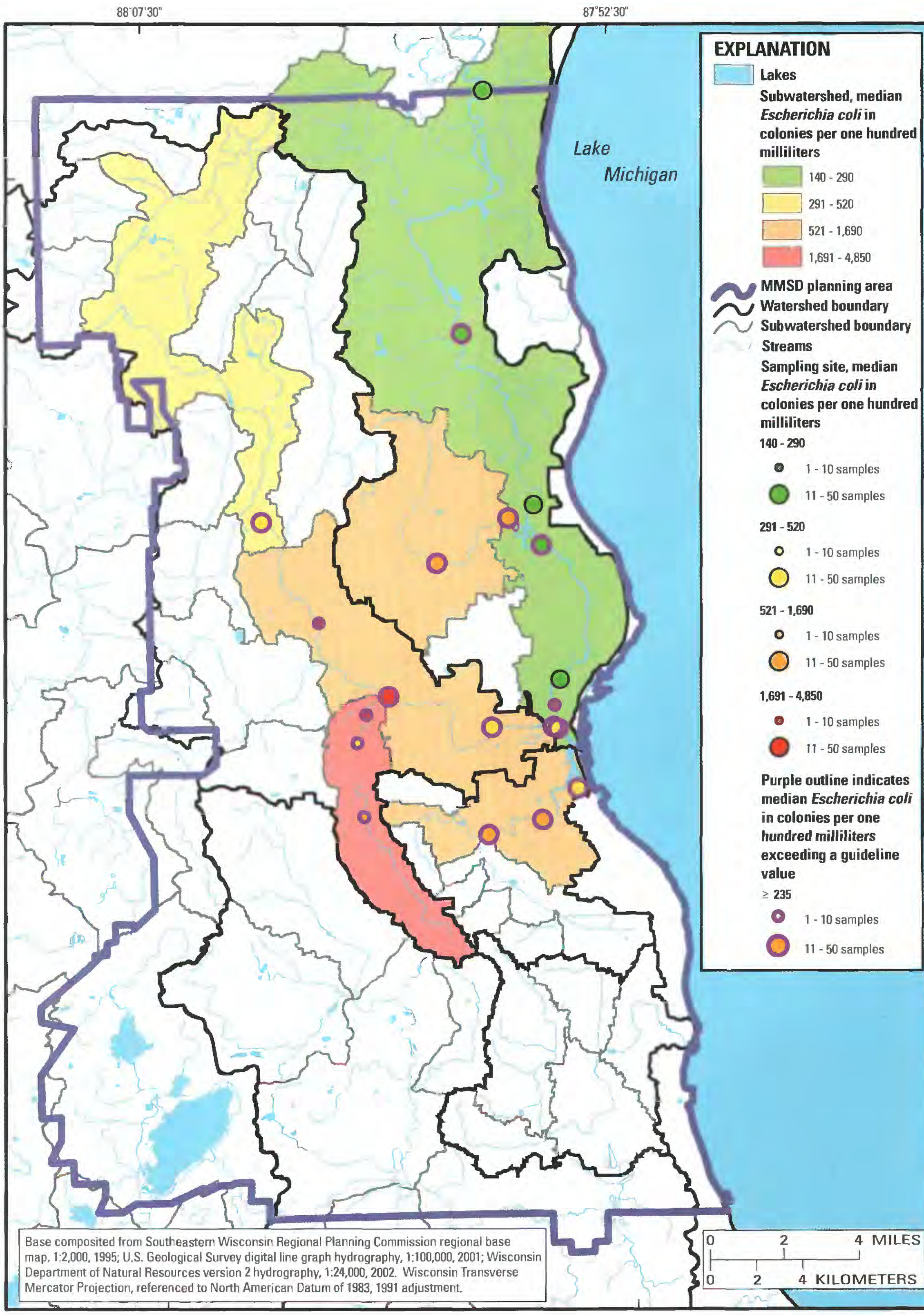

Figure 89. Sites sampled for *Escherichia coli* in the Milwaukee Metropolitan Sewerage District (MMSD) planning area, Wis.

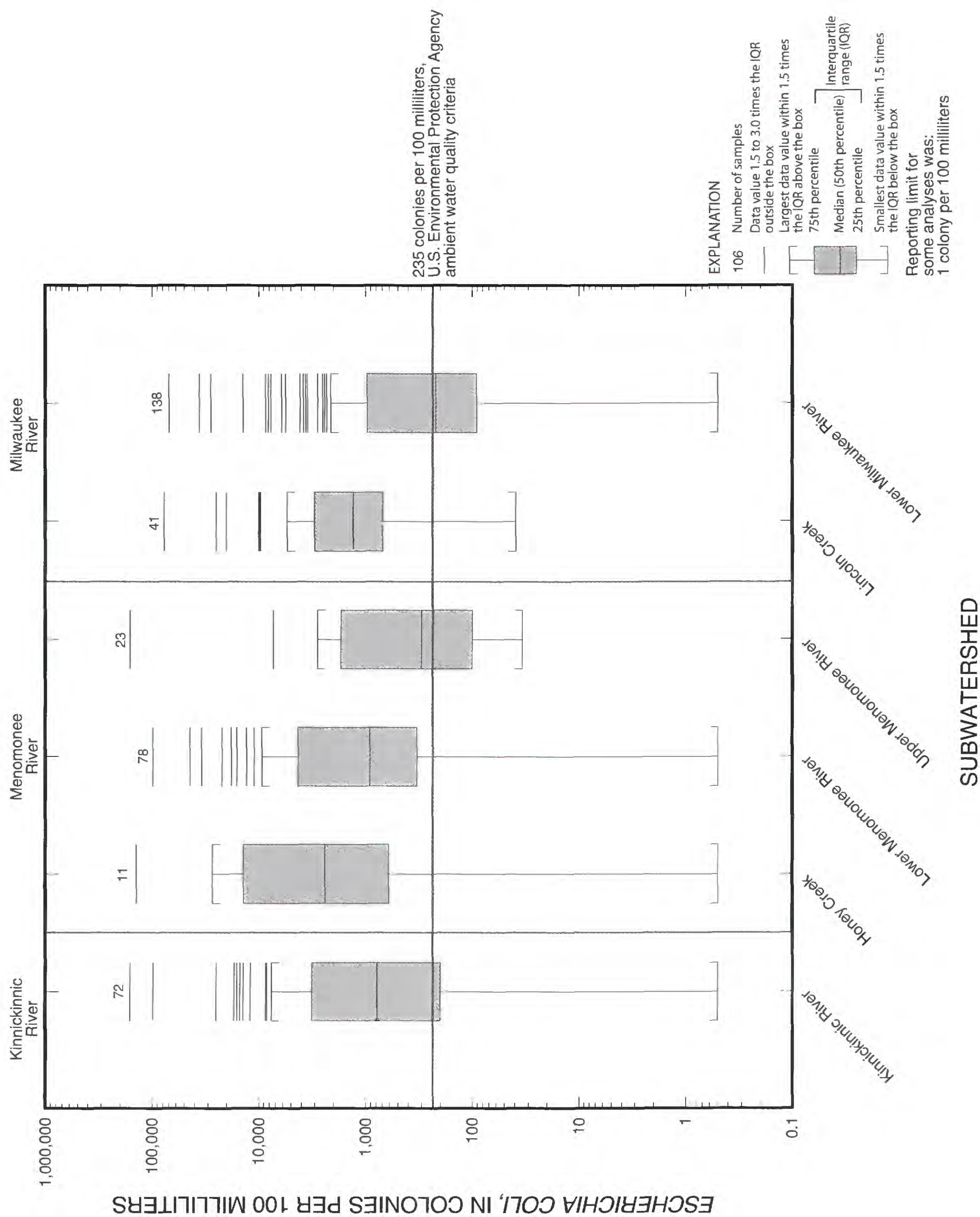

Figure 90. Statistical distribution of *Escherichia coli* counts in the Milwaukee Metropolitan Sewerage District planning area, 1970–2002.

Table 49. Summary statistics for *Escherichia coli*, by category, for the Milwaukee Metropolitan Sewerage District planning area, 1970–2002

[MMSD, Milwaukee Metropolitan Sewerage District; --, no data available; values are expressed in colony forming units per 100 milliliters (CFU/100ml); values rounded to the nearest whole number; for the purpose of statistical calculations, values reported below a reporting limit are set at one-half the reporting-limit value; some values below the reporting limit were reported as zero]

Watershed	Subwatershed	Sites per subwatershed	Count of MMSD results	Number of values below a reporting limit	Reporting limit	Earliest sample date	Latest sample date	Minimum	10th percentile	25th percentile	Median	Mean	75th percentile	90th percentile	Maximum
Kinnickinnic River	Kinnickinnic River	3	72	2	1	10/01/2000	11/27/2001	1	88	200	780	6,260	3,050	11,660	160,000
Menomonee River	Honey Creek	3	11	1	1	08/09/2001	08/21/2001	1	410	795	2,400	17,427	8,200	27,000	140,000
	Lower Menomonee River	4	78	4	1	10/01/2000	11/27/2001	1	88	332	915	4,982	4,100	9,810	98,000
	Upper Menomonee River	1	23	0	--	10/01/2000	11/27/2001	34	59	100	300	7,894	1,400	2,780	160,000
Milwaukee River	Lincoln Creek	2	41	0	--	10/01/2000	11/27/2001	39	190	690	1,300	4,929	3,000	9,800	77,000
	Lower Milwaukee River	7	138	7	1	10/01/2000	11/27/2001	1	54	92	220	1,863	960	2,590	69,000

Potential Areas for Data Collection for Phase II

A major purpose of this report is to describe the historical stream-corridor data for the MMSD planning area. Knowledge of historical conditions can then be used in planning for Phase II of the MMSD Corridor Study, base-line monitoring. Identification of spatial, temporal, or analytical gaps in data may drive decisions in where to locate sampling sites and what types of analyses to perform.

The maps of sampling locations in this report illustrate subwatersheds that may be appropirate for additional sampling. In addition, subwatersheds with few sites, relatively few samples, and (or) samples that date back to the 1970s or 1980s may receive additional sampling. Consideration also has to be given to the significance of the subwatershed within the larger system. Subwatersheds containing the headwaters of streams with few urban effects may not require as frequent sampling as subwatersheds in heavily urbanized areas with a larger drainage area. However, monitoring in the less urbanized subwatersheds is also valuable; recent studies have shown that nonurbanized systems are highly susceptible to increases in urbanization, resulting in changes related to streamflow, water chemistry, sedimentation, and ecological communities (loss of aquatic habitat and biological integrity). Less frequent sampling in these subwatersheds may be sufficient to monitor any changes in their ecosystems.

Tables of summary statistics (tables 8 through 49) indicate the number of samples collected for each subwatershed and the latest date a site in the subwatershed was sampled. Figures 9 through 12 show sites sampled at least once since January 1, 1998, for various types of analyses. Knowing the locations of sites currently monitored by MMSD, USGS, WDNR or other agencies may facilitate cooperation between the MMSD Corridor Study and the monitoring agency for data collection into Phase II or suggest locations not to sample to avoid duplication of sampling efforts.

Data for emerging contaminants such as pharmaceuticals and personal care products (PPCPs), human hormones, organic wastewater contaminants, and other constituents that indicate effects of human activity were not available in the MMSD Corridor Study database or any of its sources. There are increasing concerns for potential adverse human and ecological health effects resulting from the production, use, and disposal of numerous chemicals on the market in recent years that improve industry, agriculture, and medical treatment, as well as those used for personal and household needs. These chemicals find their way into the environment and contribute significantly to the total environmental load of anthropogenic chemical stressors (U.S. Environmental Protection Agency, 2003c). Treated wastewater from the MMSD planning area is discharged into Lake Michigan; however, sewer-overflow events, septic tanks, land application of wastewater-treatment-plant sludge, industrial discharge to water and air, veterinary pharmaceutical runoff from animal feed lot operations, and treated and untreated wastewater discharged upstream of the planning area may contribute emerging contaminants to stream corridors within the planning area. Little is known about the extent of environmental occurrence, transport, and fate of many synthetic organic compounds after their intended use, particularly hormonally active chemicals, PPCPs, and pharmaceuticals. One reason for this lack of data is that until recently low-level detection methods were not available (Kolpin and others, 2002). Researchers at the USGS have done several state-of-the-art studies of emerging contaminants in the United States (Kolpin and others, 2002; U.S. Geological Survey Toxic Substances Hydrology Program, 2003). The USGS National Water Quality Laboratory has a proven low-level analysis schedule established to analyze water samples for emerging contaminants (Lindsey and others, 2001).

E. coli is a constituent that may be used as an indicator of health risk to swimmers and other recreational water users (Great Lakes WATER Institute, 2003). Beaches on Lake Michigan may be affected by the water from rivers emptying into the lake. Therefore, additional sampling for *E. coli* would supplement the limited knowledge based on the samples collected since 2000.

The amount of data for pesticides in all media is limited. For the selected group of pesticides still in use that were examined in this report, the only two sites that had been sampled are the Milwaukee River at Estabrook Park and Lincoln Creek at 47th Street.

Data for PCBs are also somewhat limited. MMSD has provided the most recent data on PCBs in water at nearly 40 sites sampled for PCBs since 1995. Nearly all the rest of the data are from the mid-1990s, and a few samples are older yet. In examination of existing PCB data, or planning for future PCB sampling, PCB congeners that are considered to be particularly toxic may be of significant importance.

Data for trace element samples in water, bed sediment, and tissues were often collected prior to the 1980s and were collected and analyzed using outdated field and laboratory analysis methods. In particular, methods have improved significantly for the collection and analysis of mercury at the sub-parts-per-trillion level. Resampling for trace elements in bed sediment probably does not need to take place in all subwatersheds but perhaps could focus on the lower parts of the watersheds where more sediment, and perhaps trace elements, may have accumulated.

The long-term, water-chemistry monitoring program run by MMSD has collected thousands of samples over many sites in the MMSD planning area, contributing much of the water-chemistry data to the MMSD Corridor Study database. However, the MMSD monitoring program typically collects data during ice-free conditions, usually March through November (although some data have been collected in late-winter months). The absence of samples during winter months or during early snowmelt episodes limits the picture for certain nutrients that have a seasonal signal and for chloride, which may be affected by factors such as road deicing during the winter. USGS and USEPA STORET databases contributed some sample information for winter months, although these data are still probably too sparse for adequate design of future monitoring programs.

There were relatively few recent macroinvertebrate and fish-community samples available in the MMSD Corridor Study database. In particular, not many samples were collected in the 1990s. Typically, macroinvertebrate sampling was only done once or twice at a particular site, which limits the ability to show change in the community through time. The sampling frequency for macroinvertebrates has been relatively steady over the past 30 years. Fish-sampling efforts also involved visiting a site just one or twice in the past 30 years. Extensive fish sampling took place in the 1970s; however, the number of samples collected since then has dropped. Available habitat data are relatively recent, in part because of new assessment protocols. (Although data collected prior to the 1990s were available, the data-collection approach was subjective; therefore, these data were not included in the MMSD Corridor Study database.) The task of making habitat-assessment data electronic is onerous, and data-entry efforts may lag in comparison to assessments completed. For example, some recent WDNR sampling efforts produced data that are relevant to the MMSD planning area but were not available at the time for incorporation into the MMSD Corridor Study database; these data should be considered when choosing sampling sites and effort for the Phase II monitoring.

Additional data collection may be useful for physical characteristics such as stream-channel cross-section profiles, bridge-scour assessments, flood-plain maps, structures, and shoreline conditions.

Summary and Conclusions

The Milwaukee Metropolitan Sewerage District (MMSD) Corridor Study is a three-phase project designed to improve understanding of water resources in the stream corridors of the MMSD planning area and to provide tools by which the success of future projects can be predicted. The study is being conducted by the following collaborating agencies: MMSD, Wisconsin Department of Natural Resources (WDNR), Southeastern Wisconsin Regional Planning Commission (SEWRPC), U.S. Geological Survey (USGS), University of Wisconsin–Milwaukee, Marquette University, and Wisconsin Lutheran College. The study approach is to (1) initially compile existing data and (2) use the compiled information to develop a 3-year baseline and long-term monitoring plans.

A literature review of surface-water quality, surface-water quantity, and ecology studies conducted from 1970 through 2001 was completed, and summaries of each study are provided in this report. There were 195 documents that described surface-water quality issues in the MMSD planning area and 133 documents that addressed surface-water quantity questions. Surface-water quality documents included information describing nutrients, pesticides, inorganic and organic contaminants, urban issues, and modeling. Surface-water quantity documents discussed topics such as streamflow or stream stage, extreme flows, runoff calculations, and geomorphology. A total of 136 documents related to ecology. These documents presented information regarding fish, macroinvertebrates, habitat, wetlands, and management issues. In addition, an inventory of GIS spatial coverages available for the MMSD planning area was assembled. Thematic information included data regarding land use, infrastructure, geology, and hydrography.

A database of water, sediment, and tissue (fish, shellfish, and others) chemistry, macroinvertebrates, fish, algae, habitat, geomorphic, and other physical and ecological data was compiled from datasets from MMSD, USGS, WDNR, and USEPA for 1970 through 2002. More than 2.7 million results are available in the MMSD Corridor Study database and the compilation of multiple datasets allows for retrieving data from a central database rather than from each of the source datasets.

Analysis of data in the MMSD Corridor Study database must be done with caution and an understanding of the limitations of data collected for the 420-mi^2 planning area by various agencies using different field data-collection and laboratory-analysis methods. Challenges to combining data sets included varying definitions of sampling sites, minimal documentation of constituents, insufficient description of the laboratory-analysis method, differences in sample collection and laboratory analysis methods over the 30-year period and between agencies, and lack of sampling-purpose information that was available in an easily accessible format. Some data were collected as part of a routine monitoring program whereas other data were collected in areas known to be contaminated.

Some data were reported as less than a "reporting limit," definitions for which varied. Often, multiple reporting limits for each constituent were reported. Data with concentrations reported as "less than" were set to half their original concentration or half the reporting limit concentration (when the original concentration was reported as zero) for purposes of data analysis.

Chemical constituents and ecological components that are important to an urban setting and well represented in the database were selected for further investigation. Each constituent or component is described in this report with some or all of the following: a text summary, map of sampling locations, and in some cases median concentrations, statistical distribution of concentrations by subwatershed, table of summary statistics by subwatershed, and graphs of temporal and (or) seasonality trends (examined for five selected sites). Measured values and concentrations were compared to

USEPA, WDNR, and Canadian drinking-water and aquatic-life guideline values where available.

Streamgages, stream-stage gages, and meteorological stations collecting rainfall data since 1998 were distributed throughout the MMSD planning area. Collection of inorganic, nutrient, and physical field-measurement data since 1998 was also generally well distributed. Collection of pesticide, organic-chemical, and trace-element data since 1998 was not widespread. Sites where bacterial, biological, or habitat and channel-measurement data were collected since 1998 were widely distributed throughout the MMSD planning area.

Physical Data

Physical data included streamflow, stream stage, and precipitation data. Streamflow data were available from the USGS for 42 sites with various periods of record since 1970. Stream-stage data were available from MMSD for four sites, with data collection beginning in 1994. MMSD measured precipitation at 20 gages in the planning area since 1993.

Chemical Indicators of Water Quality

Chemical indicators of water quality examined in the report included field measurements and miscellaneous constituents (pH, alkalinity, specific conductance, hardness, dissolved oxygen, biochemical oxygen demand, and chloride), sediment (total suspended solids and suspended sediment), nutrients (total nitrogen, nitrate, Kjeldahl nitrogen, total phosphorus, and dissolved phosphorus), trace elements (cadmium, mercury, copper, lead, arsenic, chromium, nickel, and zinc), pesticides (historically used pesticides and pesticides still in use), and polychlorinated biphenyls.

Field Measurements and Miscellaneous Constituents

Aquatic organisms are strongly influenced by physical properties and chemical constituents of water which themselves can be influenced by natural environmental factors and the urban setting.

pH. Maximum pH measurements were above the guideline of 9.0 standard units in the Muskego Lake, Kinnickinnic River, Lower Menomonee River, Upper Menomonee River, Lincoln Creek, Lower Milwaukee River, and Lower Oak Creek subwatersheds. Minimum pH measurements were below the guideline of 6.5 standard units in the Kinnickinnic River, Lower Menomonee River, Upper Menomonee River, Lower Milwaukee River, Mitchell Field Drainage Ditch, Muskego Lake, Upper Root River, and Wilson Park Creek subwatersheds. Seasonal variations in pH measurements tended to follow the growing season of aquatic plants. Long-term trends in pH measurements for most sites had a slight upward trend in the early to mid-1980s followed by a slight downward trend until the latter 1990s and continued with an upward trend through 2002.

Alkalinity. The Upper Root River, Upper Oak Creek, Upper Menomonee River, Middle Root River, and Lower Oak Creek subwatersheds had the highest median alkalinity concentrations (262 to 325 mg/L as $CaCO_3$). Median concentrations in the Little Menomonee River, Honey Creek, Kinnickinnic River, and Muskego Lake subwatersheds were the lowest (below a reporting limit to 160 mg/L as $CaCO_3$). Patterns in seasonal and temporal trends were evident in alkalinity data, although the long-term trends were less pronounced.

Specific conductance. Median specific conductance greater than 1,000 µS/cm was measured in the Wilson Park Creek, Honey Creek, Underwood Creek, Lower Oak Creek, Middle Oak Creek, Upper Oak Creek, Middle Root River, and Upper Root River subwatersheds. The lowest median specific conductance, less than 650 µS/cm, was measured in Muskego Lake, Kinnickinnic River, Butler Ditch, and Lower Milwaukee River subwatersheds. Seasonal variability of specific conductance, paralleling the use of deicing compounds, was apparent. Temporal trends indicated year-to-year variation in specific conductance.

Hardness. The highest median hardness concentrations were measured in the Upper Oak Creek (450 mg/L as $CaCO_3$) and Upper Root River (430 mg/L as $CaCO_3$) subwatersheds. The lowest median concentrations were measured in the Little Menomonee River (63 mg/L as $CaCO_3$) and Underwood Creek (130 mg/L as $CaCO_3$) subwatersheds. A slight long-term downward trend in hardness concentrations was observed for all sites except Lincoln Creek, which had a slight upward trend.

Dissolved oxygen. The Upper Root River (5.13 mg/L) and Lower Menomonee River (6.50 mg/L) subwatersheds had the lowest median dissolved oxygen concentrations. Willow Creek (9.81 mg/L) and Honey Creek (9.47 mg/L) subwatersheds had the highest median concentrations. Dissolved oxygen concentrations varied with the season, with the lowest concentrations generally observed in warm months.

Biochemical oxygen demand, 5 day. The subwatersheds with the highest median biochemical oxygen demand (5 day) concentrations were Mitchell Field Drainage Ditch (1,865.0 mg/L) and Wilson Park Creek (100.0 mg/L), both of which receive water draining from the General Mitchell International Airport. Nearly all other subwatersheds had median concentrations less than 3.0 mg/L.

Chloride. The highest median chloride concentrations (135 to 190 mg/L) were measured in the southern part of the planning area; specifically, the Upper Root River, Middle Root River, Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek subwatersheds. Subwatersheds with the lowest median concentrations (below a reporting limit to 42 mg/L) were Dousman Ditch, Lower Milwaukee River, Wilson Park Creek, and Lake Michigan Direct. Chloride concentrations showed a rise during the winter months, likely related to road deicing. Long-term trend patterns in chloride started with a slight upward trend in the early 80s, followed by a very gradual downward trend until 1996, continued with a very gradual upward trend until 2000, and ended with a slight fall through 2002.

Sediment

The sediment load of a stream can influence the type of organisms able to exist in the stream and indicate the significance of erosion and transportation of sediment from the watershed and (or) streambanks.

Total suspended solids. The Lower, Middle, and Upper Oak Creek and Root River subwatersheds had the highest median total suspended solids concentrations (685 to 875 mg/L), with increasing median concentrations in the downstream direction for each river. The lowest median concentrations (7 to 23 mg/L) were measured in the Wilson Park Creek, Willow Creek, and Mitchell Field Drainage Ditch subwatersheds. A seasonal pattern was noted at some sites, with higher concentrations during late winter to early spring.

Suspended sediment. The Kinnickinnic River, Underwood Creek, and Upper Root River subwatersheds had the highest median suspended-sediment concentrations (204 to 356 mg/L). Median concentrations of the Lincoln Creek and the Lower Milwaukee River subwatersheds were the lowest (25 to 28 mg/L).

Nutrients

Nutrients in surface waters are a concern because high levels can result in excessive plant growth, which in turn may lead to lowered dissolved oxygen as the plants decompose.

Total nitrogen. In most cases, concentrations of total nitrogen were derived from summing data for either dissolved nitrate and dissolved Kjeldahl nitrogen concentrations or for dissolved nitrate, total organic nitrogen, and dissolved ammonia nitrogen concentrations. The highest median concentration (53.70 mg/L as N) was measured in the Mitchell Field Drainage Ditch subwatershed. In addition, median concentrations in Wilson Park Creek, Little Menomonee River, Willow Creek, Lower Milwaukee River, and the Lower Root River subwatersheds exceeded the nutrient criterion of 1.59 mg/L as N. Subwatersheds with the lowest median concentrations (0.10 to 1.07 mg/L as N) were Honey Creek, North Branch Oak Creek, and Middle Oak Creek.

Nitrate. The highest median nitrate concentrations, which were above the proposed USEPA nutrient-criterion concentration of 0.94 mg/L as N, were measured in the Lower Root River and Wilson Park Creek subwatersheds. Subwatersheds with the lowest median concentrations (at or below reporting limits) were the Little Menomonee River, Underwood Creek, Milwaukee River Non-Contributing, and North Branch Oak Creek. There was distinct seasonality in the nitrate concentrations, with concentrations lower in the summer and higher in the winter. Long-term trends in nitrate concentrations showed minimal concentrations from the late 1980s to the early 1990s at most sites.

Kjeldahl nitrogen. The highest median Kjeldahl nitrogen concentrations were measured in the Mitchell Field Drainage Ditch (18.50 mg/L as N) and Wilson Park Creek (2.58 mg/L as N) subwatersheds. Subwatersheds with the lowest median concentrations (0.20 to 0.65 mg/L as N) were Honey Creek, Middle Root River, Upper Oak Creek, and North Branch Oak Creek in the southern part of the planning area.

Total phosphorus. Subwatersheds with the highest median total phosphorus concentrations (0.112 to 0.350 mg/L as P) were Whitnall Park Creeks, Mitchell Field Drainage Ditch, and Lower Root River. Subwatersheds with the lowest median concentrations (below a reporting limit to 0.028 mg/L as P) were the Little Menomonee River, Butler Ditch, Dousman Ditch, South Branch Underwood Creek, Milwaukee River Non-Contributing, and North Branch Oak Creek.

Dissolved phosphorus. The highest median dissolved phosphorus concentrations (0.055 to 0.059 mg/L as P) were measured in the Little Menomonee River, Willow Creek, and Lower Root River subwatersheds. The Honey Creek, Kinnickinnic River, Muskego Lake, Middle Root River, Upper Oak Creek, and Lower Oak Creek subwatersheds had the lowest median concentrations (0.010 to 0.020 mg/L as P).

Trace Elements

Organisms exposed to trace elements found in surface water, sediment, and other organisms lower in the food chain can be at risk for detrimental health affects.

Cadmium. No subwatersheds had median cadmium concentrations in water above the WDNR (Wisconsin Department of Natural Resources) MCL (Maximum Contaminant Level), USEPA (U.S. Environmental Protection Agency) MCL, and Canadian MAC (Maximum Acceptable Concentration) drinking-water guideline of 5 µg/L. The highest median cadmium concentrations in sediment (3.9 to 4.4 µg/g), all above the PEL (Probable Effect Level), were measured in the Kinnickinnic River, Little Menomonee River, and Lower Menomonee River subwatersheds. The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, Muskego Lake, and Middle Root River subwatersheds had the lowest median concentrations in sediment (0.4 to 2.0 µg/g).

Mercury. The highest median mercury concentrations in water were measured in the Lower Menomonee River (0.100 µg/L) and Upper Menomonee River (0.100 µg/L) subwatersheds; however, the majority of results for both subwatersheds were below a reporting limit. The highest median mercury concentration in sediment (0.460 µg/g) was measured in the Lower Menomonee River subwatershed. The Little Menomonee Creek, Lilly Creek, Lincoln Creek, and Middle Root River subwatersheds had the lowest median concentrations in sediment (0.020 to 0.070 µg/g).

Copper. The highest median copper concentrations in water were in the Underwood Creek (19.0 µg/L) and Lincoln Creek (10.0 µg/L) subwatersheds; median concentrations in all other subwatersheds were below 10.0 µg/L. The highest median copper concentrations in sediment were measured in the Lower Menomonee River (140.0 µg/g) and Little Menomonee River (140.0 µg/g) subwatersheds. The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, and Lincoln Creek subwatersheds had the lowest median concentrations in sediment (29.0 to 39.0 µg/g).

Lead. Median lead concentrations in water (15.0 µg/L to 24.5 µg/L) in the Underwood Creek, Lower Menomonee River, Kinnickinnic River, Middle Oak Creek, Upper Oak Creek, Lower Oak Creek, and Lower Milwaukee River subwatersheds met or exceeded water-quality guideline concentrations of 15 µg/L for the WDNR TTAL (Treatment Techniques Action Level) and the USEPA MCL. The highest median lead concentration in sediment was found in the Honey Creek subwatershed (4,100.00 µg/g). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, Muskego Lake, and Middle Root River subwatersheds had the lowest median concentrations in sediment (6.5 to 80.0 µg/g).

Arsenic. Median arsenic concentrations in water were low when compared to maximum concentrations and were at reporting-limit concentrations in most cases. The Little Menomonee Creek (38.0 µg/g) and Lilly Creek (10.0 µg/g) subwatersheds had the highest median arsenic concentrations in sediment. The Upper Menomonee River, Lincoln Creek, and Middle Root River subwatersheds had the lowest median concentrations (2.0 to 4.0 µg/g).

Chromium. No median chromium concentrations in water exceeded the WDNR and USEPA MCL drinking-water guideline concentration of 100 µg/L or the Canadian drinking-water guideline concentration of 50 µg/L. The Kinnickinnic River subwatershed had the highest median chromium concentration in sediment (330.0 µg/g). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, and Middle Root River subwatersheds had the lowest median concentrations in sediment (8.0 to 30.0 µg/g).

Nickel. Nearly all median nickel concentrations in water appeared to be below a reporting limit. The Little Menomonee River subwatershed had the highest median nickel concentration in sediment (40.0 µg/g). The lowest median concentrations in sediment were in the Upper Menomonee River, Little Menomonee Creek, and Lilly Creek subwatersheds (20.0 µg/g).

Zinc. Median zinc concentrations in water (30 to 90 mg/L) in the Underwood Creek, Mitchell Field Drainage Ditch and Little Menomonee River subwatersheds matched or exceeded the Canadian aquatic-life guideline concentration of 30 mg/L. The Little Menomonee River, Lower Menomonee River, and Kinnickinnic River subwatersheds had the highest median zinc concentrations in sediment (503 to 540 mg/g). The Upper Menomonee River, Little Menomonee Creek, Lilly Creek, Lincoln Creek, and Middle Root River subwatersheds had the lowest median concentrations (52 to 160 mg/g).

Pesticides

Historically used pesticides. The following historically used pesticides were selected from the MMSD Corridor Study database for description in this report: chlordane, dieldrin, DDT, DDE, DDD, *p,p'*-DDT, *p,p'*-DDE, and *p,p'*-DDD in sediment; and dieldrin, chlordane (*cis* and *trans* isomers), nonachlor (*cis* and *trans* isomers), *p,p'*-DDT, *p,p'*-DDE, and *p,p'*-DDD in tissue (fish, shellfish, and others). Of the selected pesticides in sediment, only dieldrin was at a concentration below the reporting limit. Of the selected pesticides in tissue, the following were found only at concentrations below the reporting limit: chlordane (*cis* and *trans* isomers), nonachlor (*cis* isomer), *p,p'*-DDT, and *p,p'*-DDD. Most sites with data for pesticides in sediment were clustered around the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers. Data for pesticides in tissue were available for several sites in the Milwaukee and Kinnickinnic watersheds. Nearly all data for pesticides in sediment and tissue were collected in the early 1990s or before.

Pesticides still in use. Pesticides in current use are most likely found in surface water and include atrazine, deethyl atrazine, diazinon, metolachlor, prometon, simazine, and 2,4-D. All of the selected pesticides were observed at concentrations above the reporting limit in at least one sample; however, no maximum concentration of any of the selected pesticides was above an MCL or other health advisory level. Data selected for analysis in this report were collected at two sites: the Milwaukee River at Estabrook Park in Milwaukee and Lincoln Creek at 47th Street in Milwaukee during 1993–2002 and 2001–2002, respectively.

Polychlorinated Biphenyls

Sites with PCB data in water were distributed throughout the planning area. Sites sampled for PCBs in sediment were sparse throughout the northern part of the planning area, with a concentration of sites at the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers. Sites with PCB data in tissue were sparse. Concentrations of most PCB data were below a reporting limit, and the latest collection date was usually during the mid-1990s.

Samples from a subset of the sites where all PCBs were analyzed for were also analyzed for toxic PCBs. No data for toxic PCBs in tissues were available. Nearly all concentrations of toxic PCBs in water were below a reporting limit, whereas nearly all concentrations of toxic PCBs in sediment were above a reporting limit. All data for toxic PCBs were collected in the 1990s.

Ecological Indicators of Water Quality

Ecological indicators of water quality discussed in the report include community surveys of macroinvertebrates and fish, chlorophyll *a* concentrations, habitat assessments, channel-measurement data, and fecal coliform and *E. coli* bacterial counts.

Macroinvertebrates. Index scores based on macroinvertebrate communities can indicate relative quality of surface water. Subwatersheds with a relatively low median percentage (0 to 1 percent) of invertebrates in the insect orders Ephemeroptera Plecoptera Trichoptera (EPT) (indicating poor water quality) were the Little Menomonee River, Nor-X-Way Channel, Lincoln Creek, Kinnickinnic River, Wilson Park Creek, Deer Creek, East Branch Root River, and North Branch Oak Creek. The highest median percent EPT concentrations (40 to 51 percent) for subwatersheds were calculated for Lower Root River, Middle Root River, Middle Oak Creek, and Cedar Creek.

The Hilsenhoff Biotic Index (HBI) represents the number of arthropod invertebrates in certain species multiplied by their pollution-tolerance value, divided by the number of arthropods in the sample. Subwatersheds with median HBI scores (6.58 to 8.00) indicating "poor" or "very poor" water quality were the Little Menomonee River, Deer Creek, North Branch Oak Creek, Upper Oak Creek, Middle Oak Creek, Lower Oak Creek, Upper Root River, Lower Root River, and East Branch Root River. Only the Little Menomonee Creek (4.80) and Willow Creek (4.87) subwatersheds had median HBI scores indicating a "good" water-quality rating.

Fish. Fish collection has taken place in all but the smallest headwater streams in the MMSD planning area at one time or another; however, the majority of fish data collection took place in the 1970s. The Index of Biotic Integrity (IBI), which assesses biotic integrity and environmental quality of small streams, was calculated for fish data collected since 1990. The Lincoln Creek subwatershed had the lowest median IBI score (10), indicating "very poor" conditions. The Lower Milwaukee River subwatershed had the highest median IBI score (62), indicating "good" conditions.

Chlorophyll *a*. The highest median chlorophyll *a* concentration (11.70 mg/m^3) was measured in the Lower Milwaukee River subwatershed, and the lowest median concentration (1.46 mg/m^3) was measured in the Upper Root River subwatershed. A subtle seasonal pattern corresponding to algal-bloom periods was displayed by chlorophyll *a* data. Long-term trends at three sites showed an absence of relatively high concentrations during the late 1980s and early 1990s.

Habitat and geomorphic data. Sites where habitat assessments were done were sparse throughout the MMSD planning area but they were in many subwatersheds except those of the Fox River watershed. Data for habitat assessments were available beginning in 1991 and extending through the late 1990s or 2001 in most subwatersheds. Additional stream-channel morphology and streambed measurements were recorded during the MMSD Menomonee River Sediment Transport study (2000–01). Sites examined as part of the Menomonee River sediment transport study were exclusively in the subwatersheds of the Menomonee River watershed and were sampled once (Inter-Fluve, Inc, 2001).

Bacteria. The highest median fecal coliform concentrations were measured in the Underwood Creek (20,000 CFU/100 mL) and Honey Creek (16,650 CFU/100 mL) subwatersheds. The lowest median concentration (230 CFU/100 mL), which was above the USEPA recreational limit of 200 colonies per 100 mL, was measured in the Middle Root River subwatershed.

E. coli samples were collected in six subwatersheds in the planning area beginning in October 2000. The highest median concentrations were measured in the Honey Creek (2,400 CFU/100 mL) and Lincoln Creek (1,300 CFU/100 mL) subwatersheds. The Lower Milwaukee River (220 CFU/100 mL) and Upper Menomonee River (300 CFU/100 mL) subwatersheds had the lowest median concentrations.

Potential Areas for Data Collection for Phase II

A major purpose of this study was to determine where additional sampling should be conducted under the second phase of the Corridor Study. Additional sampling may include:

- Some subwatersheds, such as those in the headwaters.
- Emerging contaminants such as pharmaceuticals and personal care products (PPCPs), human hormones, organic wastewater contaminants, and other constituents that result from human activity.
- *E. coli*, which can serve as an indicator of health risk to swimmers and other recreationl water users.
- Pesticides in all media.
- PCBs.
- Trace elements in water, bed sediment, and tissues (fish, shellfish, and others).
- Samples during winter months or during early snowmelt episodes to address constituents such as chloride and some nutrients that have seasonal variability and that may be affected by factors such as road deicing during the winter.
- Samples for macroinvertebrate and fish-community data and habitat assessments.
- Physical data such as stream-channel cross-section profiles, bridge-scour assessments, flood-plain maps, structures, and shoreline conditions.

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Tables 1–4

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

Literature citation	Characteristics															Description
	Lake Michigan information	Stream information	Field measurements	Major ions/dissolved solids	Nutrients	Pesticides	DOC/TOC	Sediment	Bacteria/viruses	Trace elements	VOCs, PAHs, PCBs dioxins, inorganic, organic contaminants	Wastewater-treatment plants	Urban issues	Modeling	Other	
Ab Razak (1995)		x						x			x					Local study on the Kinnickinnic River to determine the sources of sedimentation and PAHs. Sources of PAHs in the early 1900s were relayed to coking operations and coal tar; more recently, PAHs have been transportation related.
Ab Razak (1999)		x	x	x	x			x	x	x		x				Study on Milwaukee, Menomonee, and Kinnickinnic Rivers before and after the operation of the Inline Storage System to determine its role in reducing pollution. Levels of phosphorus, suspended solids, fecal coliforms, zinc, chloride, and BOD were examined.
Ab Razak and others (1996)		x						x		x	x					Local study on the Kinnickinnic River. Sediment cores were analyzed for PAHs and PCBs. Results were compared with sediment characteristics, clay, silt, and organic carbon to look for correlations.
Anderson (1975)	x		x	x												Statewide classification of lakes by trophic condition. Most lakes examined were 100 acres or larger. Big Muskego Lake and Little Muskego Lake were included in the study. Also discussed were lake protection and rehabilitation procedures and classification and management programs.
Arteaga (1989)		x	x						x							Local study on the relation between bacteria and flagellate populations between Menomonee River and Lake Michigan. Levels were examined in relation to temperature and DO concentrations.
Bannerman and others (1979a)		x	x	x	x			x		x						Local study on the combined loadings of the Menomonee, Milwaukee, and Kinnickinnic Rivers. The effects of wind-induced suspension of sediment on water quality in the Milwaukee Harbor and its vicinity were also discussed.
Bannerman and others (1979b)		x	x	x	x		x	x	x	x	x					Study on the Menomonee River watershed. Water monitoring was performed to assess kinds and amounts of pollutants from land drainage of mixed and single land uses. The study focused mainly on suspended solids, phosphorus, and lead but discussed other constituents as well. Benthic macroinvertebrate surveys were done.
Bannerman and others (1983b)			x	x	x			x	x	x						Local study on characteristics, sources, and management of urban stormwater pollution in Milwaukee County. Characterization of urban stormwater-runoff volumes, contaminant concentrations, loadings, and water-quality effects on receiving waters were discussed. Also discussed were contaminant sources and an examination of the effectiveness of various frequencies of street sweeping.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

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Bannerman and others (1996)		x	x	x	x	x		x		x	x					Statewide study including nine sampling sites in Milwaukee. Samples were collected from storm-sewer pipes and urban streams to determine the quality of stormwater.
Bartošová and Novotny (1999)		x		x				x		x			x	x		Local study using Lincoln Creek to calibrate a model that evaluated the effects of snow removal and road-deicing practices on water quality of urban waters. Data for chloride, lead, suspended solids, and flow were provided.
Baumann and others (1980)		x			x			x		x	x		x			Local study of the Milwaukee and Menomonee Rivers. The study aimed to determine the effects, the characteristics of, and a strategy to deal with urban nonpoint-source pollution. Urban causes of runoff contaminants with a focus on suspended solids, phosphorus, and lead in surface water were examined.
Baun (1982)		x		x												Local study with data from the Menomonee River and Honey Creek. Three methods for estimating contaminant loads in water were discussed: integration, composite, and stratified random sampling. Recommendations were given for choosing the most effective method.
Bothwell (1977)			x	x	x											Local study of the Milwaukee Harbor and nearshore Lake Michigan, including a station at the confluence of the Milwaukee and Kinnickinnic Rivers. An investigation of phytoplankton populations in relation to nutrients was done and other factors such as temperature, chloride, and alkalinity were considered.
Boyer (1988)								x								Local study on the Milwaukee Harbor at the sediment-water interface. Sediment-profile photographs were taken to map sediment type. Gas voids and oligochaete worm tubes were also shown.
Cherkauer (1975a)		x		x				x					x			Local study to determine the effects of urban development on water quality in streams. Four small watersheds in different stages of development were examined in response to the same meteorological events. Total dissolved solids and chloride loads were examined.
Cherkauer (1975b)		x		x				x					x			Local study on two small watersheds in the Milwaukee area, one watershed with predominantly urban land use and the other with agricultural land use. Flow and contaminant loads were compared between the two watersheds after rainfall.
Cherkauer and Ostenso (1976)	x			x									x			Local study on Northridge lakes in Milwaukee. The effects of salt from surface runoff during the winter were examined. Salinity stratification occurred until the spring thaw. Salt concentration in lake outflow remained high year round.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

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Christensen and Lo (1986)								x			x					Local study on the Milwaukee Harbor. A sediment core was taken from the inner harbor, dated, and analyzed for PCBs. The results were compared with Lake Michigan information. Concentrations were shown to link to sales records of PCBs.
Christensen and others (1997a)		x						x			x			x		Local study on the Kinnickinnic River to determine sources of PAHs. A chemical mass-balance model was developed and used on dated sediment cores.
Christensen and others (1997b)			x	x	x											Local study on Milwaukee Harbor and its pollution plume. Data for ammonia, chloride, and turbidity were examined. Results of the study indicated that improved water quality could be obtained by extending or relocating the Howard intake pipe.
Citizens' Advisory Committee (1981)												x	x			A report written to educate the public on water-quality issues pertaining to the Milwaukee Water Pollution Abatement Program. The goal of the report was to show the need for public involvement in working towards improving water quality.
City of Milwaukee Wisconsin Department of Public Works and Consoer, Townsend, and Associates Consulting Engineers (1974)		x	x	x	x				x					x		Local study looking at effectiveness of detention tanks in preventing combined-sewer overflows. Five years of data and modeling studies were done on the Milwaukee River, in which the water quality was examined in relation to rainfall.
City of Milwaukee Wisconsin Department of Public Works and Consoer, Townsend, and Associates Consulting Engineers (1975)			x	x	x				x			x	x	x		Local evaluation of a combined-sewer overflow detention tank in Milwaukee. Based on modeling studies and data from sewer and river monitoring, detention tanks were shown to prevent combined-sewer-overflow contaminants from reaching receiving waters.
Corsi and others (2001a)		x	x						x							Local study of the effect of aircraft and runway deicers from General Mitchell International Airport on Wilson Park Creek and the Kinnickinnic River. The study examined the loading patterns and subsequent responses of BOD and DO with respect to precipitation events.
Corsi and others (2001b)		x														Local study of the effect of aircraft and runway deicers from General Mitchell International Airport regarding toxicity to aquatic life in receiving waters.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

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DeVault (1985)		x				x					x					Multistate study of tributaries to the Great Lakes, including the Milwaukee and Kinnickinnic Rivers. Fish samples were analyzed for contamination from pesticides and other priority pollutants, including PCBs and PAHs.
DeVita (1994)		x									x					Local study on Lincoln Creek. An evaluation of semipermeable polymeric membrane devices as concentrators of nonpolar organic contaminants, namely PAHs, was made. Concentration levels were compared in relation to storm events. Uptake by fathead minnows and rusty crayfish was also examined.
Dong and others (1979)		x			x			x		x						Study of the Menomonee River watershed. Metal composition in sand-, silt-, and clay-sized fractions of soil types, bottom sediments, suspended sediments, and dust and dirt samples were analyzed. A method for estimating soil dispersibility was developed.
Dong and others (1983b)		x						x		x						Local study on the Menomonee River and the tributaries in its watershed to determine the metal contents of soils, street dust, bottom and suspended sediments.
Dong and others (1984)		x			x			x								Study on the Menomonee River watershed. Phosphorus levels were compared with particle size of soils, street dust, and bottom and suspended sediments. An attempt was made to identify phosphorus sources by particle-size composition.
Druckenmiller (1980)	x		x	x	x					x	x					Local Environmental Impact Statement for a plan to dredge Little Muskego Lake. The goal of dredging was to improve aquatic life, aesthetic qualities, and recreational uses by deepening shallow areas and controlling macrophyte growth.
Fetter and Feyerherm (1996)					x					x	x					Statewide report on toxic releases to air, water, land and off-site transfers. Included were data on pounds released to nearby waterbodies.
Fitzgerald (1997)		x		x	x	x	x	x		x	x					Regional study of the Western Lake Michigan Drainages. The purpose of the study was to describe results of a quality-control program. Samples were collected from ground water, bed sediment, tissue, and surface water, and analyzed for nutrients, major ions, and other pollutants.
Fitzpatrick and Giddings (1997)		x						x								Regional study on the Western Lake Michigan Drainages including sites on Lincoln Creek and the Milwaukee River. The sites were evaluated for stream habitat. Channel geometry, substrate, streambank, and riparian characteristics were examined.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

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Gergerich (1978)		x	x						x							Local study on the Milwaukee and Menomonee Rivers to show the relationship of bacteriolytic organisms with fecally polluted waters. Presence of the organisms was compared with levels of sewage-indicator bacteria, and abundance was examined in relation to temperature and rainfall.
Ghosh and others (2000)								x			x					Local study on the Milwaukee Harbor sediments to determine concentrations of PAHs according to different types of particles.
Gin (1992)							x									Local study of the Milwaukee Harbor Estuary and the rivers that drain into it. Sedimentation was examined by dating cores with Pb-210 and Cs-137 methods; cores were analyzed for porosity and TOC.
Graczyk and others (1993)		x			x			x								Statewide study on nonpoint-source pollution. Rainfall, water quality, bedload, metals, DO, total and dissolved hardness, and quality control were examined. Data on precipitation and stormwater runoff was given for the Menomonee River.
Great Lakes Commission (2000)		x			x	x		x	x		x		x			Multistate review of the Lake Michigan watershed and its subwatersheds, one of which was the Milwaukee River and the estuary. Ongoing monitoring and recommendations for further actions were discussed.
Hajda (1993)		x			x									x		Local study on the Milwaukee River to estimate the effects of the removal of the North Avenue Dam by using a mathematical model. Data was given for levels of ammonia, nitrate, inorganic and organic phosphorus, chlorophyll *a*, BOD, DO, organic nitrogen, and streamflow.
Hajda and Novotny (1996)		x	x		x									x		Local study on the Milwaukee River to assess the effect on water quality by the presence or absence of the North Avenue Dam. A model incorporating phytoplankton production was used and estimated the effects the removal of the dam would have on DO, chlorophyll *a*, BOD, and nutrient levels.
Hansen and others (1983)			x	x	x			x		x						Local study on stormwater pollution in Milwaukee County. This volume presented the procedures used for the field monitoring data in volumes 1 and 2. Also described were the sites that were examined in the study.
Harsch (1972)		x	x	x	x	x	x		x	x						A collection of papers concerning the Menomonee River. Section A contained scientific investigations and research data. Section B examined sociological and economic problems of pollution and examinations of types of abatement.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Hussa and others (1973)		x									x					Local report on the Little Menomonee River written in response to children that received chemical burns from creosote after being in the river. Analysis of samples from the site were done. The report included a compilation of letters from groups examining the problem.
Jodie (1974)			x	x	x				x	x						Local study of stormwater runoff collected from two urban freeways in Milwaukee. The samples were shown to be of poor water quality and were compared to samples from Jones Island Sewerage Treatment Plant, the Menomonee River, other stormwater data, and Wisconsin standards.
Johanson (1990)		x	x	x	x					x						Local study on the Milwaukee River and the Blue Hole abandoned landfill. The purpose was to define the hydrogeology and contaminant distribution in the landfill and to determine the effects of ground water from the Blue Hole site on the water quality of the Milwaukee River.
Kammerer and Krug (1993)		x		x	x			x	x				x			Statewide study of surface-water quality, which included data for the Milwaukee River. Constituents discussed included fecal coliform, dissolved sulfate, dissolved chloride, dissolved solids, dissolved nitrite plus nitrate, and suspended sediment.
Kasun (2001)		x	x							x				x		Local study on Oak Creek and the Menomonee River. The objective of the research was to predict the bioavailable concentrations of heavy metals in interstitial porewater and examine the ecological risk by looking at benthic macroinvertebrates.
Kincaid (1981)			x	x	x					x	x					Local study on acid rain and its sources and effects in Milwaukee. Runoff was also evaluated, and the report included data on pH and other chemical constituents.
Kizlauskas (1986)	x	x			x	x		x		x	x	x	x			Local study of sediment in the Milwaukee Estuary. Sediment samples were analyzed for organic and inorganic contaminants, PCBs, and polynuclear hydrocarbons.
Kleinert (1971)		x				x							x			Local study of methoxychlor in surface water in Lincoln Creek. Methoxychlor was applied to parts of the watershed to combat Dutch elm disease.
Kleinert and Degurse (1972)	x	x								x						Statewide study of mercury concentrations in Wisconsin fish and wildlife. Included fish from the Milwaukee River and the Milwaukee Harbor.
Kohler (1982)	x		x		x											Local study on Big Muskego Lake examining the phytoplankton population. The examination included the effects on the phytoplankton population by biological and physiochemical factors such as nitrogen, phosphorus, pH, DO, and(or) zooplankton.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Konrad and Kleinert (1974)										x		x				Statewide investigation on toxic heavy metal discharge sources and effectiveness of removal treatments. Information for the Milwaukee area was included.
Konrad and others (1978)		x		x	x			x		x				x		Local study on the Menomonee River watershed. An examination of land use, phosphorus, lead, and suspended solids data was used to create a model to describe the contaminants that enter surface waters from land surfaces after a rainfall event.
Konrad and others (1979)		x	x	x	x			x	x			x	x	x		Local study describing ground-water effects on the quality of the Menomonee River. Loading rates were quantified and major contaminants and sources were identified. A predictive model was tested to measure ground-water response to changes in land-use or -management practices.
Korth (1978)		x						x			x					Local study on the Milwaukee River to determine the effect that algae had on sediment oxygen demand; it was not shown to be a significant source.
Kreutzberger and others (1980)		x	x					x				x		x		Local study on the Milwaukee River to show that sediments were the source of wet weather oxygen demand. A model was created to predict the impact of combined-sewer overflows on dissolved oxygen levels.
Krumbiegel and Hulbert (1970)		x	x	x					x			x	x			Local study on the Kinnickinnic River to determine the effect of the flushing station on water quality. Four sampling sites, one at the flushing tunnel outlet, one upstream and two downstream from the outlet were used. Samples were tested for DO, BOD, pH, turbidity, chlorides, and fecal coliform.
Lai (1995)		x						x		x				x		Local study using Monte Carlo methodology to create a model. The model was used to simulate water and sediment quality of a reach of the Milwaukee River that included an urban impoundment for toxic metal contaminants. The model was to be used to predict the effect of abatements like the removal of the North Avenue Dam on water quality.
Lee and others (1981)			x	x	x				x			x				Local study on biological and chemical water quality in the Milwaukee Harbor and Lake Michigan. The mixing and transport of wastewater-treatment-plant effluent plumes were examined. Indicator bacteria and viruses were also investigated.

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Lenz and Rheaume (2000)		x	x		x											Regional study of the Western Lake Michigan Drainages. Lincoln Creek and Milwaukee River were included in the study. Distribution and community structure of benthic invertebrates were discussed and used as water-quality indicators. Environmental setting and habitat were also examined.
Li and others (1998)		x						x			x					Local study on the Milwaukee Harbor Estuary. Sediment samples were analyzed for PAHs. Grain size, porosity, and TOC were also determined. The report discussed the effects of industrialization in the Milwaukee area.
Lo (1982)								x			x					Local study of the Milwaukee Harbor developing a simple and inexpensive way to determine PCBs in sediments using three Aroclors. Pb-210 dating was used and sedimentation rates determined.
Mace (1984)		x	x		x											Regional study on southern Wisconsin streams for the purpose of setting appropriate water-quality goals or standards for amounts of phosphorus. Milwaukee River was included in the study. Nutrient levels were compared to macrophyte and algal growth and the effect of nutrients on DO concentrations was examined.
Martin and others (1983)	x		x													Statewide examination of Wisconsin lakes. The trophic condition of about 3,000 inland lakes was assessed using Landsat satellite data. Waterbodies from Ozaukee, Washington, and Waukesha Counties were included in the study.
Masterson and Bannerman (1994)		x	x	x	x		x	x		x	x					Local study on rivers in Milwaukee County. Chemical analysis was done on sediment, fish, crayfish tissue, and water samples to determine the effects of stormwater runoff on each. Bioaccumulation was examined and an index of biotic integrity for macroinvertebrates was calculated.
Meinholz and others (1979)		x	x	x	x		x	x	x	x		x		x		Local study on the effects on the Milwaukee River following wet-weather discharges. Dissolved oxygen and fecal coliform concentrations were monitored in relation to flow. Other chemical characteristics were also examined.
Metropolitan Sewerage District of the County of Milwaukee and Stevens, Thompson, & Runyan (1975)												x	x			Plan formed in response to a study that addressed problems due to combined-sewer overflows. The report gives an overview of the project and their objectives.

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Mildner (1978)		x		x	x			x		x						Multistate study to evaluate the effect of material eroded from riverbanks on water quality of the Great Lakes. Riverbank protection measures and costs were determined. The Menomonee River and Germantown watershed were used as study sites.
Miller (1980)		x			x			x						x		The goal of this regional study was to determine the feasibility of making regional inferences from water-quality monitoring data. Data for suspended solids, soluble phosphorus, and adsorbed phosphorus for the Menomonee River were included.
Miller and others (1979)		x			x			x								Regional examination of suspended solids, soluble phosphorus, and adsorbed phosphorus data by season, year, and event status was included for the Menomonee River.
Miller and others (1992)		x										x				Local study on the Root River. Results were discussed in relation to the objectives of the 1980 Root River Nonpoint Source Water Pollution Plan to determine if the goals of the plan were being achieved.
Milwaukee Metropolitan Sewerage District (1976)			x	x	x				x			x	x			Description of the MMSD Master Facilities Plan, which was designed to reduce water pollution. The study included an analysis of alternate solutions and an explanation of the pollution problems and their causes.
Milwaukee Metropolitan Sewerage District (1980a)			x	x	x				x	x	x	x	x			Report on a plan for combined-sewer overflow abatement. Environmental effects on the Milwaukee, Menomonee, and Kinnickinnic Rivers were examined.
Milwaukee Metropolitan Sewerage District (1980b)			x	x	x				x			x	x			Report on a plan for the Franklin-Muskego Interceptor Facility. Included was an environmental assessment with information on Little Muskego Lake, Big Muskego Lake, Little Muskego Creek, Tess Corners Creek, and the Root River.
Milwaukee Metropolitan Sewerage District (1980c)		x	x	x	x				x			x	x			Report on the Franklin-Northeast Interceptor Facility plan. An examination of the status of the Root River and the effects that the proposed plan will have on it were included.
Milwaukee Metropolitan Sewerage District (1980d)			x	x	x			x	x	x	x	x	x			Local plan for Jones Island Facility. Discussed were the existing environmental status and the effects the plan will have on the Milwaukee Harbor; the report also included some information on the tributaries leading into the harbor.
Milwaukee Metropolitan Sewerage District (1980e)		x	x	x	x				x			x	x			Report on the Mitchell Field South Interceptor Facility Plan. The current status of water quality in the Mitchell Field Drainage Ditch and Oak Creek, and the effects that the plan may have on water quality in the future were discussed.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Milwaukee Metropolitan Sewerage District (1980f)			x	x	x				x			x	x			Local plan for water-pollution abatement facilities. Existing and future conditions affecting water quality in the area were discussed.
Milwaukee Metropolitan Sewerage District (1980g)		x	x	x	x				x			x	x			Local plan for the Northridge Interceptor Facility with an environmental assessment on Beaver Creek, Trinity Creek, and Milwaukee River. Land use and physical/chemical characteristics were discussed.
Milwaukee Metropolitan Sewerage District (1980h)		x	x	x	x				x			x	x			Report on the Oak Creek North Branch Interceptor Facility Plan. The study examines the status of Oak Creek and the effects the plan will have on it.
Milwaukee Metropolitan Sewerage District (1980i)		x										x				Local plan for the Root River Interceptor Facility with an environmental assessment of the Root River in New Berlin, Wis.
Milwaukee Metropolitan Sewerage District (1980j)		x	x	x	x				x			x				Local plan for the MMSD Underwood Creek Interceptor Facility with an environmental assessment on Underwood Creek, Dousman Ditch, and the Menomonee River. The study discusses land use, some point sources of pollution, and physical/chemical characteristics.
Milwaukee Metropolitan Sewerage District (1981)		x	x	x	x							x				Local study on the Milwaukee, Menomonee, Kinnickinnic, and Root Rivers. Some history of the area was given and data on pollutant loads of phosphorus, BOD, and suspended solids were included.
Milwaukee Metropolitan Sewerage District (1982)		x	x	x	x				x	x		x	x			Local reports prepared for the MMSD Water Pollution Abatement Program. The study evaluated and refined the 1980 Master Facilities Plan and included an environmental assessment.
Milwaukee River Technical Task Force (1975)		x											x			Report by the Mayor's Task Force on the Milwaukee River. The Task Force gave their recommendations for what needed to be done to improve water quality, including discussions of land use, reduction of sewer overflows, other agencies' plans, and continual study.
Mortimer (1981)					x				x			x				Overview of a court case involving the State of Illinois versus Milwaukee and nearby cities. The issue of concern was pollution of Lake Michigan by sewer overflows and discharges.
Myers and others (1994)		x						x	x		x					Study on Milwaukee Harbor, Green Bay, and Lake Erie. Sampling sites on the Milwaukee, Kinnickinnic, and Menomonee Rivers were included. An investigation of the degradation of aromatic compounds found in sediments under anaerobic conditions was done. The study also looked at the role of iron- and manganese-reducing bacteria.

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Novotny (1986)			x	x	x		x		x	x	x			x		Local study on Milwaukee metropolitan area to develop a snowmelt-runoff model. The model can be used to predict snow accumulation and snowmelt in urban areas. The study looks at accumulation of contaminants in snow, flow rates, and use of deicing chemicals. A model was used to simulate chloride concentrations and flow.
Novotny and Bendoricchio (1989)		x	x		x							x				Local study with information on the Menomonee River watershed and some of the tributaries within the watershed. The model LANDRUN (a model used to estimate the quantity and quality of runoff water and eroded particulates from watersheds with mixed land uses) was used for estimating sediment loadings from various land uses and other factors like soil characteristics and imperviousness. Phosphorus loadings were also examined.
Novotny and others (1979a)		x			x			x					x	x		Study on the Milwaukee River and the canals of Venice. The study examined nonpoint-source pollution and looked at problems associated with excess nutrients and their relationship with productivity and oxygen demand. Included were data on DO, nitrogen, and chlorophyll *a* levels from MMSD.
Novotny and others (1979b)		x			x			x						x		Local study using LANDRUN, a model used to estimate the quantity and quality of runoff water and eroded particulates from watersheds with mixed land uses. Runoff, sediment, volatile suspended solids, and phosphate data from Novey Creek, Schoonmaker Creek, and the Little Menomonee River were used to calibrate the model.
Novotny and others (1993)		x					x	x		x	x	x	x	x		Local study of the North Avenue urban impoundment on the Milwaukee River. Sediment volume, characteristics, and contamination were examined. Sources of toxic metals were found to be from urban runoff.
Novotny and others (1994)		x						x		x		x		x		Local study of the North Avenue urban impoundment on the Milwaukee River. A model was used to simulate water and sediment quality in areas contaminated by toxic metals.
Ovaska (1995)			x													Local study on the quality of the water taken in by the Howard Avenue and Linwood plants. Turbidity, pH, temperature, alkalinity, and wind velocity were examined.
Owens and others (1997)		x		x	x			x		x						Statewide evaluation of nonpoint-source contamination and management practices. Lincoln Creek and Milwaukee River were included in the study. Data were given for precipitation, flow, suspended solids, phosphorus, and metals.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Pariso and others (1983)		x				x		x		x	x					Regional study of the Wisconsin coast. Milwaukee, Kinnickinnic, Root, and Menomonee Rivers, and Oak Creek were included in the study. Fish, sediment, and effluent samples were tested for contaminants.
Peters (1995)		x				x										Summary of a meeting concerning the Western Lake Michigan Drainages, which was studied as part of the National Water-Quality Assessment Program. Included are summaries of presentations made at the meeting, which included information on pesticides in the Milwaukee River and Lincoln Creek.
Peters (1997)		x		x				x					x			Regional study on the Western Lake Michigan Drainages. The report detailed natural and anthropogenic features of the area that have an effect on water quality. These included geology, climate, vegetation, land use, and hydrologic and biological characteristics.
Peters and others (1998)		x		x	x	x		x		x	x		x		x	Summary of studies done in the Western Lake Michigan Drainages as part of the National Water-Quality Assessment Program. Included was information for the Milwaukee River and Lincoln Creek regarding the physical description of the study area; pesticide, nutrient, trace element, and organic compound concentrations; and index values for macroinvertebrates, fish, habitat, and algae.
Phoomiphakdeephan (1994)			x	x	x											Local study examining water quality taken into the Linwood and Howard Avenue Filtration Plants. A change in the location of the intake was recommended for the Howard Avenue plant, which obtained water flowing from the harbor. The study examined levels of ammonia, chloride, temperature, and turbidity coming from the Harbor.
R.A. Smith & Associates Inc. and others (1996)		x	x	x	x					x			x			Local study on the Menomonee River. The study evaluates the potential of returning the river to a more natural state and improving recreational access. Some of the proposed ideas were creating a wetland, making a trail, and removing the concrete lining.
Rachdawong and Christensen (1997)		x						x			x			x		Local study on PCBs from the Milwaukee Harbor Estuary, Inner and Outer Milwaukee Harbor, and the Kinnickinnic River. Sediment cores were dated and analyzed to try to determine sources of PCB concentrations.
Richards and others (1998)		x		x	x					x						Regional study of surface-water quality of Wisconsin streams in the Western Lake Michigan Drainages. The study included sites on the Milwaukee River and Lincoln Creek and described techniques used to collect water samples and methods for analysis.

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Robertson (1997)		x			x			x								Regional study on tributaries to Lake Michigan and Lake Superior, including the Milwaukee River. Suspended sediment and phosphorus loads were estimated for unmonitored locations using data from monitored sites. Stream gradient, land use, and soil type also were examined.
Robertson (1998)		x			x			x								Regional study of the Western Lake Michigan Drainages. Study locations included sites on Lincoln Creek, Little Menomonee River, Honey Creek, Oak Creek, and the Kinnickinnic River. Streamflow, nutrients, and suspended-sediment data were used to look at the effects on water quality by land use, surficial deposits, and bedrock type.
Robertson and Saad (1996)		x			x			x								Regional study regarding nutrients and suspended sediment in ground- and surface-waters of the Western Lake Michigan Drainages. A site on the Milwaukee River was included in the analysis.
Sawicki and Judd (1982)													x		x	Case study on the Root River watershed to determine the effectiveness of a voluntary, decentralized institutional system for managing nonpoint-source water pollution. Factors considered were land use, educational needs, economic conditions, water quality, number of agencies involved, authority, and bureaucratic requirements.
Science Applications International Corporation (1993)		x				x		x		x	x		x			Multistate study on the Lake Michigan Basin. The purpose of the study was to inform the public and get their comments on agencies' activities and future actions. Information on the effects of toxic contaminants in the Great Lakes and their sources was given.
Scudder and others (1996)											x					Regional study of the Western Lake Michigan Drainage Basin. The report contained a summary of biological aspects of the region and also had tables of references on biologic investigations.
Scudder and others (1997)		x				x	x	x		x	x		x			Regional study of the Western Lake Michigan Drainages. Sampling sites included the Milwaukee River, Kinnickinnic River, and Lincoln Creek. Trace elements and synthetic organic compounds were examined in sediment and biota.
Singh (1992)		x									x					Local study on nonpoint sources of PAHs in the Milwaukee Harbor Estuary. Samples were collected from the Milwaukee Harbor and the Milwaukee, Menomonee, and Kinnickinnic Rivers.
Singh and others (1993)		x						x			x			x		Local study on nonpoint-sources of PAHs in the Milwaukee Harbor Estuary. Sediment samples were collected from the Milwaukee, Kinnickinnic, and Menomonee Rivers, and the Inner and Outer harbor.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Skinner and Borman (1973)		x	x	x	x			x				x	x		x	Report on regional study with maps that showed topography and drainage, land use, physical setting, ground-water quality, surface-water quality, and water use for the Lake Michigan drainage basin within Wisconsin.
Sonzogni and others (1978)		x		x	x											Multistate summary on loads to the Great Lakes from their tributaries. The Milwaukee, Menomonee, and Root Rivers were included in the study. The report contained data describing levels of nutrients, chloride, and suspended solids.
Southeastern Wisconsin Regional Planning Commission (1971)		x	x	x	x				x			x	x			Regional study on the Milwaukee River to show the need for comprehensive regional planning. The study discussed existing water conditions and problems and gave possible solutions. Topics covered included flooding, water quality, water supply, and recreation.
Southeastern Wisconsin Regional Planning Commission (1976)		x	x	x	x			x	x	x	x	x				Local study on the Menomonee River watershed to provide a plan that will work on the flooding problems and increase the health of the river and its habitat. Physical description of the area was given along with wildlife that was found there. Data for flooding and surface water monitoring were also given.
Southeastern Wisconsin Regional Planning Commission (1977)			x	x	x							x				Regional study that examines point-source pollution, especially from wastewater- treatment plants. Appendix A listed companies, where they discharged sewage to, and characteristics of the water.
Southeastern Wisconsin Regional Planning Commission (1978a)			x		x				x			x	x			Regional plan to prevent water pollution in southeastern Wisconsin up to the year 2000. The study discussed sources of pollution, disposal or use of solids removed from wastewaters, and management responsibility.
Southeastern Wisconsin Regional Planning Commission (1978b)		x	x	x	x	x		x	x	x			x			Local study on the Kinnickinnic River watershed to choose a plan that would assist in decreasing flood risk and water pollution. Physical description of the area was given along with flooding and surface-water-monitoring data.
Southeastern Wisconsin Regional Planning Commission (1978c)		x	x	x	x				x			x	x			Regional study on the Lake Michigan Drainage Area in southeastern Wisconsin. The purpose was to show the need for, the major elements, and the organizations of a comprehensive planning program. The study had information on the Root River and the Milwaukee Harbor Estuary.
Southeastern Wisconsin Regional Planning Commission (1978d)			x		x			x	x	x		x	x			Regional study of point- and nonpoint-source water pollution in southeastern Wisconsin. Provided data included nitrogen, phosphorus, BOD, sediment, and fecal coliform loads from urban and rural sources to different bodies of water.

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Southeastern Wisconsin Regional Planning Commission (1978e)	x	x	x	x	x				x	x	x	x				Regional study of lakes and streams in southeastern Wisconsin. Included in the report were data on the Milwaukee, Root, Menomonee, and Kinnickinnic Rivers, and Oak Creek.
Southeastern Wisconsin Regional Planning Commission (1979)		x	x	x	x				x				x			Local study on the Oak Creek watershed, which also included the Mitchell Field Drainage Ditch. Existing water quality was evaluated and a program was developed to address flooding, water pollution, and other related problems.
Southeastern Wisconsin Regional Planning Commission (1980)		x	x	x	x				x			x	x			Local study on the Root River and its tributaries. This plan discussed the control of pollution from both urban and rural sources.
Southeastern Wisconsin Regional Planning Commission (1982b)	x	x										x	x			Local plan for the city of Muskego for sanitary sewer service. Land use and environmentally significant lands were discussed.
Southeastern Wisconsin Regional Planning Commission (1983)												x				Local plan for the city of Germantown for sanitary sewer service. Land use and environmentally significant lands were discussed.
Southeastern Wisconsin Regional Planning Commission (1984)												x				Local plan for sanitary sewer service for Butler, Wis. The plan also included proposals for an environmental corridor along the Menomonee River.
Southeastern Wisconsin Regional Planning Commission (1986c)		x	x	x	x			x	x							Local study on the Oak Creek watershed to provide a plan that will address flooding problems and increase the health of the river and its habitat. A physical description of the area was given along with a listing wildlife that was found there. Data for flooding and surface-water monitoring were also provided.
Southeastern Wisconsin Regional Planning Commission (1987a)		x	x	x	x	x	x	x	x	x	x	x				Local study on the Milwaukee Harbor Estuary, which involved the Milwaukee, Menomonee, and Kinnickinnic Rivers, and the Milwaukee Harbor. The purpose of the study was to prepare a plan that would help control pollution, mitigate flood problems, control storm damage in the harbor, and improve water quality for recreational uses. Monitoring data are provided.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

Literature citation	Characteristics															Description
	Lake Michigan information	Stream information	Field measurements	Major ions/dissolved solids	Nutrients	Pesticides	DOC/TOC	Sediment	Bacteria/viruses	Trace elements	VOCs, PAHs, PCBs dioxins, inorganic, organic contaminants	Wastewater-treatment plants	Urban issues	Modeling	Other	
Southeastern Wisconsin Regional Planning Commission (1987b)												x				Local plan for the city of New Berlin for sanitary sewer service. The plan discussed land use and environmentally significant lands.
Southeastern Wisconsin Regional Planning Commission (1993)		x				x				x	x					Local plan for flood and stormwater management for Lilly Creek subwatershed. The plan evaluated alternative plans with the purpose of eliminating current problems and avoiding future ones, while also considering nonpoint-source pollution and river habitat.
Southeastern Wisconsin Regional Planning Commission (1994)												x				Local plan for the city of Oak Creek for sanitary sewer service. The plan discussed land use and environmentally significant lands.
Southeastern Wisconsin Regional Planning Commission (1995a)	x	x	x	x	x	x		x	x	x	x	x	x	x		Regional report that described the updates to a water-quality management plan for southeastern Wisconsin. Also included was the status of the current implementation of the plan.
Southeastern Wisconsin Regional Planning Commission (1996)	x		x	x	x	x	x	x		x	x		x			Local management plan for Little Muskego Lake. Goals of the plan included reducing sediment and contaminant loading to the lake, reducing aquatic macrophyte and algal growths, promoting public awareness, improving aesthetics and use for recreation, and improving habitat for fish and other wildlife.
Southeastern Wisconsin Regional Planning Commission and others (2000)		x				x				x	x					Local study on Dousman Ditch and Underwood Creek subwatershed of the Menomonee River watershed. The study identifies stormwater management and flooding problems and their causes. The study also sets forth a management plan after examining alternatives.
Stanley and Erickson (1977)		x	x					x				x	x	x		Local study on the Milwaukee metropolitan area to design a model that predicts effects on water quality by industry. The major focus of the study was on costs and economic issues.
Steuer and others (1999)		x		x			x				x					Local study on PCBs in Cedar Creek and the Milwaukee River. PCB levels were compared with total suspended solids and chlorophyll *a* concentrations.
Sullivan and others (1980)		x		x	x			x								Regional study of the Great Lakes Basins area. This study was an update to studies and management programs of the Pollution from Land Use Activities Reference Group. The study examined pollution loadings to the Great Lakes, especially phosphorus nonpoint sources. The Menomonee River was studied, and there was some information on the Milwaukee and Root Rivers.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Sullivan and others (1995)		x	x													Regional study of the environmental settings of study sites in the Western Lake Michigan Drainages. Lincoln Creek and the Milwaukee River were included in the study. Data were given for land use, physical characteristics of the streams, and field measurements.
Sullivan and Richards (1996)		x				x										Regional study of pesticides in surface water in the Western Lake Michigan Drainages. Data were included for the Milwaukee River.
Sung (1983)				x	x					x	x			x		Eight watersheds in Milwaukee County studied to estimate nonpoint-source pollution and identify its sources. A model was created to help in the design of urban nonpoint-source control programs.
Syftestad (1985)			x	x	x											Statewide study that provided data about public water supply facilities and water chemistry data. Samples were collected for each municipal system from raw surface water, raw well water, or finished water distribution samples.
Task Force on Pollution from Sources Outside the Milwaukee Metropolitan Sewerage District (1983)		x	x		x			x	x							The task force sought to determine if improvements made by MMSD would be enough to significantly improve water quality in the district or if a point- and nonpoint-source pollution abatement program was needed outside of the district.
Taylor (1994)		x	x		x			x		x						Local study on the Kinnickinnic River examined nonpoint sources of pollution. Urban runoff and erosion from construction sites and streambanks were the main issues or concern.
Toyingtrakoon (1996)		x	x	x	x			x	x			x				Local study on the Milwaukee, Menomonee, and Kinnickinnic Rivers, and the Jones Island wastewater treatment facility to determine the effects of the Inline Storage System. Measurements included levels of phosphorus, BOD, fecal coliforms, and suspended solids after precipitation.
Tseng (1978)										x		x				Local study on sludges from Milwaukee Jones Island and South Shore wastewater- treatment plants and the Howard and Linwood Avenue purification plants. Samples were tested for heavy metals, total solids, and volatile solids.
U.S. Environmental Protection Agency (1980)		x	x	x	x				x	x		x	x			Local study addressing the MMSD Master Facilities Plan. The study analyzed the effects of the proposed actions and alternatives on the environment and the existing water quality. Data for ammonia, nitrogen, phosphorus, BOD, pH, flow, fecal coliforms, and chloride were included.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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U.S. Environmental Protection Agency and others (1980)		x	x	x	x				x	x		x	x			Local study of MMSD area addressing the proposed Master Facilities Plan. The focus of the study was the issue of overflows caused by infiltration of ground water and stormwater. Current (1980) water quality and how the plan will affect it was examined.
Veith (1970)		x	x	x							x					Study of the Milwaukee River to determine the chemical nature of organochlorine compounds found in fish. Analysis procedures were developed and the sources, fate, and concentrations of the compounds were determined.
Veith and Lee (1971)		x	x	x							x					Local study on chlorobiphenyls in the Milwaukee River. The contaminants were shown to be discharged to natural waters through municipal and industrial wastes.
Villeneuve and others (1997)		x									x					Local study to determine long-term toxicity effects on stream biota from urban stormwater runoff. Fish hepatoma cells were used and exposed to water from Lincoln Creek.
Walker and others (1995)		x	x	x	x			x								Statewide study to evaluate the effectiveness of best-management practices for controlling non-point-source contamination. Lincoln Creek and the Menomonee River were included in the study. The study discussed land-use practices, rural loads, stream-water quality, and snowmelt runoff.
Windstrup (1993)		x	x				x	x		x	x			x		Local study on Milwaukee River to create a model for predicting concentrations of heavy metals. Data for zinc, cadmium, chromium, lead, and copper in sediment and mudflat samples were provided. Total organic carbon, total volatile solids, and pH were also examined.
Wisconsin Department of Natural Resources (1971)	x		x	x	x					x		x	x			Local study on Big Muskego Lake. A description of drainage characteristics, soils, water quality, aquatic plants, fish, wildlife, recreational use, and the surrounding land use was included.
Wisconsin Department of Natural Resources (1975)		x											x		x	Regional study that summarized industrial discharges to waters in southeastern Wisconsin. The report also discussed permits and compliance schedules.
Wisconsin Department of Natural Resources (1976)		x	x	x	x	x		x		x						Regional report on southeastern Wisconsin that included the Root River and tributaries in the area. Data from water-quality sampling and an evaluation survey done during 1973 were presented.
Wisconsin Department of Natural Resources (1979)		x	x		x							x				Regional study on small streams included the Root River tributaries in New Berlin and Hales Corners. The major goal of the program was to provide data for the development of waste load allocations for discharges to streams. Secondly, it aimed to document the effects of increased treatment-plant efficiency on stream health.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Wisconsin Department of Natural Resources (1980)	x		x	x	x			x		x			x			Local report on Little Muskego Lake that described a plan for and probable environmental effects of dredging the lake.
Wisconsin Department of Natural Resources (1982, 1984, 1990, 1992, 1994, 2000)		x	x	x	x	x			x		x		x			Statewide reports on water quality with some specific information on Milwaukee County and the surrounding area. The reports cover a variety of topics including PCBs in fish and pollution and data on some chemical constituents as well. Data were given for the Milwaukee River, Milwaukee Estuary, Lincoln Creek, and North Avenue Dam.
Wisconsin Department of Natural Resources (1983a)		x		x	x				x	x						Local study on stormwater pollution in Milwaukee County. This volume examined street sweeping as well as detention and retention basins. Also evaluated were the costs of these measures and the anticipated pollution load removals.
Wisconsin Department of Natural Resources (1983b)	x		x	x	x											Statewide study on Wisconsin lakes. The majority of information was recorded by region, but chloride levels were given for Little Muskego Lake.
Wisconsin Department of Natural Resources (1986)		x	x	x	x				x	x						Surface-water-quality report based on monthly samples taken from 49 sites throughout the State. Included were sites on the Milwaukee and Kinnickinnic Rivers.
Wisconsin Department of Natural Resources (1989)		x	x		x	x		x		x	x					Report on the Milwaukee Area of Concern in the Great Lakes Basin. Menomonee, Kinnickinnic, and Milwaukee Rivers and the Milwaukee Inner Harbor were included in the study. The purpose of the report was to present water-resource problems and the stage they were at regarding remediation. Also presented were toxics data, including those contaminants found in fish.
Wisconsin Department of Natural Resources (1990)												x			x	Local study on the Menomonee River watershed with the purpose of creating a management plan. The study identified major environmental concerns and detailed strategies for improvement. Water resources information was given by subwatershed with information on wildlife and habitat, land use, solid and hazardous waste, and nonpoint-source pollution.
Wisconsin Department of Natural Resources (1991)		x			x			x		x			x			Local study on Milwaukee River South to determine nonpoint sources of pollution to the river and recommend management actions. The most information was given for levels of phosphorus, lead, and sediments.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[DOC, dissolved organic carbon; TOC, total organic carbon; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

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Wisconsin Department of Natural Resources (1992a)		x			x			x		x			x			Local study on the Menomonee River watershed. The study assessed sources of water pollution and identified management practices to be implemented. The main pollutants discussed were sediments, phosphorus, and lead.
Wisconsin Department of Natural Resources (1992b)						x					x	x	x			Statewide study to establish a database on the distribution and abundance of all fish species. The study compares the 1900–72 distributions to the studies in 1974–86.
Wisconsin Department of Natural Resources (1992c)		x										x	x			Local study on Milwaukee River South watershed. The existing water-quality and environmental concerns such as habitat and sewage- treatment plants were described and possible water pollution causes and management strategies were outlined.
Wisconsin Department of Natural Resources (1993a)	x	x			x			x		x			x			Local study on the Wind and Muskego Lakes and the tributaries draining into them. The study examined nonpoint-source pollution with the main focus on sediment loads.
Wisconsin Department of Natural Resources (1993b, 1994, 1996, 1997, 1998)		x	x					x								Statewide study using six watersheds as study areas included the Milwaukee River South. The goal of the study was to determine the extent to which management practices improved fish habitat and communities.
Wisconsin Department of Natural Resources (1994)		x				x		x		x	x	x	x			Local study of the Milwaukee Estuary and rivers draining into it. The study identified environmental problems and impaired uses and gave a brief overview of each. Also included were recommendations for plans to restore water quality.
Wisconsin Department of Natural Resources (1999)											x		x			Report for the entire Milwaukee River watershed. The purpose of the report was to develop a public process to determine useful measurements for describing ecosystem conditions. Many possible indicators including air, water, biodiversity, and education were discussed and some data was presented for VOCs, fish advisories, ozone, transportation, and land use.
Wisconsin Department of Natural Resources (2001b)												x				Statewide study with an extensive look at the MMSD area. The report contained data on sewer systems, sewer overflows, and recommendations for actions to be taken.
Wisconsin Department of Natural Resources and others (1990a)		x			x			x		x			x			Local study on the Menomonee River discussed a plan for controlling nonpoint-source pollution. The study included information on topics such as lead, phosphorus, sediments, and erosion.

Table 1. Characteristics and description of studies pertaining to surface-water quality of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Wisconsin Department of Natural Resources and others (1990b)		x						x		x			x			Local study on Milwaukee River discussing a plan for controlling nonpoint-source pollution. The report included information on toxics such as lead, sedimentation, and runoff from urban and agricultural regions.
Wisconsin Department of Natural Resources and others (2001)		x			x			x	x	x		x	x			A look at the entire Milwaukee River and the streams in its watershed. The study included individual descriptions of areas within the watershed. There was discussion of point and nonpoint sources of pollution, wetlands, and stream and shoreline modifications.
Wisconsin Department of Natural Resources and Southeastern Wisconsin Regional Planning Commission (1985)		x	x		x			x	x							Study of the Milwaukee River watershed including rivers and tributaries that flow into it. The study examined water quality and other factors in an attempt to discern the best way to carry out an effective priority watershed program.
Wisconsin District Lake-Studies Team (1996, 1997, 1998, 1999)	x		x	x	x					x						Statewide reports on the physical and chemical characteristics of Wisconsin lakes. The studies included information for Little and Big Muskego Lakes.
Witte (1996)		x								x						Local study on the metals copper, lead, and zinc in Lincoln Creek. Data were used to assess the risk to aquatic biota from urban stormwater. However, stormwater was not found to be a significant source of these metals.
Xiao and others (2001)									x							Study of the parasite *Cryptosporidium* and its distribution. Surface-water samples were collected from locations throughout the United States, including Lake Michigan near Milwaukee. Raw wastewater samples were also collected from Milwaukee.
Zanoni (1970)		x			x							x				Local study of the Menomonee River analyzing total soluble phosphorus concentrations throughout the year and phosphorus loading. Levels from agricultural lands were compared to those downstream from municipal treatment plants.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.

[PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Ab Razak (1999)		x							x				Study on Milwaukee, Menomonee, and Kinnickinnic Rivers before and after the operation of the Inline Storage System to determine its role in reducing pollution. Levels of phosphorus, suspended solids, fecal coliforms, zinc, chloride, and BOD were examined.
Bannerman and others (1979a)		x	x						x				Local study on the combined loadings of the Menomonee, Milwaukee, and Kinnickinnic Rivers. The effects of wind-induced suspension of sediment on water quality in the Milwaukee Harbor and its vicinity were also discussed.
Bannerman and others (1979b)		x	x				x		x		x		Study on the Menomonee River watershed. Water monitoring was performed to assess kinds and amounts of pollutants from land drainage of mixed and single land uses. The study focused mainly on suspended solids, phosphorus, and lead but discussed other constituents as well. Benthic macroinvertebrate surveys were done.
Bannerman and others (1983a)							x				x		Local study on characteristics, sources, and management of urban stormwater pollution in Milwaukee County. This volume was an executive summary of the entire study.
Bannerman and others (1983b)							x		x		x		Local study on characteristics, sources, and management of urban stormwater pollution in Milwaukee County. Characterization of urban stormwater-runoff volumes, contaminant concentrations, loadings, and water-quality effects on receiving waters were discussed. Also discussed were contaminant sources and an examination of the effectiveness of various frequencies of street sweeping.
Baun (1982)		x					x						Local study with data from the Menomonee River and Honey Creek. Three methods for estimating contaminant loads in water were discussed—integration, composite, and stratified random sampling. Recommendations were given for choosing the most effective method.
Camber (1993)		x	x										Local study on the Milwaukee River. The effect the North Shore Tunnel has on the amount of ground water seeping into and out of the river was measured.
CH2M Hill and others (2000)											x		Plans for 24 locations in Milwaukee to prevent pollution from stormwater. Directions for plans to be implemented were given. There were also lists of possible contaminants and sources for each site.
Cheetham (1973)		x				x							Regional report on erosion and sedimentation. The report includes some information on the Milwaukee River.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

Literature Citation	Characteristics											Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Cherkauer (1975a)		x					x		x		x		Local study to determine the effects of urban development on water quality in streams. Four small watersheds in different stages of development were examined in response to the same meteorological events. Total dissolved solids and chloride loads were examined.
Cherkauer (1975b)		x	x								x		Local study on two small watersheds in the Milwaukee area, one watershed with predominantly urban land use and the other with agricultural land use. Flow and contaminant loads were compared between the two watersheds after rainfall.
Christensen and Lo (1986)					x								Local study on the Milwaukee Harbor. A sediment core was taken from the inner harbor, dated, and analyzed for PCBs. The results were compared with Lake Michigan information. Concentrations were shown to link to sales records of PCBs.
City of Milwaukee Wisconsin Department of Public Works and Consoer, Townsend, and Associates Consulting Engineers (1974)		x					x	x	x				Local study looking at effectiveness of detention tanks in preventing combined-sewer overflows. Five years of data and modeling studies were done on the Milwaukee River, in which the water quality was examined in relation to rainfall.
City of Milwaukee Wisconsin Department of Public Works and Consoer, Townsend, and Associates Consulting Engineers (1975)		x	x				x	x	x				Local evaluation of a combined-sewer-overflow detention tank in Milwaukee. Based on modeling studies and data from sewer and river monitoring, detention tanks were shown to prevent combined-sewer-overflow contaminants from reaching receiving waters.
Conger (1971)		x	x	x					x				Statewide study to provide a way to estimate flood characteristics. Basin characteristics were used in the equations. Data was collected from gaging stations for rivers across the State. This included data from the Milwaukee, Little Menomonee, and Menomonee Rivers, and Honey and Oak Creeks.
Conger (1986)		x	x	x			x	x	x		x		Statewide study to develop equations to estimate the magnitude and frequency of flooding at ungaged urban sites. Land use was examined, and data from gaged sites in six Wisconsin cities, including Milwaukee, were used.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
DeVita (1994)		x	x										Local study on Lincoln Creek. An evaluation of semipermeable polymeric membrane devices as concentrators of nonpolar organic contaminants, namely PAHs was made. Concentration levels were compared in relation to storm events. Uptake by fathead minnows and rusty crayfish was also examined.
Dong and others (1979)		x	x			x							Study of the Menomonee River watershed. Metal composition in sand-, silt-, and clay-sized fractions of soil types, bottom sediments, suspended sediments, and dust and dirt samples were analyzed. A method for estimating soil dispersibility was developed.
Dong and others (1983a)					x								Local study on the Menomonee River watershed. Soil samples were taken and dispersed by shaking to simulate water erosion and particle transport conditions. After that, the samples were completely dispersed with ultrasound. The information gathered was used to measure ease of dispersibility of soils based on clay-sized particle content.
Dong and others (1984)		x	x		x								Study on the Menomonee River watershed. Phosphorus levels were compared with particle size of soils, street dust, and bottom and suspended sediments. An attempt was made to identify phosphorus sources by particle-size composition.
Druckenmiller (1980)	x				x		x		x				Local Environmental Impact Statement for a plan to dredge Little Muskego Lake. The goal of dredging was to improve aquatic life, aesthetic qualities, and recreational uses by deepening shallow areas and controlling macrophyte growth.
Fitzpatrick and Giddings (1997)		x	x							x			Regional study on the Western Lake Michigan Drainages including sites on Lincoln Creek and the Milwaukee River. The sites were evaluated for stream habitat. Channel geometry, substrate, streambank, and riparian characteristics were examined.
Gebert (1971)		x	x										Statewide map and description of low-flow frequency of Wisconsin streams. Included were several stations on the Milwaukee, Menomonee, and other rivers in the MMSD planning area.
Gergerich (1978)		x							x				Local study on the Milwaukee and Menomonee Rivers to show the relationship of bacteriolytic organisms with fecally polluted waters. Presence of the organisms was compared with levels of sewage-indicator bacteria, and abundance was examined in relation to temperature and rainfall.
Graczyk and others (1993)		x	x				x		x				Statewide study on nonpoint-source pollution. Rainfall, water quality, bedload, metals, DO, total and dissolved hardness, and quality control were examined. Data on precipitation and storm water runoff was given for the Menomonee River.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Great Lakes Commission (2000)		x	x										Multistate review of the Lake Michigan watershed and its subwatersheds, one of which was the Milwaukee River and the Estuary. Ongoing monitoring and recommendations for further actions were discussed.
Hajda (1993)		x	x					x					Local study on the Milwaukee River to estimate the impact of the removal of the North Avenue Dam by using a mathematical model. Data was given for levels of ammonia, nitrate, inorganic and organic phosphorus, chlorophyll *a*, BOD, DO, organic nitrogen, and streamflow.
Hansen and others (1983)		x	x				x	x	x		x		Local study on storm water pollution in Milwaukee County. This volume presented the procedures used for the field monitoring data in volumes 1 and 2. Also described were the sites that were examined in the study.
Harsch (1972)		x	x						x				A collection of papers concerning the Menomonee River. Section A contained scientific investigations and research data. Section B examined sociological and economic problems of pollution and examinations of types of abatement.
Harza Engineering Company (2001)		x								x			Local study with sites on the Menomonee River, Lincoln Creek, and Southbranch Creek. The goal of the study was to determine whether removal of concrete channel lining significantly improved stream habitat. The report provided data and recommended a methodology to evaluate stream characteristics.
Hindall and Flint (1970)		x	x			x				x			Maps of the State showing sediment yields of Wisconsin streams that included a site on the Milwaukee River.
Holmstrom (1982)		x	x	x				x	x				Regional study to form mathematical equations to estimate low flow in streams using data from gaged stations. Drainage area and base-flow index were also taken into account.
House (1987)			x					x					Local study on the Milwaukee Harbor using an unsteady-flow model. The model used channel-geometry streamflow at upstream tributaries and stage data at the estuary mouth to determine flow.
Inter-Fluve, Inc. (1998)		x	x	x		x		x		x	x		Local study on the options for removing a drop structure on the Menomonee River. The goal of removing the drop structure was to improve the river for recreation use, enhance fisheries, and promote flood control. A secondary goal was to enhance the natural channel of the river and establish a more stable geomorphic balance.
Jodie (1974)							x		x				Local study of stormwater runoff collected from two urban freeways in Milwaukee. The samples were shown to be of poor water quality and were compared to samples from Jones Island Sewerage Treatment Plant, the Menomonee River, other stormwater data, and Wisconsin standards.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District]

Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Johanson (1990)		x	x										Local study on the Milwaukee River and the Blue Hole abandoned landfill. The purpose was to define the hydrogeology and contaminant distribution in the landfill and to determine the effects of ground water from the Blue Hole site on the water quality of the Milwaukee River.
Kincaid (1981)							x		x				Local study on acid rain, and its sources and effects in Milwaukee. Runoff was also evaluated, and the report included data on pH and other chemical constituents.
Konrad and others (1978)		x				x				x			Local study on the Menomonee River watershed. An examination of land use, phosphorus, lead, and suspended solids data was used to create a model to describe the contaminants that enter surface waters from land surfaces after a rainfall event.
Konrad and others (1979)		x	x					x			x		Local study describing ground-water impacts on the quality of the Menomonee River. Loading rates were quantified and major contaminants and sources were identified. A predictive model was tested to measure ground-water response to changes in land-use or management practices.
Krug and others (1992)		x	x	x					x				Statewide study on flood-frequency characteristics of Wisconsin streams. Drainage-basin characteristics were analyzed.
Lawrence and Ellefson (1982)			x								x		Statewide report on water uses in Wisconsin. For each county the report tells how many gallons of ground water or surface water was used and whether it was for residential, industrial, commercial, irrigation, or stock purposes. The report also explains which rivers were used for hydroelectric and thermoelectric power.
Lee (1997)		x								x	x		Local study on the quantity of seepage from the Inline Storage System to the Milwaukee River. Also studied was the effect on seepage by the Milwaukee Formation, a dolomite of low hydraulic conductivity.
Lenz and Rheaume (2000)		x	x										Regional study of the Western Lake Michigan Drainages. Lincoln Creek and Milwaukee River were included in the study. Distribution and community structure of benthic invertebrates was discussed and used as water-quality indicators. Environmental setting and habitat were also examined.
Li and others (1998)		x				x							Local study on the Milwaukee Harbor Estuary. Sediment samples were analyzed for PAHs. Grain size, porosity, and TOC were also determined. The report discussed the effects of industrialization in the Milwaukee area.
Masterson and Bannerman (1994)		x	x										Local study on rivers in Milwaukee County. Chemical analysis was done on sediment, fish, crayfish tissue, and water samples to determine the effects of stormwater runoff on each. Bioaccumulation was examined and an index of biotic integrity for macroinvertebrates was calculated.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Meinholz and others (1979)		x	x						x				Local study on the effects on the Milwaukee River following wet weather discharges. Dissolved oxygen and fecal coliform concentrations were monitored in relation to flow. Other chemical characteristics were also examined.
Mildner (1978)		x				x				x			Multistate study to evaluate the effect of material eroded from riverbanks on water quality of the Great Lakes. Riverbank protection measures and costs were determined. The Menomonee River and Germantown watershed were used as study sites.
Miller (1980)		x	x						x				The goal of this regional study was to determine the feasibility of making regional inferences from water-quality monitoring data. Data for suspended solids, soluble phosphorus, and adsorbed phosphorus for the Menomonee River were included.
Miller and others (1979)		x	x										Regional examination of suspended solids, soluble phosphorus, and adsorbed phosphorus data by season, year, and event status was included for the Menomonee River.
Miller and others (1992)		x				x							Local study on the Root River. Results were discussed in relation to the objectives of the 1980 Root River Nonpoint Source Water Pollution Plan to determine if the goals of the plan were being achieved.
Milwaukee Metropolitan Sewerage District (1976)									x		x		Description of the MMSD Master Facilities Plan, which was designed to reduce water pollution. The study included an analysis of alternate solutions and an explanation of the pollution problems and their causes.
Milwaukee Metropolitan Sewerage District (1980a)			x	x					x				Report on a plan for combined-sewer overflow abatement. Environmental effects on the Milwaukee, Menomonee, and Kinnickinnic Rivers were examined.
Milwaukee Metropolitan Sewerage District (1980c)		x	x						x				Report on the Franklin-Northeast Interceptor Facility plan. An examination of the status of the Root River and the effects that the proposed plan will have on it were included.
Milwaukee Metropolitan Sewerage District (1980d)			x										Local plan for Jones Island Facility. Discussed were the existing environmental status and the effects the plan will have on the Milwaukee Harbor; the report also included some information on the tributaries leading into the harbor.
Milwaukee Metropolitan Sewerage District (1980e)		x	x						x				Report on the Mitchell Field South Interceptor Facility Plan. The current status of water quality in the Mitchell Field Drainage Ditch and Oak Creek, and the effects that the plan may have on water quality in the future were discussed.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Milwaukee Metropolitan Sewerage District (1980f)			x						x				Local plan for water-pollution abatement facilities. Existing and future conditions affecting water quality in the area were discussed.
Milwaukee Metropolitan Sewerage District (1980g)		x	x						x		x		Local plan for the Northridge Interceptor Facility with an environmental assessment on Beaver Creek, Trinity Creek, and Milwaukee River. Land use and physical/chemical characteristics were discussed.
Milwaukee Metropolitan Sewerage District (1980h)		x	x						x				Report on the Oak Creek North Branch Interceptor Facility Plan. The study examines the status of Oak Creek and the effects the plan will have on it.
Milwaukee Metropolitan Sewerage District (1980j)		x	x						x		x		Local plan for the MMSD Underwood Creek Interceptor Facility with an environmental assessment on Underwood Creek, Dousman Ditch, and the Menomonee River. The study discusses land use, some point sources of pollution, and physical/chemical characteristics.
Milwaukee Metropolitan Sewerage District (1982)		x	x	x									Local reports prepared for the MMSD Water Pollution Abatement Program. The study evaluated and refined the 1980 Master Facilities Plan and included an environmental assessment.
Morawski (1999)		x	x	x				x			x		Local study on Oak Creek using computer modeling to calculate flood risk. Land use and weather conditions were taken into account.
Morrisey (2000)		x	x	x			x	x	x	x			Local study on Underwood Creek of an area prone to flooding. Modeling techniques were used to estimate stormwater hydrographs and assess the effects a detention basin may have on discharge.
Novotny (1986)							x	x	x		x		Local study on Milwaukee metropolitan area to develop a snowmelt-runoff model. The model can be used to predict snow accumulation and snowmelt in urban areas. The study looks at accumulation of contaminants in snow, flow rates, and use of deicing chemicals. A model was used to simulate chloride concentrations and flow.
Novotny and Bendoricchio (1989)		x	x										Local study with information on the Menomonee River watershed and some of the tributaries within the watershed. The model LANDRUN (a model used to estimate the quantity and quality of runoff water and eroded particulates from watersheds with mixed land uses) was used for estimating sediment loadings from various land uses and other factors such as soil characteristics and imperviousness. Phosphorus loadings were also examined.
Novotny and others (1979a)		x					x	x	x		x		Study on the Milwaukee River and the canals of Venice. The study examined nonpoint-source pollution and looked at problems associated with excess nutrients and their relationship with productivity and oxygen demand. Included were data on DO, nitrogen, and chlorophyll *a* levels from MMSD.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Novotny and others (1979b)		x	x				x	x	x		x		Local study using LANDRUN, a model used to estimate the quantity and quality of runoff water and eroded particulates from watersheds with mixed land uses. Runoff, sediment, volatile suspended solids, and phosphate data from Novey Creek, Schoonmaker Creek, and the Little Menomonee River were used to calibrate the model.
Novotny and others (1994)		x				x							Review of a court case regrading the concrete lining that was put into Crayfish Creek in the city of Oak Creek, Wis.
Nowak (1995)		x							x	x	x		Local look into a court case regarding the concrete lining that was put into Crayfish Creek in the city of Oak Creek, Wis.
Owens and others (1997)		x	x						x				Statewide evaluation of nonpoint-source contamination and management practices. Lincoln Creek and Milwaukee River were included in the study. Data were given for precipitation, flow, suspended solids, phosphorus, and metals.
Parker and others (1970)		x		x								x	Local study on the Root River watershed. The study investigated the relation between areas subject to flooding and detailed soil maps in order to predict flood-plain boundaries in glaciated landscapes.
Peters (1997)		x	x	x			x		x				Regional study on the Western Lake Michigan Drainages. The report detailed natural and anthropogenic features of the area that have an effect on water quality. These included geology, climate, vegetation, land use, and hydrologic and biological characteristics.
Peters and others (1998)		x	x						x	x	x		Summary of studies done on the Western Lake Michigan Drainages as part of the National Water-Quality Assessment Program. Included was information for the Milwaukee River and Lincoln Creek regarding the physical description of the study area; pesticide, nutrient, trace element, and organic compound concentrations; and index values for macroinvertebrates, fish, habitat, and algae.
Port of Milwaukee (1995)		x				x				x			Local study on the Milwaukee, Kinnickinnic, and Menomonee Rivers, and the South Menomonee and Burnham Canals. The report discussed problems concerning erosion, dock walls, and land use. Shoreline and streambank-protection measures were presented.
R.A. Smith and Associates Inc. and others (1996)		x		x						x	x		Local study on the Menomonee River. The study evaluates the potential of returning the river to a more natural state and improving recreational access. Some of the proposed ideas were creating a wetland, making a trail, and removing the concrete lining.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Richards (1990)		x	x										Study on tributaries to the Great Lakes in Canada and the United States, including the Milwaukee River. Because pollutant-concentration data were lacking for many rivers, flux rates were looked at in terms of flow. Tributaries were classified on the basis of flow variability and responsiveness.
Richards and others (1998)		x	x						x				Regional study of surface-water quality of Wisconsin streams in the Western Lake Michigan Drainages. The study included sites on the Milwaukee River and Lincoln Creek and described techniques used to collect water samples and methods for analysis.
Robertson (1997)		x	x	x									Regional study on tributaries to Lake Michigan and Lake Superior, including the Milwaukee River. Suspended sediment and phosphorus loads were estimated for unmonitored locations using data from monitored sites. Stream gradient, land use, and soil type were also examined.
Robertson (1998)		x	x							x			Regional study of the Western Lake Michigan Drainages. Study locations included sites on Lincoln Creek, Little Menomonee River, Honey Creek, Oak Creek, and the Kinnickinnic River. Streamflow, nutrients, and suspended sediment data were used to look at the effects on water quality by land use, surficial deposits, and bedrock type.
Robertson and Saad (1996)		x	x						x	x			Regional study regarding nutrients and suspended sediment in ground- and surface-waters of the Western Lake Michigan Drainages. A site on the Milwaukee River was included in the analysis.
Rose (1978)				x					x	x			Local geologic study of the soils adjacent to the Milwaukee, Menomonee, and Kinnickinnic Rivers for foundation construction. The report included some information about climate and flooding.
Skinner and Borman (1973)		x	x	x	x		x			x			Report on a regional study with maps showing topography and drainage, land use, physical setting, ground-water quality, surface-water quality, and water use for the Lake Michigan drainage basin within Wisconsin.
Southeastern Wisconsin Regional Planning Commission (1971)		x	x	x					x	x	x		Regional study on the Milwaukee River to show the need for comprehensive regional planning. The study discussed existing water conditions and problems, and gave possible solutions. Topics covered included flooding, water quality, water supply, and recreation.
Southeastern Wisconsin Regional Planning Commission (1974)		x		x									Local study on the Kinnickinnic River watershed. The purpose of the study was to show the need for a comprehensive watershed planning program to reduce pollution and flooding.
Southeastern Wisconsin Regional Planning Commission (1976)		x	x	x		x		x	x	x	x		Local study on the Menomonee River watershed to provide a plan that will work on the flooding problems and increase the health of the river and its habitat. Physical description of the area was given along with wildlife that was found there. Data for flooding and surface-water monitoring were also given.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Southeastern Wisconsin Regional Planning Commission (1978b)		x	x	x		x	x	x	x	x	x		Local study on the Kinnickinnic River watershed to choose a plan that would assist in decreasing flood risk and water pollution. Physical description of the area was given along with flooding and surface-water-monitoring data.
Southeastern Wisconsin Regional Planning Commission (1978c)		x							x				Regional study on the Lake Michigan Drainage Area in southeastern Wisconsin. The purpose was to show the need for, the major elements of, and the organizations of a comprehensive planning program. The study had information on the Root River and the Milwaukee Harbor Estuary.
Southeastern Wisconsin Regional Planning Commission (1978d)		x	x				x				x		Regional study of point- and nonpoint-source water pollution in southeastern Wisconsin. Provided data included nitrogen, phosphorus, BOD, sediment, and fecal coliform loads from urban and rural sources to different bodies of water.
Southeastern Wisconsin Regional Planning Commission (1978e)		x	x										Regional study of lakes and streams in southeastern Wisconsin. Included in the report were data on the Milwaukee, Root, Menomonee, and Kinnickinnic Rivers and Oak Creek.
Southeastern Wisconsin Regional Planning Commission (1979)		x	x							x			Local study on the Oak Creek watershed, which also included the Mitchell Field Drainage Ditch. Existing water quality was evaluated and a program was developed to address flooding, water pollution, and other related problems.
Southeastern Wisconsin Regional Planning Commission (1980)		x				x				x			Local study on the Root River and its tributaries. This plan discussed the control of pollution from both urban and rural sources.
Southeastern Wisconsin Regional Planning Commission (1982a)		x		x			x	x		x			Local study on flooding of Lincoln Creek. The report discussed the various plans to control flooding. The final recommendation was to restructure the creekbed.
Southeastern Wisconsin Regional Planning Commission (1986a)		x		x						x			Examination of all the rivers that flow through the MMSD area. The report looked for improvements for flood control and examined floodlands along the streams.
Southeastern Wisconsin Regional Planning Commission (1986b)				x		x	x		x		x		Local plan for managing stormwater in Hales Corners, Wis. The report discussed the effect of precipitation and increased urbanization on runoff.
Southeastern Wisconsin Regional Planning Commission (1986c)		x	x	x		x	x	x	x	x	x		Local study on the Oak Creek watershed to provide a plan that will address flooding problems and increase the health of the river and its habitat. A physical description of the area was given along with a listing of wildlife that was found there. Data for flooding and surface-water monitoring was also provided.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Southeastern Wisconsin Regional Planning Commission (1987a)		x	x				x		x	x			Local study on the Milwaukee Harbor Estuary, which involved the Milwaukee, Menomonee, and Kinnickinnic Rivers, and the Milwaukee Harbor. The purpose of the study was to prepare a plan that would help control pollution, mitigate flood problems, control storm damage in the harbor, and improve water quality for recreational uses. Monitoring data were provided.
Southeastern Wisconsin Regional Planning Commission (1988a)		x		x							x		Local description of flooding and stormwater-drainage problems of the Crayfish Creek subwatershed. The report identified causes of the problems and provided evaluations of proposed solutions.
Southeastern Wisconsin Regional Planning Commission (1988b)						x					x		Regional report on conference proceedings discussing achieving water quality through land management. Issues addressed included erosion control, stormwater management, nonpoint-source water pollution, environmental corridors, flood plains, and wetlands.
Southeastern Wisconsin Regional Planning Commission (1989)		x		x									Local study on flood control for the Menomonee River Estuary. The report identifies areas prone to floods and damage. An examination of possible solutions and final selection of a plan was included.
Southeastern Wisconsin Regional Planning Commission (1990)		x	x	x						x			Local plan for the area of MMSD for stormwater drainage and flood control. Alternative and proposed plans were given for each of the following watersheds: Kinnickinnic River, Lake Michigan Direct Drainage, Oak Creek, Root River, Milwaukee River, and Menomonee River.
Southeastern Wisconsin Regional Planning Commission (1992)		x		x									Local study on Grantosa Creek, a tributary to the Menomonee River. Problems with flooding were discussed, and flood control plans were evaluated.
Southeastern Wisconsin Regional Planning Commission (1993)		x							x	x	x		Local plan for flood and stormwater management for Lilly Creek subwatershed. The plan evaluated alternative plans with the purpose of eliminating current problems and avoiding future ones, while also considering nonpoint-source pollution and river habitat.
Southeastern Wisconsin Regional Planning Commission and others (2000)							x		x		x		Local study on Dousman Ditch and Underwood Creek subwatershed of the Menomonee River watershed. The study identifies stormwater management and flooding problems and their causes. The study also sets forth a management plan after examining alternatives.
Sullivan and others (1995)		x	x							x			Regional study of the environmental settings of study sites in the Western Lake Michigan Drainages. Lincoln Creek and the Milwaukee River were included in the study. Data were given for land use, physical characteristics of the streams, and field measurements.
Sullivan and Richards (1996)		x	x							x			Regional study of pesticides in surface water in the Western Lake Michigan Drainages. Data were included for the Milwaukee River.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Sung (1983)						x	x	x			x		Eight watersheds in Milwaukee County studied to estimate nonpoint-source pollution and identify its sources. A model was created to help in the design of urban nonpoint-source control programs.
Taylor (1994)		x				x	x		x		x		Local study on the Kinnickinnic River examined nonpoint sources of pollution. Urban runoff and erosion from construction sites and streambanks were the main issues or concern.
Toyingtrakoon (1996)		x	x						x				Local study on the Milwaukee, Menomonee, and Kinnickinnic Rivers, and the Jones Island wastewater treatment facility to determine the effects of the Inline Storage System. Measurements included levels of phosphorus, BOD, fecal coliforms, and suspended solids after precipitation.
U.S. Environmental Protection Agency (1980)			x										Local study addressing the MMSD Master Facilities Plan. The study analyzed the effects of the proposed actions and alternatives on the environment and the existing water quality. Data for ammonia, nitrogen, phosphorus, BOD, pH, flow, fecal coliforms, and chloride were included.
U.S. Environmental Protection Agency and others (1980)		x	x										Local study of MMSD area addressing the proposed Master Facilities Plan. The focus of the study was the issue of overflows caused by infiltration of ground water and stormwater. Current (1980) water quality and how the plan will affect it was examined.
Walesh and others (1979)						x			x	x	x		Local study on the effects of land use on water quality in the Menomonee River watershed. The report discussed methods for obtaining land-cover information. The watershed was described and climate, soil, geology, land use, imperviousness, and erosion potential were examined.
Wisconsin Department of Agriculture, Trade, and Consumer Protection Soil and Water Resource Management Program and Wisconsin Department of Natural Resources Nonpoint Source Water Pollution Abatement Program (1991, 1993, 1994, 1995, 1997)						x							Statewide updates on the progress of Soil and Water Resource Management Goals. These annual reports discussed erosion and high phosphorus levels resulting mostly from agricultural runoff.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Wisconsin Department of Natural Resources (1971)	x	x					x		x	x	x		Local study on Big Muskego Lake. A description of drainage characteristics, soils, water quality, aquatic plants, fish, wildlife, recreational use, and the surrounding land use was included.
Wisconsin Department of Natural Resources (1976)		x	x	x					x				Regional report on southeastern Wisconsin that included the Root River and tributaries in the area. Data from water-quality sampling and an evaluation survey done during 1973 was presented.
Wisconsin Department of Natural Resources (1979)		x	x										Regional study on small streams included the Root River tributaries in New Berlin and Hales Corners. The major goal of the program was to provide data for the development of waste load allocations for discharges to streams. Secondly, it aimed to document the effects of increased treatment plant efficiency on stream health.
Wisconsin Department of Natural Resources (1980)	x				x		x		x	x			Local report on Little Muskego Lake that described a plan for and probable environmental effects of dredging the lake.
Wisconsin Department of Natural Resources (1983a)		x	x				x				x		Local study on stormwater pollution in Milwaukee County. This volume examined street sweeping as well as detention and retention basins. Also evaluated were the costs of these measures and the anticipated pollution load removals.
Wisconsin Department of Natural Resources (1991)		x				x					x		Local study on Milwaukee River South to determine nonpoint sources of pollution to the river and recommend management actions. The most information was given for levels of phosphorus, lead, and sediments.
Wisconsin Department of Natural Resources (1992a)		x				x					x		Local study on the Menomonee River watershed. The study assessed sources of water pollution and identified management practices to be implemented. The main pollutants discussed were sediments, phosphorus, and lead.
Wisconsin Department of Natural Resources (1992c)		x								x			Local study on Milwaukee River South watershed. The existing water quality and environmental concerns such as habitat and sewage-treatment plants were described and possible water pollution causes and management strategies were outlined.
Wisconsin Department of Natural Resources (1993a)		x				x							Local study on the Wind and Muskego Lakes and the tributaries draining into them. The study examined nonpoint-source pollution with the main focus on sediment loads.
Wisconsin Department of Natural Resources (1993b, 1994, 1996, 1997, 1998)		x	x							x			Statewide study using six watersheds as study areas included the Milwaukee River South. The goal of the study was to determine the extent to which management practices improved fish habitat and communities.

Table 2. Characteristics and description of studies pertaining to surface-water quantity and flow of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Literature Citation	Characteristics												Description
	Lake Michigan information	Stream information	Stream flow	Extreme flows (flood, drought)	Hydrologic budget	Erosion/sedimentation	Runoff calculations	Modeling	Precipitation/climate	Geomorphology	Urban issues	Other	
Wisconsin Department of Natural Resources (1994)		x				x	x				x		Local study of the Milwaukee Estuary and rivers draining into it. The study identified environmental problems and impaired uses and gave a brief overview of each. Also included were recommendations for plans to restore water quality.
Wisconsin Department of Natural Resources and others (1990a)		x				x					x		Local study on the Menomonee River discussed a plan for controlling nonpoint-source pollution. The study included information on topics such as lead, phosphorus, sediments, and erosion.
Wisconsin Department of Natural Resources and others (1990b)		x				x					x		Local study on Milwaukee River discussing a plan for controlling nonpoint-source pollution. The report included information on toxics such as lead, sedimentation, and runoff from urban and agricultural regions.
Wisconsin Department of Natural Resources and others (2001)		x					x				x		A look at the entire Milwaukee River and the streams in its watershed. The study included individual descriptions of areas within the watershed. There was discussion of point and nonpoint sources of pollution, wetlands, and stream and shoreline modifications.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.

[VOCs, volatile organic compounds; PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District; IBI, Index of Biotic Integrity]

Literature Citation	Characteristics																					Description
	Lake Michigan information	Stream information	Fish	Macroinvertebrates	Algae/macrophytes	Amphibians/reptiles	Birds	Mussels	Wildlife	Toxic bioassays	Endangered/threatened species	Tolerant/intolerant species	Non-native/invader species	Habitat	Wetlands	Human effects/urban issues	Community surveys	Management issues	Water-quality interpretations based on ecology	Biotic index values	Other	
Amin and others (1973)		x	x											x							x	Local study on fish collected from the Root River from sites in Milwaukee and Racine counties. The fish were examined for infestation by the copepod *Lernaea cyprinacea*. Location and frequency of infestation was discussed in relation to fish body size and stream conditions.
Anderson (1975)	x				x													x				Statewide classification of lakes by trophic condition. Most lakes examined were 100 acres or larger. Big Muskego Lake and Little Muskego Lake were included in the study. Also discussed were lake protection and rehabilitation procedures and classification and management programs.
Anderson (2001)		x	x	x															x	x		Local study of the Menomonee River and Oak Creek to determine water quality. An index of biotic integrity for fish composition, a family biotic index, and a multimeric comparison for macroinvertebrates were used.
Auer (1982)			x																			Multistate study of the Great Lakes region with emphasis on Lake Michigan drainages. The study contained ecological information on larval fishes and illustrations for identification.
Bacon and others (1995)							x															Statewide study on duck and geese populations and the amount of wetlands available for habitat. Information was given by region.
Bannerman and others (1979b)		x		x												x			x	x		Study on the Menomonee River watershed. Water monitoring was performed to assess kinds and amounts of pollutants from land drainage of mixed and single land uses. The study focused mainly on suspended solids, phosphorus, and lead but discussed other constituents as well. Benthic macroinvertebrate surveys were done.
Becker (1976)			x																			Multistate examination of fish in the Lake Michigan region. The report contained distribution maps and a description for each species.
Becker and Johnson (1970)			x																			Statewide study on minnows in Wisconsin. Contained a key for identification and included illustrations. There were also some notes on minnow abundance and distribution.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[VOCs, volatile organic compounds; PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District; IBI, Index of Biotic Integrity]

Literature Citation	Characteristics																					Description
	Lake Michigan information	Stream information	Fish	Macroinvertebrates	Algae/macrophytes	Amphibians/reptiles	Birds	Mussels	Wildlife	Toxic bioassays	Endangered/threatened species	Tolerant/intolerant species	Non-native/invader species	Habitat	Wetlands	Human effects/urban issues	Community surveys	Management issues	Water-quality interpretations based on ecology	Biotic index values	Other	
Bothwell (1977)					x																	Local study of the Milwaukee Harbor and nearshore Lake Michigan, including a station at the confluence of the Milwaukee and Kinnickinnic Rivers. An investigation of phytoplankton populations in relation to nutrients was done, and other factors such as temperature, chloride, and alkalinity were considered.
Boyer (1988)				x																		Local study on the Milwaukee Harbor at the sediment-water interface. Sediment-profile photographs were taken to map sediment type. Gas voids and oligochaete worm tubes were also shown.
Brynildson (1980)			x			x		x			x											Statewide study on endangered reptiles, fish, and molluscs. The report had descriptions of 14 species and their distributions.
Casper (1996)						x																Statewide study on amphibian and reptile distribution. The report contained distribution maps for each species.
Corsi and others (2001b)		x		x						x						x						Local study of the effect of aircraft and runway deicers from General Mitchell International Airport regarding toxicity to aquatic life in receiving waters.
Cumming and Mayer (1992)								x														Multistate information on freshwater mussels. There was a one-page description of each mussel with colored picture and distribution map.
DeVault (1985)		x	x																			Multistate study of tributaries to the Great Lakes, including the Milwaukee and Kinnickinnic Rivers. Fish samples were analyzed for contamination from pesticides and other priority pollutants, including PCBs and PAHs.
DeVita (1994)		x	x	x																		Local study on Lincoln Creek. An evaluation of semipermeable polymeric membrane devices as concentrators of nonpolar organic contaminants, namely PAHs was made. Concentration levels were compared in relation to storm events. Uptake by fathead minnows and rusty crayfish was also examined.
Druckenmiller (1980)	x		x		x									x				x				Local Environmental Impact Statement for a plan to dredge Little Muskego Lake. The goal of dredging was to improve aquatic life, aesthetic qualities, and recreational uses by deepening shallow areas and controlling macrophyte growth.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Eggers and Reed (1988)					x										x							Multistate guide to wetland plant communities. Plants were grouped by type of wetland they were found in, ranging from open water to seasonally flooded basins.
Emmling (1976)				x										x								Local study on the Milwaukee Harbor and its tributaries. Macroinvertebrate distributions were compared to the type of sediment present.
Fago (1984)		x	x								x											Regional study in southeastern Wisconsin. The report examined fish populations and contained distribution maps. The report also talked about some species that were threatened or on a watch list.
Fitzpatrick and Giddings (1997)		x												x		x						Regional study on the Western Lake Michigan Drainages, including sites on Lincoln Creek and the Milwaukee River. The sites were evaluated for stream habitat. Channel geometry, substrate, streambank, and riparian characteristics were examined.
Fox (1971)																		x				Statewide examination of water-resources policies and issues involved in a metropolitan region. The southeastern region of Wisconsin, including Milwaukee, was selected for study. Wastewater treatment and flooding were discussed.
Gerber (1994)					x									x								Study in Wisconsin and Michigan of the genus *Myriophyllum* (water millfoil family). The goals of the study were to characterize habitats and see if there was a relation between leaf shape and size and nutrient uptake with the habitat. Sites of nutrient uptake were also examined.
Great Lakes Commission (2000)		x	x	x					x													Multistate review of the Lake Michigan watershed and its subwatersheds, one of which was the Milwaukee River and the estuary. Ongoing monitoring and recommendations for further actions were discussed.
Harding (1997)						x																Regional guide to the reptiles and amphibians of the Great Lakes region. Habitat, ecology, reproduction, and conservation issues were discussed. Descriptions and photographs were given along with information on distribution and abundance.
Harsch (1972)		x			x																	A collection of papers concerning the Menomonee River. Section A contained scientific investigations and research data. Section B examined sociological and economic problems of pollution and examinations of types of abatement.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Harza Engineering Company (2001)		x	x	x										x				x				Local study with sites on the Menomonee River, Lincoln Creek, and Southbranch Creek. The goal of the study was to determine whether removal of concrete channel lining significantly improved stream habitat. The report provided data and recommended a methodology to evaluate stream characteristics.
Hausmann (1974)				x																		Local study on macroinvertebrate populations in the Milwaukee Harbor and Lake Michigan, which included one sample site on the Milwaukee River. Results were compared to previous findings; in many species populations were found to be declining.
Hine and others (1981)						x																Statewide study of leopard frog distributions with data from 1974–76. There was an in-depth study of East Central Wis.; there was information for the rest of the State by region.
Hobbs and Jass (1988)				x																		Statewide study on the crayfish and shrimp of Wisconsin. Ecological and life history information was given about each species along with a key for identification. Distribution maps were also included.
Hunt (1990)		x	x											x				x				Statewide study including the Kinnickinnic River. Brown trout size and populations were examined in response to habitat-improvement techniques.
Inskip (1986)			x																			Statewide study on the occurrence of muskellunge and northern pike. The report discusses the effects of these species on population size due to their interaction with each other.
Inter-Fluve, Inc. (1998)		x	x											x		x		x				Local study on the options for removing a drop structure on the Menomonee River. The goal of removing the drop structure was to improve the river for recreational use, enhance fisheries, and promote flood control. A secondary goal was to enhance the natural channel of the river and establish a more stable geomorphic balance.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Jerger and others (1978)		x		x												x	x		x			Regional study on the potential for contamination of aquatic species from non-point- and point-source pollution in the Great Lakes. Included were data sampled at seven stations on the Menomonee River of trace elements, chlorinated pesticides, and PCBs.
Kaemmerer and others (1992)		x	x						x							x						Local study looking at the Milwaukee Harbor and parts of the Milwaukee, Menomonee, and Kinnickinnic Rivers. The report discussed the biological problems with the area and explained how various agencies and groups were trying to address them.
Kasun (2001)		x		x																		Local study on Oak Creek and the Menomonee River. The objective of the research was to predict the bioavailable concentrations of heavy metals in interstitial porewater and examine the ecological risk by looking at benthic macroinvertebrates.
Kleinert and Degurse (1972)	x	x	x						x													Statewide study of mercury concentrations in Wisconsin fish and wildlife. Included fish from the Milwaukee River and the Milwaukee Harbor.
Kleinert and others (1974)	x	x	x																			Statewide examination of toxic metal concentrations in fish. Fish from the Milwaukee River were included in the study. Fish were tested for arsenic, cadmium, chromium, lead, and zinc.
Kohler (1982)	x			x	x																	Local study on Big Muskego Lake examining the phytoplankton population. The examination included the effects on the phytoplankton population by factors such as nitrogen, phosphorus, pH, DO, and (or) zooplankton.
Korth (1978)		x			x																	Local study on the Milwaukee River to determine the effect that algae had on sediment oxygen demand; it was not shown to be a significant source.
Lee and others (1981)				x																		Local study on biological and chemical water quality in the Milwaukee Harbor and Lake Michigan. The mixing and transport of wastewater-treatment-plant effluent plumes were examined. Indicator bacteria and viruses were also investigated.
Legler and others (1998)																					x	Statewide examination of dragonflies. The report provided color pictures for identification and maps of their distributions.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Lenz and Rheaume (2000)		x		x										x					x	x		Regional study of the Western Lake Michigan Drainages. Lincoln Creek and Milwaukee River were included in the study. Distribution and community structure of benthic invertebrates was discussed and used as water-quality indicators. Environmental setting and habitat were also examined.
Lueschow (1972)	x	x			x													x				Statewide study on algae and macrophyte control. The report also examined control of swimmers itch. A table lists chemical treatments used in bodies of water including Little Muskego Lake and the Milwaukee River.
Lyons (1989)		x	x											x								Statewide study to see if fish-assemblage distribution corresponded to Omernik's ecoregions. Characteristics were given for each of the four regions that cover most of Wisconsin. Temperature, gradient, substrate, and shoreline vegetation were shown to be better predictors than geographic location.
Lyons (1992a)		x	x																			Study on nine streams in southern Wisconsin to determine the length that a sampling station should be for sampling fish. The Menomonee River was one of the sampling sites.
Lyons (1992b)		x	x									x							x	x		Statewide study for developing a version of the Index of Biotic Integrity (IBI) for Wisconsin warmwater streams. The report describes how the IBI for fish should be applied and interpreted. The appendix contained IBI scores for various rivers, including the Milwaukee and Menomonee.
Lyons and Kanehl (1993)		x	x																			Statewide comparison of smallmouth bass sampling methods. Sites across the State were studied, including the Milwaukee River. Guidelines were provided for estimating abundances in shallow wadable streams.
Mace (1984)		x			x																	Regional study on southern Wisconsin streams for the purpose of setting appropriate water-quality goals or standards for amounts of phosphorus. Milwaukee River was included in the study. Nutrient levels were compared to macrophyte and algal growth; the effect of nutrients on DO concentrations was examined.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Martin and others (1983)	x				x																	Statewide examination of Wisconsin lakes. The trophic condition of about 3,000 inland lakes were assessed using Landsat satellite data. Waterbodies from Ozaukee, Washington, and Waukesha Counties were included in the study.
Masterson and Bannerman (1994)		x	x	x										x								Local study on rivers in Milwaukee County. Chemical analysis was done on sediment, fish, crayfish tissue, and water samples to determine the effects of stormwater runoff on each. Bioaccumulation was examined and an IBI for macroinvertebrates was calculated.
Mathiak (1979)		x						x														Statewide study on mussels found in rivers. The report described each mussel type; color photographs and distribution maps were also included.
Miller and others (1992)		x	x	x															x			Local study on the Root River. Results were discussed in relation to the objectives of the 1980 Root River Nonpoint Source Water Pollution Plan to determine if the goals of the plan were being achieved.
Milwaukee Metropolitan Sewerage District (1980a)		x	x	x								x										Report on a plan for combined-sewer overflow abatement. Environmental impacts on the Milwaukee, Menomonee, and Kinnickinnic Rivers was examined.
Milwaukee Metropolitan Sewerage District (1980b)		x				x	x		x			x										Report on a plan for the Franklin-Muskego Interceptor Facility. Included was an environmental assessment with information on Little Muskego Lake, Big Muskego Lake, Little Muskego Creek, Tess Corners Creek, and the Root River.
Milwaukee Metropolitan Sewerage District (1980c)		x				x	x		x			x										Report on the Franklin-Northeast Interceptor Facility plan. An examination of the status of the Root River and the effects that the proposed plan will have on it were included.
Milwaukee Metropolitan Sewerage District (1980d)												x										Local plan for Jones Island Facility. Discussed were the existing environmental status and the effects the plan will have on the Milwaukee Harbor; the report also included some information on the tributaries leading into the harbor.
Milwaukee Metropolitan Sewerage District (1980e)		x										x										Report on the Mitchell Field South Interceptor Facility Plan. The current status of water quality in the Mitchell Field Drainage Ditch and Oak Creek, and the effects the plan may have on future water quality were discussed.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Milwaukee Metropolitan Sewerage District (1980h)		x										x										Report on the Oak Creek North Branch Interceptor Facility Plan. The study examines the status of Oak Creek and the plan's effects.
Milwaukee Metropolitan Sewerage District (1980j)			x	x	x							x										Local plan for the MMSD Underwood Creek Interceptor Facility with an environmental assessment on Underwood Creek, Dousman Ditch, and the Menomonee River. The study discusses land use, some point sources of pollution, and physical/chemical characteristics.
Milwaukee River Revitalization Council (1990, 1991, 1992, 1993, 1994, 1995)		x																x				Local report on the Milwaukee River. The report stated what has been done in the past year to improve water quality on the river and informed the reader of upcoming projects.
Milwaukee River Revitalization Council and Wisconsin Department of Natural Resources (1991)		x																x				Regional examination of the Milwaukee River. The study area was divided into sections; the problems of each were discussed, but no hard data were presented.
Mortimer (1981)				x	x																	Overview of a court case involving the State of Illinois versus Milwaukee and nearby cities. The issue of concern was pollution of Lake Michigan by sewer overflows and discharges.
Mymudes (1991)					x																	Multistate study on the varying characteristics of the aquatic plant species *Plantago cordata* throughout its range.
Nichols (1974)					x									x				x				Statewide examination of aquatic plant control methods. The report looked at control by harvesting and habitat manipulation. Milwaukee County was in the harvesting experiences table.
Nichols and Vennie (1991)	x		x		x		x		x					x								Statewide study on lake plants. Habitat preferences were given, as well as their value to the environment and wildlife. There was also information on propagation and herbicide susceptibility.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Novitzki (1979)															x							Statewide description of wetlands in Wisconsin. The report gave descriptions of different types of wetlands that were found in the state.
Novotny and Bendoricchio (1989)		x			x																	Local study with information on the Menomonee River watershed and some of the tributaries within the watershed. The model LANDRUN (a model used to estimate the quantity and quality of runoff water and eroded particulates from watersheds with mixed land uses) was used for estimating sediment loadings from various land uses and other factors such as soil characteristics and imperviousness. Phosphorus loadings were also examined.
Nowak (1995)														x	x	x		x				Review of a local court case regarding the concrete lining that was put into Crayfish Creek in the city of Oak Creek, Wis.
Oberts (1977)																x		x				Discussion of water-quality effects of commonly used management practices used to control pollution from urban activities. These included construction, runoff, litter, and combined-sewer overflows. There was some information for Milwaukee.
Pariso and others (1983)		x	x																			Regional study of the Wisconsin coast. Milwaukee, Kinnickinnic, Root, and Menomonee Rivers, and Oak Creek were included in the study. Fish, sediment, and effluent samples were tested for contaminants.
Pentecost and Vogt (1976)						x						x		x								Multistate examination of amphibian and reptile distribution. The report also discussed plant communities found in the area and their associated herptofauna.
Peters (1995)		x		x	x														x			Summary of a meeting concerning the Western Lake Michigan Drainages, which was studied as part of the National Water-Quality Assessment Program. Included are summaries of presentations made at the meeting, which included information on pesticides in the Milwaukee River and Lincoln Creek.
Peters (1997)			x	x	x																	Regional study on the Western Lake Michigan Drainages. The report detailed natural and anthropogenic features of the area that have an effect on water quality. These included geology, climate, vegetation, land use, and hydrologic and biological characteristics.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Peters and others (1998)		x	x	x	x									x		x	x		x	x		Summary of studies done in the Western Lake Michigan Drainages as part of the National Water-Quality Assessment Program. Included was information for the Milwaukee River and Lincoln Creek regarding the physical description of the study area; pesticide, nutrient, trace element, and organic compound concentrations; and index values for macroinvertebrates, fish, habitat, and algae.
R.A. Smith and Associates Inc. and others (1996)														x		x						Local study on the Menomonee River. The study evaluates the potential of returning the river to a more natural state and improving recreational access. Some of the proposed ideas were creating a wetland, making a trail, and removing the concrete lining.
Read (1976)					x																	Statewide report on endangered and threatened plants in Wisconsin. The study provided lists of plants by region and habitat type.
Rice (1992)			x	x	x	x	x				x			x	x			x		x		Report on the nonpoint-source water-pollution abatement program for the Root River. The report evaluated the degree to which the project objectives of reducing levels of fecal coliform, dissolved phosphorus, and DO were accomplished.
Science Applications International Corporation (1993)			x				x															Multistate study on the Lake Michigan Basin. The purpose was to inform the public and get their comments on agencies' activities and future actions. Information on the effects of toxic contaminants in the Great Lakes and their sources was given.
Scudder and others (1996)			x	x	x	x	x			x	x								x			Regional study of the Western Lake Michigan Drainage Basin. The report contained a summary of biological aspects of the region and also had tables of references on biologic investigations.
Scudder and others (1997)		x	x	x	x																	Regional study of the Western Lake Michigan Drainages. Sampling sites included the Milwaukee River, Kinnickinnic River, and Lincoln Creek. Trace elements and synthetic organic compounds were examined in sediment and biota.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Southeastern Wisconsin Regional Planning Commission (1971)							x		x						x							Regional study on the Milwaukee River to show the need for comprehensive regional planning. The study discussed existing water conditions and problems and gave possible solutions. Topics covered included flooding, water quality, water supply, and recreation.
Southeastern Wisconsin Regional Planning Commission (1974)																		x				Local study on the Kinnickinnic River watershed. The purpose of the study was to show the need for a comprehensive watershed planning program to reduce pollution and flooding.
Southeastern Wisconsin Regional Planning Commission (1976)		x	x			x	x		x			x		x								Local study on the Menomonee River watershed to provide a plan that will work on the flooding problems and increase the health of the river and its habitat. Physical description of the area was given along with wildlife that was found there. Data for flooding and surface-water monitoring were also given.
Southeastern Wisconsin Regional Planning Commission (1978c)			x																			Regional study on the Lake Michigan Drainage Area in southeastern Wisconsin. The purpose was to show the need for, the major elements of, and the organizations of a comprehensive planning program. The study had information on the Root River and the Milwaukee Harbor Estuary.
Southeastern Wisconsin Regional Planning Commission (1979)		x		x								x										Local study on the Oak Creek watershed, which also included the Mitchell Field Drainage Ditch. Existing water quality was evaluated and a program was developed to address flooding, water pollution, and other related problems.
Southeastern Wisconsin Regional Planning Commission (1980)		x		x																x		Local study on the Root River and its tributaries. This plan discussed the control of pollution from both urban and rural sources.
Southeastern Wisconsin Regional Planning Commission (1982b)	x	x												x		x		x				Local plan for the city of Muskego for sanitary sewer service. Land use and environmentally significant lands were discussed.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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Southeastern Wisconsin Regional Planning Commission (1986c)		x	x			x	x		x			x		x	x							Local study on the Oak Creek watershed to provide a plan that will address flooding problems and increase the health of the river and its habitat. A physical description of the area was given along with wildlife that was found there. Data for flooding and surface-water monitoring were also provided.
Southeastern Wisconsin Regional Planning Commission (1987a)		x	x	x	x		x		x			x		x	x						x	Local study on the Milwaukee Harbor Estuary, which involved the Milwaukee, Menomonee, and Kinnickinnic Rivers, and the Milwaukee Harbor. The purpose of the study was to prepare a plan that would help control pollution, mitigate flood problems, control storm damage in the harbor, and improve water quality for recreational uses. Monitoring data are provided.
Southeastern Wisconsin Regional Planning Commission (1988b)															x			x				Regional report on conference proceedings discussing how to achieve water-quality goals through land management. Issues addressed included erosion control, stormwater management, nonpoint-source water pollution, environmental corridors, floodplains, and wetlands.
Southeastern Wisconsin Regional Planning Commission (1993)		x	x	x										x				x				Local plan for flood and stormwater management for Lilly Creek subwatershed. The plan evaluated alternative plans with the purpose of eliminating current problems and avoiding future ones, while also considering nonpoint-source pollution and river habitat.
Southeastern Wisconsin Regional Planning Commission (1995a)	x	x	x	x	x											x	x	x	x	x		Regional report that described the updates to a water-quality management plan for southeastern Wisconsin. Also included was the status of the current implementation of the plan.
Southeastern Wisconsin Regional Planning Commission (1996)	x		x		x	x	x		x					x				x				Local management plan for Little Muskego Lake. Goals of the plan included reducing sediment and contaminant loading to the lake, reducing aquatic macrophyte and algal growths, promoting public awareness, improving aesthetics and use for recreation, and improving habitat for fish and other wildlife.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

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	Lake Michigan information	Stream information	Fish	Macroinvertebrates	Algae/macrophytes	Amphibians/reptiles	Birds	Mussels	Wildlife	Toxic bioassays	Endangered/threatened species	Tolerant/intolerant species	Non-native/invader species	Habitat	Wetlands	Human effects/urban issues	Community surveys	Management issues	Water-quality interpretations based on ecology	Biotic index values	Other	
Southeastern Wisconsin Regional Planning Commission and others (2000)			x	x								x		x						x		Local study on Dousman Ditch and Underwood Creek subwatershed of the Menomonee River watershed. The study identifies stormwater-management and flooding problems and their causes. The study also sets forth a management plan after examining alternatives.
Sullivan (1997)		x	x											x						x		Regional study on the Western Lake Michigan Drainages, including Lincoln Creek. Fish communities were analyzed, as was the river habitat. They were then used as water-quality indicators.
Taylor (1994)		x									x											Local study on the Kinnickinnic River examined nonpoint sources of pollution. Urban runoff and erosion from construction sites and streambanks were the main issues or concern.
Thompson and others (1976)			x						x					x								Regional study of townships in Wisconsin along the Lake Michigan shoreline. The report looked at fish and wildlife habitat and classified it into three categories.
Torke (1976)			x																			Statewide study of cyclopoid copepods. The report contained a key for identification and had information on their distributions and ecology.
U.S. Environmental Protection Agency and others (1980)			x								x				x							Local study of MMSD area addressing the proposed Master Facilities Plan. The focus of the study was the issue of overflows caused by infiltration of ground water and stormwater. Current (1980) water quality and how the plan's effect was examined.
Van Dyke (1977)							x															Local study on mallard duck populations and production in Juneau Park, Milwaukee County. The study examined winter populations, sex ratios, molting, weights, and behavior.
Veith and Lee (1971)	x	x	x												x	x						Regional study on PCBs in fish in the Milwaukee River and Lake Michigan. Changes in the composition of PCBs in fish tissue depended on where the fish was caught.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[VOCs, volatile organic compounds; PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District; IBI, Index of Biotic Integrity]

Literature Citation	Characteristics																					Description
	Lake Michigan information	Stream information	Fish	Macroinvertebrates	Algae/macrophytes	Amphibians/reptiles	Birds	Mussels	Wildlife	Toxic bioassays	Endangered/threatened species	Tolerant/intolerant species	Non-native/invader species	Habitat	Wetlands	Human effects/urban issues	Community surveys	Management issues	Water-quality interpretations based on ecology	Biotic index values	Other	
Villenueve and others (1997)		x								x												Local study to determine long-term toxicity effects on stream biota from urban stormwater runoff. Fish hepatoma cells were used and exposed to water from Lincoln Creek.
Wisconsin Department of Natural Resources (1971)	x		x		x		x		x					x	x	x		x	x			Local study on Big Muskego Lake. A description of drainage characteristics, soils, water quality, aquatic plants, fish, wildlife, recreational use, and the surrounding land use was included.
Wisconsin Department of Natural Resources (1975)																		x				Regional study that summarized industrial discharges to waters in southeastern Wisconsin. The report also discussed permits and compliance schedules.
Wisconsin Department of Natural Resources (1976)												x										Regional report on southeastern Wisconsin that included the Root River and tributaries in the area. Data from water-quality sampling and an evaluation survey done during 1973 were presented.
Wisconsin Department of Natural Resources (1982, 1984, 1990, 1992, 1994, 2000)			x										x					x				Statewide reports on water quality with some specific information on Milwaukee County and the surrounding area. The reports cover a variety of topics including PCBs in fish, pollution, and data on some chemical constituents as well. Data were given for the Milwaukee River, Milwaukee Estuary, Lincoln Creek, and North Avenue Dam.
Wisconsin Department of Natural Resources (1989)			x																			Report on the Milwaukee Area of Concern in the Great Lakes Basin. Menomonee, Kinnickinnic, and Milwaukee Rivers and the Milwaukee Inner Harbor were included in the study. The purpose of the report was to present water-resource problems and the stage they were at regarding remediation. Also presented were toxics data, including those contaminants found in fish.
Wisconsin Department of Natural Resources (1990)			x			x	x		x		x			x		x						Local study on the Menomonee River watershed with the purpose of creating a management plan. The study identified major environmental concerns and detailed strategies for improvement. Water-resources information was given by subwatershed with information on wildlife and habitat, land use, solid and hazardous waste, and nonpoint-source pollution.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[VOCs, volatile organic compounds; PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District; IBI, Index of Biotic Integrity]

Literature Citation	Characteristics																					Description
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Wisconsin Department of Natural Resources (1992b)			x																			Statewide study to establish a database on the distribution and abundance of all fish species. The study compares the 1900-72 distributions to the studies in 1974-86.
Wisconsin Department of Natural Resources (1992c)	x	x	x			x	x		x		x			x	x			x				Local study on Milwaukee River South watershed. The existing water-quality and environmental concerns such as habitat and sewage-treatment plants were described and possible water pollution causes and management strategies were outlined.
Wisconsin Department of Natural Resources (1993a)	x	x	x																			Local study on the Wind and Muskego Lakes and the tributaries draining into them. The study examined nonpoint-source pollution with the main focus on sediment loads.
Wisconsin Department of Natural Resources (1993b, 1994, 1996, 1997, 1998)		x	x	x										x						x		Statewide study using six watersheds as study areas included the Milwaukee River South. The goal of the study was to determine the extent to which management practices improved fish habitat and communities.
Wisconsin Department of Natural Resources (1994)		x	x	x	x				x		x	x		x				x				Local study of the Milwaukee Estuary and rivers draining into it. The study identified environmental problems and impaired uses and gave a brief overview of each. Also included were recommendations for plans to restore water quality.
Wisconsin Department of Natural Resources (1995)													x		x							Statewide information on purple loosestrife and its effect on wetlands. The report gave distribution, identification, and control information.
Wisconsin Department of Natural Resources (1999)			x																			Report for the entire Milwaukee River watershed. The purpose of the report was to develop a public process to determine useful measurements for describing ecosystem conditions. Many possible indicators including air, water, biodiversity, and education were discussed and some data was presented for VOCs, fish advisories, ozone, transportation, and land use.

Table 3. Characteristics and description of studies pertaining to ecology of the Milwaukee Metropolitan Sewerage District planning area, Wis.—Continued

[VOCs, volatile organic compounds; PAHs, poly aromatic hydrocarbons; PCBs, polychlorinated biphenyls; BOD, biochemical oxygen demand; DO, dissolved oxygen; MMSD, Milwaukee Metropolitan Sewerage District; IBI, Index of Biotic Integrity]

Literature Citation	Characteristics																					Description
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Wisconsin Department of Natural Resources and others (2001)														x	x							A look at the entire Milwaukee River and the streams in its watershed. The study included individual descriptions of areas within the watershed. There was discussion of point- and nonpoint-sources of pollution, wetlands, and stream and shoreline modifications.
Wisconsin Department of Natural Resources and Southeastern Wisconsin Regional Planning Commission (1985)		x	x	x										x								Study of the Milwaukee River watershed including rivers that flow into it. The study examined water quality and other factors in an attempt to discern the best way to carry out an effective priority watershed program.
Wisconsin District Lake-Studies Team (1996, 1997, 1998, 1999)	x				x																	Statewide reports on the physical and chemical characteristics of Wisconsin lakes. The studies included information for Little and Big Muskego Lakes.

Table 4. Selected GIS Coverages available for the Milwaukee Metropolitan Sewerage District planning area

[NA, not available, MMSD, Milwaukee Metropolitan Sewerage District; SEWRPC, Southeastern Wisconsin Regional Planning Commission; USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; GMUs, Geographic Management Units; DEM, digital elevation model; LICGF, Land Information and Computer Graphics Facility; SSURGO, Soil Survey Geographic Data base; STATSGO, State Soil Geographic Survey; USDA, U.S. Department of Agriculture; NRCS, National Resources Conservation Service; WGNHS, Wisconsin Geologic and Natural History Survey; USEPA, U.S. Environmental Protection Agency; DLGs, digital line graphs; MIS, Metropolitan Interceptor System; ISS, Inline Storage System; NSC, Near Surface Collector System; CSO, combined sewer overflow; NHAP, National High-Altitude Photography; WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NLCD, National Land Cover Data; GIRAS, Geographic Information Retrieval and Analysis; LUDA, Land Use Data Analysis]

Data set name	Source year	Data provider	Description	Scale	Data extent
			Boundary		
MMSD planning area	NA	SEWRPC[1]	Boundary of the 42-square-mile MMSD service area, which includes Milwaukee County plus parts of Ozaukee, Racine, Washington, and Waukesha counties	NA	MMSD planning area
County base maps	1985, 1990, 1995	SEWRPC	County boundaries	1:4,800	SEWRPC counties[2]
Civil Division	1985, 1990, 1995	SEWRPC	Municipality boundaries	1:4,800	SEWRPC counties
Minor Civil Divisions	1992	WDNR	Incorporated and unincorporated cities, civil townships (commonly known as "towns"), and villages of Wisconsin as of 1991 as derived from the U.S. Census Bureau 1991 TIGER/Line files	1:100,000	Wisconsin
Landnet locations	Various	WDNR[3]	Public Land Survey System section and townships as derived from USGS 7.5-minute topographic quadrangles (source data from various years)	Various	Wisconsin
State of Wisconsin	1992	WDNR	Wisconsin state boundary as derived from the U.S. Census Bureau 1990 TIGER/Line files.	1:100,000	Wisconsin
WDNR Geographic Management Units	1996	WDNR	Geographic Management Units (GMUs) are administrative units established by the Wis. DNR primarily for internal management purposes. Most GMU boundaries are based upon water-basin boundaries, though in some areas GMU boundaries have been adjusted to coincide with county boundaries. Scales of data vary from 1:24,000 (boundaries derived from watersheds coverage) to 1:100,000 (boundaries derived from counties coverage).	1:24,000 to 1:100,000	Wisconsin
WDNR Administrative Regions	1998	WDNR	WDNR administrative region boundaries generally coincide with county boundaries. WDNR administrative regions were established circa 1997 as part of the agency's re-organization.	1:100,000	Wisconsin
			Elevation		
Digital planimetric and topographic maps (2-foot contours)	Various	SEWRPC	Planimetric features include building footprints, road edges and curblines, sidewalks, and trees. Topographic features are those that define elevation information. See Land Information and Computer Graphics Facility (LICGF) Web page for more information: http://www.lic.wisc.edu/	1:100 or 1:200	Milwaukee, Ozaukee, Racine Counties
1-Degree Digital Elevation Model	NA	WDNR	A detailed USGS 7.5-minute digital elevation model (DEM) is derived from 1:24,000-scale, 7.5-minute topographic maps, and have a 30-meter pixel cell size, or resolution. WDNR also has Digital Elevation Model data sets that are available at a detailed and generalized level as derived from 1:250,000-scale map data.	1:24,000 (30 meter)	Wisconsin

Table 4. Selected GIS Coverages available for the Milwaukee Metropolitan Sewerage District planning area—Continued

[NA, not available, MMSD, Milwaukee Metropolitan Sewerage District; SEWRPC, Southeastern Wisconsin Regional Planning Commission; USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; GMUs, Geographic Management Units; DEM, digital elevation model; LICGF, Land Information and Computer Graphics Facility; SSURGO, Soil Survey Geographic Data base; STATSGO, State Soil Geographic Survey; USDA, U.S. Department of Agriculture; NRCS, National Resources Conservation Service; WGNHS, Wisconsin Geologic and Natural History Survey; USEPA, U.S. Environmental Protection Agency; DLGs, digital line graphs; MIS, Metropolitan Interceptor System; ISS, Inline Storage System; NSC, Near Surface Collector System; CSO, combined sewer overflow; NHAP, National High-Altitude Photography; WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NLCD, National Land Cover Data; GIRAS, Geographic Information Retrieval and Analysis; LUDA, Land Use Data Analysis]

Data set name	Source year	Data provider	Description	Scale	Data extent
			Soils		
Soil mapping units	NA	SEWRPC	Soil mapping units data from the USDA and NRCS	1:15,840	SEWRPC counties
NRCS Soil Survey Geographic (SSURGO) Data base	Various	NRCS	SSURGO data include soil survey area boundaries, soil boundaries, water boundaries, and conventional and special soil features. Please see the following Web site for more information: http://www.ftw.nrcs.usda.gov/ssur_data.html	1:12,000 to 1:63,360	United States
NRCS State Soil Geographic Survey (STATSGO) Data base	1998	NRCS	STATSGO data is generalized from detail soil survey data and contains information regarding available water capacity, soil reaction, salinity, flooding, water table, bedrock, and interpretations for engineering uses. Please see the following Web site for more information: http://www.ftw.nrcs.usda.gov/stat_data.html	1:250,000	United States
Surficial deposits	1980's	WDNR	Surficial deposits	1:500,000	Wisconsin
Soil associations	1968	WDNR	Soil associations based on the "Regional Soil Map of Wisconsin," by F. D. Hole, 1968	1:250,000	Wisconsin
Soil permeability	1992	USGS	Soil permeability	1:250,000	Wisconsin
			Ground-water resources		
Depth to water table	NA	SEWRPC	Depth to water table based on data from the WGNHS and SEWRPC	1:48,000	SEWRPC counties
Depth to bedrock	NA	SEWRPC	Depth to bedrock based on data from the WGNHS and SEWRPC	1:48,000	SEWRPC counties
Soil contamination attenuation potential	NA	SEWRPC	Soil contamination attenuation potential based on data from the WGNHS and SEWRPC	1:48,000	SEWRPC counties
Groundwater contamination potential	NA	SEWRPC	Ground-water contamination potential based on data from the WGNHS and SEWRPC	1:48,000	SEWRPC counties
			Watershed and hydrography		
Floodplain boundaries	NA	SEWRPC	Flood-plain boundaries	1:1,200 or 1:2,400	SEWRPC counties
Watershed	Continuous updates	SEWRPC	Watersheds covering the SEWRPC counties	1:24,000	SEWRPC counties
Subwatershed	Continuous updates	SEWRPC	Subwatersheds covering the SEWRPC counties	1:1,200	SEWRPC counties
Subbasin	Continuous updates	SEWRPC	Subbasins covering the SEWRPC counties	1:2,400	SEWRPC counties

Table 4. Selected GIS Coverages available for the Milwaukee Metropolitan Sewerage District planning area—Continued

[NA, not available, MMSD, Milwaukee Metropolitan Sewerage District; SEWRPC, Southeastern Wisconsin Regional Planning Commission; USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; GMUs, Geographic Management Units; DEM, digital elevation model; LICGF, Land Information and Computer Graphics Facility; SSURGO, Soil Survey Geographic Data base; STATSGO, State Soil Geographic Survey; USDA, U.S. Department of Agriculture; NRCS, National Resources Conservation Service; WGNHS, Wisconsin Geologic and Natural History Survey; USEPA, U.S. Environmental Protection Agency; DLGs, digital line graphs; MIS, Metropolitan Interceptor System; ISS, Inline Storage System; NSC, Near Surface Collector System; CSO, combined sewer overflow; NHAP, National High-Altitude Photography; WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NLCD, National Land Cover Data; GIRAS, Geographic Information Retrieval and Analysis; LUDA, Land Use Data Analysis]

Data set name	Source year	Data provider	Description	Scale	Data extent
			Watershed and hydrography—Continued		
Hydrography (version 2)	2002	WDNR	Hydrography data include information about surface-water features represented on the USGS 1:24,000-scale topographic map series, such as perennial and intermittent streams, lakes, and so on.	1:24,000	Wisconsin
National Hydrography Dataset (NHD)	2001	USEPA/ USGS	The hydrography data layer is derived from the 1:100,000-scale Digital Line Graphs (DLGs) of the USGS.	1:100,000	Wisconsin
Water lines	1990, 1995	SEWRPC	Water-line data include watershed boundaries, rivers, channelized rivers, and breakwaters. Data for Milwaukee, Ozaukee, and Racine Counties from 1995; data for Washington and Waukesha Counties from 1990.	NA	SEWRPC counties
Water related	1990, 1995	SEWRPC	Water related data include waterbody and marsh locations. Data for Milwaukee, Ozaukee, and Racine Counties from 1995; data for Washington and Waukesha Counties from 1990.	NA	SEWRPC counties
WDNR watersheds	1990	WDNR	WDNR watershed delineations generally indicate areas that drain into a common river system or lake but may also be based on WDNR basin-management criteria.	1:24,000	Wisconsin
			Infrastructure		
Sewer service areas	NA	SEWRPC	Sewer service areas	1:48,000	SEWRPC counties
Roads	1998	WDNR	Highways, roads, trails, and associated features. The data are derived from a subset of the Transportation files of the U.S. Geological Survey DLGs.	1:100,000	Wisconsin
Roads	2000	US Dept of Commerce: Bureau of Census	Roads based on data from U.S. Department of Commerce, the Bureau of Census	1:100,000	United States
Dams	1997	WDNR	Dam locations	NA	Wisconsin
Miscellaneous infrastructure (airports, pipelines, and so on.)	1992	WDNR	Airports, pipelines, electric transmission lines, and associated infrastructure. This data set is derived from a subset of the Transportation files of the U.S. Geological Survey DLGs.	1:100,000	Wisconsin
State trunk highways	1998	WDNR	State trunk highway data were derived from a data set developed by the Wisconsin Dept. of Transportation, and called the "1:100,000-scale Roadway Chain" database. Data set contains spatial object chain representing the centerline of Wisconsin State, U.S. and interstate roadways, and selected supporting state-owned roadways such as ramps, connectors, frontage roads.	1:100,000	Wisconsin

Table 4. Selected GIS Coverages available for the Milwaukee Metropolitan Sewerage District planning area—Continued

[NA, not available, MMSD, Milwaukee Metropolitan Sewerage District; SEWRPC, Southeastern Wisconsin Regional Planning Commission; USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; GMUs, Geographic Management Units; DEM, digital elevation model; LICGF, Land Information and Computer Graphics Facility; SSURGO, Soil Survey Geographic Data base; STATSGO, State Soil Geographic Survey; USDA, U.S. Department of Agriculture; NRCS, National Resources Conservation Service; WGNHS, Wisconsin Geologic and Natural History Survey; USEPA, U.S. Environmental Protection Agency; DLGs, digital line graphs; MIS, Metropolitan Interceptor System; ISS, Inline Storage System; NSC, Near Surface Collector System; CSO, combined sewer overflow; NHAP, National High-Altitude Photography; WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NLCD, National Land Cover Data; GIRAS, Geographic Information Retrieval and Analysis; LUDA, Land Use Data Analysis]

Data set name	Source year	Data provider	Description	Scale	Data extent
			Infrastructure—Continued		
Railroads	1998	WDNR	Railroad data were derived from the Wisconsin Department of Transportation "1:100,000-scale Rails Chain Database." This data set includes all main track and sidings identified in railroad timetables; does not include abandonments.	1:100,000	Wisconsin
Transportation related features	1990, 1995	SEWRPC	Transportation related features such as roads, railroads, and airport terminals. Data for Milwaukee, Ozaukee, and Racine from 1995; data for Washington and Waukesha from 1990	NA	SEWRPC counties
Stream corridors	NA	SEWRPC	Stream corridors are defined as the land within the greatest distance from the watercourse marked by the SEWRPC primary or secondary environmental corridor boundary; the 100-year regulatory flood-plain boundary; the edge of an adjoining wetland; or 75 feet from the watercourse channel or shoreline.	NA	MMSD planning area
Perennial stream lines	NA	SEWRPC	Perennial streams	NA	MMSD planning area
Intermittent stream lines	NA	SEWRPC	Intermittent streams	NA	MMSD planning area
Sewers: Metropolitan Interceptor System	2003	MMSD	Sewerline locations that are part of the Metropolitan Interceptor System (MIS)	NA	Milwaukee County
Sewers: Inline Storage System	2003	MMSD	Sewerline location that are part of the Inline Storage System (ISS), otherwise known as the "Deep Tunnel"	NA	Milwaukee County
Sewers: Near Surface Collector System	2003	MMSD	Sewerline locations that are part of the Near Surface Collector System (NSC)	NA	Milwaukee County
Sewers: Combined Sewer Overflow	2003	MMSD	Sewerline locations that are part of the Combined Sewer Overflow (CSO)	NA	Milwaukee County
			Land use/land cover		
Land use	1963, 1970, 1975, 1980, 1985, 1990, 1995	SEWRPC	Land use	1:4,800	SEWRPC counties
Historical urban growth	1995	SEWRPC	Historical urban growth	1:4,800	SEWRPC counties
Vegetation	1985, 1995	SEWRPC	Vegetation	1:4,800	SEWRPC counties
Wildlife habitat	1985, 1995	SEWRPC	Wildlife habitat	1:4,800	SEWRPC counties

Table 4. Selected GIS Coverages available for the Milwaukee Metropolitan Sewerage District planning area—Continued

[NA, not available, MMSD, Milwaukee Metropolitan Sewerage District; SEWRPC, Southeastern Wisconsin Regional Planning Commission; USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; GMUs, Geographic Management Units; DEM, digital elevation model; LICGF, Land Information and Computer Graphics Facility; SSURGO, Soil Survey Geographic Data base; STATSGO, State Soil Geographic Survey; USDA, U.S. Department of Agriculture; NRCS, National Resources Conservation Service; WGNHS, Wisconsin Geologic and Natural History Survey; USEPA, U.S. Environmental Protection Agency; DLGs, digital line graphs; MIS, Metropolitan Interceptor System; ISS, Inline Storage System; NSC, Near Surface Collector System; CSO, combined sewer overflow; NHAP, National High-Altitude Photography; WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NLCD, National Land Cover Data; GIRAS, Geographic Information Retrieval and Analysis; LUDA, Land Use Data Analysis]

Data set name	Source year	Data provider	Description	Scale	Data extent
			Land use/land cover—Continued		
Pre-european settlement vegetation	1836	SEWRPC	Pre-European-settlement vegetation	1:4,800	SEWRPC counties
Regional land-use plan	2010, 2020	SEWRPC	Regional land-use plan	1:96,000	SEWRPC counties
Parks and open space sites	NA	SEWRPC	Parks and open space locations	1:48,000	SEWRPC counties
Public lands	1990, 1995	SEWRPC	Public lands by county. Data for Milwaukee, Ozaukee, and Racine from 1995; data for Washington and Waukesha from 1990	1:4,800	SEWRPC counties
Land use and land cover	1970's - 1980's	WDNR	Land-use land-cover data are derived from the U.S. Geological Survey Land Use and Land Cover digital dataset at 1:250,000 scale. Land surface features were interpreted by the USGS using National Aeronautics and Space Administration high-altitude aerial photographs, and National High-Altitude Photography (NHAP) program photographs at scales of 1:60,000 or smaller.	1:250,000	Wisconsin
Original vegetation cover	mid-1800's	WDNR	Original vegetation cover data was digitized from a 1976 map created from land survey notes written in the mid-1800s when Wisconsin was first surveyed	1:500,000	Wisconsin
WISCLAND land cover	1993	WDNR	WISCLAND (Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data) state land-use data was interpreted from land cover from satellite images. More information is available at URL http://www.dnr.state.wi.us/org/at/et/geo/data/wlc.htm	30 meter	Wisconsin
National Land Cover Data (NLCD)	1992	USGS	National Land Cover Data (NLCD) developed from early to mid-90s Landsat Thematic Mapper satellite data with 21 classes of land cover. More information is available at URL http://landcover.usgs.gov/natllandcover.html	30 meter	United States
			Population		
1990 Census	1990	Geolytics	Data describing population statistics from the year 1990 U.S. Census.	NA	United States
2000 Census	2000	Geolytics	Data describing population statistics from the year 2000 U.S. Census.	NA	United States
			Other		
Aerial photography	1963, 1967, 1970, 1975, 1980, 1985, 1990, 1995, 2000	SEWRPC	Aerial photography. More information is available at URL http://www.sewrpc.org/aerialsandmaps/aerials.shtm	NA	Parts of southeastern Wisconsin
Environmental corridors	1990, 1995	SEWRPC	Inventory of environmental corridors	1:4,800	SEWRPC counties
Natural areas and critical species habitat	NA	SEWRPC	Natural areas and critical species habitat	1:4,800	SEWRPC counties

Table 4. Selected GIS Coverages available for the Milwaukee Metropolitan Sewerage District planning area—Continued

[NA, not available, MMSD, Milwaukee Metropolitan Sewerage District; SEWRPC, Southeastern Wisconsin Regional Planning Commission; USGS, U.S. Geological Survey; WDNR, Wisconsin Department of Natural Resources; GMUs, Geographic Management Units; DEM, digital elevation model; LICGF, Land Information and Computer Graphics Facility; SSURGO, Soil Survey Geographic Data base; STATSGO, State Soil Geographic Survey; USDA, U.S. Department of Agriculture; NRCS, National Resources Conservation Service; WGNHS, Wisconsin Geologic and Natural History Survey; USEPA, U.S. Environmental Protection Agency; DLGs, digital line graphs; MIS, Metropolitan Interceptor System; ISS, Inline Storage System; NSC, Near Surface Collector System; CSO, combined sewer overflow; NHAP, National High-Altitude Photography; WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NLCD, National Land Cover Data; GIRAS, Geographic Information Retrieval and Analysis; LUDA, Land Use Data Analysis]

Data set name	Source year	Data provider	Description	Scale	Data extent
			Other—Continued		
Water Permit Compliance System (PCS)	2001	USEPA	Water discharge permits, locations and associated descriptions. More information is available at URL http://www.epa.gov/enviro/html/pcs/pcs_query_java.html	Various	United States
Toxic Release Inventory (TRI)	2001	USEPA	Locations of and descriptions of toxic chemical releases and other waste-management activities, which are reported annually by certain industry groups and Federal facilities. More information is available at URL http://www.epa.gov/tri/	Various	United States
Wastewater outfalls	2002	WDNR	Locations of wastewater-outfall locations in Wisconsin	Various	Wisconsin

[1]For more information on SEWRPC data, see http://www.sewrpc.org/data_publications/default.htm

[2]SEWRPC counties include Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, Waukesha.

[3]For more information on WDNR Geographic data, see http://www.dnr.state.wi.us/org/at/et/geo/. Data descriptions of WDNR data taken in part from metadata describing each dataset available at that Web site.