Chapter VII

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE MILWAUKEE RIVER WATERSHED

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in the urban and urbanizing areas of the Milwaukee River watershed, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

Comprehensive water quality planning efforts such as the regional water quality management plan update, should include an evaluation of historical, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Milwaukee River watershed have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past thirty years; indicates the location and type of the numerous and varied sources of wastewater, industrial, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the water quality plan update.

DESCRIPTION OF THE WATERSHED

The Milwaukee River watershed is located in the north central portion of the Southeastern Wisconsin Region and covers an area of approximately 700 square miles. The mainstem of the Milwaukee River originates in southeastern Fond du Lac County and flows approximately 101 miles in a southerly and easterly direction to its confluence with Lake Michigan in the City of Milwaukee in Milwaukee County. Tributaries of the Milwaukee River extend into Dodge, Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. Approximately 62 percent, or 434 square miles, of the watershed is located within the Southeastern Wisconsin Region. The remaining 38 percent, or 266 square miles, is located in Dodge, Fond du

Lac, and Sheboygan Counties. The boundaries of the basin, together with the locations of the main channels of the Milwaukee River watershed and its principal tributaries, are shown on Map 47. The Milwaukee River watershed contains 20 lakes with a surface area of 50 acres or more, along with numerous smaller named lakes and ponds.

Civil Divisions

Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 48, the watershed lies in Dodge, Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties. Fifty-six civil divisions lie partially, or entirely, within the Milwaukee River watershed, as also shown on Map 48 and in Table 83. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional water quality management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Milwaukee River watershed since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update, as shown in Table 84. Although much of the watershed is urbanized, about 79 percent of the watershed was still in rural and other open space land uses in 2000. These rural and open space uses included about 4 percent of the total area of the watershed in unused and other open lands and about 17 percent in surface water and wetlands. Most of the rural and open spaces remaining in the watershed are located in southeastern Fond du Lac County, northeastern Ozaukee County, southwestern Sheboygan County, and eastern Washington County. The remaining approximately 21 percent of the total watershed was devoted to urban uses, as shown on Map 49.

While urban development exists throughout much of the Milwaukee River watershed, it is especially concentrated in the southeastern portion of the watershed in Milwaukee and Ozaukee Counties and the west-central portion of the watershed in and around the City of West Bend. As shown in Table 84, residential land represents about one-half of the urban land use in the watershed. The historic urban growth within the Milwaukee River watershed is summarized on Map 50 and in Table 85. Since 1990, much, though not all, of the urban growth in the watershed has occurred near existing urban centers such as the Cities of Cedarburg, Mequon, and West Bend and the Villages of Campbellsport, Grafton, Jackson, Kewaskum, Random Lake, and Saukville.

The changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the watershed has decreased. From 1970 through 1990, the population in the watershed decreased by about 20,253, from 511,010 to 490,757; however, during that time period the number of households increased by 18,152, from 165,099 to 183,251. Between 1990 and 2000 the size of the population in the watershed continued to decline, decreasing to 484,199 persons, or a decrease of 6,558 persons. During this decade of decreasing population, the number of households in the watershed increased by 5,360 units to 188,611.

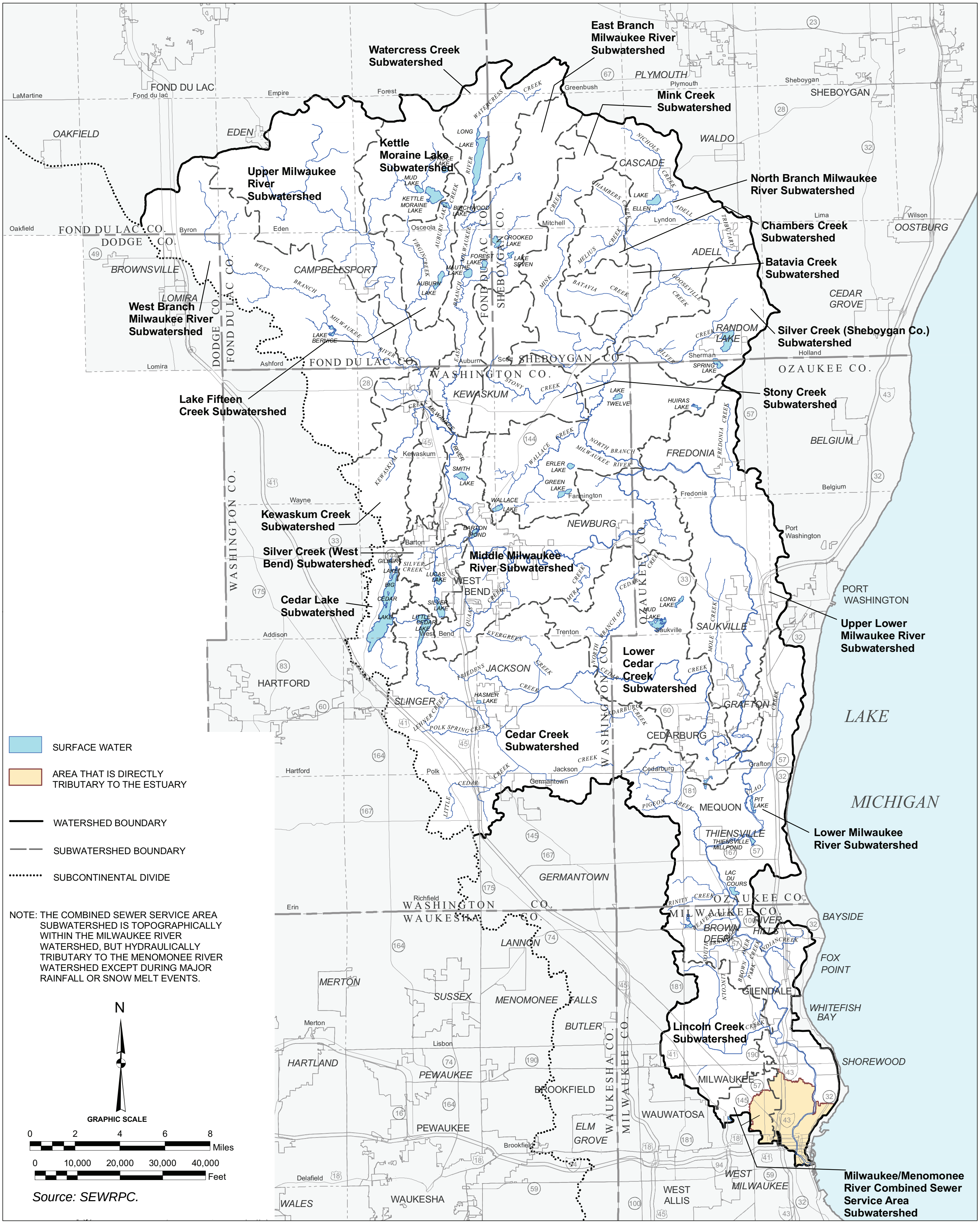
QUANTITY OF SURFACE WATER

Since 1963, measurements of discharge have been taken at a number of locations along the Milwaukee River and its tributaries. The period of record for some of these stations is rather short, with data collection occurring over periods ranging from about four months to about 14 months. Three stations on the mainstem of the Milwaukee River at Pioneer Road, Estabrook Park, and Waubeka, have periods of record of about 23, 29, and nine years, respectively. Three stations along tributaries, those on the East Branch Milwaukee River at New Fane, the North Branch Milwaukee River near Fillmore, and Cedar Creek at Cedarburg, have periods of record of seven, seven, and 27 years, respectively.

Figure 106 shows historical and baseline period discharge for the five stations along the mainstem of the River and Figure 107 shows similar discharge data for tributaries to the Milwaukee River. Generally similar annual

Map 47

SURFACE WATER WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Map 48

CIVIL DIVISIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

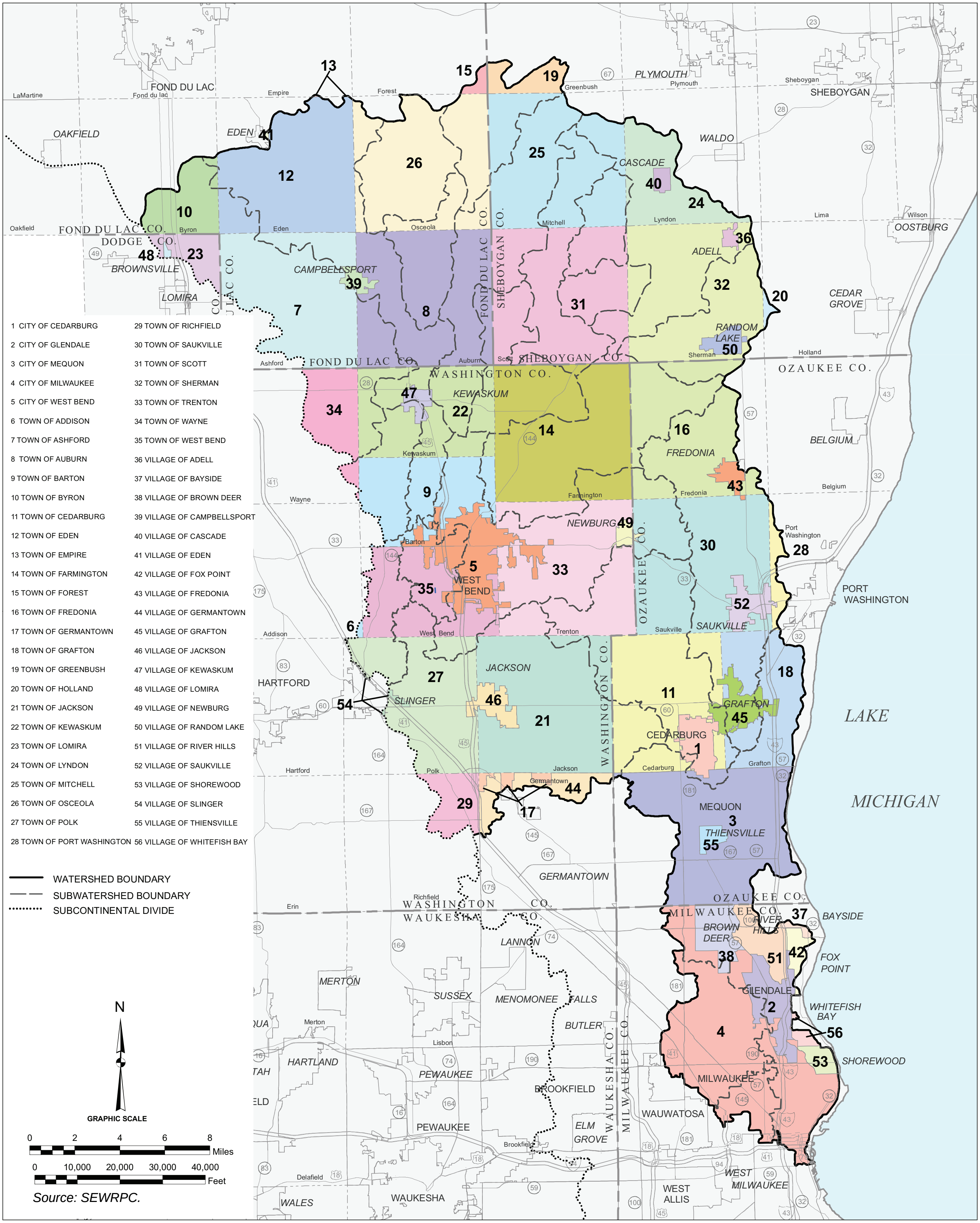


Table 83

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE MILWAUKEE RIVER WATERSHED

Civil Division	Area (square miles)	Percent of Total
Dodge County		
Town of Lomira	4.40	0.63
Village of Lomira	0.16	0.02
Subtotal	4.56	0.65
Fond du Lac County		
Town of Ashford	29.36	4.19
Town of Auburn	35.81	5.11
Town of Byron	8.85	1.26
Town of Eden	29.69	4.24
Town of Empire	0.03	0.00
Town of Forest	0.84	0.12
Town of Osceola	33.52	4.79
Village of Campbellsport	1.12	0.16
Village of Eden	0.05	0.01
Subtotal	139.29	19.88
Milwaukee County		
City of Glendale	5.93	0.85
City of Milwaukee	38.84	5.54
Village of Bayside	0.38	0.06
Village of Brown Deer	4.39	0.63
Village of Fox Point	1.60	0.23
Village of River Hills	4.28	0.61
Village of Shorewood	1.48	0.21
Village of Whitefish Bay	0.75	0.11
Subtotal	57.68	8.23
Ozaukee County		
City of Cedarburg	3.65	0.52
City of Mequon	31.47	4.49
Town of Cedarburg	25.96	3.71
Town of Fredonia	28.06	4.01
Town of Grafton	16.49	2.35
Town of Port Washington	2.42	0.35
Town of Saukville	33.42	4.77
Village of Fredonia	1.30	0.19
Village of Grafton	4.12	0.59
Village of Saukville	2.89	0.41
Village of Thiensville	1.05	0.15
Subtotal	150.87	21.54
Sheboygan County		
Town of Greenbush	3.66	0.52
Town of Holland	0.45	0.07
Town of Lyndon	12.58	1.80
Town of Mitchell	33.47	4.78
Town of Scott	36.54	5.22
Town of Sherman	32.63	4.66
Village of Adell	0.55	0.08
Village of Cascade	0.77	0.11
Village of Random Lake	1.70	0.24
Subtotal	122.40	17.47

Table 83 (continued)

Civil Division	Area (square miles)	Percent of Total
Washington County		
City of West Bend	12.62	1.80
Town of Addison	0.18	0.03
Town of Barton	18.00	2.57
Town of Farmington	36.78	5.25
Town of Germantown	1.06	0.15
Town of Jackson	34.24	4.89
Town of Kewaskum	22.93	3.27
Town of Polk	24.17	3.45
Town of Richfield	5.62	0.80
Town of Trenton	33.47	4.78
Town of Wayne	9.14	1.30
Town of West Bend	17.20	2.46
Village of Germantown	5.02	0.72
Village of Jackson	2.54	0.36
Village of Kewaskum	1.41	0.20
Village of Newburg	0.89	0.13
Village of Slinger	0.38	0.05
Subtotal	224.92	32.22
Total	700.00	100.00

Source: SEWRPC.

patterns are seen in the baseline period mean discharge at the main stem and tributary sites. Mean monthly streamflow tends to reach a low point during the late summer or early fall. Mean monthly discharge remains reasonably constant through December. This is followed by a sharp increase during late winter and early spring that is associated with spring snowmelt and rains. It then declines through the spring and early summer to the late summer/early fall minimum. Considerable variability is associated with these patterns, but some of this variability is more likely attributed to sampling conditions rather than actual changes in discharge.

For the most part, stream flow from the baseline period is within historical ranges at the stations with long-term flow data. During winter and spring months, monthly maximum discharges during the baseline period were higher than the historical monthly maxima at the station at Jones Island. This may reflect the small amount of historical data available at this station. Baseline period monthly mean discharges tended to be lower than the historical means during the fall at the Pioneer Road and Estabrook Park stations. By contrast, baseline period monthly mean discharges were higher than the historical means during the spring at the Waubeka station. This may reflect the small amount of data from the baseline period for this station.

Flow fractions were calculated for all stations relative to the discharge at the Estabrook Park station using the procedure described in Chapter III of this report. The results are shown on Map 51. Several generalizations emerge from this analysis:

- The magnitude of average discharge increases rapidly in the headwaters of the River. For example, while median discharge at the gauge in the upper reaches of the West Branch Milwaukee River (river mile 15.90) represents about 2 percent of the median discharge at Estabrook Park, median discharge along the mainstem near Kewaskum represents about 23 percent of the median discharge at Estabrook Park. Much of the increase in discharge represents contributions of water from the mainstem of the Milwaukee River, the West Branch of the Milwaukee River, and Auburn Lake Creek. Similarly, median discharge along the North Branch of the Milwaukee River increases from about 9 percent to about 20 percent of the median discharge at Estabrook Park between the stations near Random

Lake (River Mile 10.09) and at Fillmore (River Mile 2.22). Much of this increase in discharge represents contributions from Silver Creek (Sheboygan County), Stony Creek and Wallace Creek.

- Much of the discharge at downstream stations can be accounted for by discharge from stations upstream and from tributaries entering the River upstream. For instance, median discharge from the Milwaukee River and its tributaries upstream at the Newburg station (River Mile 78.10) represents about 42 percent of the median discharge at the Estabrook Park Station. Much of this, about 23 percent of the median discharge at the Estabrook Park station, is contributed by the mainstem of the Milwaukee River, the West Branch of the Milwaukee River, and their tributaries upstream of the Village of Kewaskum. Given that Quaas Creek contributes less than 2 percent of the median discharge at Estabrook Park, the remaining 19 percent from the area at, and downstream from, Kewaskum is contributed by Kewaskum Creek, Myra Creek, and other tributaries along the mainstem between Kewaskum and Newburg.

- Similarly, median discharge at the station along the mainstem of the River at Waubeka (River Mile 45.44) represents about 60 percent of the median discharge at the Estabrook Park station. Most of the increase in discharge between Newburg and Waubeka can be accounted for by contributions from the North Branch of the Milwaukee River.

Table 84

LAND USE IN THE MILWAUKEE RIVER WATERSHED: 2000[a,b]

Category	2000[c] Square Miles	2000[c] Percent of Total
Urban		
Residential	71.64	10.2
Commercial	6.32	0.9
Industrial and Extractive	8.89	1.3
Transportation, Communication, and Utilities[d]	44.54	6.3
Governmental and Institutional	6.90	1.0
Recreational	10.30	1.5
Subtotal	148.58	21.2
Rural		
Agricultural and Related	342.45	48.9
Water	12.05	1.7
Wetlands	104.86	15.0
Woodlands	62.24	8.9
Unused and Other Open Lands	29.81	4.3
Subtotal	551.42	78.8
Total	700.00	100.0

[a]As approximated by whole U.S. Public Land Survey one-quarter sections.

[b]Prior to 2000, detailed land use data are not available for the portions of the watershed outside the Southeastern Wisconsin Region.

[c]This represents the entire watershed, including those portions in Dodge, Fond du Lac, and Sheboygan Counties.

[d]Off-street parking of more than 10 spaces is included with the associated land use.

Source: SEWRPC.

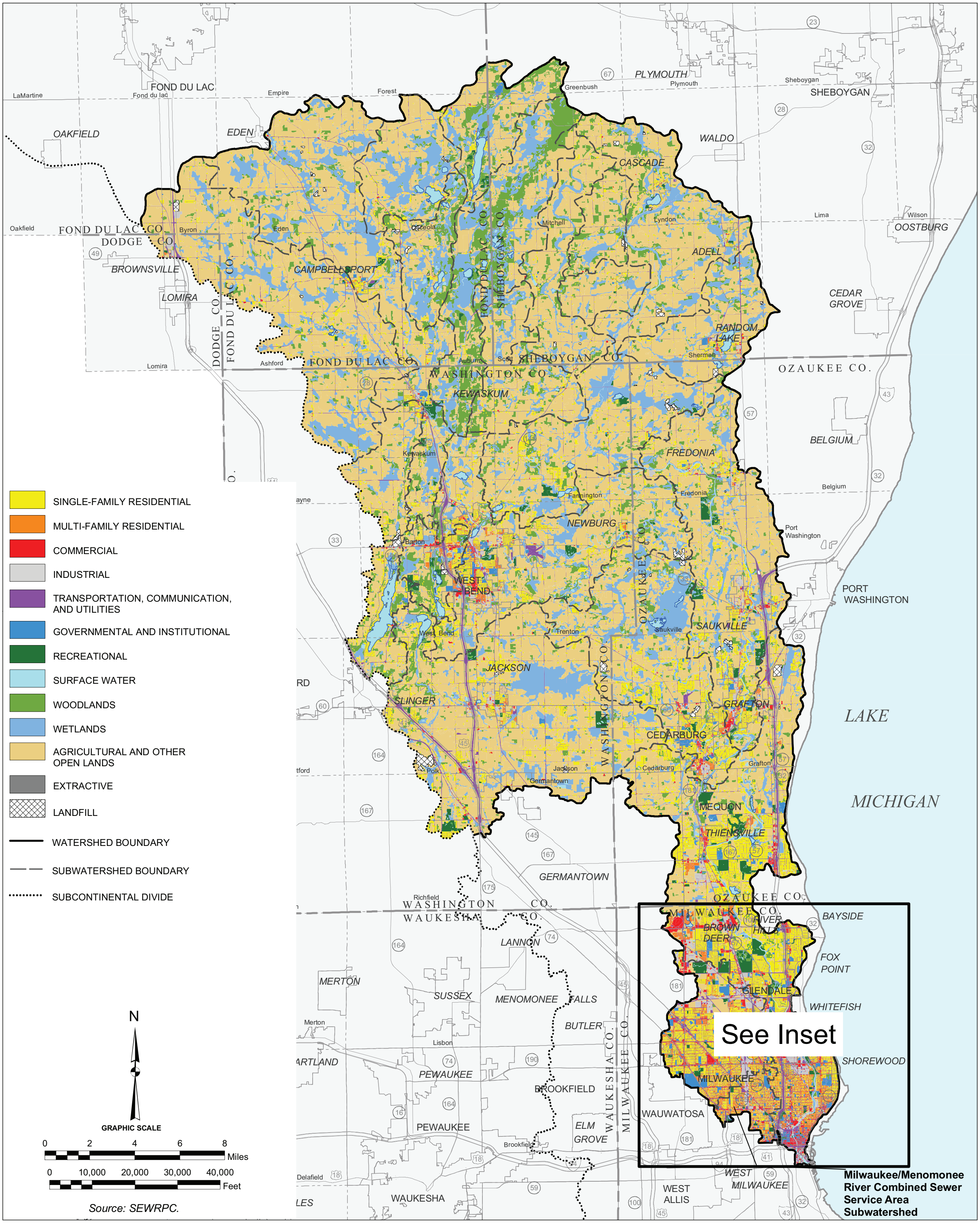
- Median discharge at the station along the mainstem of the River at Pioneer Road (River Mile 26.25) represents about 85 percent of the median discharge at the Estabrook Park station. Much of the increase between Waubeka and Pioneer Road can be accounted for by contributions from Cedar Creek. Discharge at the Cedar Creek gauge at STH 60 (River Mile 6.77) represents about 16 percent of the median discharge at Estabrook Park. This suggests that contributions from Fredonia Creek, Mole Creek, and other tributaries entering the River between Waubeka and Pioneer Road represent about 9 percent of the flow at Estabrook Park.

- Contributions from a number of tributaries, as well as direct runoff, account for the increase in median discharge between Pioneer Road and Estabrook Park.

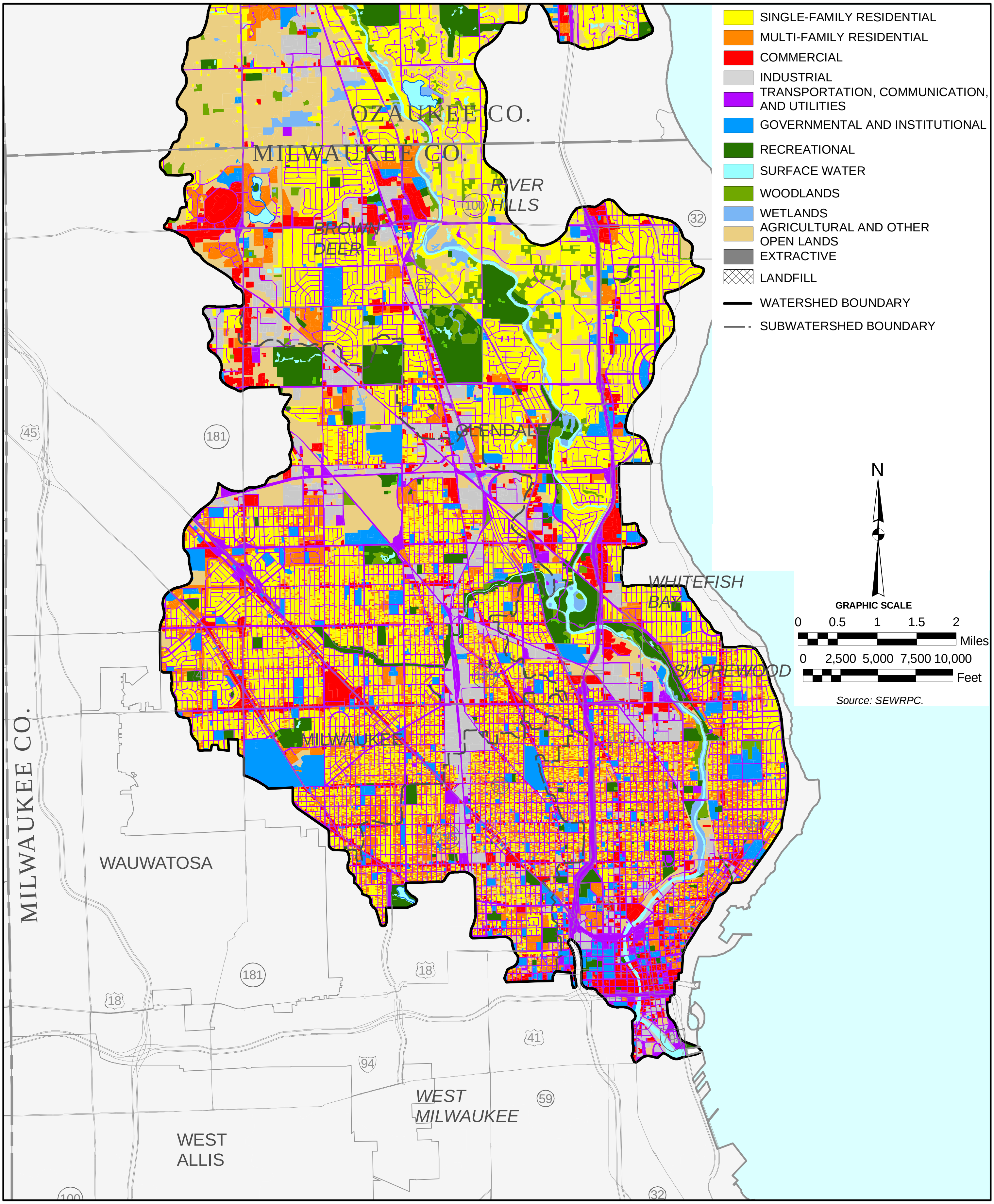
- Median discharge at Jones Island, which includes contributions from the Kinnickinnic and Menomonee Rivers, represents about 132 percent the median discharge at Estabrook Park. Through comparison of that percentage with the 100 percent contribution at Estabrook Park, suggests that the Milwaukee River contributes about three quarters of the median discharge into the harbor.

Map 49

EXISTING LAND USE WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

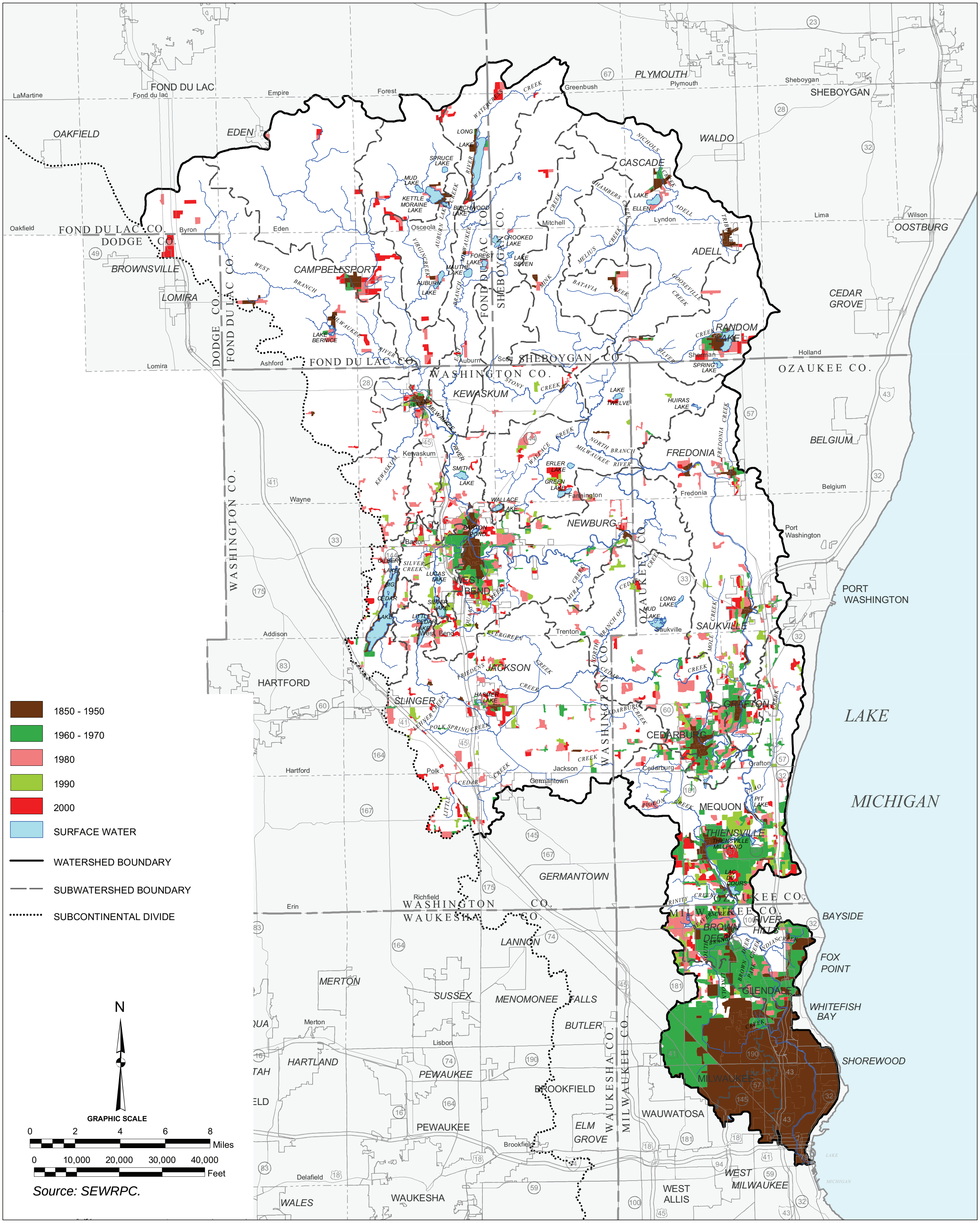


INSET to Map 49



Map 50

HISTORICAL URBAN GROWTH WITHIN THE MILWAUKEE RIVER WATERSHED: 1850-2000



Source: SEWRPC.

SURFACE WATER QUALITY OF THE MILWAUKEE RIVER WATERSHED: 1975-2004

Water Quality of Streams

The earliest systematic collection of water quality data in the Milwaukee River watershed occurred in the mid-1960s.[1] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected, especially on the mainstem of the River. The major sources of data include the Milwaukee Metropolitan Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), the U.S. Geological Survey (USGS), the Washington County Land and Water Conservation Division, the University of Wisconsin-Milwaukee, and the U.S. Environmental Protection Agency's (USEPA) STORET legacy and modern databases (see Map 52). In addition, the Commission staff reviewed data collected by citizen monitoring programs including the Testing the Waters Program and the Water Action Volunteers Program. These data are presented in Appendix B. Most of these data were obtained from sampling stations along the mainstem of the River. In addition, sufficient data were available for several tributaries to assess baseline period water quality for several water quality parameters. These tributaries are listed in Table 86. The data record for the other tributary streams in the watershed is fragmentary.

Table 85

EXTENT OF URBAN GROWTH WITHIN THE MILWAUKEE RIVER WATERSHED: 1850-2000

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	2,680	2,680	0.6
1880	2,773	5,453	1.2
1900	1,614	7,067	1.6
1920	3,751	10,818	2.4
1940	6,943	17,761	3.9
1950	7,441	25,202	5.6
1963	14,592	39,794	8.9
1970	5,487	45,281	10.1
1975	5,116	50,397	11.2
1980	8,054	58,451	13.0
1985	3,232	61,683	13.7
1990	2,780	64,463	14.4
1995	3,127	67,590	15.1
2000	4,608	72,198	16.1

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby, indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2004. Bimonthly data records exist from several of MMSD's long-term monitoring stations beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System (ISS), or Deep Tunnel, came online. The remaining period from 1998-2004 defines the baseline water quality conditions of the river system, since the Inline Storage System came online.

Under this plan update, baseline water quality conditions were graphically compared to historical conditions on a monthly basis. As shown in the sample graph presented in Figure 23 of Chapter III of this report, for each water quality parameter examined, the background of the graph summarizes the historical conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The upper and lower boundaries between the white and gray areas show historical maxima and minima, respectively. A blue background indicates months for which no historical data were available. The black dashed line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2004. Relative to the Kinnickinnic River, Menomonee River, and Oak Creek watersheds, the baseline period examined for the Milwaukee River was extended to 2004 in order to take advantage of data collected specifically for the regional water quality management plan update in 2004 by the USGS and by the Washington County Land and Water Conservation Division during the period 2003-2004. The black dots show the monthly mean value of the parameter for the 1998-2004 period. The black bars show the monthly ranges of parameter for the same period.

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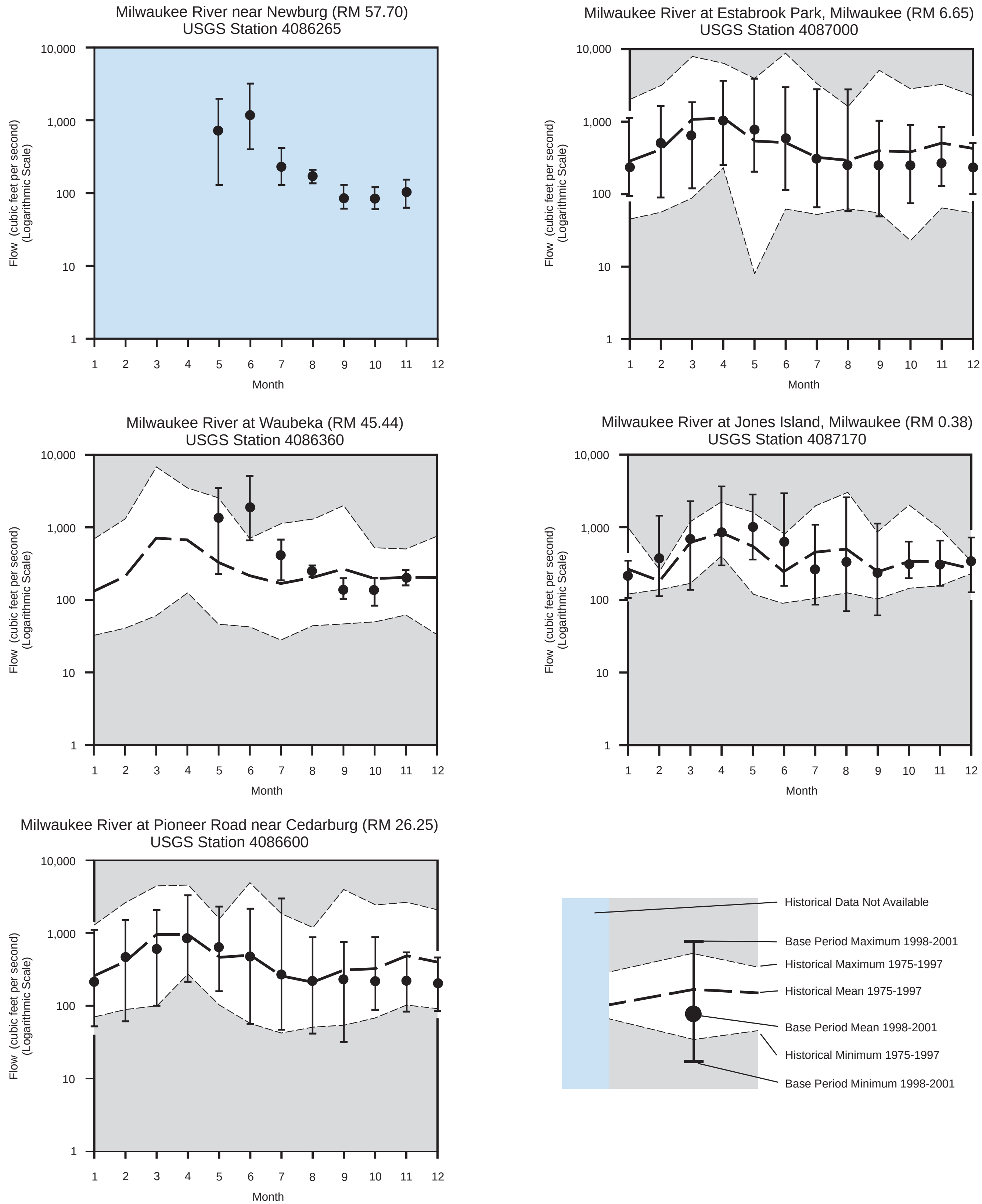
[1]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin, *April 1964.*

Figure 106

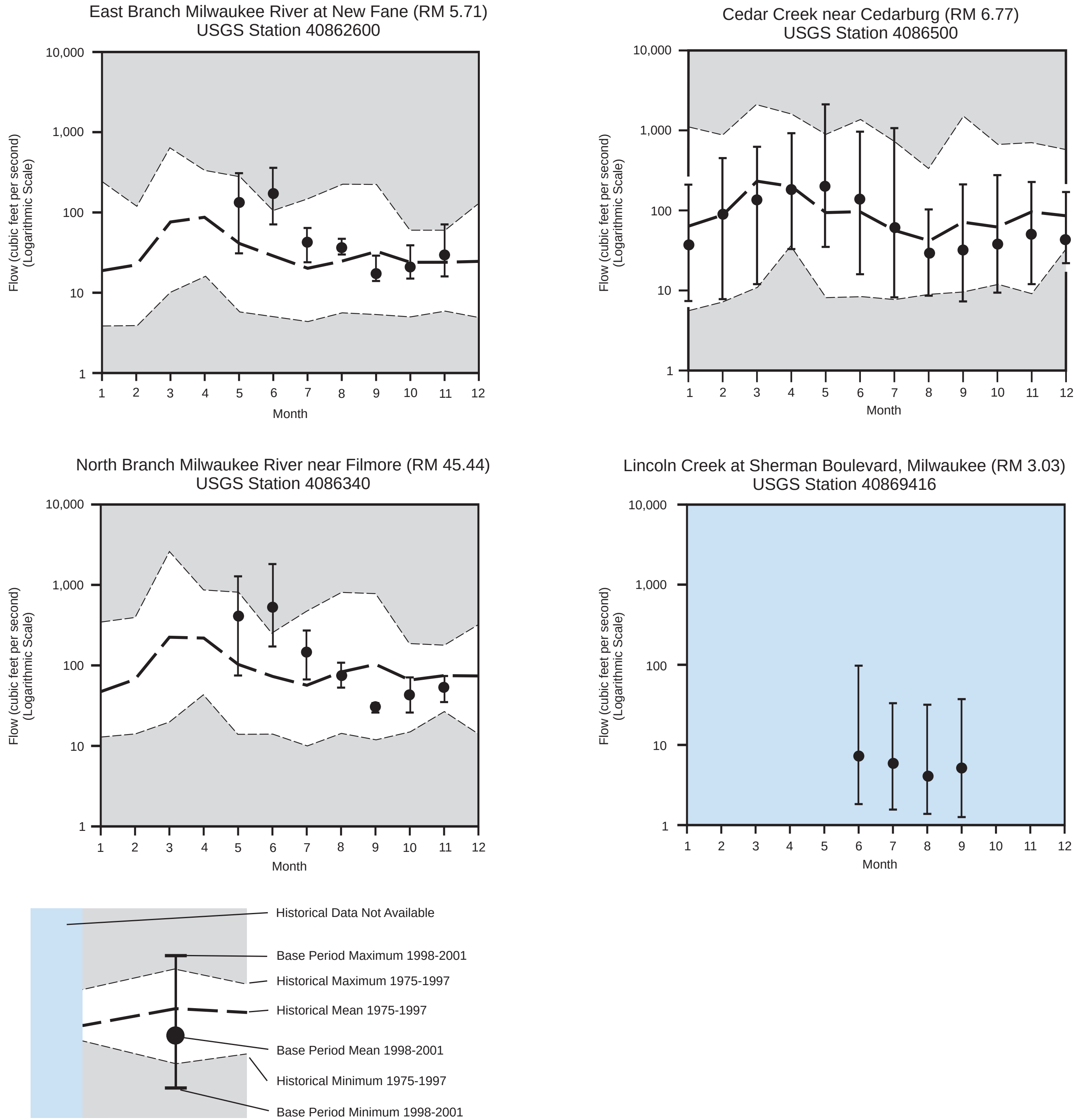
HISTORICAL AND BASE PERIOD FLOW ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey and SEWRPC.

Figure 107

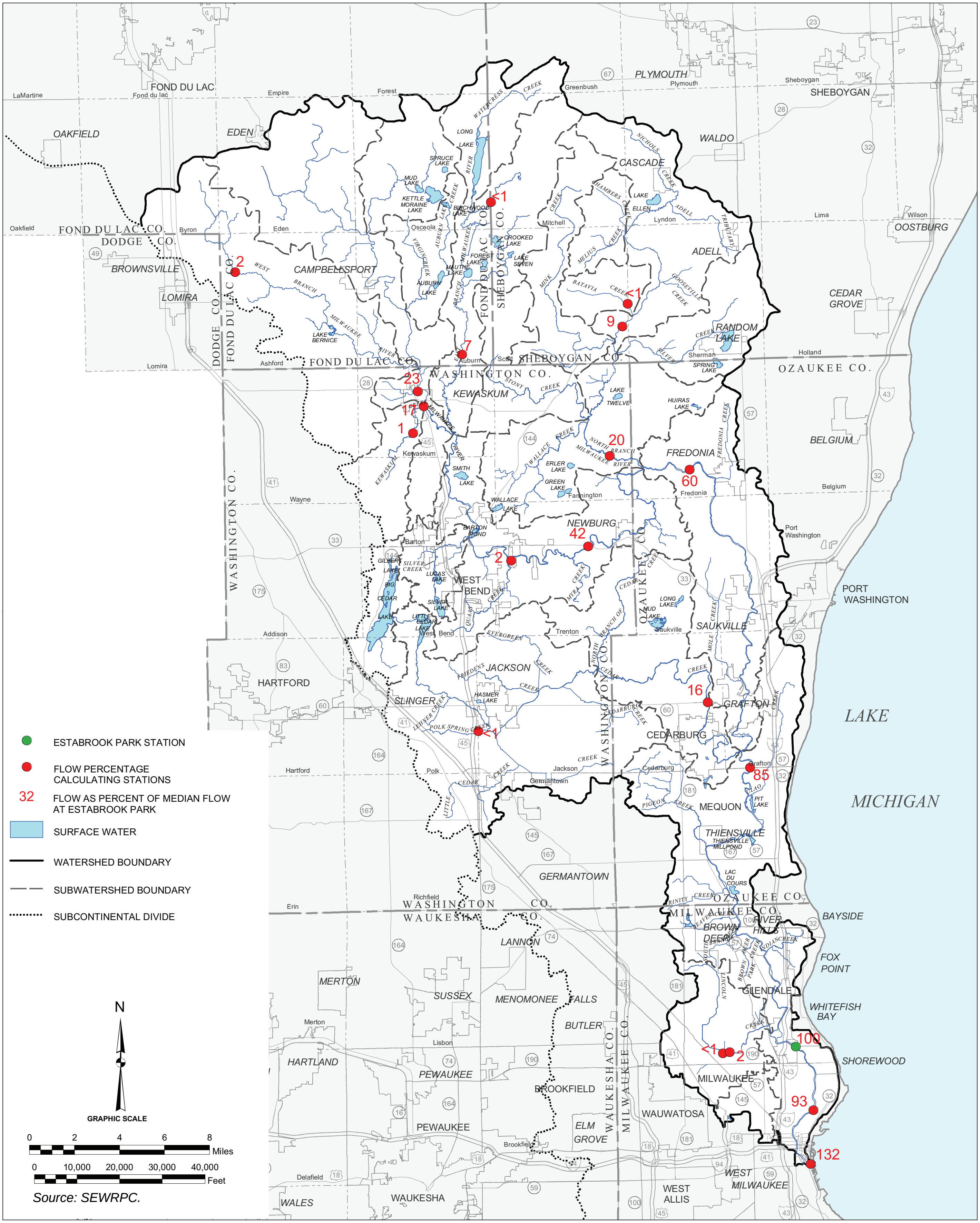
HISTORICAL AND BASE PERIOD FLOW IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey and SEWRPC.

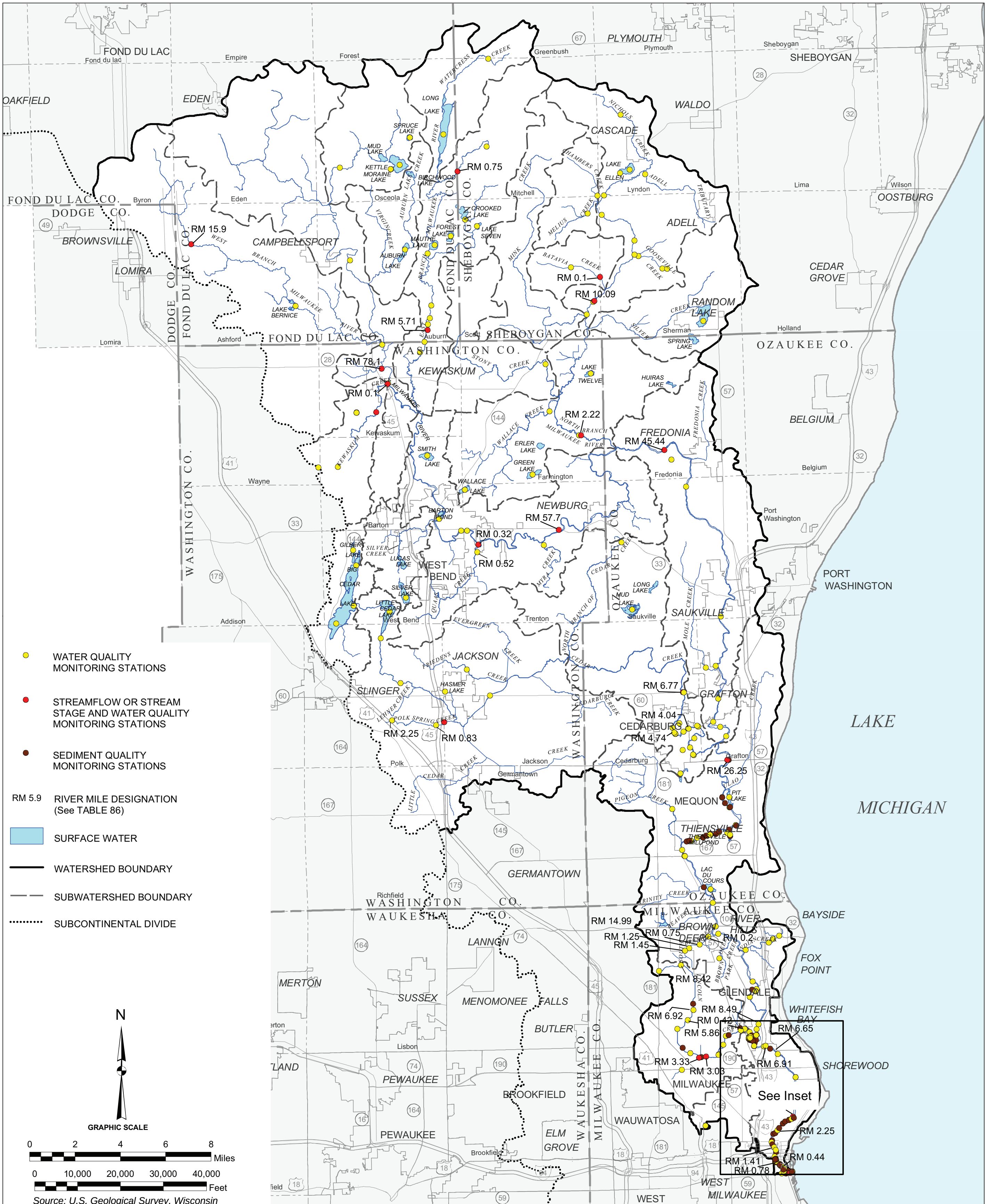
Map 51

FLOW PERCENTAGES AMONG STATIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2004



Map 52

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

INSET to Map 52

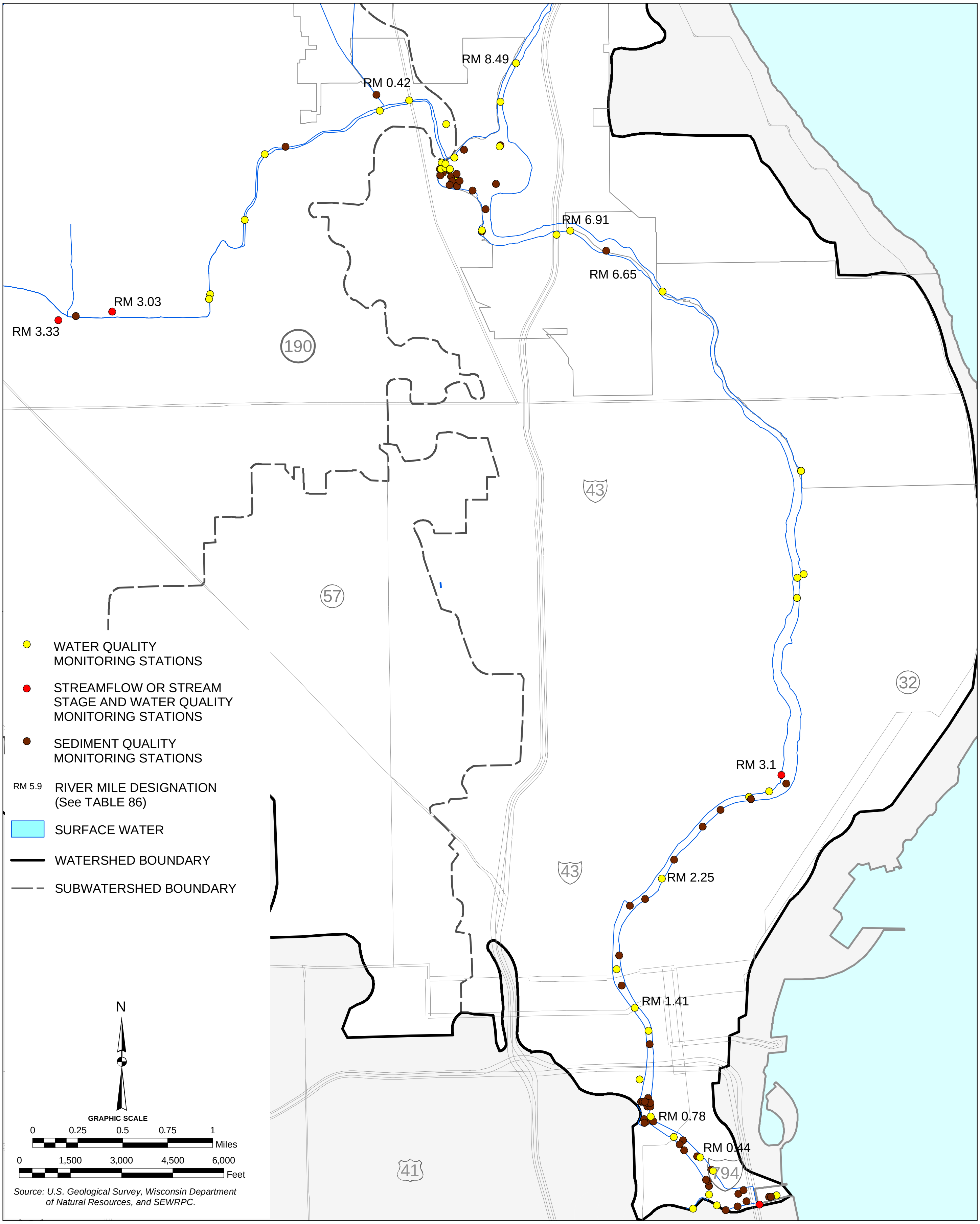


Table 86

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE MILWAUKEE RIVER

Location	River Mile	Period of Record	Data Sources
Tributaries			
West Branch Milwaukee River at Drumlin Drive near Lomira	15.90[a]	1998-1999, 2001	USGS, USEPA
Kewaskum Creek at USH 45 at Kewaskum	0.10[a]	1998-1999	USGS, USEPA
Parnell Creek near Dundee	0.75[b]	1996-1997; 2001-2002	USGS
East Branch Milwaukee River at New Fane	5.71[a]	1993, 1995, 2004	USGS, USEPA, WDNR
Quaas Creek upstream of Decorah Road near West Bend	0.52[a]	2000-2003	UW-Milwaukee, Washington County Land and Water Conservation Division
Quaas Creek at Decorah Road near West Bend	0.32[a]	1998-1999	USGS, USEPA
Batavia Creek near Batavia	0.10[c]	1993-1994, 1998-1999	USGS, USEPA
North Branch Milwaukee River near Random Lake	10.09[a]	1992-1995, 2001-2002	USGS
North Branch Milwaukee River near Fillmore	2.22[a]	2004	USGS
Polk Springs Creek downstream of CTH Z near Jackson	2.25[d]	2003	Washington County Land and Water Conservation Division
Polk Springs Creek at CTH P near Jackson	0.83[d]	1998-2001, 2003-2004	USGS, EPA, Washington County Land and Water Conservation Division
Cedar Creek at STH 60 near Cedarburg	6.77[a]	1970, 1973-1987, 1990-2004	USGS, WDNR
Cedar Creek at Columbia Road at Cedarburg	4.74[a]	1990-1991, 1994-1995, 2001	USGS
Cedar Creek at Highland Road at Cedarburg	4.04[a]	1990-1991, 1994-1995, 2001	USGS
Southbranch Creek at Bradley Road	1.45[a]	1999-2002	MMSD
Southbranch Creek at 55th Street	1.25[a]	1999-2002	MMSD
Southbranch Creek at 47th Street	0.75[a]	1999-2002	MMSD
Southbranch Creek at Teutonia Avenue	0.20[a]	1999-2002	MMSD
Lincoln Creek at 60th Street	8.42[a]	1997-2002	MMSD
Lincoln Creek at 51st Street	6.92[a]	1997-2002	MMSD
Lincoln Creek at 55th Street	5.86[a]	1997-2002	MMSD
Lincoln Creek at 47th Street	3.33[a]	1992-2004	USGS, USEPA, WDNR, MMSD
Lincoln Creek at Sherman Boulevard	3.03[a]	2003-2004	USGS
Lincoln Creek at Green Bay Avenue	0.42[a]	1997-2002	MMSD
Mainstem			
Milwaukee River above Dam at Kewaskum	78.10[e]	2004	USGS
Milwaukee River at CTH M near Newburg	57.70[e]	2004	USGS
Milwaukee River at Waubeka	45.44[e]	2004	USGS
Milwaukee River at Pioneer Road near Cedarburg	26.25[e]	1981-2004	USGS, USEPA, WDNR, MMSD
Milwaukee River at Brown Deer Road	14.99[e]	1975; 1981-2002	USEPA, MMSD
Milwaukee River at Silver Spring Drive	8.49[e]	1975, 1976, 1981-2002	USEPA, MMSD
Milwaukee River at Port Washington Road	6.91[e]	1975, 1981-2002	MMSD
Milwaukee River at Estabrook Park	6.65[e]	1971-2004	USGS, USEPA, WDNR
Milwaukee River at North Avenue Dam	3.10[e]	1975-1976, 1979-2002	USGS, USEPA, MMSD
Milwaukee River at Walnut Street	2.25[e]	1975, 1980-2002	MMSD
Milwaukee River at Wells Street	1.41[e]	1975, 1980-2002	USEPA, MMSD
Milwaukee River at Water Street	0.78[e]	1975, 1980-2002	MMSD
Milwaukee River at Union Pacific Railroad (formerly Chicago & North Western Railway)	0.44[e]	1975, 1982-2002	MMSD

[a]*River Mile is measured as distance upstream from the confluence with the mainstem of the Milwaukee River.*

[b]*River Mile is measured as distance upstream from the confluence with the East Branch Milwaukee River.*

[c]*River Mile is measured as distance upstream from the confluence with the North Branch Milwaukee River.*

[d]*River Mile is measured as distance upstream from the confluence with Cedar Creek.*

[e]*River Mile is measured as distance upstream from the confluence with Lake Michigan.*

Source: SEWRPC.

In addition to this summarization, water quality parameters from the Milwaukee River were examined for the presence of several different types of trends: differences between the average values of parameters from sampling stations located in upstream areas and the average values of parameters from sampling stations located in the Milwaukee River Estuary, changes along the length of the River, changes at individual sampling stations over time, and seasonal changes throughout the year. Map 52 and Table 86 show the 13 sampling stations on the Milwaukee River, designated by their River Mile locations, which had sufficiently long periods of sampling to be used for these analyses. Trends over time and seasonal changes were examined along a section of the Milwaukee River from the confluence with Lake Michigan to a station 78.10 river miles upstream. Longitudinal trends and comparisons between water quality in the estuary and at stations upstream from the estuary were examined along a section of Milwaukee River from the confluence with Lake Michigan to a station 26.25 river miles upstream. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Appendix C. Where sufficient data were available, water quality parameters from tributary streams were also examined for the presence of trends. It is important to note that only limited data were available to assess baseline water quality conditions for tributary streams. Figure 108 shows photographs of selected river sampling stations along the mainstem of the Milwaukee River and several tributaries.

Bacterial and Biological Parameters

Bacteria

Fecal coliform bacteria data for selected locations are shown in Figure 109. Based on data for all of the sampling locations analyzed, median concentrations of fecal coliform bacteria in the Milwaukee River during the period of record ranged from about 50 to 2,300 cells per 100 milliliters (ml). Fecal coliform counts in the River varied over seven orders of magnitude, ranging from as low as one cell per 100 ml to over 1,100,000 cells per 100 ml. The range of variability appears to be higher during late spring, summer, and fall as shown in Figure 110, although it is important to note that this may reflect the larger numbers of samples that were taken during the these months than during other months. Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. In addition, the fecal coliform bacteria concentrations in the estuary in many samples exceed the standard of 1,000 cells per 100 ml applied by the variance covering the estuary portion of the Milwaukee River. Table 87 shows that prior to 1994, the mean concentrations of fecal coliform bacteria in the estuary were significantly higher than the mean concentrations of fecal coliform bacteria in the section of the River upstream from the estuary. This relationship changed after 1994. During the period 1994-1997, there were no differences between the mean concentrations of fecal coliform bacteria in the estuary and the mean concentrations of fecal coliform bacteria in the section of the River upstream of the estuary. This change was the result of a decrease in fecal coliform bacterial concentrations in the estuary (see Figure 109) after the Inline Storage System came online in 1994. After 1997, the relationship between the mean concentrations of fecal coliform bacteria in the estuary and in the section of the River upstream of the estuary changed again. During the period 1998-2004, the mean concentrations in the estuary were significantly higher than those in the section of the River upstream from the estuary (see Table 87). This change is attributable to increases in the concentration of fecal coliform bacteria at most stations in the estuary (see Figure 109). At some stations, these increases in concentration during the period 1998-2004 were accompanied by increases in variability. For example, the coefficient of variation, a measure of variability in a data set, at the sampling station at the Union Pacific Railroad increased from 3.10 during the period 1994-1997 to 3.52 during the period 1998-2004. The higher concentrations of fecal coliform bacteria in the estuary suggest that water in the estuary was receiving more contamination from sources containing these bacteria than water in the nonestuary sections of the River. It is important to note, that since 1994, median concentrations of fecal coliform bacteria in the estuary have tended to decrease from upstream to downstream. This is consistent with the trends seen in the Kinnickinnic River (see Chapter V of this report) and may be the result of dilution effects from the influence of Lake Michigan. Table 88 shows that there is a statistically significant trend toward concentrations of fecal coliform bacteria increasing from upstream to downstream along the portion of the mainstem of the Milwaukee River upstream of the estuary. This relationship accounts for a small portion of the variation in the concentrations of fecal coliform bacteria in the River. This may be the result of water in the downstream sections of the River receiving more contamination from sources containing these bacteria than water in the upstream sections. Several generalizations emerge from the comparison of baseline period fecal coliform concentrations to historical concentrations shown in Figure 110: First, fecal coliform concentrations in the

Figure 108

SAMPLE STATION LOCATIONS ALONG THE MILWAUKEE RIVER: 2003-2005

MILWAUKEE RIVER AT RIVER MILE 76.97

MILWAUKEE RIVER AT RIVER MILE 14.99

MILWAUKEE RIVER AT RIVER MILE 45.44

MILWAUKEE RIVER AT RIVER MILE 6.45

MILWAUKEE RIVER AT RIVER MILE 26.25

MILWAUKEE RIVER AT RIVER MILE 0.71

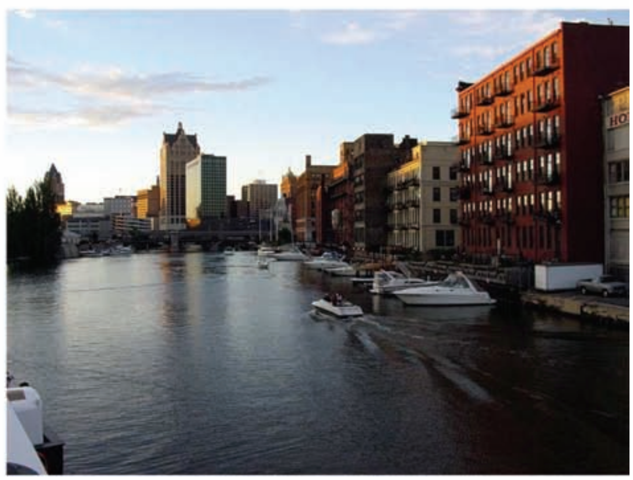


Figure 108 (continued)

NORTH BRANCH MILWAUKEE RIVER AT RIVER MILE 10.09

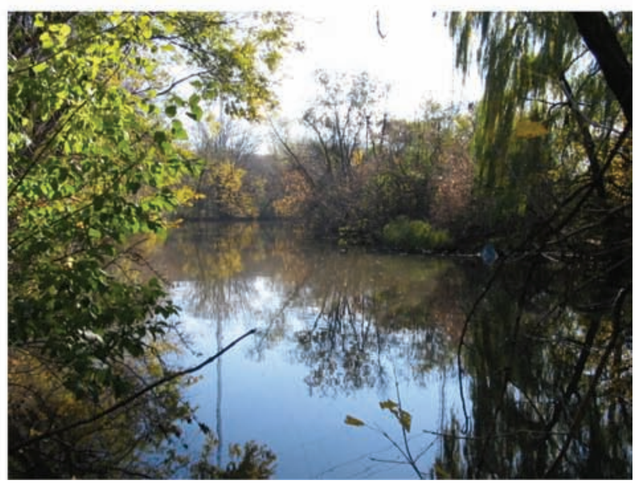
CEDAR CREEK NEAR RIVER MILE 4.74

EAST BRANCH MILWAUKEE RIVER AT RIVER MILE 2.21

SOUTHBRANCH CREEK AT RIVER MILE 0.75

QUAAS CREEK AT RIVER MILE 0.16

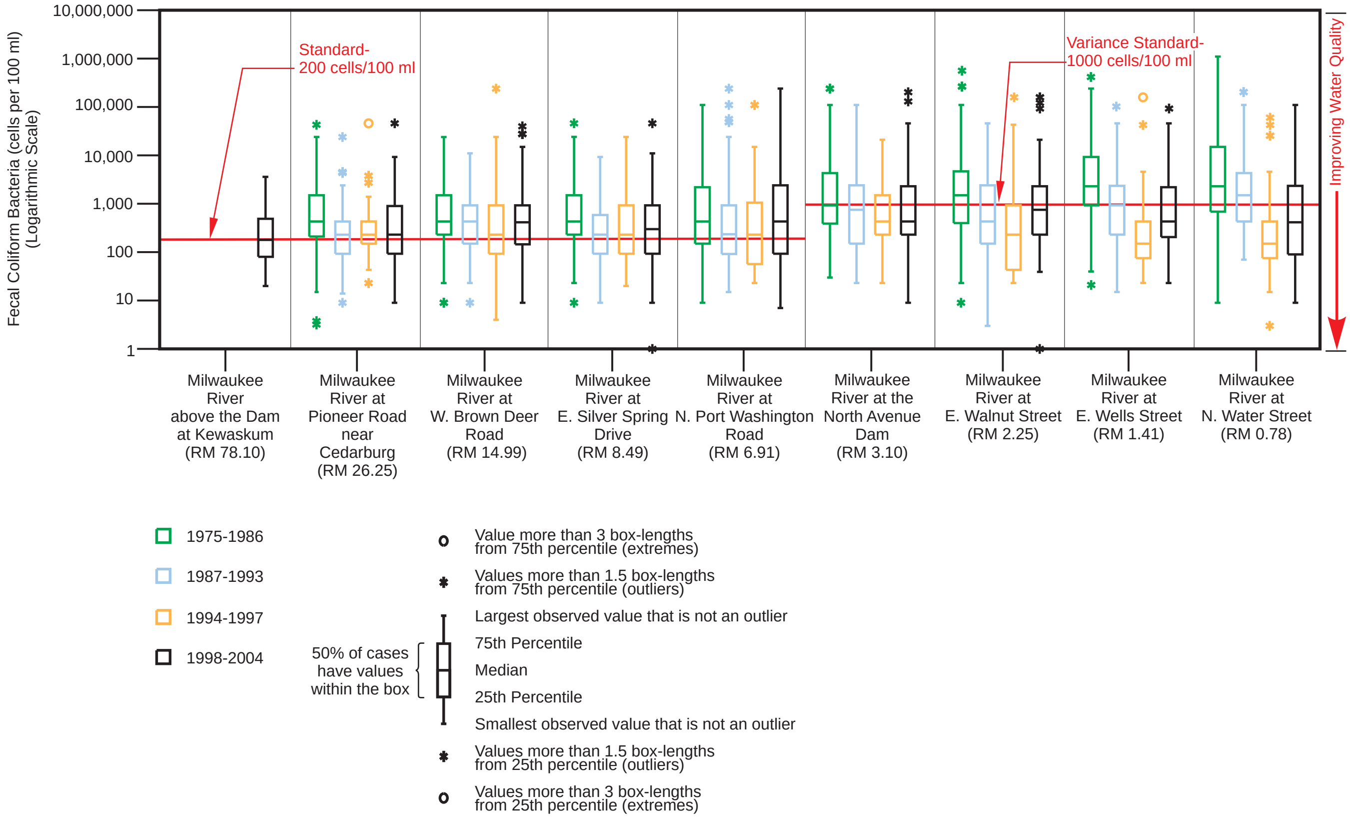
LINCOLN CREEK AT RIVER MILE 0.42



Source: Inter-Fluve, Inc., and SEWRPC.

Figure 109

FECAL COLIFORM BACTERIA ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



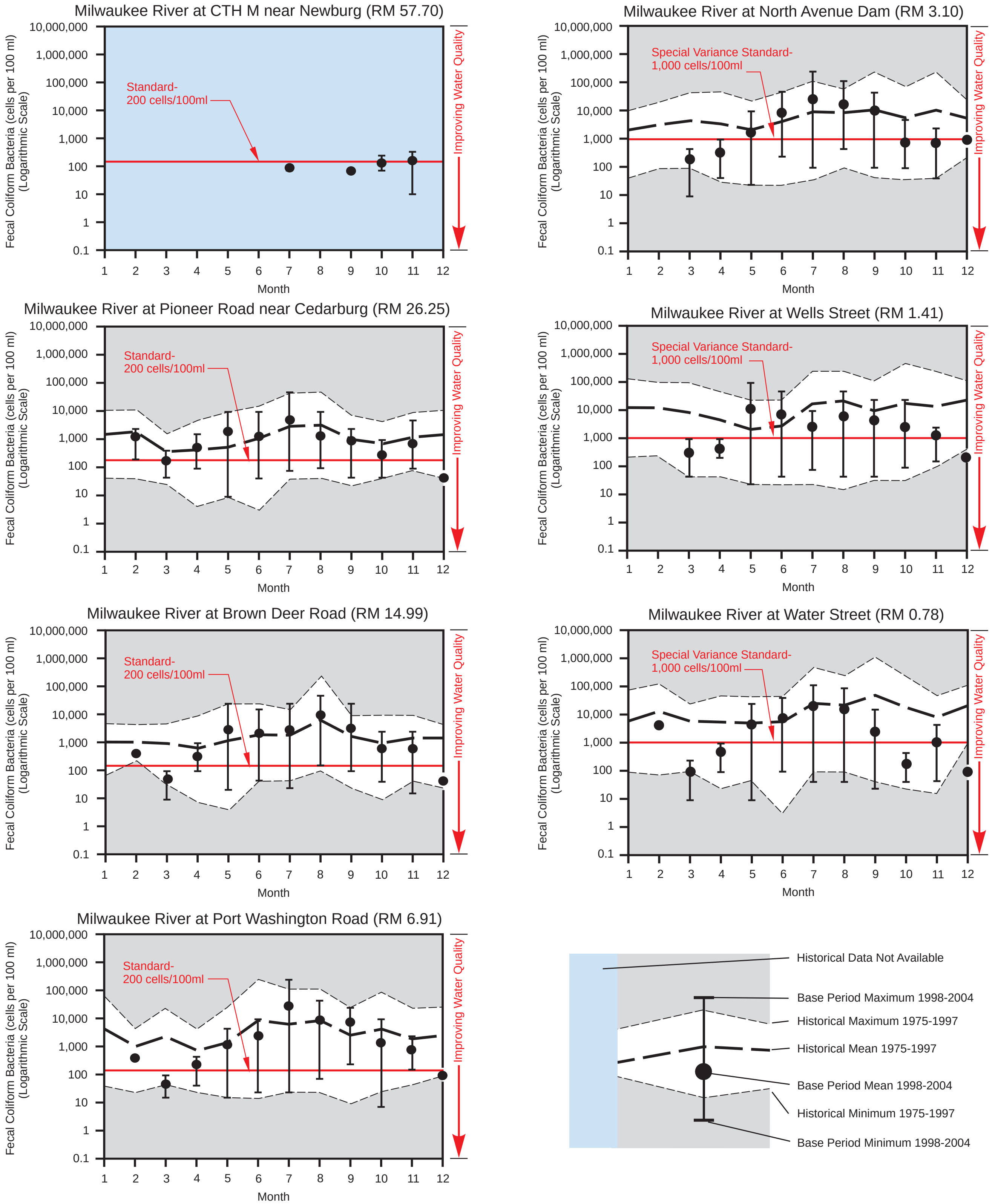
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Milwaukee River tend to be relatively low during the late winter and early spring. They increase sharply during the spring and early summer. This is followed by a decrease that, depending upon the station, occurs during summer or fall. Second, baseline period monthly mean concentrations of fecal coliform bacteria during the late winter, early spring, and fall were lower than the historical monthly mean concentrations. During the late spring and summer, baseline period mean monthly concentrations of fecal coliform bacteria were near or above the historical monthly mean concentrations. These patterns varied somewhat among the sampling stations.

As shown in Table C-5 in Appendix C of this report, several time-based trends in fecal coliform bacteria concentrations were detected in the Milwaukee River. When analyzed on an annual basis, all the long-term sampling sites in the estuary showed statistically significant trends toward decreasing fecal coliform concentrations. In addition, statistically significant decreasing trends were detected at two stations upstream from the estuary, those at Brown Deer Road and Silver Spring Drive. These trends account for small fractions of the variation observed at these stations. When examined on a seasonal basis, decreasing trends in the concentrations of fecal coliform bacteria were detected at most stations during the spring and several stations during the summer and fall. Fecal coliform bacteria concentrations in the Milwaukee River tend to be positively correlated with concentrations of biochemical oxygen demand, especially in the estuary, and with concentrations of several nutrients including ammonia, dissolved phosphorus, total phosphorus, and total nitrogen. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. Fecal coliform bacteria concentrations are also strongly positively correlated with concentrations of *E. coli*, reflecting the fact that *E. coli* constitute a major component of fecal coliform bacteria. In addition, fecal coliform bacteria concentrations in the River are negatively correlated with several measures of dissolved material, such as

Figure 110

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 87

COMPARISON OF WATER QUALITY BETWEEN THE MILWAUKEE RIVER AND THE MILWAUKEE RIVER ESTUARY: 1975-2004[a]

Parameters	Years			
	1975-1986[b]	1987-1993[b]	1994-1997[b]	1998-2004[b]
Biological/Bacteria				
Fecal Coliform[c]	Estuary	Estuary	0	Estuary
E. coli [c]	- -	- -	- -	Estuary
Chlorophyll-*a*[c]	0	River	River	River
Chemical/Physical				
Alkalinity	River	River	River	River
Biochemical Oxygen Demand[c]	Estuary	River	River	0
Dissolved Oxygen	River	River	River	River
Hardness	River	River	River	River
pH	River	River	River	River
Specific Conductance	River	River	River	River
Suspended Material				
Total Suspended Solids	River	River	River	River
Nutrients				
Ammonia, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Kjeldahl Nitrogen[c]	0	River	River	0
Nitrate, Dissolved[c]	River	0	0	River
Nitrite, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Organic Nitrogen[c]	River	River	River	0
Phosphorus, Dissolved[c]	River	River	0	0
Total Nitrogen[c]	River	River	River	River
Total Phosphorus[c]	0	River	0	0
Metals/Salts				
Arsenic[c]	- -	0	0	0
Cadmium[c]	Estuary	Estuary	0	0
Chloride[c]	Estuary	River	0	River
Chromium[c]	Estuary	Estuary	0	0
Copper[c]	Estuary	Estuary	Estuary	Estuary
Lead[c]	Estuary	Estuary	Estuary	Estuary
Mercury[c]	- -	- -	River	River
Nickel[c]	0	0	0	0
Zinc[c]	Estuary	Estuary	Estuary	Estuary

NOTE: The following symbols were used:

"Estuary" indicates that the mean value from the estuary is statistically significantly higher than the mean value from the upstream section.

"River" indicates that the mean value from the estuary is statistically significantly lower than the mean value from the upstream section.

0 indicates that no differences were detected.

- - indicates that the data were insufficient for the analysis.

[a]*The estuary sites used in this analysis were located within the Milwaukee River estuary.*

[b]*Differences between means were assessed through analysis of variance (ANOVA). Means were considered significantly different at a probability of P = 0.05 or less.*

[c]*These data were log-transformed before being entered into ANOVA.*

Source: SEWRPC.

Table 88

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG THE MILWAUKEE RIVER 1975-2004[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	↑	<-0.01	2.699	<0.01
E. coli [b]	↑	-0.02	2.434	0.02
Chlorophyll-*a*[b]	↑	<-0.01	1.336	<0.01
Chemical				
Alkalinity	↓	0.76	241.715	0.02
Biochemical Oxygen Demand[b]	↑	<-0.01	0.440	0.01
Chloride[b]	↑	<-0.01	1.682	<0.01
Dissolved Oxygen	↓	0.11	8.590	0.10
Hardness	↓	0.54	286.424	0.01
pH	0	- -	- -	- -
Specific Conductance	↓	0.64	642.664	<0.01
Temperature	0	- -	- -	- -
Suspended Material				
Total Suspended Sediment	↑	-0.58	42.089	0.01
Total Suspended Solids	↓	0.31	28.400	0.01
Nutrients				
Ammonia[b]	↓	<0.01	-1.212	<0.01
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	↓	0.02	-0.582	0.06
Nitrite[b]	↓	<0.01	-1.923	<0.01
Organic Nitrogen[b]	↑	<-0.01	-0.033	<0.01
Total Nitrogen[b]	↓	<0.01	0.206	0.03
Dissolved Phosphorus[b]	↓	<0.01	-1.517	0.04
Total Phosphorus[b]	0	- -	- -	- -
Metals				
Arsenic[b]	↑	<-0.01	0.275	<0.01
Cadmium[b]	↓	<0.01	-0.424	<0.01
Chromium[b]	↓	<0.01	0.672	0.02
Copper[b]	0	- -	- -	- -
Lead[b]	0	- -	- -	- -
Mercury[b]	0	- -	- -	- -
Nickel[b]	↓	<0.01	0.939	0.01
Zinc[b]	↑	<-0.01	1.110	<0.01

NOTE: The following symbols were used:

↑ indicates a statistically significant increase from upstream to downstream.

↓ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher R^2 values indicate that higher portions of the variation in the data are attributable to the trend. Lower R^2 values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

alkalinity, hardness, specific conductance, and pH. The long-term trends toward declining fecal coliform bacteria concentrations at several stations represent a long-term improvement in water quality in the Milwaukee River. The recent increases in fecal coliform bacteria concentrations at many of these same stations suggest that water quality may currently be declining although the long-term trend still indicates an improvement.

Figure 111 shows concentrations of fecal coliform bacteria in three tributaries to the Milwaukee River: Cedar Creek, Southbranch Creek, and Lincoln Creek. The median concentration of fecal coliform bacteria in Cedar Creek during the period of record was 140 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the Creek varied over three orders of magnitude, ranging between 10 cells per 100 ml and 1,500 cells per 100 ml. Concentrations appear to be higher during summer than during other seasons (see Figure 112), although this may reflect the larger numbers of samples that were taken during this season. Counts in many samples exceed the standard for full recreational use of 200 cells per 100 ml. No time-based trends were detected in fecal coliform bacteria concentrations in Cedar Creek (Table C-5 in Appendix C). The median concentration of fecal coliform bacteria in Southbranch Creek during the period of record was 930 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the Creek varied over five orders of magnitude, ranging between one cell per 100 ml and 46,000 cells per 100 ml. Figure 111 shows that fecal coliform concentrations in the Creek tend to increase from upstream to downstream. While this trend was statistically significant, it accounted for a relatively small portion of the variation in fecal coliform bacteria concentrations (see Table 89). Concentrations of fecal coliform bacteria appear to be highest during the mid-summer and late fall (see Figure 112). Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. Few time-based trends were detected in fecal coliform bacteria concentrations in Southbranch Creek (Table C-5 in Appendix C). This may be due to the short period of record for this stream (see Tables 86 and 89). The median concentration of fecal coliform bacteria in Lincoln Creek during the period of record was 1,200 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the Creek varied over seven orders of magnitude, ranging between one cell per 100 ml and 1,100,000 cells per 100 ml. Figure 111 shows that fecal coliform concentrations in the Creek tend to increase from upstream to downstream. While this trend was statistically significant, it accounted for a relatively small portion of the variation in fecal coliform bacteria concentrations (see Table 90). Concentrations of fecal coliform bacteria appear to be highest during the summer (see Figure 112). Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. In addition, counts in many samples exceed the variance standard of 1,000 cells per 100 ml which applies to Lincoln Creek. The proportion of samples in which fecal coliform bacteria concentrations exceed the variance standard increases from upstream to downstream along the Creek (see Figure 111). At most sampling stations, the median concentrations of fecal coliform bacteria has decreased over time; however, this has been accompanied by an increase in the maximum concentrations (see Figure 111). Few statistically significant time-based trends were detected in fecal coliform bacteria concentrations in Lincoln Creek (Table C-5 in Appendix C).

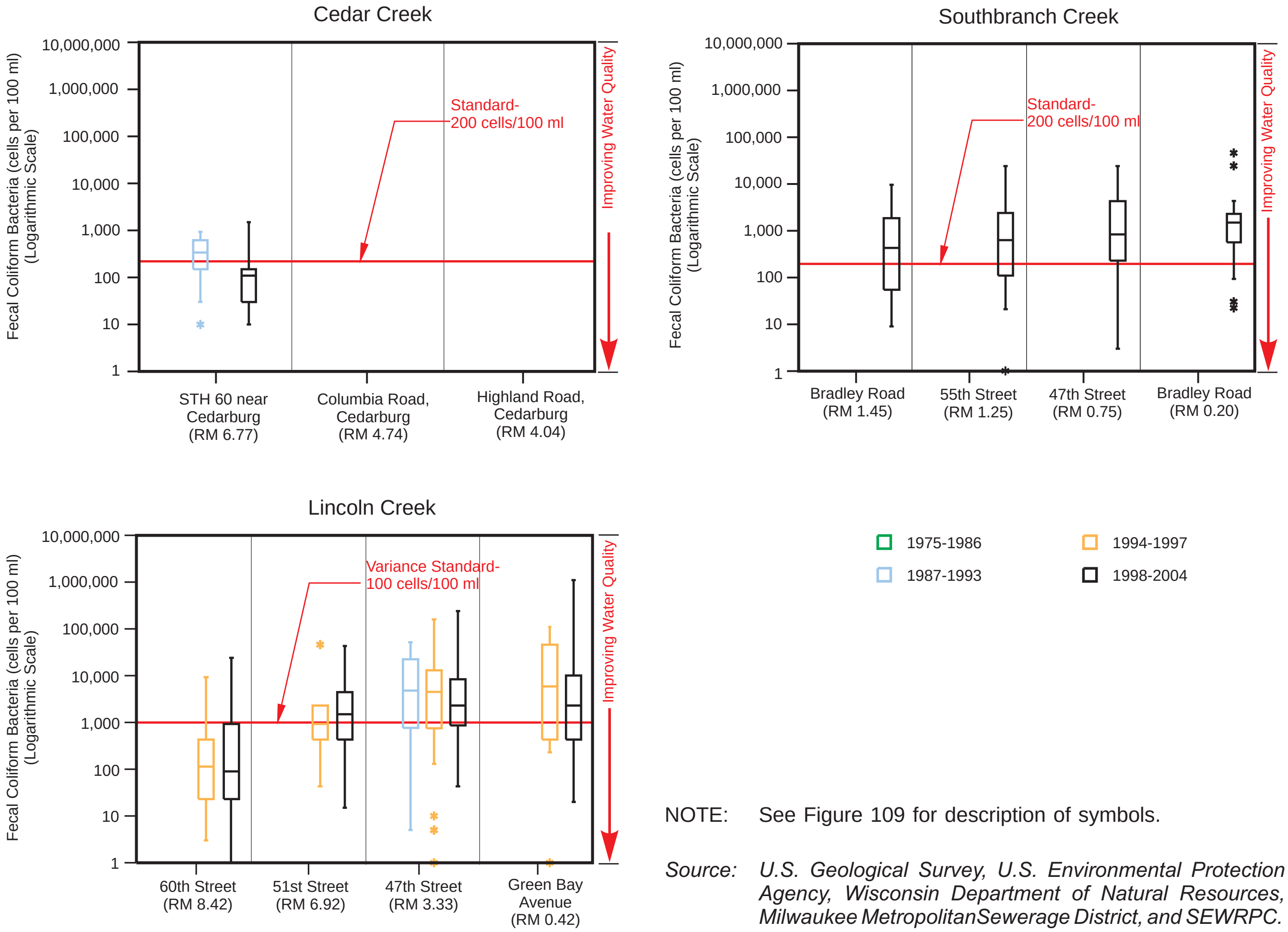
MMSD began regular sampling for *E. coli* in the Milwaukee River at six long-term sampling stations along the mainstem and two sampling stations along Lincoln Creek in 2000. In addition, the USGS and WDNR have conducted some sampling for *E. coli* in the Milwaukee River watershed. Figure 113 shows the concentrations of *E. coli* at eight sites along the mainstem of the Milwaukee River. Concentrations of *E. coli* in the River ranged from 0.5 cells per 100 ml to 130,000 cells per 100 ml. During the baseline period, mean concentrations of *E. coli* in the estuary were significantly higher than mean concentrations in the portion of the River upstream from the estuary (see Table 87). A statistically significant decreasing trend in *E. coli* concentration was detected from upstream to downstream along the portion of the Milwaukee River upstream from the estuary (see Table 88). Few statistically significant time-based trends were detected in *E. coli* concentrations (see Table C-5 in Appendix C of this report). Figure 114 shows baseline period monthly mean concentrations of *E. coli* for two stations along the mainstem of the Milwaukee River and one station along Lincoln Creek. Concentrations of *E. coli* in these streams tend to be highest during the summer. Variability in *E. coli* concentrations is also high during the summer.

Chlorophyll-a

Over the period of record, the mean concentration of chlorophyll-*a* in the Milwaukee River was 28.3 micrograms per liter (μg/l). Individual samples of this parameter ranged from below the limit of detection to 628.4 μg/l. Figure 115 shows that concentrations of chlorophyll-*a* at most stations along the mainstem of the Milwaukee

Figure 111

FECAL COLIFORM BACTERIA AT SITES IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

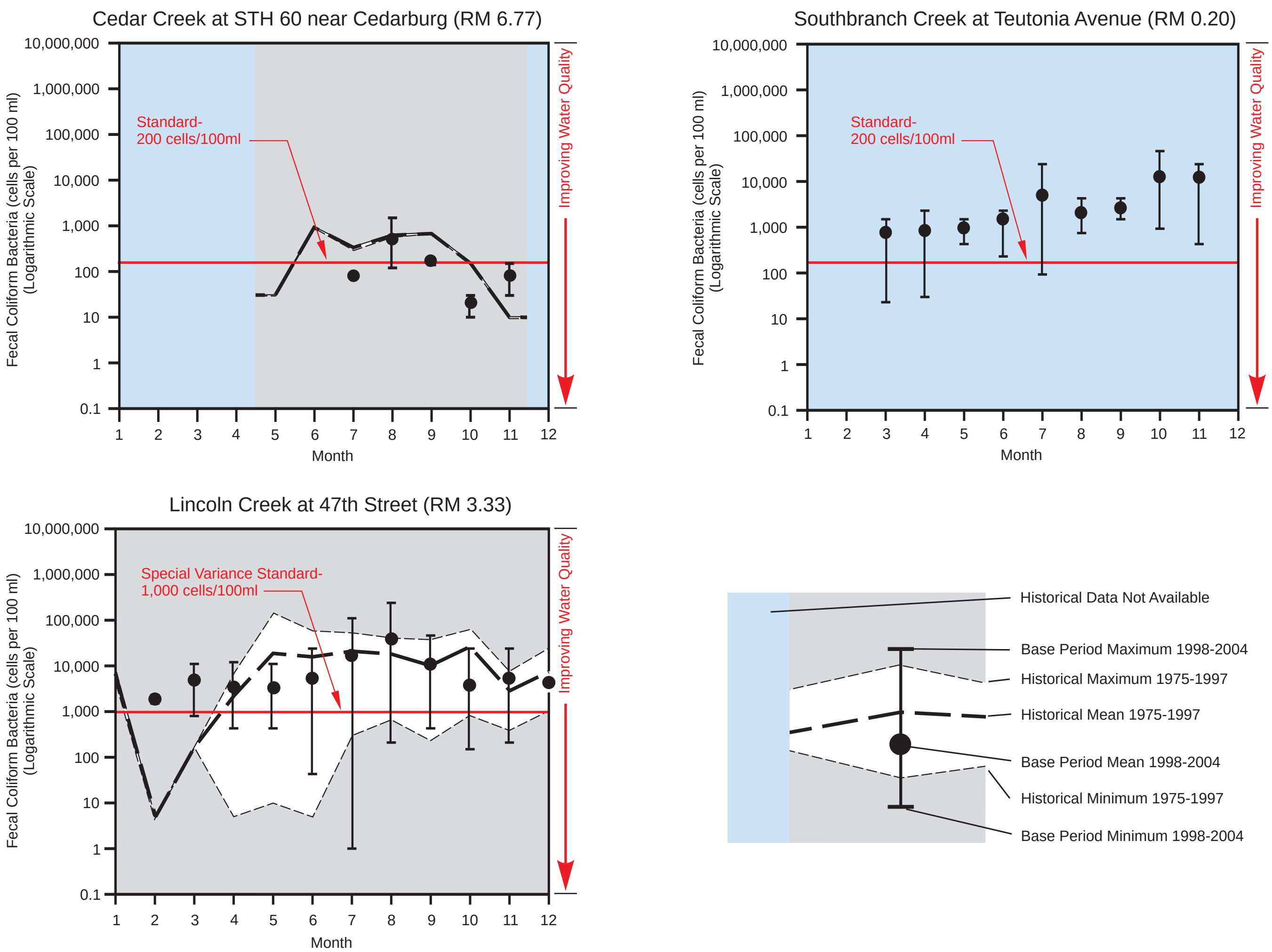
Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

River were lower during the period 1998-2004 than they were during previous periods. With one exception, mean chlorophyll-*a* concentrations in the estuary were lower than mean chlorophyll-*a* concentrations in the section of the River upstream of the estuary (see Table 87). During the period 1975-1986, there was no difference between mean chlorophyll-*a* concentrations in these two sections of the River. Table 88 shows that there is a statistically significant trend toward chlorophyll-*a* concentration increasing from upstream to downstream in the section of the River upstream from the estuary. When examined on an annual basis, few statistically significant time-based trends were detected in chlorophyll-*a* concentrations at stations along the mainstem (Table C-5 in Appendix C). Trends toward decreasing chlorophyll-*a* concentrations were detected at the stations at Water Street and the Union Pacific Railroad, the two stations farthest downstream. When examined on a seasonal basis, trends toward decreasing chlorophyll-*a* concentrations during the summer were detected at most stations along the mainstem of the River.

Mean concentrations of chlorophyll-*a* in tributary streams were generally lower than the mean concentration in the mainstem of the River, ranging from 2.48 μg/l in the East Branch Milwaukee River to 13.58 μg/l in Lincoln Creek. Mean concentrations of chlorophyll-*a* tended to be lower in tributaries in the upper reaches of the watershed than in lower reaches of the watershed, though this generalization may be an artifact of the small number of tributaries in which this parameter was sampled. In Lincoln Creek, chlorophyll-*a* concentrations tended to decrease from upstream to downstream (see Table 90). The opposite trend was observed in Southbranch Creek (see Table 89). Some time-based trends were detected in tributaries (Table C-5 in Appendix C). In Lincoln and Southbranch Creeks, trends toward increasing chlorophyll-*a* concentrations over time were detected at some sites,

Figure 112

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

especially during the summer. By contrast, when examined on an annual basis, trends toward decreasing chlorophyll-*a* concentrations over time were detected at all three stations along Cedar Creek.

At most stations along the mainstem, chlorophyll-*a* concentrations are negatively correlated with concentrations of nitrate and dissolved phosphorus. This reflects the role of these compounds as nutrients for algal growth. As algae grow, they remove these compounds from the water and incorporate them into cellular material. Chlorophyll-*a* concentrations are also positively correlated with temperature. Chlorophyll-*a* concentrations are also negatively correlated with alkalinity. Since chlorophyll-*a* concentrations in water strongly reflect algal productivity, this correlation probably reflects lowering of alkalinity during photosynthesis through removal of inorganic carbon, mostly carbon dioxide, bicarbonate, and carbonate, from the water. The trends toward decreasing chlorophyll-*a* concentrations along the mainstem of the River and along Cedar Creek represent improvements in water quality. The trends toward increasing chlorophyll-*a* concentrations at some stations along Lincoln and Southbranch Creeks represent reductions in water quality.

Table 89

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG SOUTHBRANCH CREEK 1999-2004[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬆	-0.42	3.176	0.05
E. coli [b]	0	- -	- -	- -
Chlorophyll-*a*[b]	⬆	-0.43	0.969	0.08
Chemical				
Alkalinity	0	- -	- -	- -
Biochemical Oxygen Demand[b]	0	- -	- -	- -
Chloride[b]	⬆	-0.13	2.202	0.05
Dissolved Oxygen	0	- -	- -	- -
Hardness	0	- -	- -	- -
pH	0	- -	- -	- -
Specific Conductance	⬆	-170.14	991.198	0.05
Temperature	0	- -	- -	- -
Suspended Material				
Total Suspended Sediment	0	- -	- -	- -
Total Suspended Solids	⬆	-98.55	611.196	0.05
Nutrients				
Ammonia[b]	⬇	0.50	-1.962	0.07
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	⬇	0.40	-0.721	0.11
Nitrite[b]	⬇	0.32	-1.818	0.10
Organic Nitrogen[b]	0	- -	- -	- -
Total Nitrogen[b]	⬇	0.16	-0.029	0.09
Dissolved Phosphorus[b]	⬇	0.30	-1.102	0.20
Total Phosphorus[b]	⬇	0.30	-0.976	0.20
Metals				
Arsenic[b]	0	- -	- -	- -
Cadmium[b]	0	- -	- -	- -
Chromium[b]	0	- -	- -	- -
Copper[b]	0	- -	- -	- -
Lead[b]	0	- -	- -	- -
Mercury[b]	0	- -	- -	- -
Nickel[b]	0	- -	- -	- -
Zinc[b]	⬇	0.19	1.344	0.11

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher R^2 values indicate that higher portions of the variation in the data are attributable to the trend. Lower R^2 values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

Table 90

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG LINCOLN CREEK 1997-2004[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬆	-0.14	3.733	0.14
E. coli [b]	- -	- -	- -	- -
Chlorophyll-*a*[b]	⬇	0.02	0.682	0.01
Chemical				
Alkalinity	0	- -	- -	- -
Biochemical Oxygen Demand[b]	⬆	-0.02	0.447	0.01
Chloride[b]	0	- -	- -	- -
Dissolved Oxygen	0	- -	- -	- -
Hardness	0	- -	- -	- -
pH	⬆	-0.02	7.831	0.02
Specific Conductance	0	- -	- -	- -
Temperature	0	- -	- -	- -
Suspended Material				
Total Suspended Sediment	- -	- -	- -	- -
Total Suspended Solids	⬆	-11.32	607.460	0.01
Nutrients				
Ammonia[b]	0	- -	- -	- -
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	⬆	-0.06	-0.249	0.08
Nitrite[b]	⬆	-0.05	-1.456	0.14
Organic Nitrogen[b]	0	- -	- -	- -
Total Nitrogen[b]	⬆	-0.02	0.171	0.05
Dissolved Phosphorus[b]	⬆	-0.06	-0.147	0.15
Total Phosphorus[b]	⬆	-0.05	-0.792	0.12
Metals				
Arsenic[b]	0	- -	- -	- -
Cadmium[b]	0	- -	- -	- -
Chromium[b]	0	- -	- -	- -
Copper[b]	0	- -	- -	- -
Lead[b]	⬆	-0.04	0.639	0.09
Mercury[b]	⬆	-0.07	-1.363	0.14
Nickel[b]	0	- -	- -	- -
Zinc[b]	0	- -	- -	- -

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

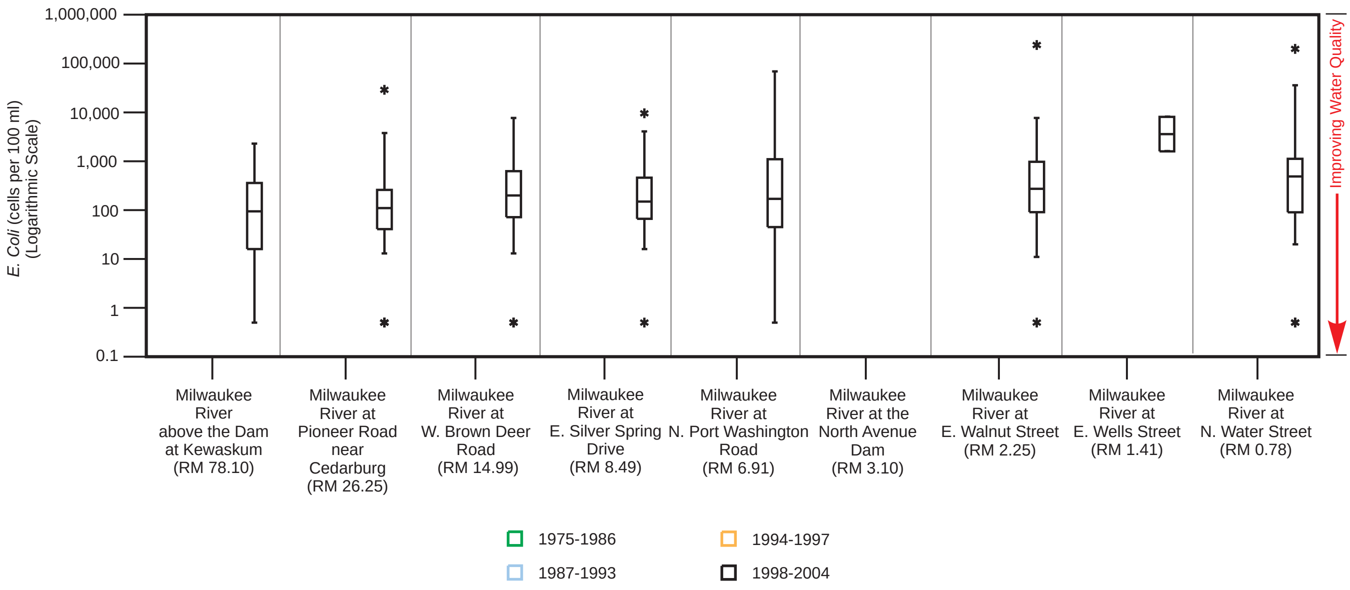
[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher R^2 values indicate that higher portions of the variation in the data are attributable to the trend. Lower R^2 values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

Figure 113

E. COLI **BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004**



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Chemical and Physical Parameters

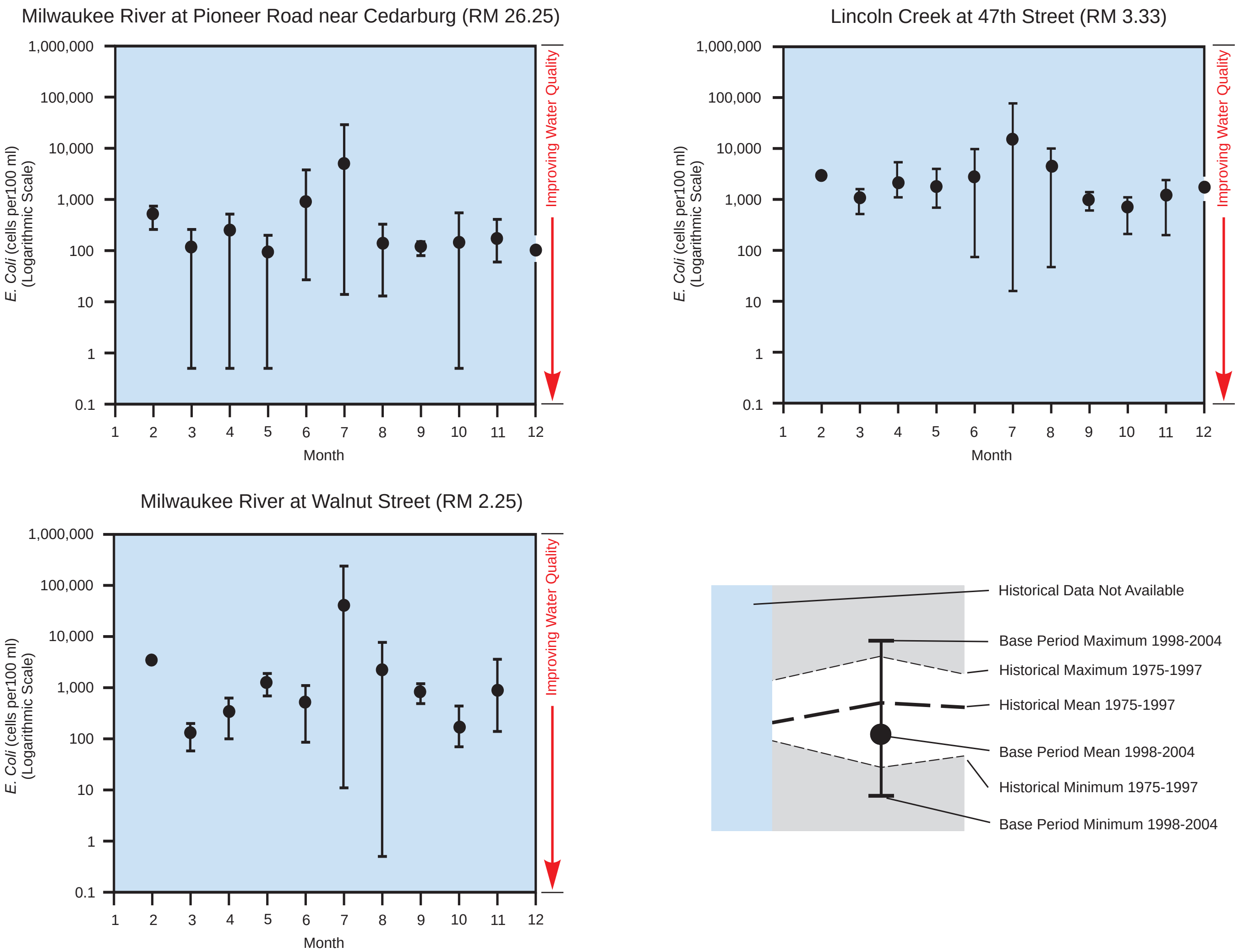
Temperature

Figure 116 shows water temperature at nine sites along the mainstem of the Milwaukee River. The median water temperature in the Milwaukee River during the period 1998-2004 ranged from 9.8 degrees Celsius (ºC) at Estabrook Park to 19.0ºC at CTH M near Newburg. The low median at the Estabrook Park station is probably due to this site having a high proportion of samples collected during the winter. The next lowest median temperature during this period was 15.0ºC at Silver Spring Drive. Because few samples were collected during the winter at most stations during the period 1998-2004, the median from the Silver Spring Drive station is probably a more representative number than the median from Estabrook Park. As shown in Table 88, no statistically significant longitudinal trends in water temperatures were detected along the Milwaukee River. Figure 117 shows historical and baseline period monthly mean temperatures for seven sampling stations along the mainstem of the River. At most of the stations for which historical data were available, water temperatures from the baseline period generally tended to be within historical ranges. During summer months, monthly mean baseline period water temperatures at most stations tended to be slightly higher than historical monthly means. Few trends over time were detected in water temperatures at stations along the River (see Table C-5 in Appendix C). When examined on an annual basis, slight trends toward increasing water temperatures were detected at three estuary stations: Wells Street, Water Street, and the Union Pacific Railroad. These trends account for a very small portion of the variation in the data and are likely attributable to slight increasing trends during summer months.

Mean water temperatures for downstream sections of the River are shown in Figure 118. The greatest difference in mean water temperatures observed at the stations between Pioneer Road and the Union Pacific Railroad was about 1.3ºC. In the estuary, mean water temperature increased from 15.0ºC at the Wells Street station to 15.3ºC at the Water Street station. Some of the increase between the Wells Street and Water Street stations can be accounted for by contributions of warmer water entering the Milwaukee River from the Menomonee River. The mean water temperature of the Menomonee River at the station at S. 2nd Street, near the confluence with the Milwaukee River, during the same time period was 17.3ºC. Downstream from Water Street along the Milwaukee

Figure 114

HISTORICAL AND BASE PERIOD *E. COLI* BACTERIA CONCENTRATIONS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



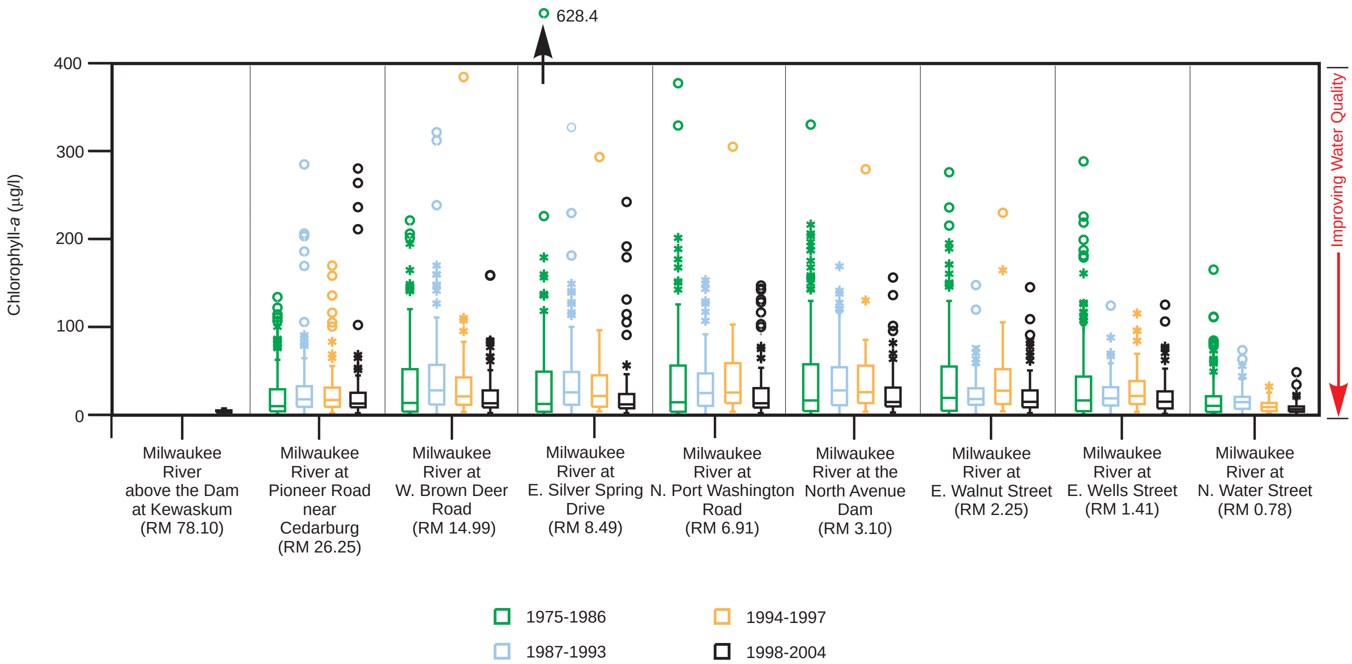
Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

River, mean water temperature decreases. This may be the result of complex flow interactions with Lake Michigan.

Due to the complexity of temperature trends in a River the length of the Milwaukee River, the data were further analyzed using a three-factor analysis of variance. This type of analysis tests for statistically significant differences among mean temperatures based upon three different factors which may account for any differences. In addition, it tests for significant effects on mean temperatures of any interactions between the factors. In this instance, the independent factors examined were sampling station, time period, and season. The sampling stations examined in the analysis include the station at Pioneer Road and all major stations downstream from Pioneer Road. Four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2004. Data from winter months were not included in this analysis because of the small number of samples taken during the winter. This analysis revealed no statistically significant differences among mean water temperatures at different sampling stations. The results did indicate that mean water temperatures in the Milwaukee River were significantly lower during the period 1975-1986 than during subsequent periods. In addition, the analysis found a significant

Figure 115

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004

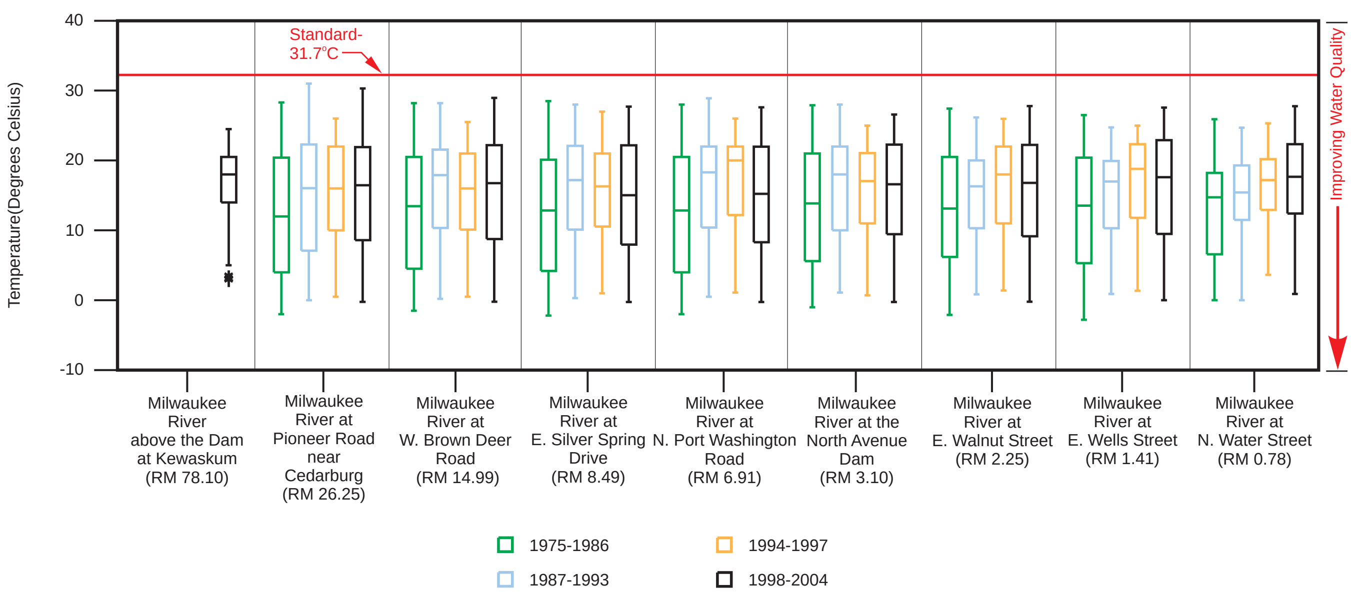


NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 116

WATER TEMPERATURE AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004

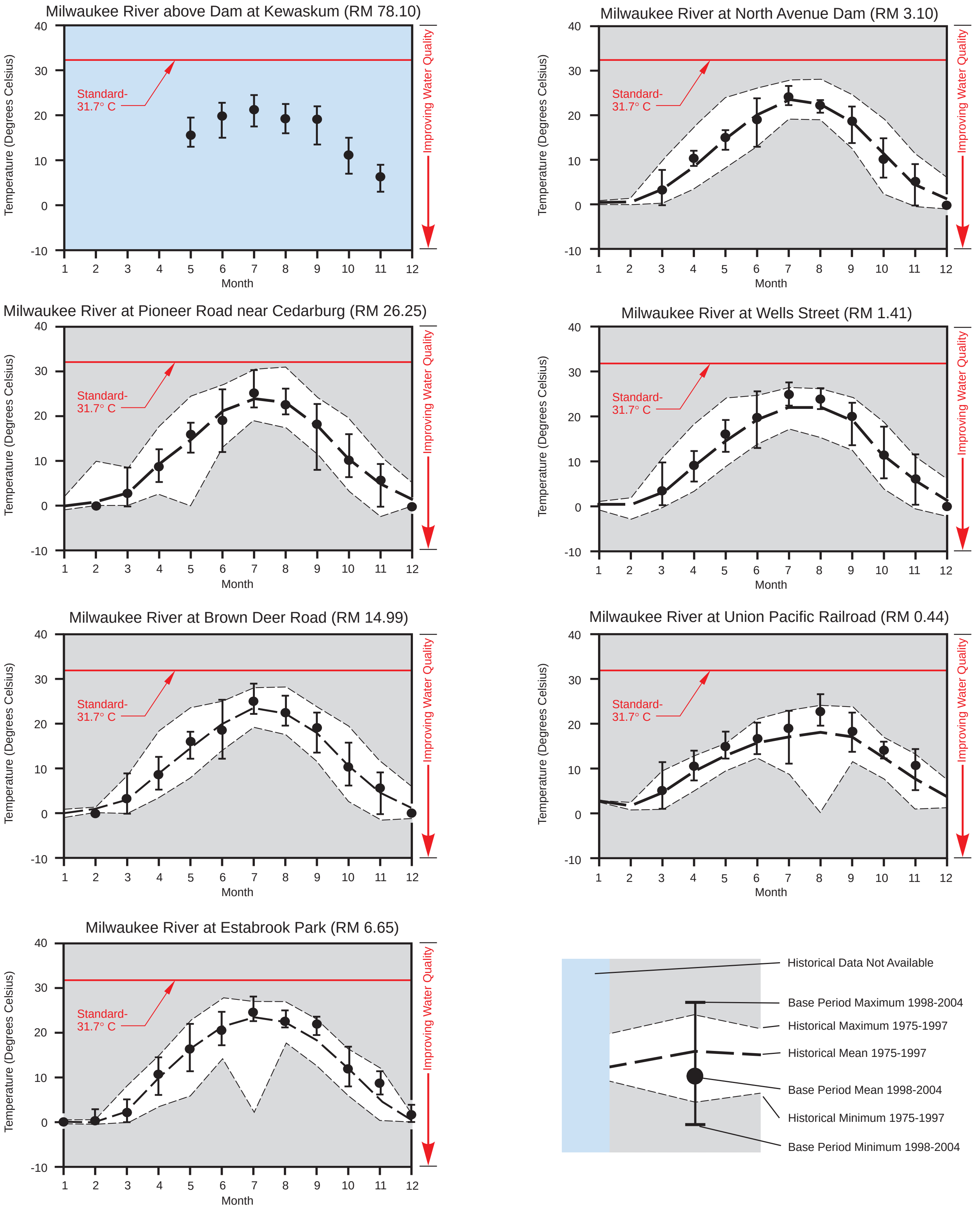


NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 117

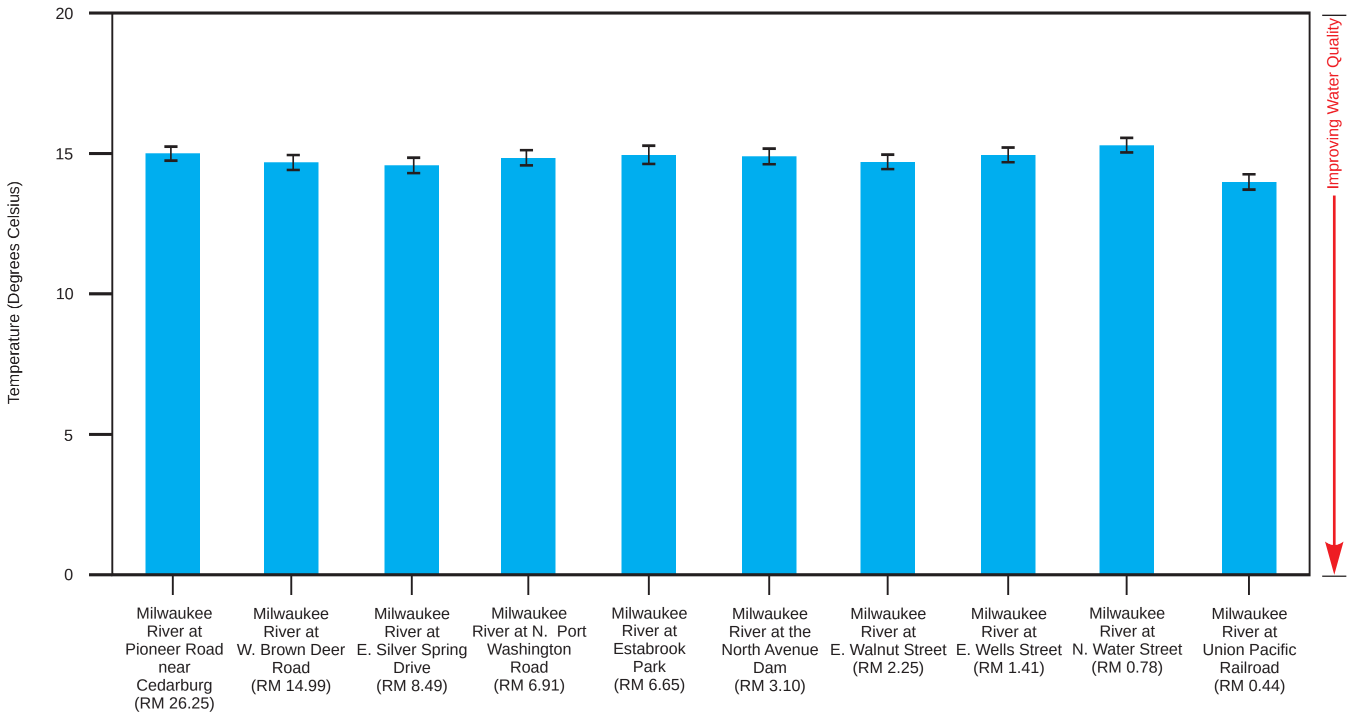
HISTORICAL AND BASE PERIOD WATER TEMPERATURE ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 118

MEAN WATER TEMPERATURES AT STATIONS ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTES: The temperature standard is 31.7 degrees Celsius, which is outside the limits of the graph.

Error Bars (I) indicate one standard error of the mean.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

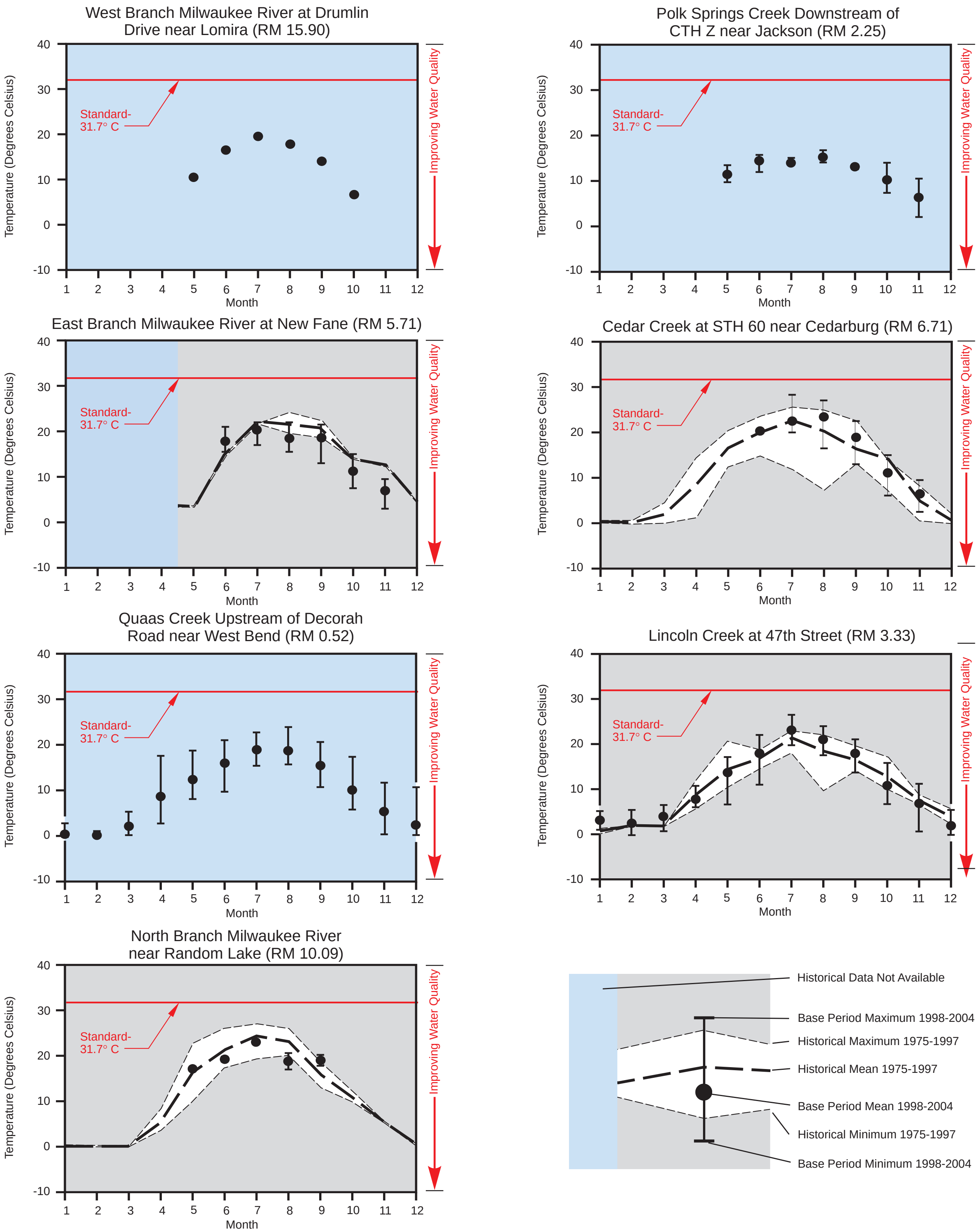
interaction between the effects of sample site and season. Seasonal differences in mean water temperature were less pronounced at the two stations farthest downstream, Water Street and the Union Pacific Railroad. These differences most likely result from interactions with water from Lake Michigan.

Figure 119 shows historical and baseline period mean water temperatures for sampling stations on seven Milwaukee River tributaries. In some tributaries, such as Cedar Creek at STH 60 and Lincoln Creek at N. 47th Street, baseline period monthly mean temperatures during the late summer and early fall were higher than the historical means. At other tributaries, such as the East Branch Milwaukee River at New Fane, period monthly mean temperatures during the late summer and early fall were lower than the historical means. No statistically significant longitudinal trends were found in water temperature along Lincoln Creek (see Table 90) or Southbranch Creek (see Table 89). Statistically significant increasing trends in water temperature were detected at some tributary sampling stations (Table C-5 in Appendix C). The increasing trend detected at the N. 47th Street station on Lincoln Creek accounts for over half the variation in the data. Increasing trends were also detected at two stations along Southbranch Creek; however, the short length of the period of record for this stream makes it difficult to determine whether this represents a long-term trend or short-period interannual variation.

The trends toward increasing water temperature at some estuary stations on the mainstem and at some tributary stations represent a reduction in water quality.

Figure 119

HISTORICAL AND BASE PERIOD WATER TEMPERATURE IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, Washington County Land and Water Conservation Division, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Alkalinity

The mean value of alkalinity in the Milwaukee River over the period of record was 235.6 milligrams per liter (mg/l) expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 5.0 to 999.0 mg/l as $CaCO_3$. During all periods, mean alkalinity in the estuary was significantly lower than mean alkalinity in the portion of the River upstream from the estuary (see Table 87). In addition, Table 88 shows that there is a statistically significant trend toward alkalinity decreasing from upstream to downstream along the length of the River. Few stations showed any evidence of significant time-based trends when analyzed annually or seasonally. Where significant trends were detected, they generally indicated increasing concentrations and accounted for a small portion of the variation in the data (see Table C-5 in Appendix C). These differences and trends may reflect changes in the relative importance of groundwater and surface runoff on the chemistry of water in the River from upstream to downstream with surface runoff becoming increasingly influential downstream. Alkalinity concentrations in the Milwaukee River are strongly positively correlated with hardness, pH, specific conductance, and concentrations of chloride, all parameters which, like alkalinity, measure amounts of dissolved material in water. Alkalinity is negatively correlated with chlorophyll-*a*, reflecting the removal of carbon dioxide from the water through photosynthesis. At some stations, alkalinity is negatively correlated with temperature, reflecting the fact that it indirectly measures concentrations of carbon dioxide in water and that solubility of gases in water decreases with increasing temperature.

Biochemical Oxygen Demand (BOD)

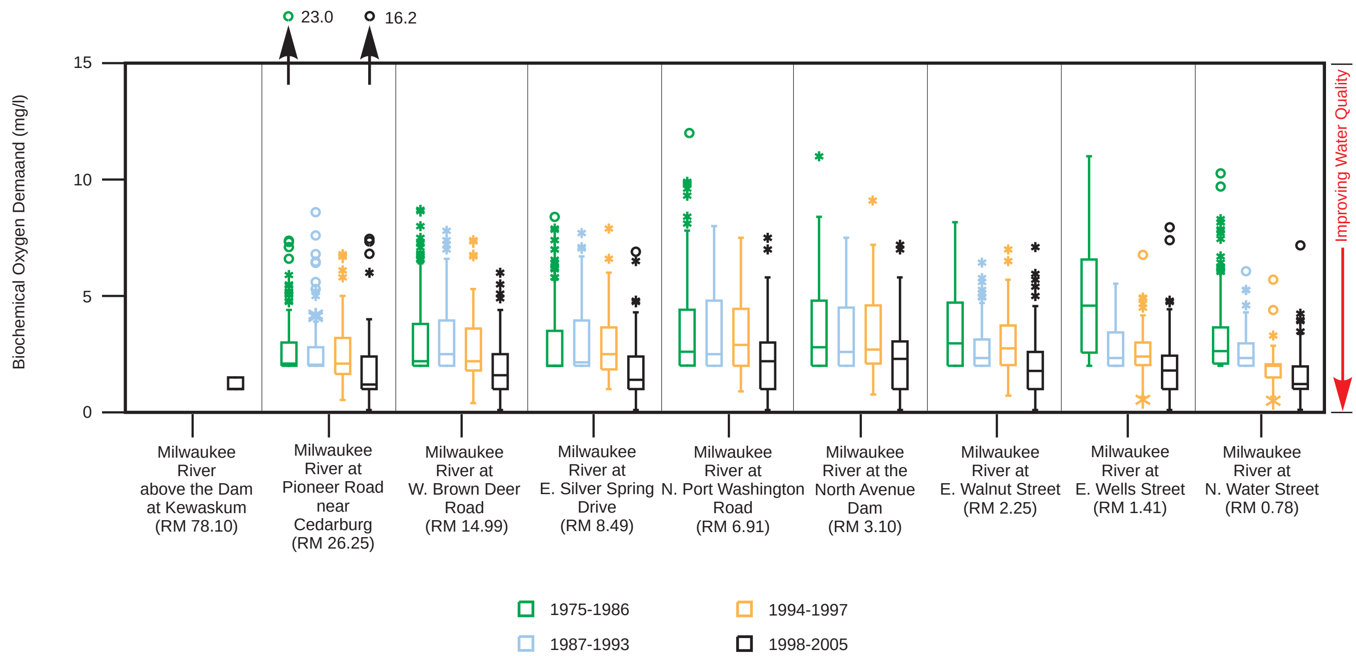
The mean concentration of BOD in the Milwaukee River during the period of record was 2.90 mg/l. Individual samples varied from below the limit of detection to 23.00 mg/l. As shown in Figure 120, the concentrations of BOD have declined at those sampling stations that have sufficiently long data records to permit comparison. Figure 121 shows a monthly comparison of baseline and historical concentrations of BOD at three sites along the mainstem of the River and sites along four tributaries. At stations along the mainstem of the River, baseline period monthly mean concentrations are generally below the historical monthly mean concentrations and are often near or below the historical minima. Baseline period monthly minimum concentrations in many months are at or near the limit of detection. The relationship between mean BOD concentrations in the estuary and mean BOD concentrations in the portion of the River upstream from the estuary has changed over time (see Table 87). During the period 1975-1986, mean BOD concentrations in the estuary were higher than mean BOD concentrations in the section of the River upstream from the estuary. This changed after 1986. During the periods 1987-1993 and 1994-1997, mean BOD concentrations in the section of the River upstream from the estuary were higher than mean BOD concentrations in the estuary. This changed again after 1997. During the period 1998-2004, there were no significant differences between the mean BOD concentrations in these two sections of the River. In the section of the River upstream from the estuary, there is a statistically significant trend toward BOD concentrations along the mainstem increasing from upstream to downstream (see Table 88). This trend accounts for a small portion of the variation in the data. When examined on an annual basis, statistically significant decreasing trends in BOD concentration over time were detected at all stations along the mainstem of the River (see Table C-5 in Appendix C of this report).

BOD concentrations in most tributaries for which data exist are comparable to concentrations in the mainstem of the River (see Figure 121). In some months, historical monthly maximum BOD concentrations in Lincoln Creek are higher than those detected in other tributaries or in the mainstem of the River. There is a statistically significant trend toward BOD concentrations in Lincoln Creek increasing from upstream to downstream (see Table 90). This trend accounts for a small portion of the variation in the data. Few time-based trends were detected in BOD concentration in tributaries (Table C-5 in Appendix C). When examined on an annual basis, trends toward decreasing BOD concentrations over time were detected at two stations along Lincoln Creek. By contrast, a trend toward increasing BOD concentration over time was detected at one station along Southbranch Creek. Because of the short period of record for this creek, it is uncertain whether this latter trend represents a long-term trend or interannual variation.

Several factors may influence BOD concentrations in the Milwaukee River. BOD concentrations in the River are positively correlated at most stations with concentrations of fecal coliform bacteria and some nutrients such as organic nitrogen, and total phosphorus. In addition, at some stations BOD concentrations are negatively correlated

Figure 120

BIOCHEMICAL OXYGEN DEMAND AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

with dissolved oxygen concentrations. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. In addition, aerobic metabolism of many organic nitrogen compounds requires oxygen and thus these compounds contribute to BOD. In some parts of the River, decomposition of organic material in the sediment acts as a source of BOD to the overlying water. This may especially be the case in the estuary and in impoundments associated with dams.

The declining trends in BOD concentrations over time detected at all of the stations along the mainstem of the River and two stations along Lincoln Creek represent an improvement in water quality.

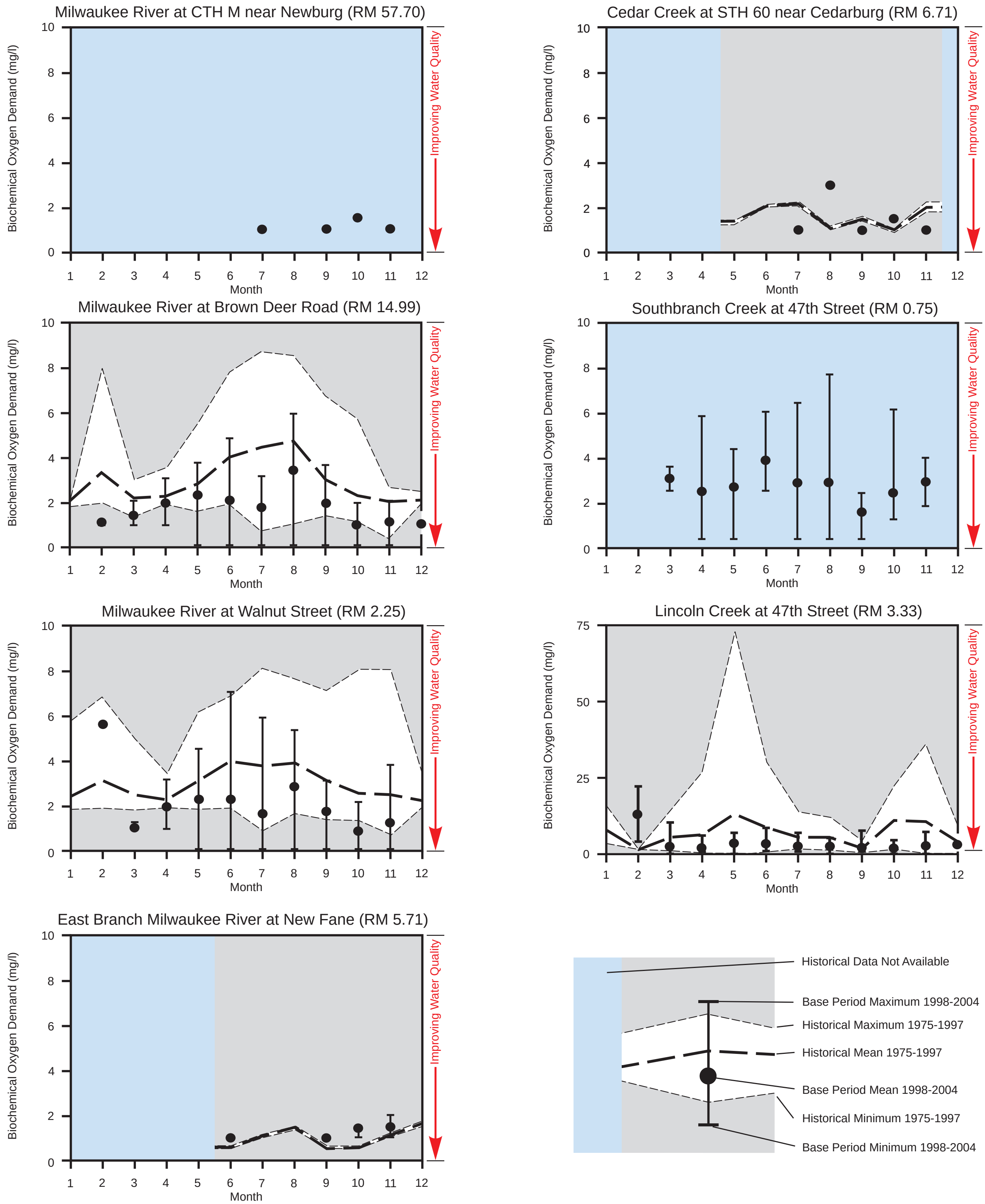
Chloride

The mean chloride concentration in the Milwaukee River for the period of record was 50.1 mg/l. All sites show wide variations between minimum and maximum values. Figure 122 shows that concentrations of chloride in the River increased over time at all stations for which historical data are available. Table C-5 in Appendix C of this report shows statistically significant trends toward mean chloride concentrations increasing over time at all sampling stations along the mainstem of the River, except for the Estabrook Park station. The lack of detection of a trend at this station probably results from the small number of samples analyzed for chloride concentration. Chloride concentrations show a strong seasonal pattern. For the period during which winter data are available, mean chloride concentrations were highest in winter or early spring. This is likely to be related to the use of deicing salts on streets and highways. These concentrations declined through the spring to reach lows during summer and fall. In the section of the River upstream from the estuary, there was a significant trend toward chloride concentrations increasing from upstream to downstream (see Table 88). This trend accounted for a small portion of the variation in the data.

Figure 123 shows chloride concentrations for three tributaries of the Milwaukee River. Chloride concentrations have been increasing with time in each of these tributaries.

Figure 121

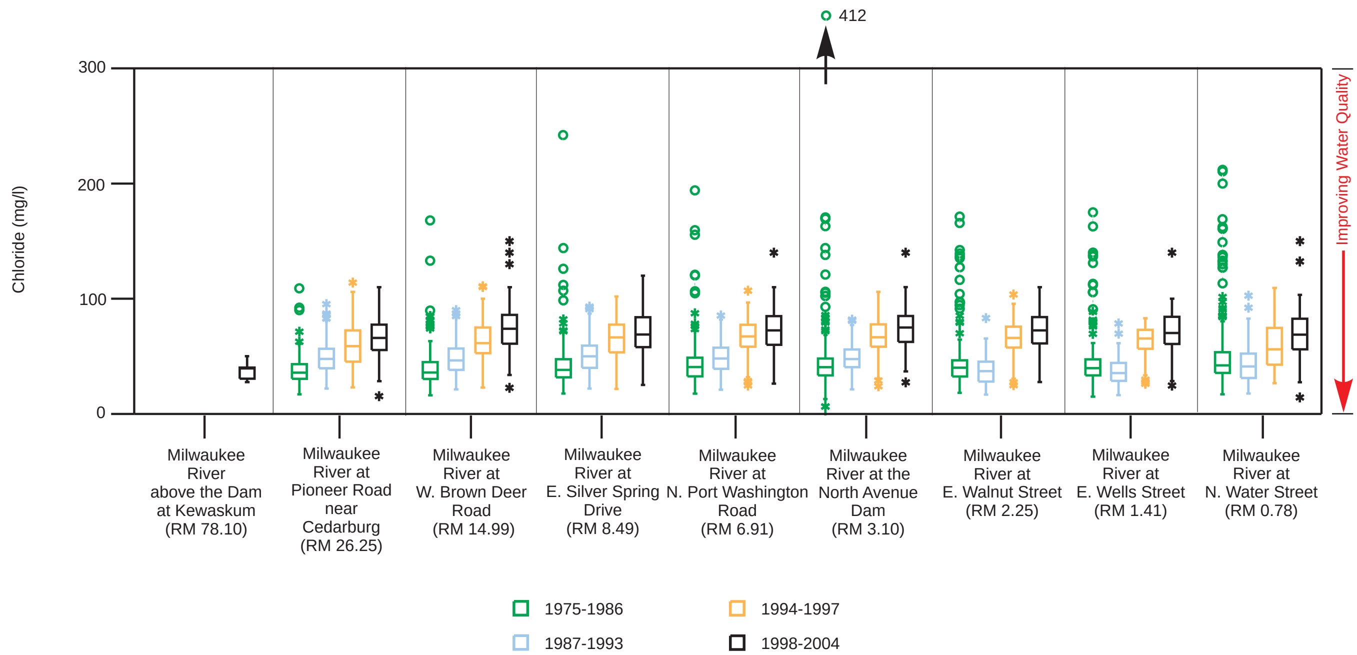
HISTORICAL AND BASE PERIOD CONCENTRATIONS OF BIOCHEMICAL OXYGEN DEMAND IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, Washington County Land and Water Conservation Division, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Figure 122

CHLORIDE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTES: See Figure 109 for description of symbols.

The acute toxicity criterion for fish and aquatic life is 757 mg/l, and the chronic toxicity criterion for fish and aquatic life is 395 mg/l.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Observed instream chloride concentrations in the main stem of the Milwaukee River and tributaries for which measurements are available have not approached the planning standard of 1,000 milligrams per liter (mg/l) that was adopted under the original regional water quality management plan. Observed instream concentrations in the Milwaukee River rarely approached the 250 mg/l secondary drinking water standard.[2] In the North Branch of the Milwaukee River and Cedar Creek, observed concentrations have always been considerably less than the secondary drinking water standard. Also, observed instream concentrations in those two streams have also been well below both the chronic toxicity criterion of 395 mg/l and the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," of the *Wisconsin Administrative Code*. Observed concentrations in the Milwaukee River were generally below the State chronic and acute toxicity criteria.

In Lincoln Creek, observed instream chloride concentrations relatively frequently exceeded the 250 mg/l secondary drinking water standard, but they did not often exceed the chronic toxicity criterion, and they have not exceeded the acute toxicity criterion.

As shown in Figure 148 on page 438, in the lakes of the Milwaukee River watershed for which data are available, chloride concentrations were generally less than 50 mg/l, although concentrations appear to be increasing over time.

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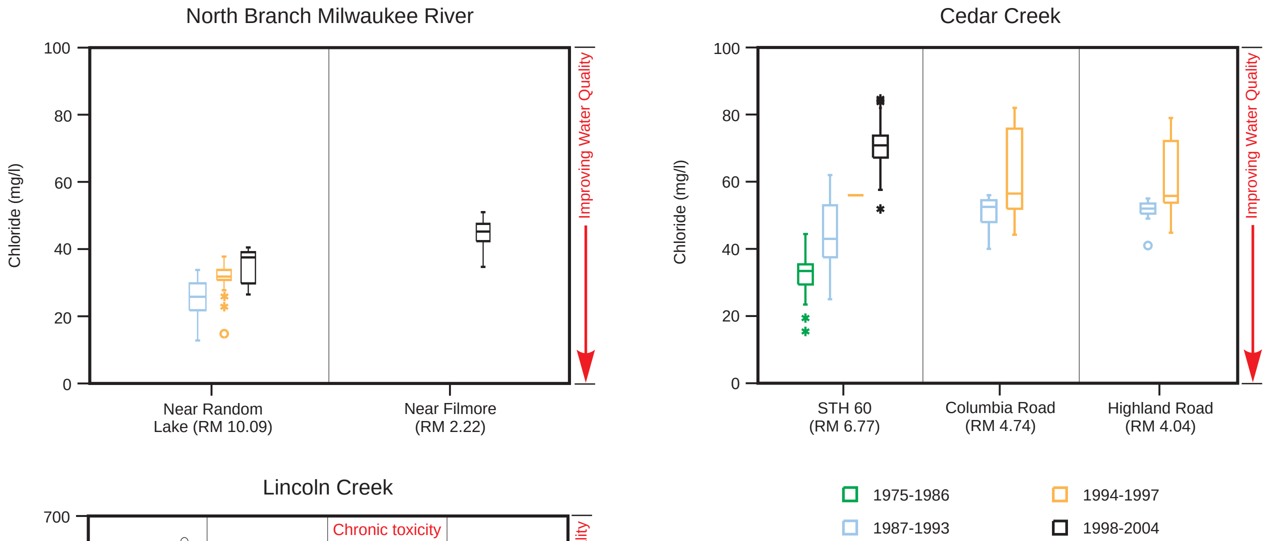
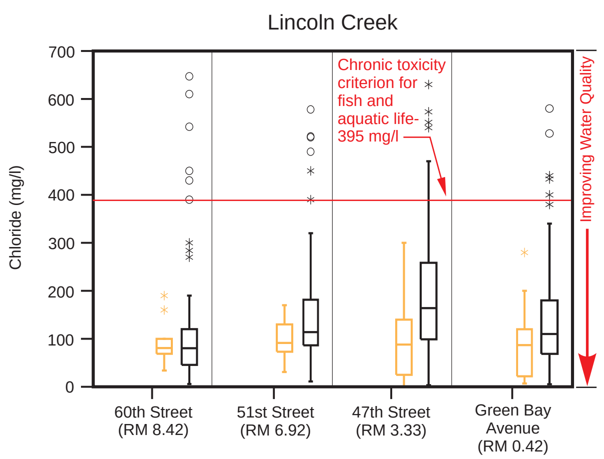
[2]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 123

CHLORIDE CONCENTRATIONS AT SITES IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004





NOTES: See Figure 109 for description of symbols.

The acute toxicity criterion for fish and aquatic life, which is 757 mg/l, is greater than the maximum values on each vertical axis; therefore, it is not shown. Also, the chronic toxicity criterion for fish and aquatic life, which is 395 mg/l, exceeds the maximum values on the vertical axes for the North Branch and Cedar Creek.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

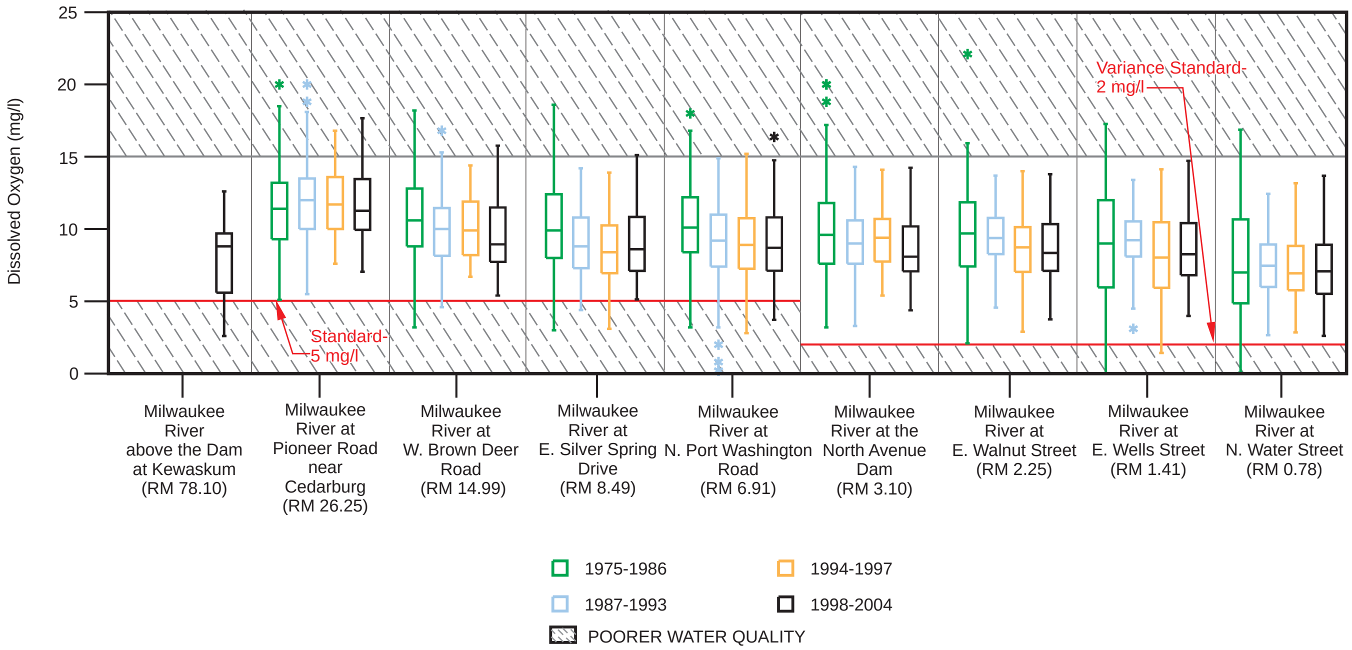
Chloride concentrations in the Milwaukee River show strong positive correlations with alkalinity, hardness, and specific conductance, all parameters which, like chloride, measure amounts of dissolved material in water. This may reflect common mechanisms of entry into the River. The increase in chloride concentrations detected at some stations along the Milwaukee River represents a decline in water quality.

Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the Milwaukee River was 9.4 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. Figure 124 shows the distributions of dissolved oxygen concentrations at nine sampling stations along the River. Considerable variability in dissolved oxygen concentration is present at individual sample sites. At two stations upstream of the estuary, Pioneer Road and Brown Deer Road, median dissolved oxygen concentrations in the samples collected during the period 1998-2004 were lower than the median dissolved oxygen concentrations in the samples collected during the period 1994-1997. Declines in median dissolved oxygen concentration were also observed in the estuary: at the Walnut Street and Wells Street stations after 1993 and at the North Avenue dam station after 1997. Figure 125 indicates that these decreases are probably attributable to lower concentrations of dissolved oxygen in the late spring and summer. Figure 124 also shows that the range of dissolved oxygen concentrations decreased at most stations after 1986. Because the solubility of oxygen in water is dependent on water temperature (i.e. as water temperatures decrease dissolved oxygen concentrations increase), this does not reflect any change in the range of dissolved oxygen concentrations in the River. Rather it reflects the fact that MMSD discontinued sampling during the winter after 1986.

Figure 124

DISSOLVED OXYGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTES: See Figure 109 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

The Milwaukee River below the site of the abandoned North Avenue dam is subject to a special variance under which dissolved oxygen concentrations are not to be less than 2.0 mg/l.

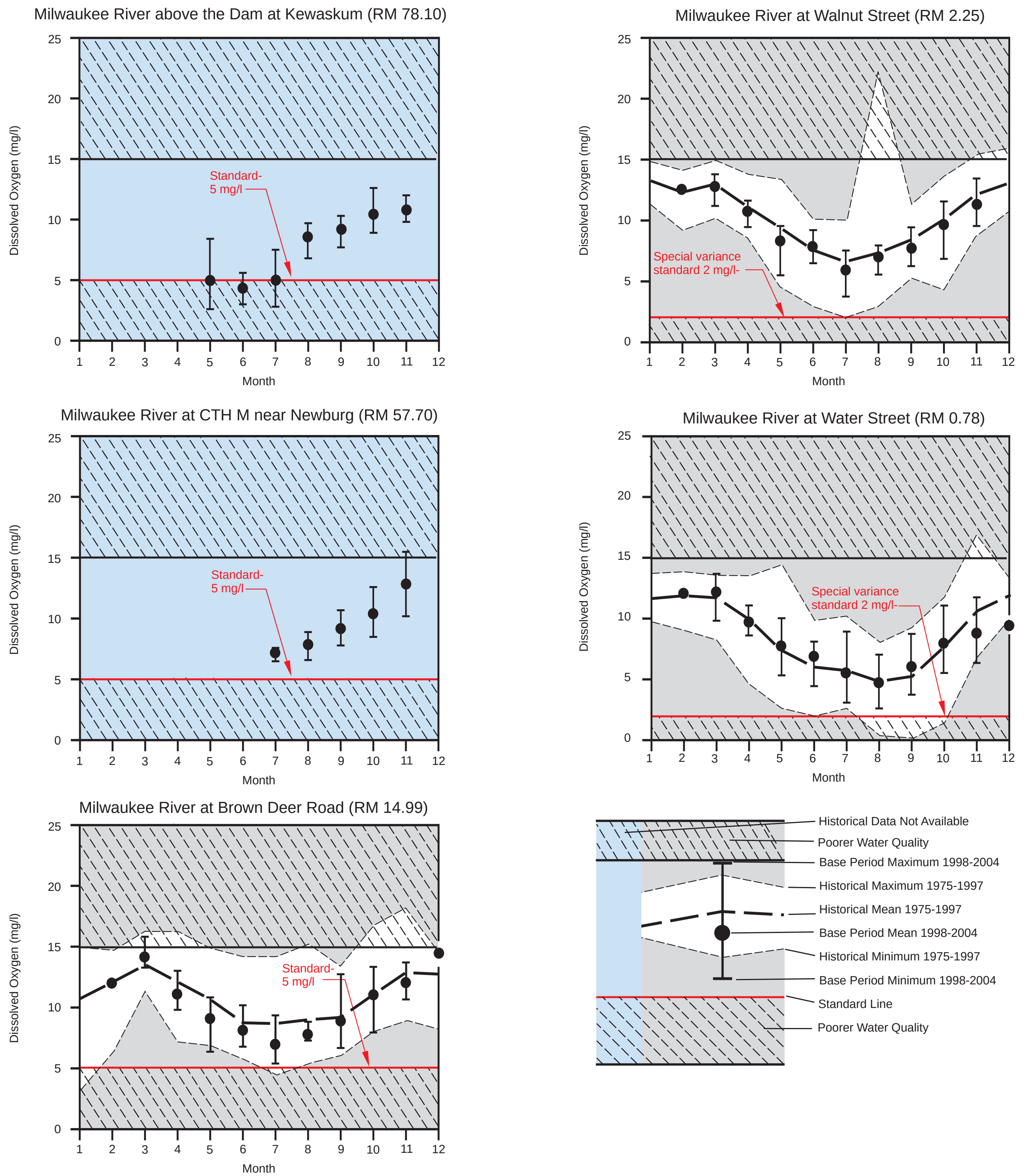
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 125 compares monthly baseline period concentrations of dissolved oxygen to historical concentrations at five stations along the mainstem of the River. At those stations for which historical data exist, baseline period monthly minimum dissolved oxygen concentrations were generally higher than the historical minimum concentrations. Baseline period monthly mean dissolved oxygen concentrations were below historical monthly means at the Brown Deer Road station during the spring and summer. With the exception of the station at Pioneer Road, this was observed at all stations in the section of the River upstream from the estuary for which historical data exist. This pattern was also observed in the upper estuary at the North Avenue dam site and Walnut Street stations. In the lower estuary, baseline period mean monthly dissolved oxygen concentrations during the summer and fall tended to be near or slightly above historical means.

There were several trends in dissolved oxygen concentration in the Milwaukee River. During all time periods examined, dissolved oxygen concentrations were lower in the estuary than in the section of the River upstream from the estuary (see Table 87). There was a statistically significant trend toward dissolved oxygen concentrations decreasing from upstream to downstream along the mainstem of the River (see Table 88). Few time-based trends were detected in dissolved oxygen concentrations (see Table C-5 in Appendix C of this report). When examined on an annual basis, significant trends toward decreasing dissolved oxygen concentrations were detected at three nonestuary stations: Brown Deer Road, Silver Spring Drive, and Port Washington Road. These decreasing trends are attributable to lower concentrations at these stations during the summer. Upstream from these stations, an increasing trend over time was detected at the Pioneer Road station. When examined on a seasonal basis,

Figure 125

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF DISSOLVED OXYGEN ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: The Milwaukee River below the site of the abandoned North Avenue dam is subject to a special variance under which dissolved oxygen concentrations are not to be less than 2.0 mg/l.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

statistically significant increasing trends in dissolved oxygen concentration during the summer were detected at three stations in the estuary. Comparison of these trends toward increasing dissolved oxygen concentrations in the lower estuary to trends toward decreasing BOD and decreasing ammonia suggests that a decrease in loadings of organic pollutants may be responsible for the increase in dissolved oxygen concentration at these sites during the summer. This is a likely consequence of a reduction in loadings from combined sewer overflows since MMSD's Inline Storage System went on line.

The data show strong seasonal patterns to the mean concentrations of dissolved oxygen (see Figure 125). The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises though the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer.

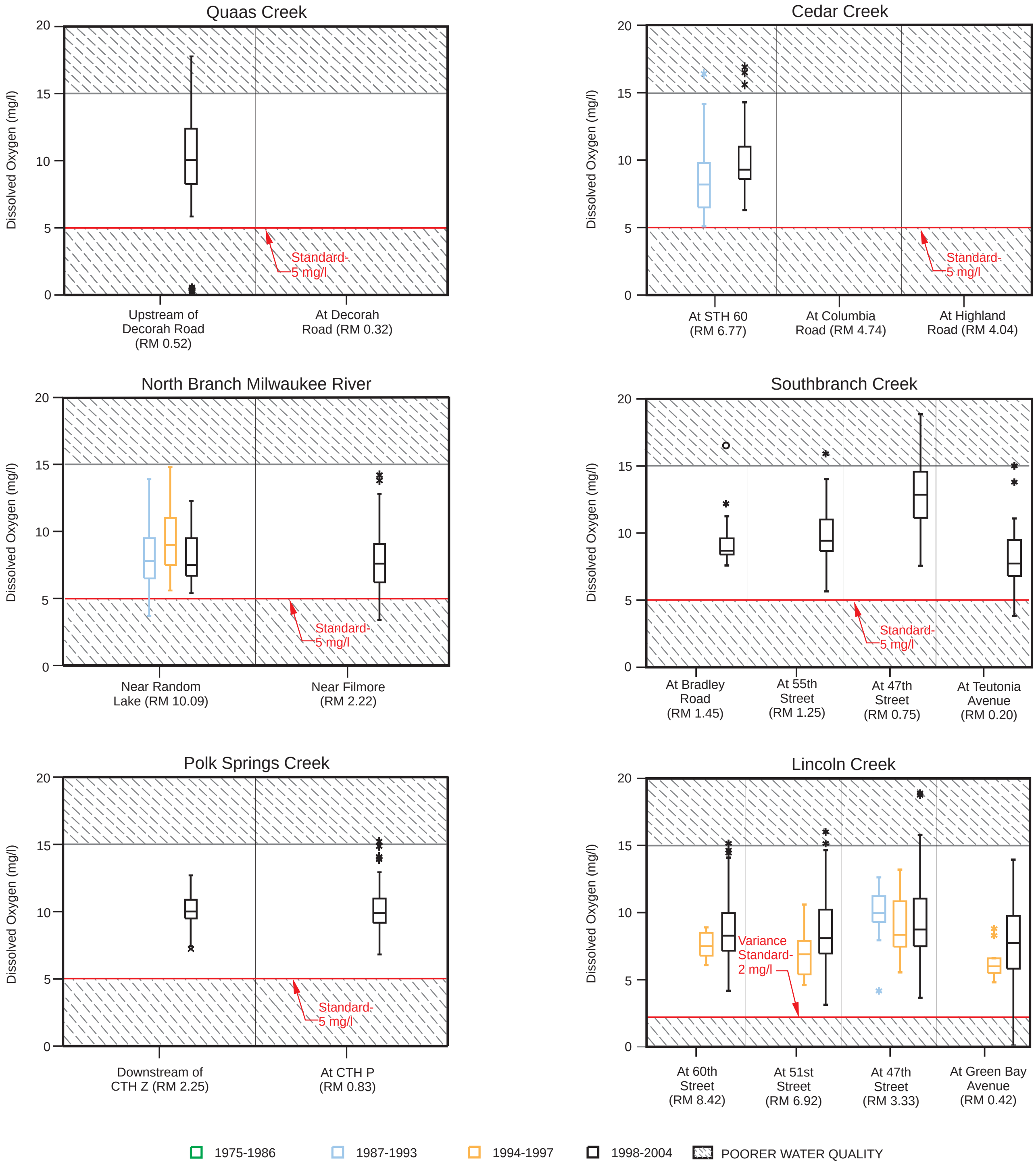
Figure 126 shows dissolved oxygen concentrations at sampling stations along six Milwaukee River tributaries. Dissolved oxygen concentrations in these tributaries are generally above the applicable standards; however, dissolved oxygen concentrations below the standards are occasionally detected in samples from Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek. No statistically significant longitudinal trends in dissolved oxygen concentration were detected in those streams with more than one sampling station. Dissolved oxygen concentrations at the STH 60 station along Cedar Creek were higher during the period 1998-2004 than during the period 1987-1993. This difference represents a statistically significant increasing trend (Table C-5 in Appendix C). Figure 126 shows that dissolved oxygen concentrations at several stations along Lincoln Creek were higher during the period 1998-2004 than during the period 1994-1997. This represented a significant increasing trend only at the station at N. 55th Street (Table C-5 in Appendix C).

Several other factors can affect dissolved oxygen concentrations in the Milwaukee River. First, portions of the estuary act as a settling basin in which material suspended in water sink and fall out into the sediment. This is indicated by the lower concentrations of total suspended solids (TSS) in the estuary (see Table 87 and the section on TSS below). Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. This process can also occur in impoundments upstream of dams. Second, influxes of water from Lake Michigan and the Menomonee and Kinnickinnic Rivers may influence dissolved oxygen concentrations in the downstream portions of the estuary. When dissolved oxygen concentrations in these waterbodies are higher than in the estuary, mixing may act to increase dissolved oxygen concentrations in the lower estuary. Similarly, when dissolved oxygen concentrations in these waterbodies are lower than in the estuary, mixing may act to decrease dissolved oxygen concentrations in the lower estuary. Third, dissolved oxygen concentrations at some stations along the Milwaukee River are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the pH of the water. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. Fourth, dissolved oxygen concentrations in water can be affected by numerous other factors including the presence of aquatic plants, sunlight, and the amount of and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

The increase in dissolved oxygen concentrations at some stations in the estuary during the summer and the increases at some stations along Cedar and Lincoln Creek represent an improvement in water quality. The decreases in dissolved oxygen at some upstream stations along the mainstem of the River represent a decline in water quality.

Figure 126

DISSOLVED OXYGEN CONCENTRATIONS IN THE MILWAUKEE RIVER TRIBUTARIES: 1975-2004



NOTES: See Figure 109 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Lincoln Creek is subject to a special variance under which dissolved oxygen concentrations are not to be less than 2.0 mg/l.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, Washington County Land and Water Conservation Division, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Hardness

Over the period of record, the mean hardness in the Milwaukee River was 284.8 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[3] The range of the data runs from 18.6 to 818.8 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. Table 87 shows that water in the section of the River upstream from the estuary is significantly harder than water in the estuary. This probably results, at least in part, from interactions between the estuary and Lake Michigan. In the section of the River upstream from the estuary, there is a statistically significant trend toward hardness decreasing from upstream to downstream (see Table 88). When examined on an annual basis, significant trends toward increasing hardness concentrations over time were detected at six stations along the mainstem of the River (Table C-5 in Appendix C). These trends appear to be attributable to increases during the spring. They account for a small portion of the variation in the data. Hardness concentrations in the Milwaukee River show strong positive correlations with alkalinity, chloride, pH, and specific conductance, all parameters which, like hardness, measure amounts of dissolved material in water.

Mean hardness in tributaries to the Milwaukee River range from 228.5 mg/l as $CaCO_3$ to 354 mg/l as $CaCO_3$. No statistically significant longitudinal trends were found in Lincoln Creek (see Table 90) or Southbranch Creek (see Table 89). Few time-based trends were detected in hardness in Milwaukee River tributaries. Trends toward increasing hardness were detected at one station along Cedar Creek and one station along Lincoln Creek (Table C-5 in Appendix C).

pH

The mean pH in the Milwaukee River over the period of record was 8.2 standard units. The mean values at individual sampling stations along the mainstem of the River ranged from 7.8 to 8.3 standard units. At most stations, pH varied only by $\pm$1.0 standard unit from the stations' mean values. Variability in pH was very similar among stations, with coefficients of variation ranging from 0.03 to 0.05. No longitudinal trends were detected in pH along the Milwaukee River. Table C-5 in Appendix C, shows that at four stations, significant trends were detected toward pH decreasing over time. These trends account for a small portion of the variation in the data. Mean pHs in tributaries to the Milwaukee River range from 7.4 standard units to 8.2 standard units. Positive correlations are seen between pH and alkalinity, hardness, and specific conductance at some stations but they are neither as common nor as strong as the correlations detected among alkalinity, hardness, and specific conductance. At some stations, dissolved oxygen concentrations and chlorophyll-*a* concentrations are positively correlated with pH. These correlations reflect the effect of photosynthesis on these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. This often results in increased algal growth, which is reflected in higher chlorophyll-*a* concentrations. In summary, pH concentrations at most stations along the Milwaukee River have not changed substantially during the time period examined from 1975 to 2004.

Specific Conductance

The mean value for specific conductance in the Milwaukee River over the period of record was 635.7 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific conductance ranged from below the limit of detection to 2,100.0 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the River. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the River. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the River. This will tend to raise specific conductance in the River. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Figure 127 shows that specific conductance has been consistently increasing at most stations along the mainstem of the River since the period 1975-1986. These increases represent statistically significant trends toward specific conductance in the Milwaukee River increasing over time

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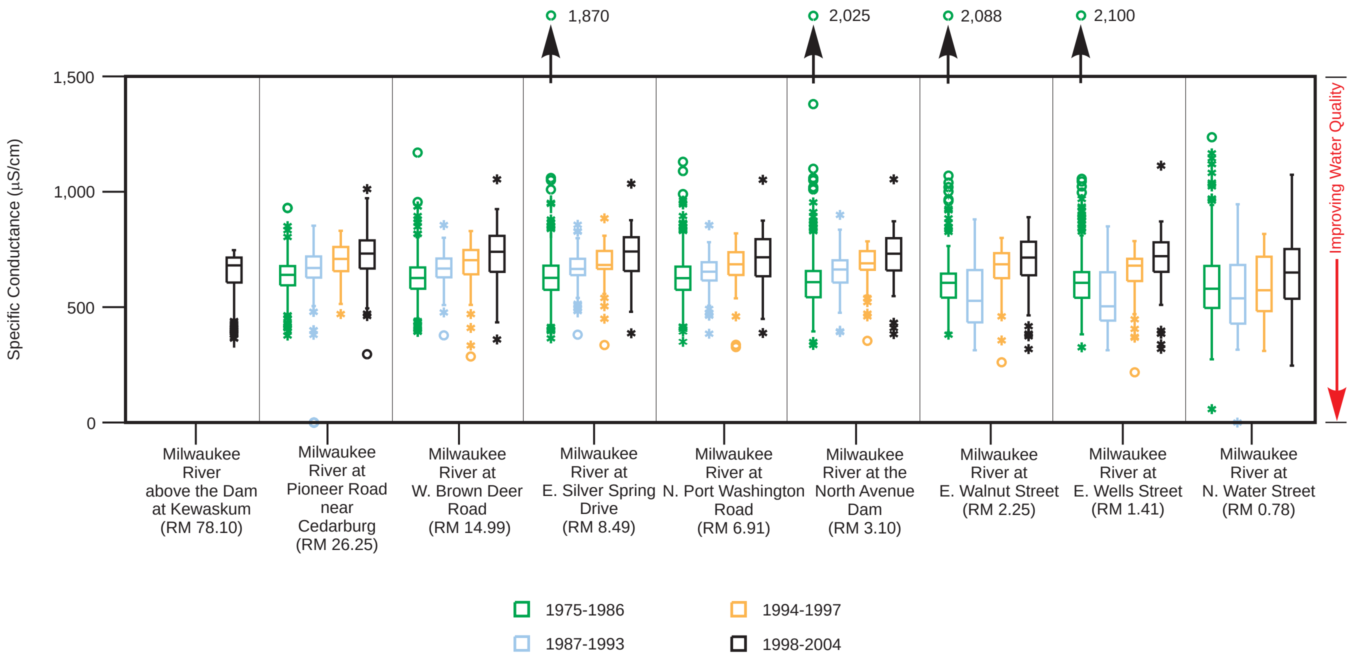
[3]*E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

Figure 127

SPECIFIC CONDUCTANCE AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

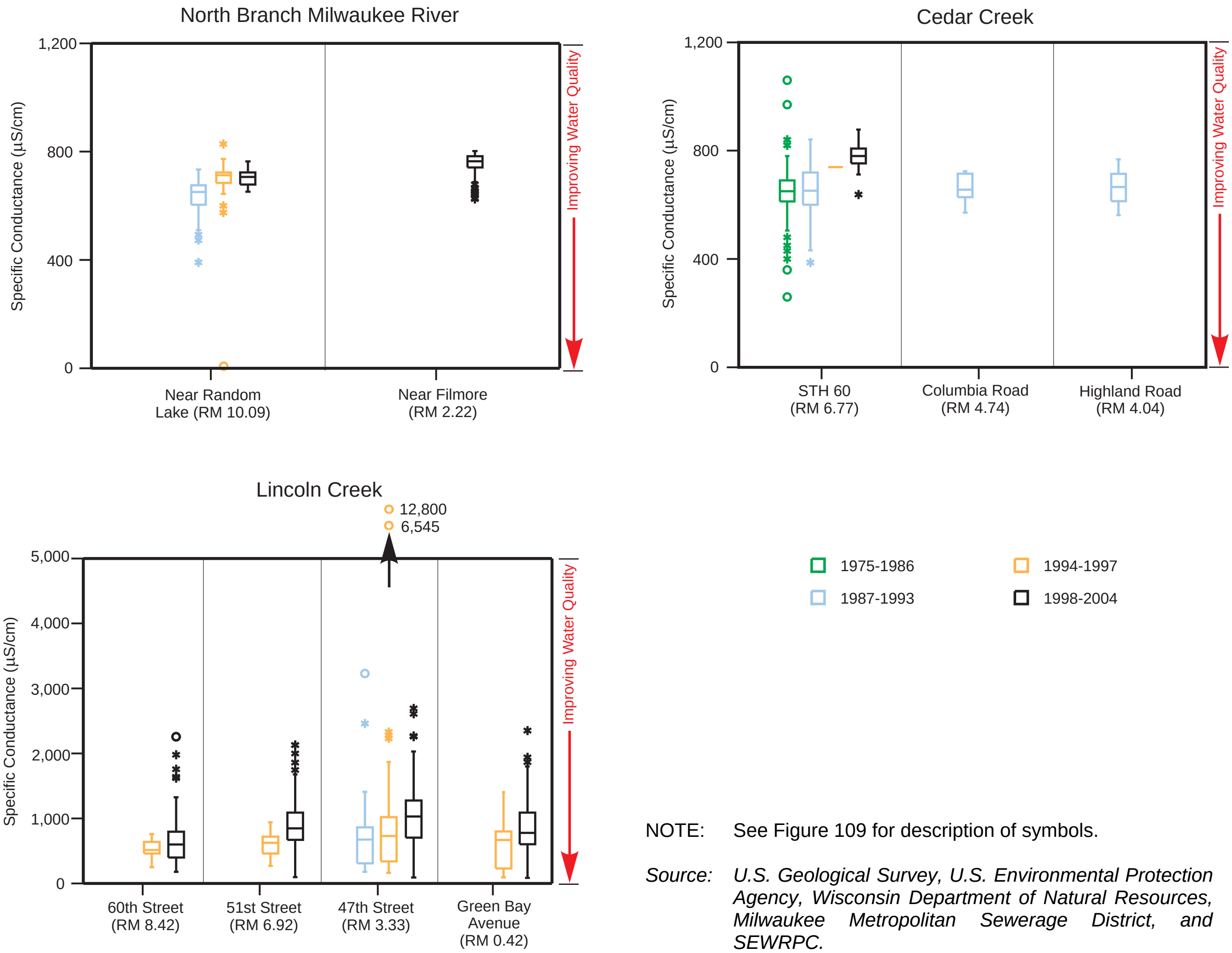
(Table C-5 in Appendix C). Mean specific conductance in the estuary was lower than mean specific conductance in the section of the River upstream from the estuary in all periods (see Table 87). In addition, Table 88 shows that there was a statistically significant trend toward specific conductance decreasing from upstream to downstream in the section of the River upstream from the estuary. The data show a seasonal pattern of variation in specific conductance. For those years in which data were available, specific conductance was highest during the winter. It then declined during the spring to reach lower levels in the summer and early fall. Specific conductance in the Milwaukee River show strong positive correlations with alkalinity, chloride, hardness, and pH, all parameters which, like specific conductance, measure amounts of dissolved material in water. At most stations, specific conductance also shows negative correlations with water temperature, reflecting the fact that specific conductance in the River tends to be lower during the summer. Figure 128 shows specific conductance in three Milwaukee River tributaries: Cedar Creek, Lincoln Creek, and the North Branch Milwaukee River. In each of these streams, specific conductance has increased over time. Table C-5 in Appendix C shows that statistically significant trends toward specific conductance increasing over time were detected at three stations along Lincoln Creek and one station along Cedar Creek. In summary, specific conductance was shown to have increased at stations along the mainstem of the Milwaukee River and at least three tributaries. These increases in specific conductance indicate that the concentrations of dissolved materials in water in the River and some tributaries are increasing and represent a decline in water quality.

Suspended Material

The mean value for total suspended solids (TSS) concentration in the Milwaukee River over the period of record was 25.1 mg/l. Considerable variability was associated with this mean, with values ranging from 1.2 to 892.0 mg/l. Figure 129 shows that TSS concentrations at most stations along the mainstem of the River for which data exist have increased over time. At several stations along the mainstem of the River, these increased concentrations represent statistically significant trends (Table C-3 in Appendix C). When analyzed on an annual

Figure 128

SPECIFIC CONDUCTANCE AT SITES IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



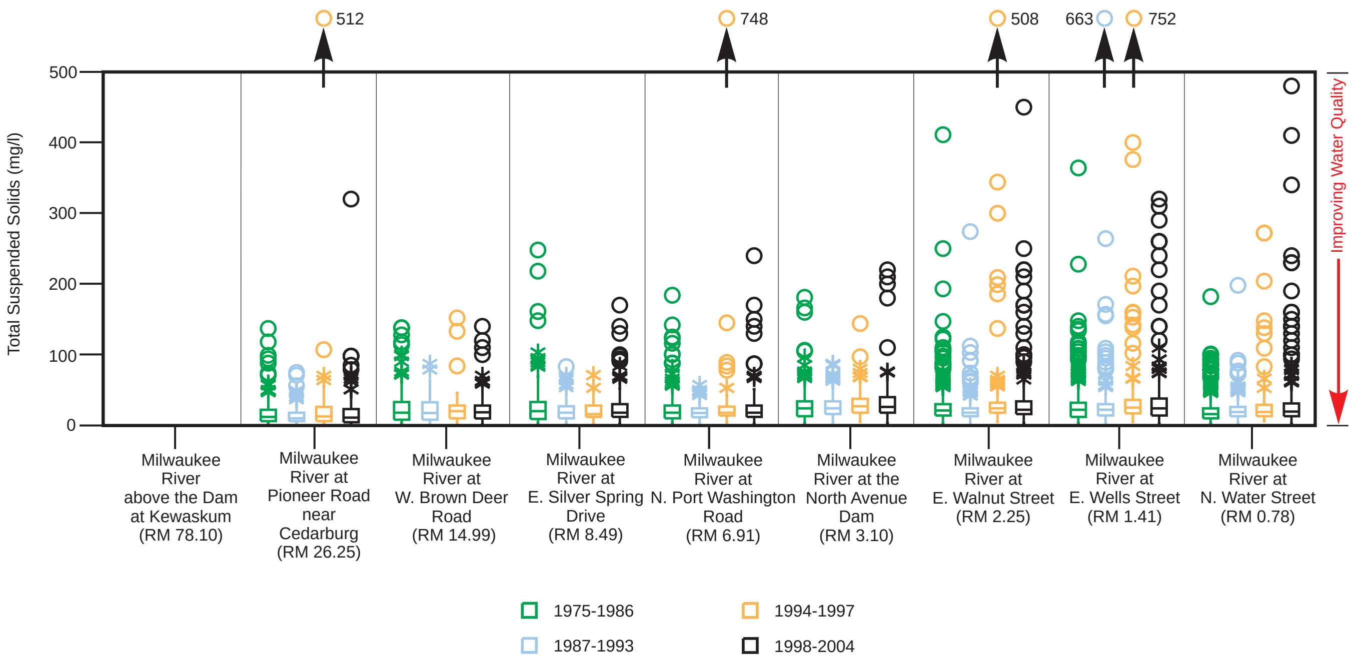
NOTE: See Figure 109 for description of symbols.

Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

basis, statistically significant trends toward increasing TSS concentrations were detected at several sampling stations in the estuary. When analyzed on a seasonal basis, statistically significant trends toward increasing TSS concentrations were detected at most stations along the mainstem of the River. In the section of the River upstream from the estuary, TSS concentrations tended to decrease from upstream to downstream (see Table 88). Mean concentrations of TSS were lower at estuary stations than at stations upstream from the estuary in all periods (see Table 87). This reflects the fact that portions of the estuary act as a settling basin in which material suspended in water sink and fall out into the sediment. Data on TSS concentrations exist for only a few tributary streams. Mean TSS concentrations for Cedar, Indian, Lincoln, and Southbranch Creeks were 12.7, 14.4, 16.7, and 12.3 mg/l, respectively. TSS concentrations in the Milwaukee River showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform bacteria, BOD, and nutrients. TSS concentrations were negatively correlated with some measures of dissolved materials, such as alkalinity, hardness, pH, and specific conductance. The trends toward increasing TSS concentrations at some sampling stations represent a decline in water quality.

Figure 129

CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

In addition to TSS, total suspended sediment concentration was sampled at four sites along the mainstem of the Milwaukee River. The mean value for total suspended sediment concentration over the period of record was 33.7 mg/l. Considerable variability was associated with this mean, with values ranging from 1.0 to 323.0 mg/l. Table 87 shows that there was a statistically significant trend toward total suspended sediment concentrations increasing along the length of the River. This parameter was not sampled at stations in the estuary, so the relationship between mean concentrations of total suspended sediment in the estuary and mean concentrations in the section of the River upstream from the estuary is not known; however it is reasonable to assume that if portions of the estuary are acting as a settling basin, then concentrations of total suspended sediment are probably lower in the estuary. The lower concentrations of TSS in the estuary support this idea. Few time-based trends in total suspended sediment concentrations were detected in the Milwaukee River (Table C-5 in Appendix C). It is important to note that total suspended sediment concentrations are not comparable to TSS concentrations.[4]

Nutrients

Nitrogen Compounds

The mean concentration of total nitrogen in the Milwaukee River over the period of record was 1.87 milligrams per liter measured as nitrogen (mg/l as N). Concentrations ranged from below the limit of detection to 12.94 mg/l as N. Figure 130 shows changes in total nitrogen concentrations over time since 1975 at several stations along the mainstem of the River. At all stations, concentrations of total nitrogen during the period 1987-1993 were lower

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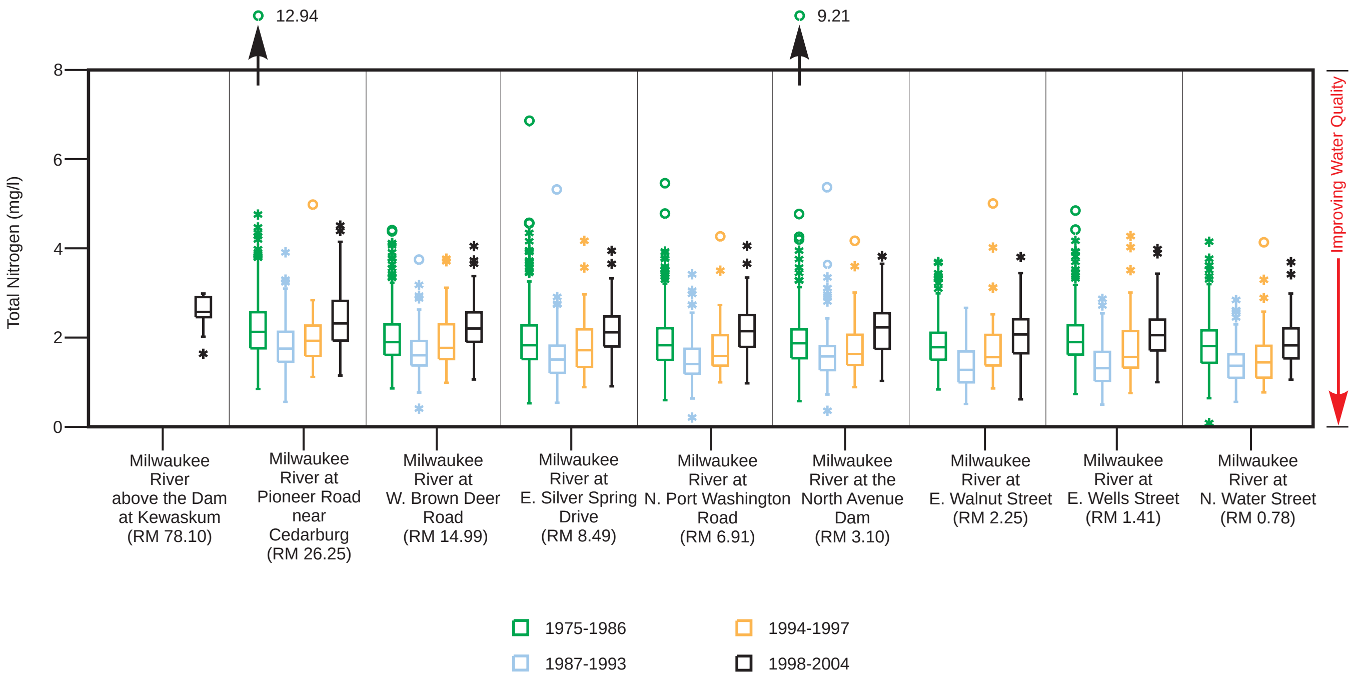
[4]*J.R. Gray, G.D. Glysson, L.M. Turcios, and G.E. Schwartz,* Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data, *U. S. Geological Survey Water-Resources Investigations Report No. 00-4191, 2000.*

Figure 130

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

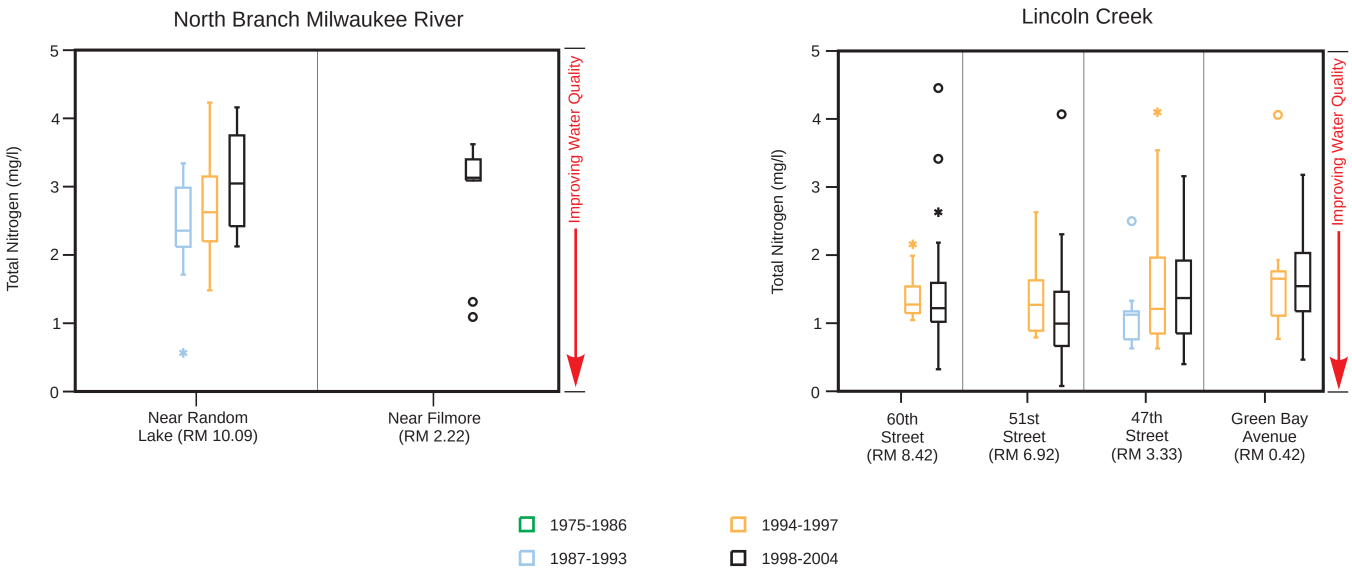
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

than during the period 1975-1986. In subsequent periods, concentrations of total nitrogen increased. By the period 1994-1997, mean concentrations of total nitrogen had returned to levels similar to the mean concentrations from 1975-1986. During all periods, mean concentrations of total nitrogen were higher in the section of the River upstream of the estuary than in the estuary (see Table 87). In addition, there was a statistically significant trend toward total nitrogen concentrations decreasing from upstream to downstream along the River (see Table 88). Table C-5 in Appendix C shows that significant trends toward increasing total nitrogen concentrations were detected in the Milwaukee River. When examined on an annual basis, increasing concentrations were detected at six stations. Trends were not detected at the three stations in the estuary that are farthest downstream. This may reflect the influence of mixing with water from Lake Michigan and the Menomonee and Kinnickinnic Rivers at these stations. When examined on a seasonal basis, increasing concentrations of total nitrogen were detected during the summer at all stations except Estabrook Park. Given that concentrations decreased between the periods 1975-1986 and 1987-1994, the results set forth in Table C-5 in Appendix C may understate current trends. The concentration of total nitrogen in the Milwaukee River is positively correlated with the concentrations of nitrate and organic nitrogen, reflecting the fact that these tend to be the major forms of nitrogen compounds in the River. In addition, concentrations of total nitrogen were positively correlated with concentrations of total phosphorus at most stations. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus. Finally, total nitrogen concentrations in the Milwaukee River are negatively correlated with temperature, reflecting the fact that total nitrogen concentrations tend to be highest during the winter.

Mean concentrations of total nitrogen in some upstream tributaries are higher than the mean concentration of total nitrogen in the mainstem of the River, but this generalization is based upon much less extensive sampling in the tributaries. Figure 131 shows changes in total nitrogen concentrations in two tributaries of the Milwaukee River. Concentrations of total nitrogen at the station near Random Lake along the North Branch Milwaukee River have

Figure 131

TOTAL NITROGEN CONCENTRATIONS IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

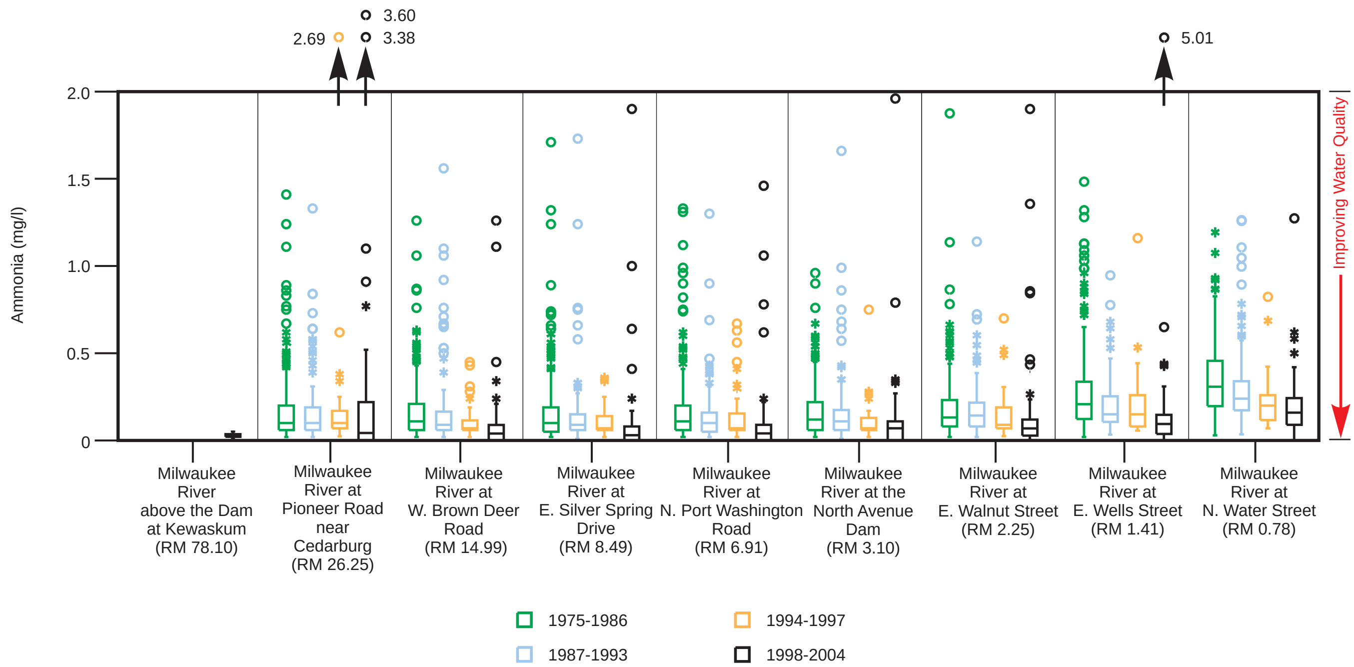
increased over time. A more complicated situation emerges for Lincoln Creek. At upstream stations, concentrations of total nitrogen have decreased. This is especially true of the minimum concentrations detected. Concentrations at downstream stations have increased or remained the same. Table C-5 in Appendix C shows significant trends toward total nitrogen concentrations decreasing at upstream stations in Lincoln Creek.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the Milwaukee River was 0.20 mg/l as N. Over the period of record, ammonia concentrations varied from below the limit of detection to 5.01 mg/l as N. Figure 132 shows that ammonia concentrations have decreased over time at all stations. These decreases represent significant decreasing trends in ammonia concentrations when examined on an annual basis and during all seasons (Table C-5 in Appendix C). Ammonia concentrations in the Milwaukee River tend to be higher during the winter than during other seasons. Mean ammonia concentrations in the estuary are significantly higher than mean concentrations of ammonia in the section of the River upstream from the estuary (see Table 87). In the section of the River upstream from the estuary, there is a significant trend toward ammonia concentrations decreasing from upstream to downstream. Mean concentrations of ammonia in many tributary streams were lower than the mean concentrations detected in the mainstem of the River. This is not the case, however, in all tributaries. Mean ammonia concentrations in Lincoln Creek, Parnell Creek, and Polk Springs Creek were 0.15 mg/l as N, 0.28 mg/l as N, and 0.35 mg/l as N respectively. Significant trends toward ammonia concentrations decreasing over time were detected in Lincoln Creek (Table C-5 in Appendix C). Ammonia concentrations at several stations, especially in the estuary, are positively correlated with concentrations of fecal coliform bacteria. This may reflect common sources and modes of transport into the River for these two pollutants.

Figure 132

AMMONIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



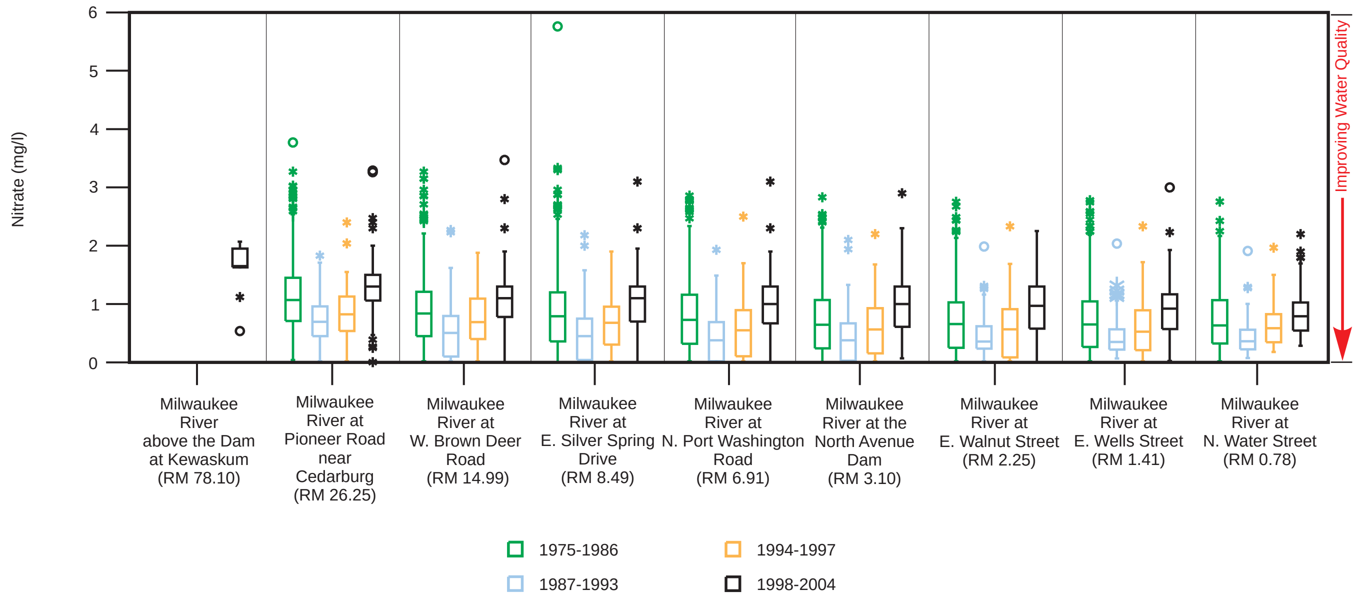
NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

The mean concentration of nitrate in the Milwaukee River for the period of record was 0.78 mg/l as N. During this time, concentrations in the River varied from below the limit of detection to 5.76 mg/l as N. In general, the changes in nitrate concentrations at most stations along the mainstem of the River (see Figure 133) are similar to the changes in concentrations of total nitrogen. At all stations, concentrations of nitrate during the period 1987-1993 were lower than during the period 1975-1986. In subsequent periods, concentrations of nitrate increased. This suggests that the changes over time in nitrate concentrations within the River may be driving the changes over time in total nitrogen concentrations. In the section of the River upstream from the estuary, there is a statistically significant trend for nitrate concentrations to decrease from upstream to downstream along the mainstem of the River. The relationship between the mean concentrations of nitrate in the estuary and in the section of the River upstream from the estuary has changed over time (see Table 87). During the period 1975-1986, mean concentrations of nitrate in the estuary were lower than those in the section of the River upstream from the estuary. This changed after 1986. During the periods 1987-1993 and 1994-1997, there were no statistically significant differences between mean nitrogen concentrations in these two sections of the River. It changed again after 1997. During the period 1998-2004, concentrations of nitrate in the estuary were lower than those in the section of the River upstream from the estuary. Table C-5 in Appendix C shows that significant trends toward nitrate concentrations increasing over time were detected at most stations along the mainstem of the River. The data show evidence of seasonal variations in nitrate concentration. Nitrate concentration was highest in the winter. It declined through fall to reach lower levels during summer or early fall. In the fall, the concentration began to climb again. At some stations, nitrate concentrations rise during late spring and early summer to reach a second peak. Mean nitrate concentrations in tributary streams were quite variable, ranging from 0.12 mg/l as N on the East Branch Milwaukee River to 13.7 mg/l as N on Polk Springs Creek. Few time-based trends were detected in nitrate concentrations in tributaries (Table C-5 in Appendix C). Trends toward nitrate concentrations decreasing over time were detected at three stations along Southbranch Creek; however, the short period of record on this stream make it difficult to determine whether these actually represent long term trends. Nitrate concentrations in

Figure 133

NITRATE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

the Milwaukee River were negatively correlated with concentrations of chlorophyll-*a* and organic nitrogen. These correlations reflect the role of nitrate as a nutrient for algal growth. During periods of high algal productivity, algae remove nitrate from water and incorporate it into cellular material.

The mean concentration of nitrite in the Milwaukee River was 0.024 mg/l as N over the period of record. Nitrite concentrations showed more variability than nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. Mean nitrite concentrations in the estuary were higher than mean nitrite concentrations in the section of the River upstream from the estuary in all periods (see Table 87). Nitrite concentrations tended to decrease from upstream to downstream in the section of the River upstream from the estuary (see Table 88). When examined on an annual basis, there were few trends in nitrite concentration over time (Table C-5 in Appendix C). Some significant trends were detected when the data were analyzed on a seasonal basis, but the directions of the trends varied by station and season. None of these trends accounted for more than a small portion of the variation in the data. Mean nitrite concentrations in tributary streams range from 0.010-0.060 mg/l as N.

During the period of record the mean concentration of organic nitrogen in the Milwaukee River was 0.90 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 10.46 mg/l as N. Few time-based trends were detected in organic nitrogen concentrations (Table C-5 in Appendix C). There is a statistically significant trend toward organic nitrogen concentration increasing from upstream to downstream in the section of the River upstream from the estuary (see Table 88). During most periods, mean concentrations of organic nitrogen in the estuary were lower than mean concentrations in the section of the River upstream from the estuary (see Table 87). Organic nitrogen concentrations in the Milwaukee River tend to be high during the summer. Mean concentrations of organic nitrogen in tributary streams range from 0.65 mg/l as N to 0.98 mg/l as N. Organic nitrogen concentrations in the Milwaukee River show positive correlations with chlorophyll-*a*, temperature, and total phosphorus. These correlations may reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. These periods usually occur during warmer weather. In addition, concentrations of organic nitrogen in the Milwaukee River are negatively correlated with concentrations of dissolved oxygen. This reflects the fact that aerobic metabolism of many organic nitrogen compounds requires oxygen. Concentrations of organic nitrogen in the Milwaukee River do not appear to have changed much over time.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

Several things emerge from this analysis of nitrogen chemistry in the Milwaukee River:

- Concentrations of total nitrogen have been increasing at several stations along the mainstem of the River. This represents a decrease in water quality.

- The relative proportions of different nitrogen compounds in the River seem to be changing with time.

- Ammonia concentrations have been declining over time. This represents an improvement in water quality.

- Concentrations of nitrate have been increasing at most stations along the mainstem of the River. This appears to account for at least some of the increase in total nitrogen concentrations. This represents a decrease in water quality.

- Concentrations of other forms of nitrogen in the River do not appear to be changing with time.

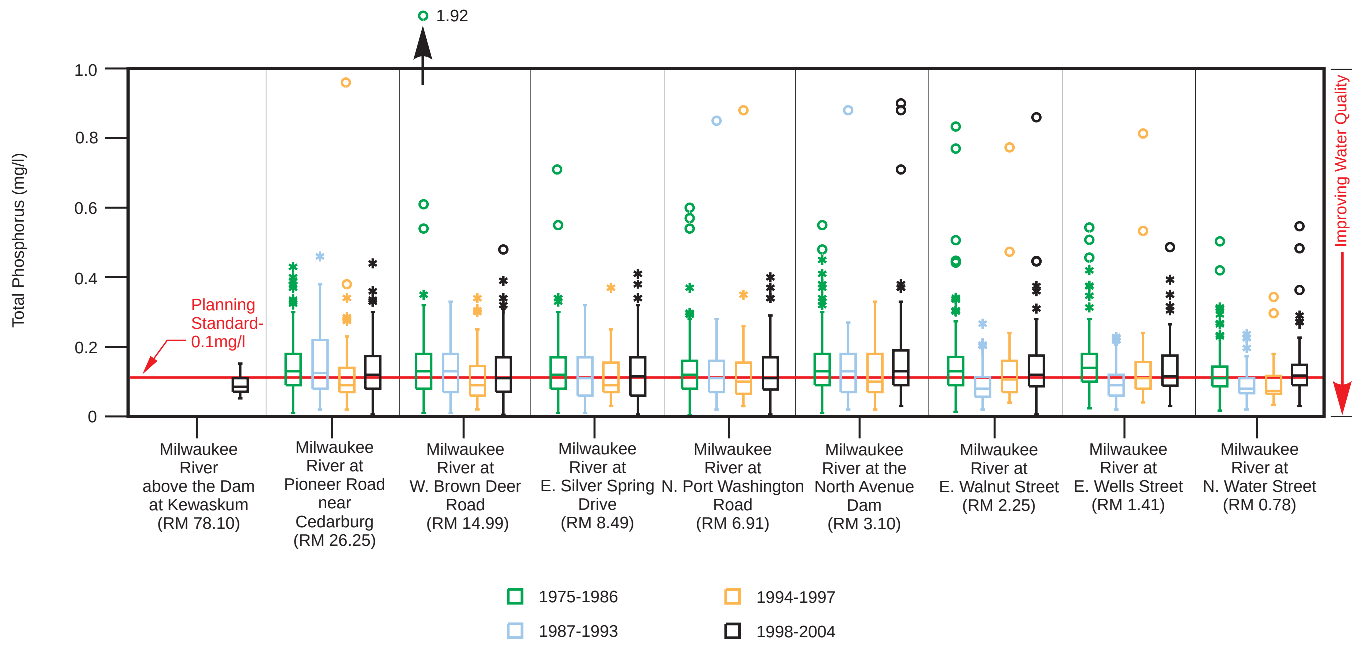
Total and Dissolved Phosphorus

Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

The mean concentration of total phosphorus in the Milwaukee River during the period of record was 0.129 mg/l, and the mean concentration of dissolved phosphorus in the Milwaukee River over the period of record was 0.050 mg/l. Total phosphorus concentrations varied over four orders of magnitude, ranging from 0.004 to 1.920 mg/l. Dissolved phosphorus concentrations varied over three orders of magnitude from 0.003 to 0.870 mg/l. At most sampling sites, the data showed moderate variability. Figure 134 shows the pattern of changes in total phosphorus concentrations over time along the mainstem of the River. At most estuary stations, median concentrations of total phosphorus during the period 1987-1993 were lower than median concentrations of total phosphorus during the period 1975-1986. This decrease was followed by increases in median concentrations of total phosphorus in the subsequent periods. The pattern followed by median concentrations of total phosphorus at stations in the section of the River upstream from the estuary was similar, except that the decrease in median concentrations occurred later, following the period 1987-1994. Median total phosphorus concentrations at one estuary station, the site of the former North Avenue dam, followed this latter pattern. At all stations during all periods, total phosphorus concentrations in a substantial fraction of samples exceeded the planning standard of 0.1 mg/l recommended in the regional water quality management plan. During most periods, there were no statistically significant differences between mean total phosphorus concentrations in the estuary and mean total phosphorus concentrations in the section of the River upstream from the estuary (see Table 87). The exception to this generalization occurred during the period 1987-1993 when the mean concentration in the section of the River upstream from the estuary were higher than the mean concentration in the estuary. During the periods 1975-1986 and 1987-1993, mean concentrations of dissolved phosphorus in the section of the River upstream from the estuary were higher than

Figure 134

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

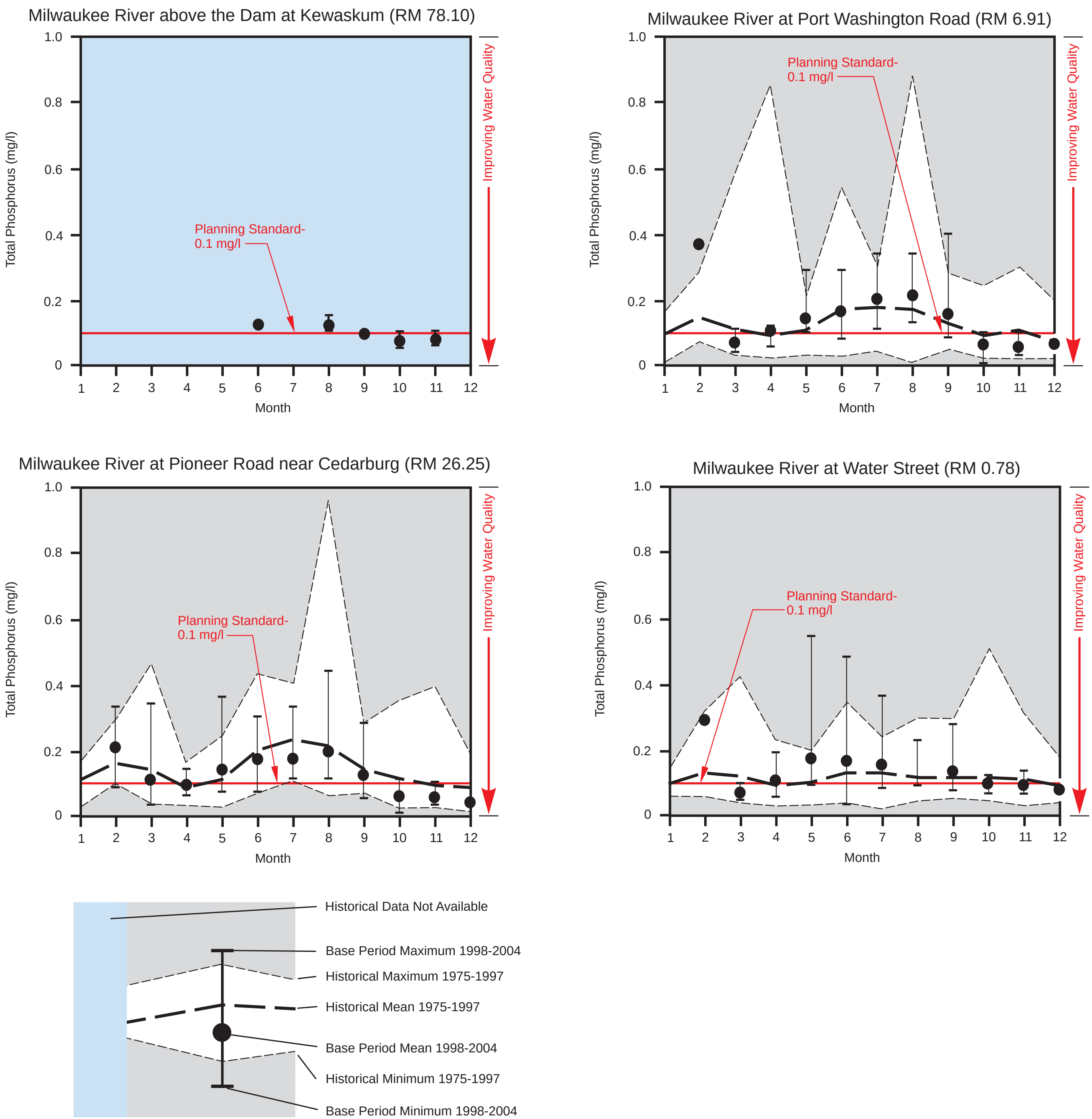
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

mean concentrations of dissolved phosphorus in the estuary. In subsequent periods, there were no significant differences between mean dissolved phosphorus concentrations in these two sections of the River. A statistically significant trend toward dissolved phosphorus concentration decreasing from upstream to downstream in the Milwaukee River was detected (see Table 88). No longitudinal trend was detected for total phosphorus concentration.

Figure 135 shows a monthly comparison of the historical and baseline concentrations of total phosphorus at four sampling stations along the length of the mainstem of the Milwaukee River. All stations except the Kewaskum station show a distinct seasonal pattern in total phosphorus concentrations. Total phosphorus concentrations are highest in the summer. At upstream stations, such as Pioneer Road or Port Washington Road, this peak concentration tends to occur in June. It tends to occur later in the summer downstream. At the Pioneer Road station, mean monthly total phosphorus concentrations during the baseline period were lower than historical means during summer and fall. At some downstream stations, baseline period mean monthly total phosphorus concentrations during the summer were near or above historical means. On an annual basis, trends toward decreasing total phosphorus concentrations over time were detected at most stations along the mainstem of the River (see Table C-5 in Appendix C). These trends appear to result largely from declines during the fall. These trends represent an improvement in water quality. Dissolved phosphorus concentrations show a more complicated pattern of time-based trends. When examined on an annual basis, trends toward dissolved phosphorus concentrations decreasing over time were detected at three stations in the section of the River upstream from the estuary. A trend toward dissolved phosphorus concentrations increasing over time was detected at one estuary station. When examined on a seasonal basis, statistically significant trends toward increases in dissolved phosphorus concentration during the summer were detected at most stations along the mainstem. These trends represent a decline in water quality. Trends toward decreases in dissolved phosphorus concentrations during the fall were detected at several stations. These trends represent an improvement in water quality.

Figure 135

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

In tributary streams, mean concentrations of total phosphorus ranged from 0.043 to 0.258 mg/l and mean concentrations of dissolved phosphorus ranged from 0.039 to 0.199 mg/l. Figure 136 shows historical and baseline period total phosphorus concentrations for stations on seven tributary streams. At those stations where sufficient data are available to assess seasonal trends, total phosphorus concentrations in tributary streams appear to be highest during the summer. At some stations, such as the STH 60 station on Cedar Creek and the N. 47th Street station on Lincoln Creek, baseline period monthly mean total phosphorus concentrations were below historical means.

Dissolved phosphorus concentrations in the Milwaukee River were negatively correlated with concentrations of chlorophyll-*a*. Total phosphorus concentrations were positively correlated with temperature, chlorophyll-*a* concentrations, and concentrations of organic nitrogen and total nitrogen. These correlations reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. Because the rates of biological reactions are temperature dependent, these periods tend to occur when water temperatures are warmer. At most stations, concentrations of total phosphorus were also positively correlated with concentrations of BOD and fecal coliform bacteria. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River.

Figure 137 shows the annual mean total phosphorus concentrations in the Milwaukee River for the years 1985 to 2002. While mean annual total phosphorus concentrations from the years 1996-2002 were within the range of variation from previous years, they increased after 1996. The increase in the Milwaukee River was not as significant as those observed in the Kinnickinnic and Menomonee Rivers (see Figures 45 and 84 in Chapters V and VI, respectively, in this report). One possible cause of this increase was phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The City of Milwaukee, for example, began treating its municipal water with orthophosphate to inhibit release of copper and lead from pipes in the water system and private residences in 1996. In 2004, for instance, concentrations of orthophosphate in plant finished water from the Milwaukee Water Works ranged between 1.46 mg/l and 2.24 mg/l,[5] considerably above average concentrations of total phosphate in the Milwaukee River. In addition, between 1992 and 2003, a number of other municipalities in the Milwaukee River watershed began treating their municipal water with orthophosphate or polyphosphate for corrosion control (see Table 91). The weaker increase in mean annual total phosphorus concentrations after 1996 in the Milwaukee River relative to the increases in the Kinnickinnic and Menomonee River may be due to the greater volume of water flowing through the Milwaukee River.

Metals

Arsenic

The mean value for the concentration of arsenic in the water of the Milwaukee River over the period of record was 1.94 μg/l. The data ranged from below the limit of detection to 14.00 μg/l. No differences were detected between mean arsenic concentrations in the estuary and mean arsenic concentrations in the section of the River upstream from the estuary (see Table 87). In the section of the River upstream from the estuary, there was a statistically significant trend toward arsenic concentrations increasing from upstream to downstream. This trend accounts for a small portion of the variation in the data. When examined on an annual basis, decreasing concentrations of arsenic over time were detected at all stations examined along the mainstem of the River (Table C-5 in Appendix C). This may reflect changes in the amount and types of industry within the Milwaukee River watershed such as the loss of tanneries which utilized arsenic in the processing of hides. In addition, sodium arsenite has not been used in herbicides in Wisconsin since 1969. Data on arsenic concentrations are available for few Milwaukee River tributaries. Mean concentrations of arsenic in Indian Creek, Lincoln Creek, and Southbranch Creek over the period of record were 1.25 μg/l, 1.68 μg/l, and 1.08 μg/l respectively. Significant trends toward arsenic concentrations decreasing over time were detected at all stations along Lincoln Creek (Table C-5 in Appendix C). Trends toward decreasing arsenic concentrations over time were also detected at stations along

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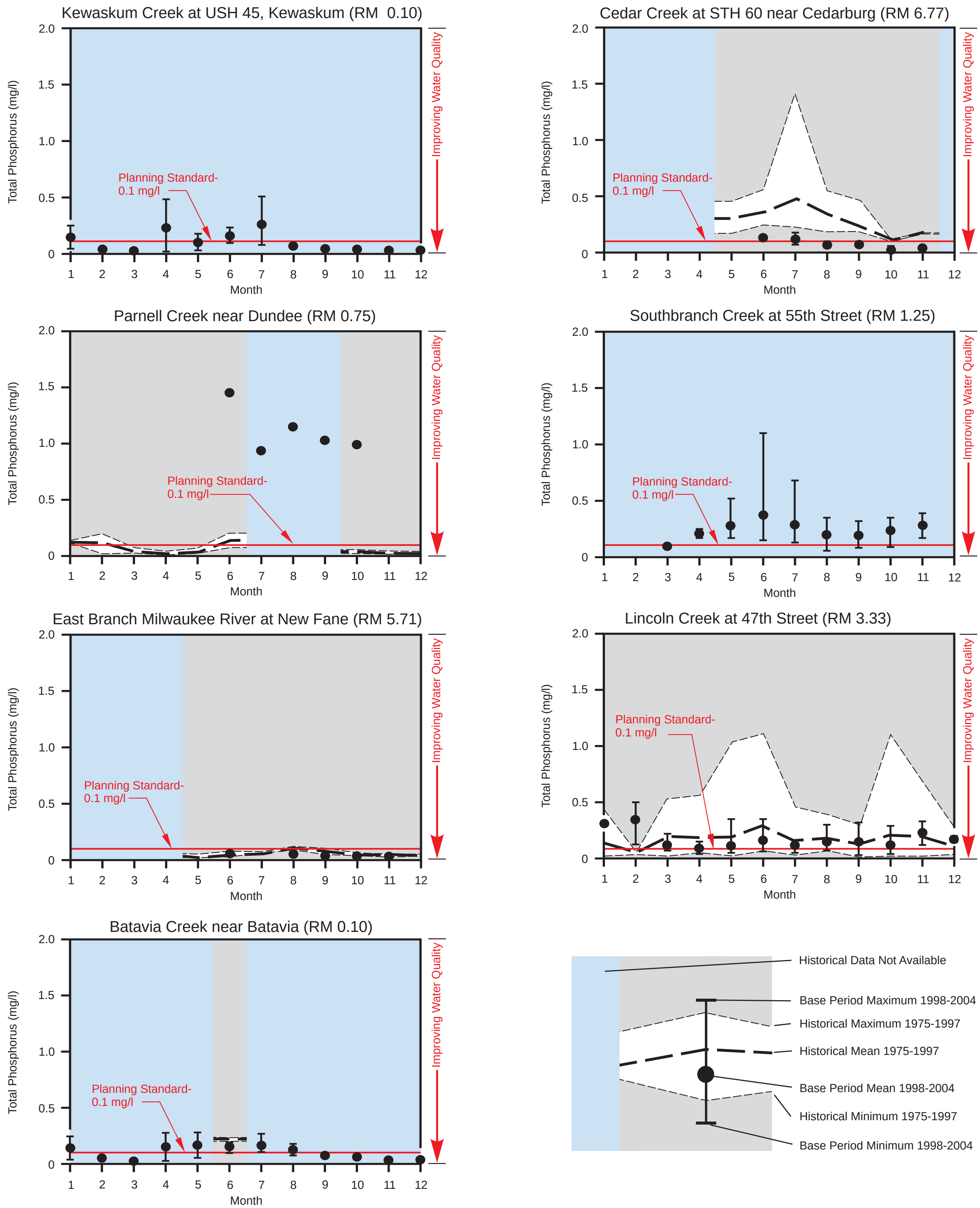
[5]*Milwaukee Water Works*, Annual Water Quality Report, 2004, *February 2005.*

Figure 136

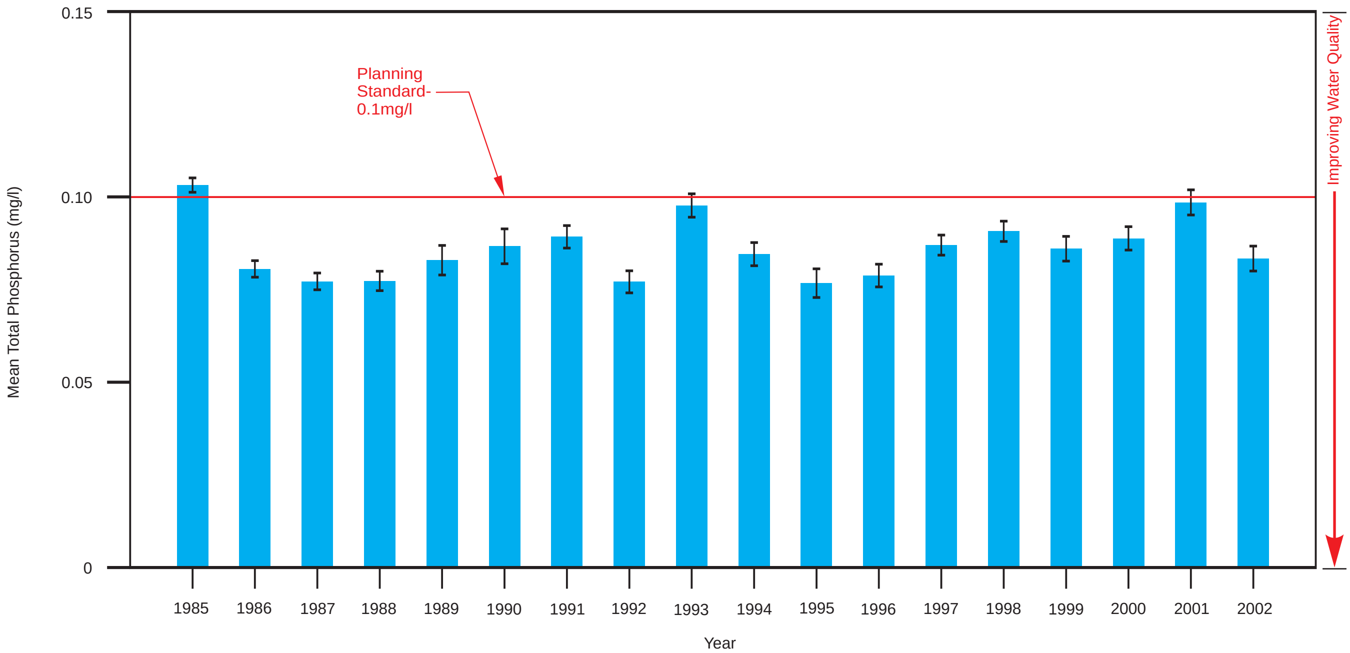
HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 137

MEAN ANNUAL CONCENTRATIONS OF TOTAL PHOSPHORUS IN THE MILWAUKEE RIVER WATERSHED: 1985-2002



NOTE: Error bars (I) represent one standard error of the mean.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 91

MUNICIPAL WATER UTILITIES THAT USE PHOSPHATES AS CORROSION INHIBITORS IN THE MILWAUKEE RIVER WATERSHED

Water Utility	Treatment	Year Treatment Began
Adell Waterworks	Polyphosphate	2000
Cascade Waterworks	Polyphosphate	2000
Cedarburg Light & Water Commission	Orthophosphate	2000
Grafton Waterworks	Polyphosphate	1992
Milwaukee Waterworks	Orthophosphate	1996
North Shore Water Commission	Polyphosphate	2000
Slinger Water Utility	Polyphosphate	2000
West Bend Waterworks	Polyphosphate	2000

Source: Wisconsin Department of Natural Resources and SEWRPC.

Southbranch Creek; however, the short period of record for this stream makes it difficult to ascertain whether these represent long-term trends (Table C-5 in Appendix C). The reductions in arsenic concentration in the Milwaukee River and Lincoln Creek represent an improvement in water quality.

Cadmium

The mean concentration of cadmium in the Milwaukee River over the period of record was 1.53 μg/l. A moderate amount of variability was associated with this mean. Individual samples ranged from below the limit of detection to 17.8 μg/l. Concentrations tended to be slightly more variable at stations in the estuary than at stations in the section of the River upstream from the estuary. The relationship between mean concentrations in the estuary and mean concentrations in the section of the River upstream of the estuary has changed over time (see Table 87). Prior to 1994, mean concentrations in the estuary were significantly higher than mean concentrations in the section of the River upstream from the estuary. Since 1994, there has been no significant difference between these means. Table 88 shows a significant trend toward cadmium concentrations in the section of the River upstream of the estuary decreasing from upstream to downstream. This trend accounts for a very small portion of the variation in the data. Table C-5 in Appendix C shows the presence of strong decreasing trends in cadmium concentration at all stations along the mainstem of the River for which data were available when the data were analyzed on an annual basis. These declines in cadmium concentration may reflect changes in the number and types of industry present in the watershed, reductions due to treatment of industrial discharges, and reductions in airborne deposition of cadmium to the Great Lakes region. Cadmium concentrations in the River showed no evidence of seasonal variation. Data on cadmium concentrations are available for few tributaries to the Milwaukee River. Mean concentrations of cadmium in samples from Indian, Lincoln, and Southbranch Creeks are 0.13 μg/l, 0.18 μg/l, and 0.11 μg/l respectively. These means are about an order of magnitude lower than the mean from the mainstem of the River. In part, this reflects the shorter period of record for these streams. The mean concentration of cadmium in the only headwater stream for which data are available, Parnell Creek, is 0.01 μg/l, another order of magnitude lower. The reduction in cadmium concentrations in the Milwaukee River represents an improvement in water quality.

Chromium

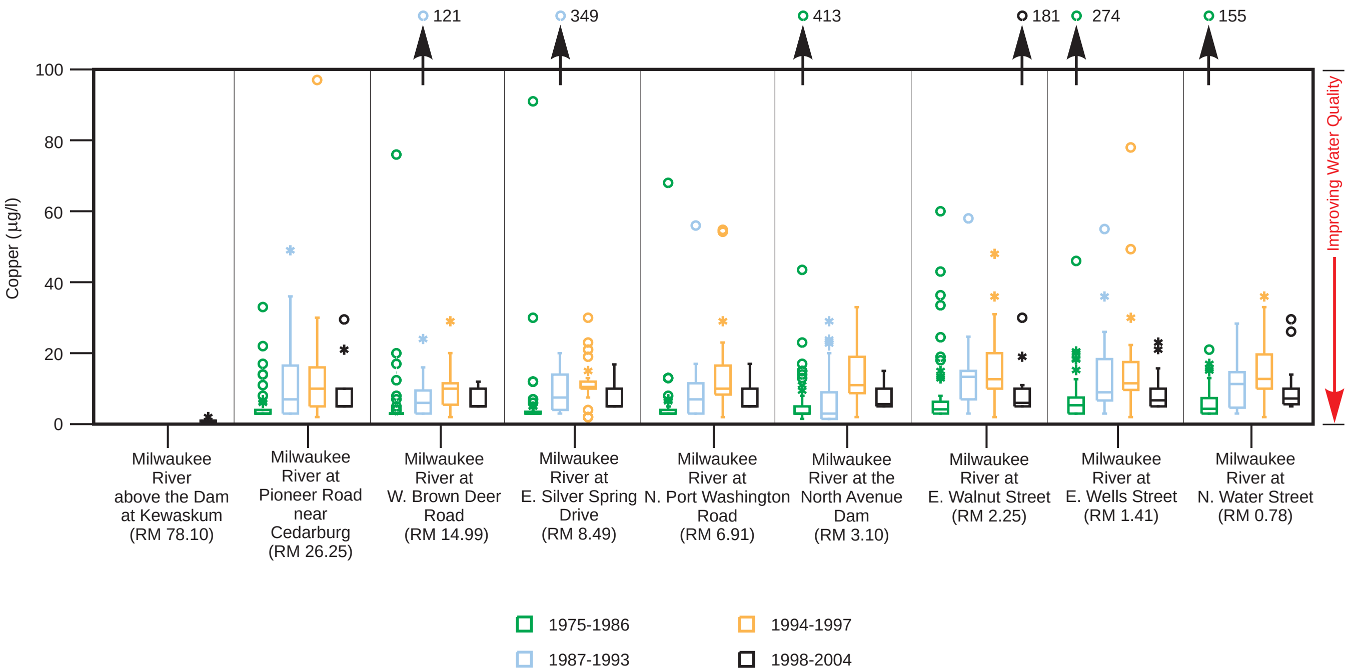
The mean concentration of chromium in the Milwaukee River over the period of record was 14.2 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from below the limit of detection to 8,866.4 μg/l. Prior to 1994, mean concentrations of chromium in the estuary were higher than mean concentrations in the section of the River upstream from the estuary (see Table 87). Since 1994, there have been no significant differences between the mean concentrations of chromium in these two sections of the River. There is a statistically significant trend toward chromium concentrations in the section of the River upstream from the estuary decreasing from upstream to downstream (see Table 88). As shown in Table C-5 in Appendix C, analysis of time-based trends suggests that chromium concentrations are declining within much, though not all, of the River. Only a few Milwaukee River tributaries have been sampled for chromium concentrations. Mean concentrations for Lincoln Creek and Southbranch Creek were 6.78 μg/l and 6.37 μg/l respectively. Significant trends toward decreasing chromium concentrations were detected in both of these tributaries (Table C-5 in Appendix C). The decline in chromium concentration in the Milwaukee River may reflect the loss of industry in some parts of the watershed and the decreasing importance of the metal plating industry in particular, as well as the establishment of treatment of discharges instituted for the remaining and new industries since the late 1970s. There is no evidence of seasonal variation in chromium concentrations in the Milwaukee River. The decline in chromium concentrations represents an improvement in water quality.

Copper

The mean concentration of copper in the Milwaukee River during the period of record was 8.96 μg/l. Concentrations varied from below the limit of detection to 413.00 μg/l. Figure 138 shows copper concentrations at several stations along the mainstem of the River. At most stations, median (and mean) copper concentration increased over time, reaching their highest levels during the period 1994-1997. Table C-5 in Appendix C shows that these trends were statistically significant at several stations. At most stations, median (and mean) copper concentrations were lower during the period 1998-2004 than during the period 1994-1997; however, they were

Figure 138

COPPER CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

still higher than during the period 1975-1986. During all periods, mean copper concentrations in the estuary were higher than mean concentrations in the section of the River upstream of the estuary. Mean copper concentrations in tributaries to the Milwaukee River range from 1.05 μg/l in the East Branch Milwaukee River to 8.72 μg/l in Lincoln Creek. Figure 139 shows copper concentrations at four stations along Lincoln Creek. Concentrations of copper in Lincoln Creek were lower during the period 1998-2004 than during the period 1994-1997. At most stations this represents a significant trend toward decreasing concentrations of copper over time (Table C-5 in Appendix C). The recent decreases in copper concentrations in the Milwaukee River and the trend toward decreasing copper concentrations in the Lincoln Creek represent improvements in water quality.

Lead

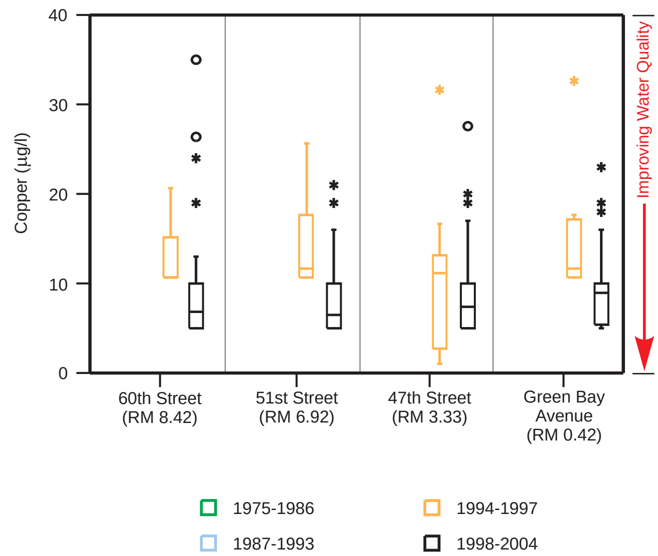
The mean concentration of lead in the Milwaukee River over the period of record was 26.5 μg/. This mean is not representative of current conditions because lead concentrations in the water of the River have been decreasing since the late 1980s, as shown in Figure 140. At all sampling stations for which sufficient data exist to assess trends in lead concentrations, baseline period monthly mean lead concentrations are quite low when compared to historical means and ranges. These decreases represent statistically significant decreasing trends (Table C-5 in Appendix C). A major factor causing the decline in lead concentrations has been the phasing out of lead as a gasoline additive. From 1983 to 1986, the amount of lead in gasoline in the United States was reduced from 1.26 grams per gallon (g/gal) to 0.1 g/gal. In addition, lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in the Milwaukee River followed this reduction in use. In freshwater, lead has a strong tendency to adsorb to particulates suspended in water.[6] As these particles are deposited, they

[6] *H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology *Volume 25, 1991.*

carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the actions of three processes: reduction of lead entering the environment, washing out of lead into the estuary and Lake Michigan, and deposition of adsorbed lead in the sediment. Lead concentrations in the Milwaukee River show no evidence of patterns of seasonal variation. Few data are available for lead concentrations in tributaries of the Milwaukee River. Trends toward lead concentrations decreasing over time were detected at several sampling stations along Lincoln and Southbranch Creeks. The decrease in lead concentrations over time in the Milwaukee River represents an improvement in water quality.

Figure 139

COPPER CONCENTRATIONS AT SITES ALONG LINCOLN CREEK: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Mercury

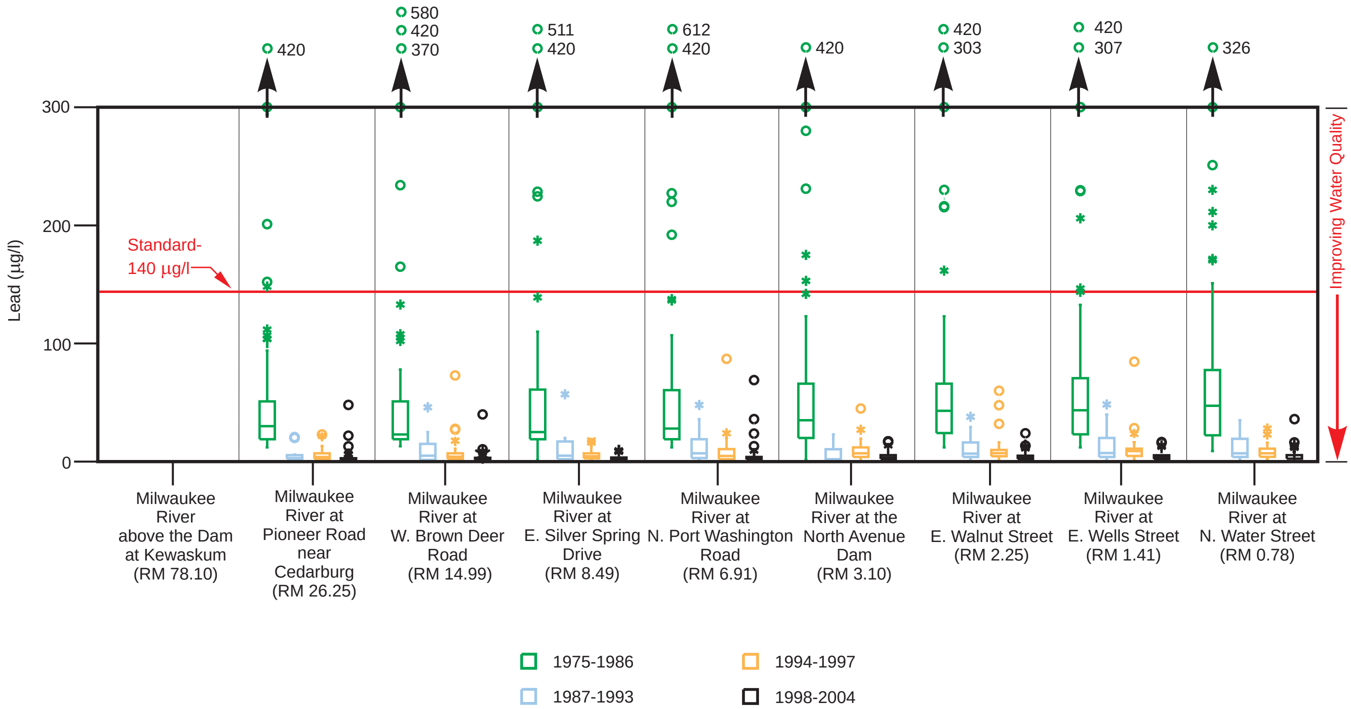
Few historical data on the concentration of mercury in the water of the Milwaukee River exist. Most sampling for mercury in water in the River was taken during or after 1995. The mean concentration of mercury in the River over the period of record was 0.105 μg/l. Mercury concentrations showed moderate variability, with a range from below the limit of detection to 0.880 μg/l. The means at individual stations ranged from 0.001 μg/l at the station at CTH M near Newburg and the stations near the River's mouth to 0.194 μg/l at Pioneer Road. Table 87 shows that during the periods 1994-1997 and 1998-2004, mean concentrations of mercury were higher in the section of the River upstream from the estuary than in the estuary. When examined on an annual basis, significant trends toward decreasing mercury concentrations were detected at all stations in the estuary (Table C-5 in Appendix C). No time-based trends were detected at stations in the section of the River upstream from the estuary. There is no evidence of seasonal variation of mercury concentrations in the Milwaukee River. Few data exist on mercury concentrations in tributary streams. Mean concentrations of mercury detected in Lincoln Creek and Southbranch Creek were 0.045 μg/l and 0.038 μg/l respectively. Significant trends toward mercury concentrations decreasing over time were detected at most stations along Lincoln Creek and two stations along Southbranch Creek (Table C-5 in Appendix C). The trends toward decreasing mercury concentrations at stations in the Milwaukee River estuary and Lincoln and Southbranch Creeks represent improvements in water quality.

Nickel

The mean concentration of nickel in the Milwaukee River over the period of record was 13.5 μg/l. Concentrations in individual samples ranged from below the limit of detection to 3,810.8 μg/l. No significant differences were found between mean concentrations in the estuary and in the section of the River upstream from the estuary (see Table 87). A significant trend toward nickel concentration decreasing from upstream to downstream in the section of the River upstream from the estuary was detected (see Table 88). When examined on an annual basis, significant declines over time were observed at several sampling stations along the mainstem of the River (Table C-5 in Appendix C). This may reflect changes in the amount and types of industry within the Milwaukee River watershed. There was no evidence of seasonal variation in nickel concentration in the Milwaukee River. Data on nickel concentrations are available for few Milwaukee River tributaries. Mean concentrations of nickel in Indian Creek, Lincoln Creek, and Southbranch Creek over the period of record were 8.7 μg/l, 10.5 μg/l, and 8.1 μg/l respectively. Significant trends toward nickel concentrations decreasing over time were detected at all stations along Lincoln Creek (see Table 87). Trends toward decreasing nickel concentrations over time were also

Figure 140

LEAD CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

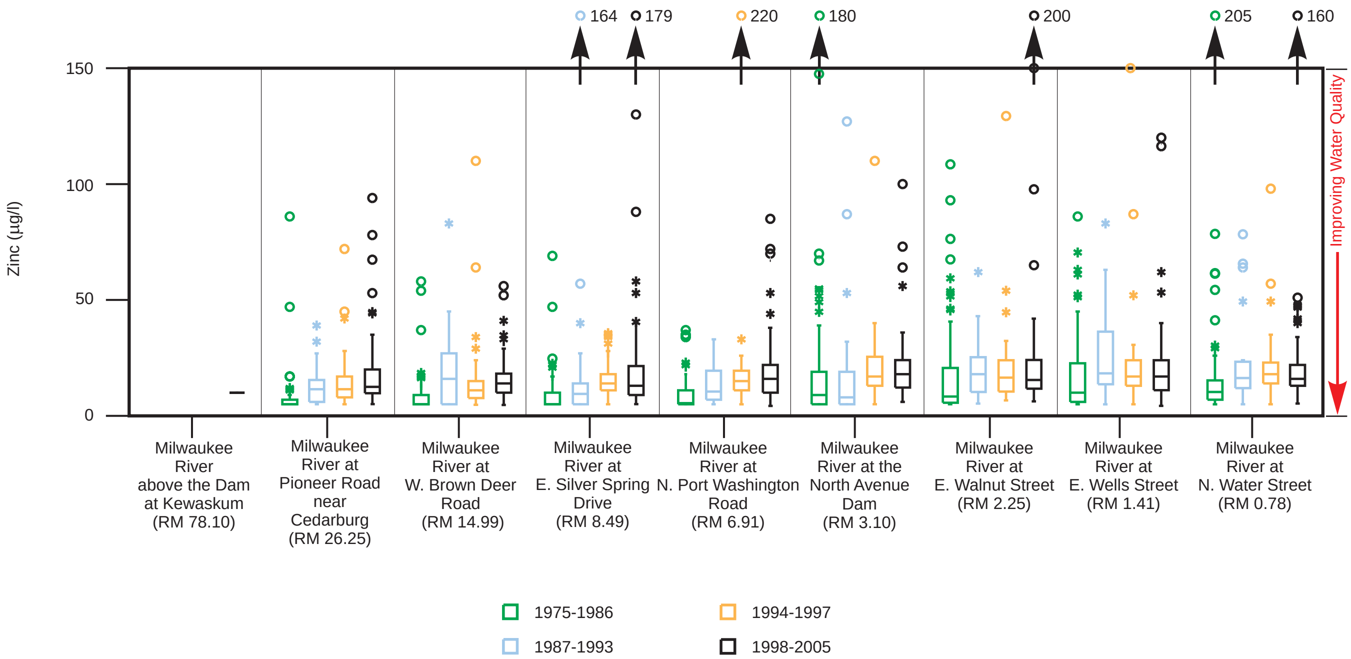
detected at stations along Southbranch Creek; however, the short period of record for this stream makes it difficult to ascertain whether these represent long-term trends (Table C-5 in Appendix C). The decreases in nickel concentrations in the Milwaukee River and Lincoln Creek represent an improvement in water quality.

Zinc

The mean concentration of zinc in the Milwaukee River during the period of record was 18.2 µg/l. Zinc concentrations showed moderate variability. Concentrations in individual samples ranged from 4.3 to 220.0 µg/l. Mean concentrations of zinc were higher in the estuary than in the section of the River upstream of the estuary in all periods (see Table 87). Figure 141 shows that zinc concentrations in the section of the River upstream from the estuary tended to increase from upstream to downstream. This represented a statistically significant trend (see Table 88). The higher concentrations of zinc at the downstream stations may reflect higher amounts of zinc washing into the River during snowmelt and spring rains caused by higher amounts of vehicle traffic in this portion of the watershed. Wear and tear on automobile brake pads and tires are major sources of zinc in the environment. In addition, zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. Stormwater can carry zinc from these sources into the River. Table C-5 in Appendix C of this report shows that there were statistically significant trends toward zinc concentrations increasing over time at most stations along the River. The station at Estabrook Park was an exception to this generalization. There is no evidence of seasonal variation in the concentration of zinc in the Milwaukee River. Data on zinc concentrations are available for only a few Milwaukee River tributaries. Mean concentrations of zinc in tributaries range from 4.6 µg/l in Parnell Creek to 40.2 µg/l in Southbranch Creek. Trends toward zinc concentrations decreasing over time were detected at two stations along Lincoln Creek (Table C-5 in Appendix C). While similar decreasing trends were also detected at stations along Southbranch Creek, the short period of record for this stream makes it difficult to assess whether

Figure 141

ZINC CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

this represents a long-term trend. The trend toward decreasing zinc concentrations at two stations along Lincoln Creek represents an improvement in water quality. The trends toward increasing zinc concentrations in the mainstem of the Milwaukee River represents a reduction in water quality.

Organic Compounds

Between February and June 2004, samples were collected by the USGS on three dates from three sites along the Milwaukee River—Pioneer Road, Estabrook Park, and Jones Island—and at N. 47th Street along Lincoln Creek. Those samples were examined for the presence and concentrations of several organic compounds dissolved in water. Whole water samples were also collected from the Lincoln Creek site on eight dates during the winter of 2001-2002. Bromoform, a disinfectant byproduct, was detected in one sample from Lincoln Creek collected in 2002 at a concentration of 0.06 µg/l. It was not detected in the Milwaukee River or Lincoln Creek during the 2004 sampling. Dissolved isophorone, a solvent, was detected in 2004 in one sample each from the Milwaukee River at Pioneer Road and Jones Island and from Lincoln Creek at a concentration of 0.1 µg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human threshold criterion for public health and welfare for fish and aquatic life waters. Carbazole, a component of dyes, lubricants, and pesticides, was detected in two samples from Lincoln Creek and one sample from the Milwaukee River at Jones Island in 2004 at a concentration of 0.1 µg/l. In 2004, the plasticizer triphenyl phosphate was found in all samples collected from Lincoln Creek and from samples collected from the Milwaukee River at Estabrook Park and Jones Island at a concentration of 0.1 µg/l. Three flame retardant chemicals were detected in samples from the Milwaukee River and Lincoln Creek. Tri(2-chloroethyl) phosphate was detected in all three samples collected from Lincoln Creek in 2004 at concentrations ranging between 0.1 µg/l and 0.2 µg/l. It was also detected in five samples from the Milwaukee River at a concentration of 0.1 µg/l. In 2004, Tri(dichloroisopropyl) phosphate was detected in all samples collected from Lincoln Creek and four samples collected from the Milwaukee River at a concentration of 0.1 µg/l. Tributyl phosphate was detected in two samples collected from Lincoln Creek and one sample from each

Milwaukee River station at a concentration of 0.1 μg/l. Vinyl chloride was detected in eight whole water samples collected from Lincoln Creek in 2001 and 2002 at concentrations ranging between 0.21 μg/l and 0.94 μg/l. Finally, the compound p-nonylphenol, a metabolite of nonionic detergents, was detected in two samples in Lincoln Creek and one sample each at Pioneer Road and Jones Island at concentrations ranging between 1.0 μg/l and 2.0 μg/l. This compound is known to be an endocrine disruptor.

Pharmaceuticals and Personal Care Products

During fall 2001, the Milwaukee River at Estabrook Park and Lincoln Creek at N. 47th Street were sampled for the presence of caffeine in water. In addition, in February, March, and May 2004, the USGS sampled water from three sites along the Milwaukee River—Pioneer Road, Estabrook Park, and Jones Island—and at N. 47th Street along Lincoln Creek for the presence of several compounds found in pharmaceuticals and personal care products. Caffeine, a stimulant found in beverages and analgesics, was detected in all of the samples collected from Lincoln Creek at concentrations ranging between 0.08 μg/l and 0.65 μg/l. It was detected in some samples from the Milwaukee River at concentrations ranging between 0.004 μg/l and 0.200 μg/l. N,N-diethyl-meta-toluamide (DEET), the active ingredient used in many insect repellants, was detected in most of the samples collected in Lincoln Creek and the Milwaukee River at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Cotinine, a metabolite of nicotine, was detected in two samples from Lincoln Creek at concentrations of about 0.24 μg/l. It was not detected in samples from the Milwaukee River. Camphor, a fragrance and flavoring agent, was detected in samples from both Lincoln Creek and the Milwaukee River at a concentration of 0.1 μg/l. Menthol, another fragrance and flavoring agent, was detected in samples from Lincoln Creek at a concentration of 0.1 μg/l. Acetophenone, a fragrance used in soaps and detergents was detected in two samples from Lincoln Creek and two samples from the Milwaukee River at a concentration of 0.1 μg/l. Benzophenone, a fixative used in soaps and perfumes, was detected in all samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Acetyl-hexamethyl-tetrahydro-naphthalene (AHTN), a synthetic musk fragrance, was detected in most samples at a concentration of 0.1 μg/l. Hexahydrohexamethylcyclopentabenzopyran (HHCB), another musk fragrance, was detected in samples from each site at a concentration of 0.1 μg/l. A final fragrance, d-limonene, was detected in one sample collected from Lincoln Creek at a concentration of 0.1 μg/l. Finally, triethyl citrate, a component of cosmetics, was detected at least once at each station at a concentration of 0.1 μg/l. The sources of these compounds to the Milwaukee River are not known. Given that no combined sewer overflows or separate sanitary sewer overflows were reported in the week before each of the 2001 samplings for caffeine, it is unlikely that sewer overflows are the source of this compound in Lincoln Creek and the Milwaukee River. Additional information on pharmaceuticals and personal care products, including general descriptions of possible sources of these pollutants, is set forth in Chapter II of this report.

Water Quality of Lakes and Ponds

The Milwaukee River watershed contains 20 lakes with a surface area of 50 acres or more, as well as numerous other named lakes and ponds with surface areas of less than 50 acres. These lakes are distributed within 12 subwatersheds: the Cedar Creek, Cedar Lake, East Branch Milwaukee River, Kettle Moraine Lake, Lake Fifteen Creek, Lower Cedar Creek, Lower Milwaukee River, Middle Milwaukee River, North Branch Milwaukee River, Silver Creek (Sheboygan County), Silver Creek (Washington County), and Watercress Creek subwatersheds. The major lake in the Cedar Creek subwatershed is Little Cedar Lake. The major lake in the Cedar Lake subwatershed is Big Cedar Lake. The three major lakes in the East Branch Milwaukee River subwatershed are Crooked, Forest, and Mauthe Lakes. The two major lakes in the Kettle Moraine Lake subwatershed are Kettle Moraine Lake and Mud Lake (Fond du Lac County). The major lake in the Lake Fifteen Creek subwatershed is Auburn Lake. The major lake in the Lower Cedar Creek subwatershed is Mud Lake (Ozaukee County). The major lake in the Lower Milwaukee River subwatershed is Lac du Cours. The two major lakes in the Middle Milwaukee subwatershed are Barton Pond and Smith Lake. The four major lakes in the North Branch subwatershed are Lake Ellen and Green, Twelve, and Wallace Lakes. The two major lakes in the Silver Creek (Sheboygan County) subwatershed are Random Lake and Spring Lake. The two major lakes in the Silver Creek (Washington County) subwatershed are Lucas Lake and Silver Lake. The major lake in the Watercress Creek subwatershed is Long Lake (Fond du Lac County). The physical characteristics of the lakes and ponds in the Milwaukee River watershed are given in Table 92.

Table 92

LAKES AND PONDS OF THE MILWAUKEE RIVER WATERSHED

Name	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Allis Lake	9	34	- -	Seepage lake	- -
Auburn Lake (Lake Fifteen)	107	29	14	Drainage lake	Walk in trail
Barton Pond	67	5	3	Drainage lake	Walk in trail
Batavia Pond	1	5	- -	Drainage lake	- -
Beechwood Lake	11	20	- -	Seepage lake	Boat ramp
Big Cedar Lake	932	105	34	Spring lake	Barrier free boat ramp
Birchwood Lake	31	- -	- -	- -	- -
Boltonville Pond	10	10	5	- -	- -
Brickyard Lake	1	4	- -	Seepage lake	- -
Brown Deer Park Pond	6	6	4	Drainage lake	- -[a]
Butler Lake	7	13	- -	Drainage lake	Boat Ramp
Buttermilk Lake	13	6	2	Seepage lake	Roadside
Butzke Lake	16	8	4	Drainage lake	Walk in trail
Cambellsport Millpond	22	10	4	Drainage lake	Walk in trail
Cascade Millpond	7	3	- -	Drainage lake	Walk in trail
Cedar Lake (Fond du Lac County)	19	19	9	Seepage lake	Walk in trail
Cedar Lake (Sheboygan County)	10	10	6	Seepage lake	Wilderness in public ownership
Cedarburg Pond	14	9	- -	Drainage lake	- -
Cedarburg Stone Quarry	6	10	- -	Seepage lake	- -
Chair Factory Millpond	6	7	- -	Drainage lake	- -
Columbia Pond	- -	- -	- -	- -	- -
Crooked Lake	91	32	12	Seepage lake	Barrier free boat ramp
Daly Lake	13	8	- -	Seepage lake	- -
Dickman Lake	9	12	7	Seepage lake	- -
Dineen Park Pond	2	5	- -	Drainage lake	- -[a]
Donut Lake	4	3	- -	Drainage lake	- -
Drzewiceki Lake	2	17	- -	Spring lake	- -
Ehne Lake	18	15	5	Spring lake	- -
Erler Lake	37	34	14	Spring lake	- -
Estabrook Park Lagoon	1	6	- -	Drainage lake	- -[a]
Forest Lake	51	32	11	Seepage lake	Walk in trail
Fromm Pit	4	28	- -	Spring lake	Navigable water
Gilbert Lake	44	30	3	Spring lake	Navigable water
Gooseville Millpond	38	7	- -	Drainage lake	- -
Gough Lake	5	29	- -	Seepage lake	- -
Grafton Millpond	25	8	- -	Drainage lake	Boat ramp
Green Lake	71	37	17	Seepage lake	Boat ramp
Haack Lake	16	18	7	Drainage lake	- -
Hamilton Pond[b]	6	18	- -	Seepage lake	- -
Hanneman Lake	6	18	- -	Seepage lake	- -
Hansen Lake	6	9	- -	Seepage lake	- -
Hasmer Lake	15	34	17	Drainage lake	Walk in trail
Hawthorn Lake	8	12	- -	Seepage lake	- -
Hawthorn Hills Pond	- -	- -	- -	- -	- -
Horn Lake	12	30	- -	Seepage lake	- -
Hurias Lake	26	7	- -	Seepage lake	- -
Juneau Park Lagoon	15	6	4	Drainage lake	- -[a]
Kelling Lakes #1	1	7	- -	Seepage lake	Wilderness in public ownership
Kelling Lakes #2	1	7	- -	Seepage lake	Wilderness in public ownership
Kelling Lakes #3	3	7	- -	Seepage lake	Wilderness in public ownership
Keowns Pond	1	15	- -	Drainage lake	- -
Kettle Moraine Lake	227	30	6	Seepage lake	Roadside
Kewaskum Millpond	5	8	- -	Drainage lake	Walk in trail
Lake Bernice	35	11	5	Drainage lake	Roadside
Lake Ellen	121	42	16	Drainage lake	Barrier free boat ramp
Lake Lenwood	15	38	19	Spring lake	- -
Lake Seven	27	25	12	Seepage lake	Barrier free boat ramp

Table 92 (continued)

Name	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Lake Sixteen	8	13	- -	Seepage lake	- -
Lake Twelve	53	20	6	Spring lake	- -
Lehner Lake	3	22	15	Spring lake	- -
Lent Lake	8	7	- -	Drainage lake	Navigable water
Lime Kiln Millpond	4	7	- -	Drainage lake	Walk in trail
Lincoln Park Lagoon	- -	- -	- -	- -	- -
Lindon Pond	2	15	- -	Spring lake	- -
Mauthe Lake	78	23	12	Drainage lake	Boat ramp, Barrier free pier
McGovern Park Pond	5	5	3	Drainage lake	- -[a]
Mee-Quon Park Pond	- -	- -	- -	- -	- -
Miller Lake	3	16	- -	Seepage lake	- -
Moldenhaur Lake	3	32	- -	Seepage lake	Walk in trail
Mud Lake (Ozaukee County)	245	4	3	Seepage lake	Wilderness in public ownership
Mud Lake (Fond du Lac County)	55	17	8	Drainage lake	- -
New Fane Millpond	5	5	3	Drainage lake	Navigable water
Newburg Pond	7	8	- -	Drainage lake	Walk in trail
Paradise Valley Lake	9	35	- -	Drainage lake	- -
Pit Lake	35	14	- -	Seepage lake	- -
Proschinger Lake	6	23	- -	Seepage lake	- -
Quaas Lake	7	12	- -	Spring lake	- -
Radke Lake	10	14	7	Seepage lake	- -
Random Lake	209	21	6	Drainage lake	Boat ramp
Roeckl Lake	3	12	- -	Seepage lake	- -
Ruck Pond	- -	- -	- -	- -	- -
Schwietzer Pond	8	4	- -	Drainage lake	- -
Senn Lake	16	8	6	Drainage lake	- -
Silver Lake	118	47	20	Drainage lake	- -
Smith Lake	86	5	3	Seepage lake	Boat ramp
Spring Lake (Fond du Lac County)	10	2	2	Seepage lake	- -
Spring Lake (Ozaukee County)	57	22	7	Seepage lake	- -
Spruce Lake	34	4	3	Seepage lake	Walk in trail
Thiensville Millpond	45	8	- -	Drainage lake	Boat ramp
Tily Lake	13	48	24	Spring lake	- -
Tittle Lake	17	26	- -	Drainage lake	Navigable water
Uihlein Pond	1	8	- -	Drainage lake	- -
Unnamed Lake (T11N R21E S17)	12	5	- -	- -	- -
Wallace Lake	52	35	11	Spring lake	Boat ramp
Washington Park Pond	11	5	3	Drainage lake	- -[a]
Wire and Nail Pond	- -	- -	- -	- -	- -
Zeunert Pond	- -	- -	- -	- -	- -

[a]*Private boats of any kind are not allowed on ponds in Milwaukee County Parks. Where available, commercial facilities provide boat liveries operated by the park.*

[b]*The dam at Hamilton Pond failed in 1996.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Rating of Trophic Condition

Lakes and ponds are commonly classified according to their degree of nutrient enrichment—or trophic status. The ability of lakes and ponds to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated with their degrees of nutrient enrichment. Three terms are generally used to describe the trophic status of a lake or pond: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes and ponds. These lakes characteristically support relatively few aquatic plants and often do not contain very productive fisheries. Oligotrophic lakes and ponds may provide excellent opportunities for swimming, boating, and waterskiing. Because of the naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

Mesotrophic lakes and ponds are moderately fertile lakes and ponds which may support abundant aquatic plant growths and productive fisheries. However, nuisance growths of algae and macrophytes are usually not exhibited by mesotrophic lakes and ponds. These lakes and ponds may provide opportunities for all types of recreational activities, including boating, swimming, fishing, and waterskiing. Many lakes and ponds in southeastern Wisconsin are mesotrophic.

Eutrophic lakes and ponds are nutrient-rich lakes and ponds. These lakes and ponds often exhibit excessive aquatic macrophyte growths and/or experience frequent algae blooms. If they are shallow, fish winterkills may be common. While portions of such lakes and ponds are not ideal for swimming and boating, eutrophic lakes and ponds may support very productive fisheries.

The Trophic State Index (TSI) assigns a numerical trophic condition rating based on Secchi-disc transparency, and total phosphorus and chlorophyll-*a* concentrations. The original Trophic State Index, developed by Carlson,[7] has been modified for Wisconsin lakes by the Wisconsin Department of Natural Resources using data on 184 lakes throughout the State.[8] The Wisconsin Trophic State Index (WTSI) ratings for Ellen, Forest, Green, and Wallace Lakes are shown in Figure 142 as a function of sampling date. Figure 143 shows the WTSI ratings for Big Cedar, Little Cedar, Long (Fond du Lac County), and Random Lakes as a function of sampling date.

Based on the Wisconsin Trophic State Index ratings shown, the eight lakes for which data were available may be classified as meso-eutrophic, although the Wisconsin Trophic State Index values ranged from oligotrophic to eutrophic during the periods of record. The data shown in Figures 142 and 143 suggest that the eight lakes behaved in a similar manner during the study period, although, for some of the lakes, the data are not sufficient to assess whether the trophic status of these lakes have changed over the study period. Nevertheless, viewed in their totality, it could be suggested that the eight lakes all behaved in a similar manner. Data on water clarity form the most complete data sets for all eight lakes, with Green, Big Cedar, Long (Fond du Lac County), and Random Lakes having data sets that encompassed all or most of the study period.

These data suggest an approximately decadal periodicity, with high WTSI values occurring during the mid-1980s, declining to lower values during the early 1990s, and returning to slightly high values toward the middle of the decade. This period repeated, with lower values being observed during the late 1990s. For a given lake, the significant degree of overlap among years, as shown in Figures 142 and 143, would suggest that these differences are not statistically significant. These same distribution patterns are reflected in the chlorophyll-*a* and total phosphorus concentration data, to the extent that they are available. Also, the pattern of periodicity is consistent among both larger and smaller lakes, those with a surface area of less than 200 acres and those with a surface area of greater than 200 acres. Green, Long (Fond du Lac County), and Big Cedar Lakes have the most complete records of the eight lakes for which data are presented.

Based on the Wisconsin Trophic State Index ratings shown, Ellen Lake may be classified as meso-eutrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 45 to about 55, or from mesotrophic to slightly eutrophic as would be consistent with a meso-eutrophic status. Available chlorophyll-*a* data and total phosphorus data are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 46 to 49 in the mid-1980s to about 47 in 1997, while the median WTSI values based upon total phosphorus concentrations range from about 41 to 47 during the mid-1980s to about 48 in 1997. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

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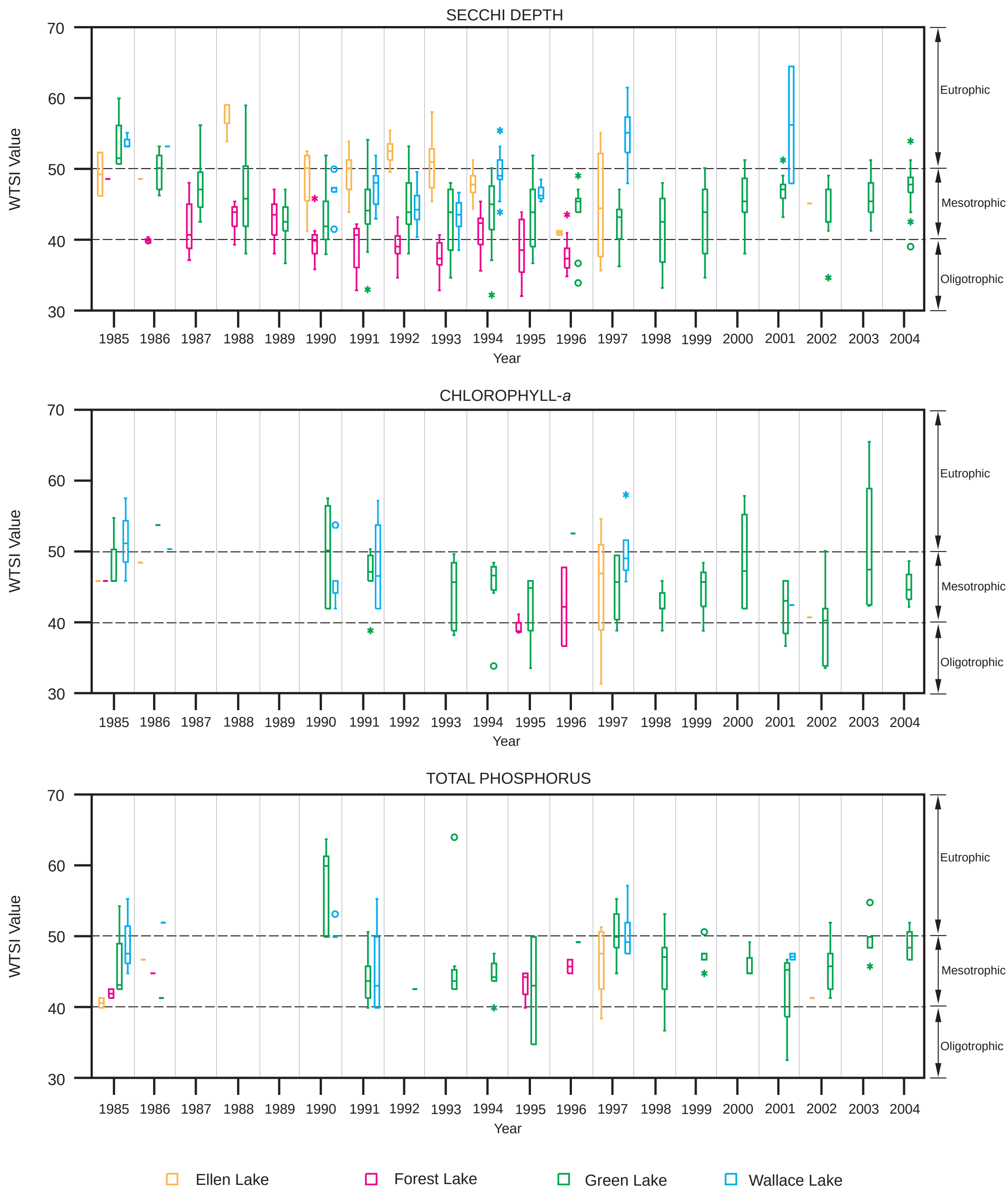
[7]*R.E. Carlson, "A Trophic State Index for Lakes,"* Limnology and Oceanography, *Vol. 22, No. 2, 1*977.

[8]*R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings, *Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

Figure 142

WISCONSIN TROPHIC STATE INDEX (WTSI) OF LAKES UNDER 200 ACRES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004

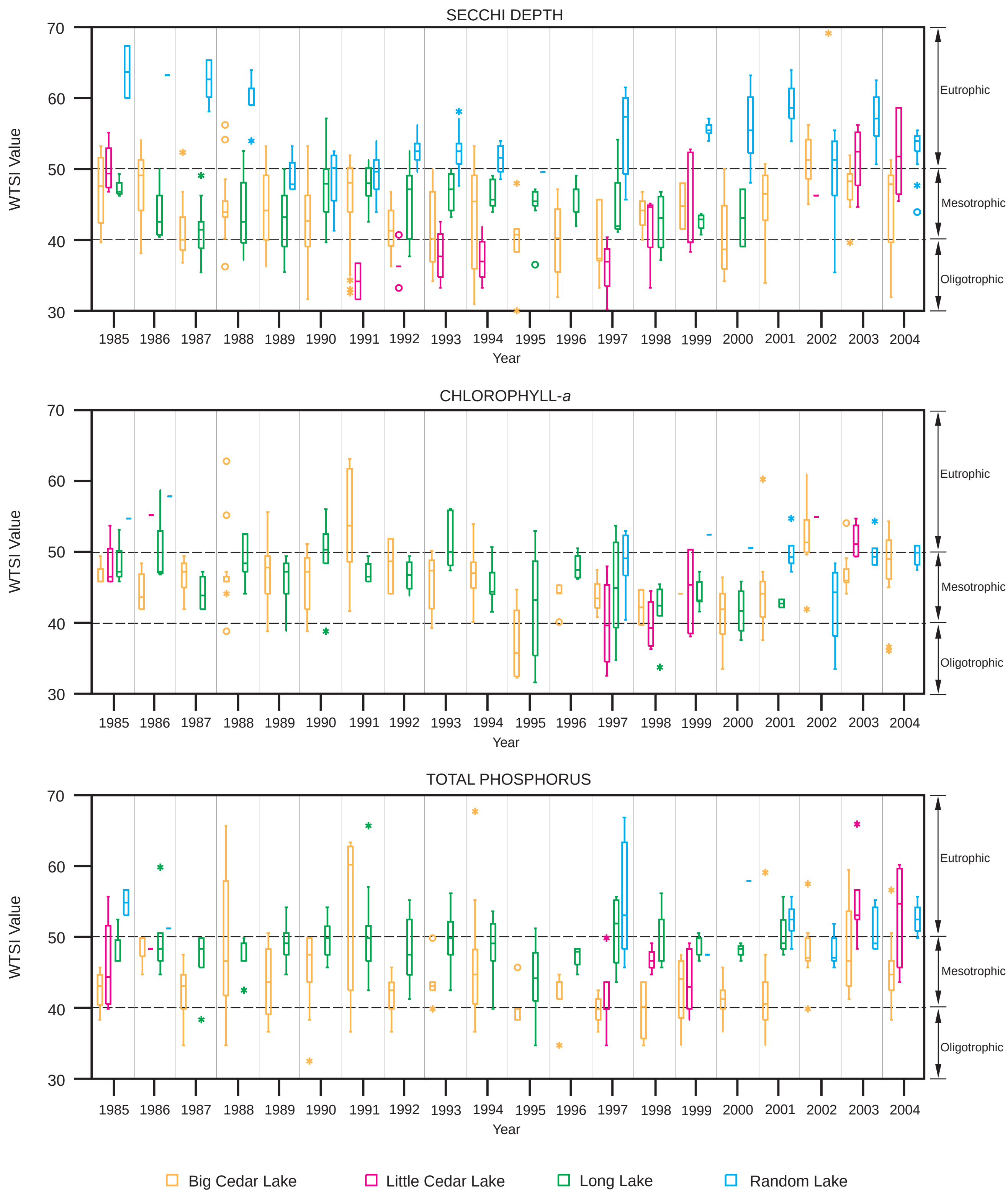


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 143

WISCONSIN TROPHIC STATE INDEX (WTSI) OF LAKES OVER 200 ACRES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Based on the Wisconsin Trophic State Index ratings shown, Forest Lake may be classified as oligo-mesotrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 37 to about 45, or from oligotrophic to moderately mesotrophic. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 46 in the mid-1980s to about 39 to 43 in 1995 and 1996. The median WTSI values based upon total phosphorus concentrations range from about 41 to 45 during the mid-1980s to about 45 and 46 in 1995 and 1996. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Green Lake may be classified as mesotrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 42 to about 51, or from mesotrophic to slightly eutrophic as would be consistent with a mesotrophic status. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 40 in 2002 to about 50 in 1990, while the median WTSI values based upon total phosphorus concentrations range from about 43 during the mid-1980s to about 60 in 1990, although the majority of the total phosphorus-based WTSI values were at or below a value of 50.[9] The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Wallace Lake may be classified as meso-eutrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 44 in 1992 and 1993 to about 55 to 57 during 1997 and 2001, or from mesotrophic to moderately eutrophic. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 51 in the mid-1980s to about 46 in the early 1990s to about 49 in 1997. The median WTSI values based upon total phosphorus concentrations range from about 43 during 1991 to about 48 to 49 in 1985, 1997, and 2001. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Big Cedar Lake may be classified as mesotrophic.[10] The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 38 to about 51, or from slightly oligotrophic to slightly eutrophic as would be consistent with a mesotrophic status. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 36 in the mid-1990s to about 53 in 1991, while the median WTSI values based upon total phosphorus concentrations range from about 40 during the mid-1990s to about 60 in 1991. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Little Cedar Lake may be classified as meso-eutrophic.[11] The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 33 to about 52, or from oligotrophic to moderately mesotrophic. Available chlorophyll-*a* data and total

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[9]*The total phosphorus-based WTSI values reported during 1990 suggest that the Lake was eutrophic and high in total phosphorus; however, the corresponding Secchi disk and chlorophyll-a based WTSI values are inconsistent with this and suggest a mesotrophic classification.*

[10]*See also SEWRPC Memorandum Report No. 137,* A Water Quality Protection and Stormwater Management Plan for Big Cedar Lake, Washington County, Wisconsin*, Volume 1.* Inventory Findings, Water Quality Analyses, Recommended Management Measures, *August 2001.*

[11]*See also SEWRPC Memorandum Report No. 146,* An Aquatic Plant Management Plan for Little Cedar Lake, Washington County, Wisconsin*, May 2004.*

phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 40 in 1997 and 1998 to about 51 in 2003. The median WTSI values based upon total phosphorus concentrations range from about 40 during 1997 to about 54 and 55 in 2003 and 2004. The annual ranges set forth in Figure 143 suggest that any trends in WTSI ratings for this lake probably are the result of interannual variability, at least through the end of the 1990s, with consistently higher values being reported during the 2000s, which may be suggestive of a trend toward increasing trophic state during these more recent years.

Based on the Wisconsin Trophic State Index ratings shown, Long Lake (Fond du Lac County) may be classified as mesotrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 41 to about 48, consistent with a mesotrophic status. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 42 in the late-1990s to about 50 in the early 1990s, while the median WTSI values based upon total phosphorus concentrations range from about 44 during the mid-1990s to about 52 during the late-1990s. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Random Lake may be classified as eutrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 48 to about 65, or from meso-eutrophic to highly eutrophic. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the meso-eutrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 46 in 2002 to about 50 in 2004. The median WTSI values based upon total phosphorus concentrations range from about 47 during 2002 to between about 53 and 55 in 1985, 1997, 2001 and 2004. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Bacterial Parameters

No data on concentrations of fecal coliform bacteria were available for lakes within the Milwaukee River watershed. Some limited data on concentrations of *E. coli* were available for four lakes. During the period 1998-2004, the concentrations of *E. coli* in 22 samples from Big Cedar Lake ranged between 37 cells per 100 ml and 62 cells per 100 ml, with a mean of 48.7 cells per 100 ml. During the period 1998-2004, the concentrations of *E. coli* in 29 samples from Green Lake ranged between 35 cells per 100 ml and 66 cells per 100 ml, with a mean of 44.8 cells per 100 ml. During 2004, the concentrations of *E. coli* in 4 samples from Little Cedar Lake ranged between 51 cells per 100 ml and 61 cells per 100 ml, with a mean of 52.8 cells per 100 ml. During the period 2002-2004, the concentrations of *E. coli* in 13 samples from Green Lake ranged between 40 cells per 100 ml and 55 cells per 100 ml, with a mean of 49.2 cells per 100 ml. The USEPA requires that beaches be posted with warning signs informing the public of increased health risks when the concentration of *E. coli* exceeds 235 cells per 100 ml. All of the samples collected from these four lakes during the baseline period are below this threshold.

Chemical and Physical Parameters

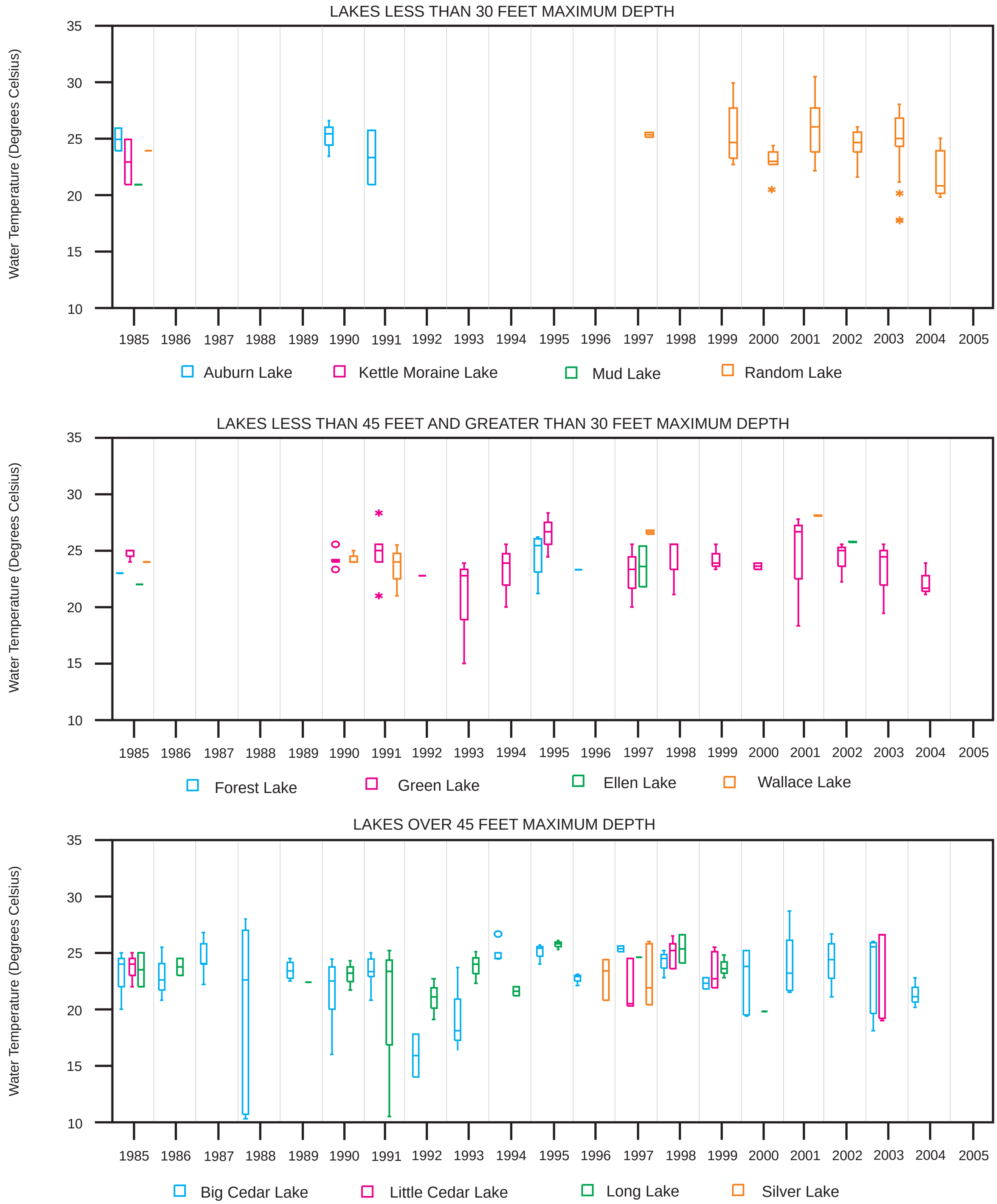
Data on water chemistry were available for twelve lakes in the Milwaukee River watershed: Auburn, Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Long (Fond du Lac County), Mud (Fond du Lac County), Random, Silver, and Wallace Lakes.

Figures 144 and 145 show the summer surface and hypolimnetic water temperatures in the twelve lakes for which data are available for the years 1985 through 2004. Surface water temperatures represent those samples taken within three feet of the lake’s surface. Hypolimnetic temperatures represent samples taken from depths below 15 feet from the lake’s surface.

The temperature data indicate that the majority of lakes for which data are available thermally stratify during the summer months, with hypolimnetic water temperatures being about 5°C to 15°C below surface water temperatures on average. Lakes with a maximum depth of less than 35 feet typically have a lesser thermal

Figure 144

SURFACE WATER TEMPERATURES IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004

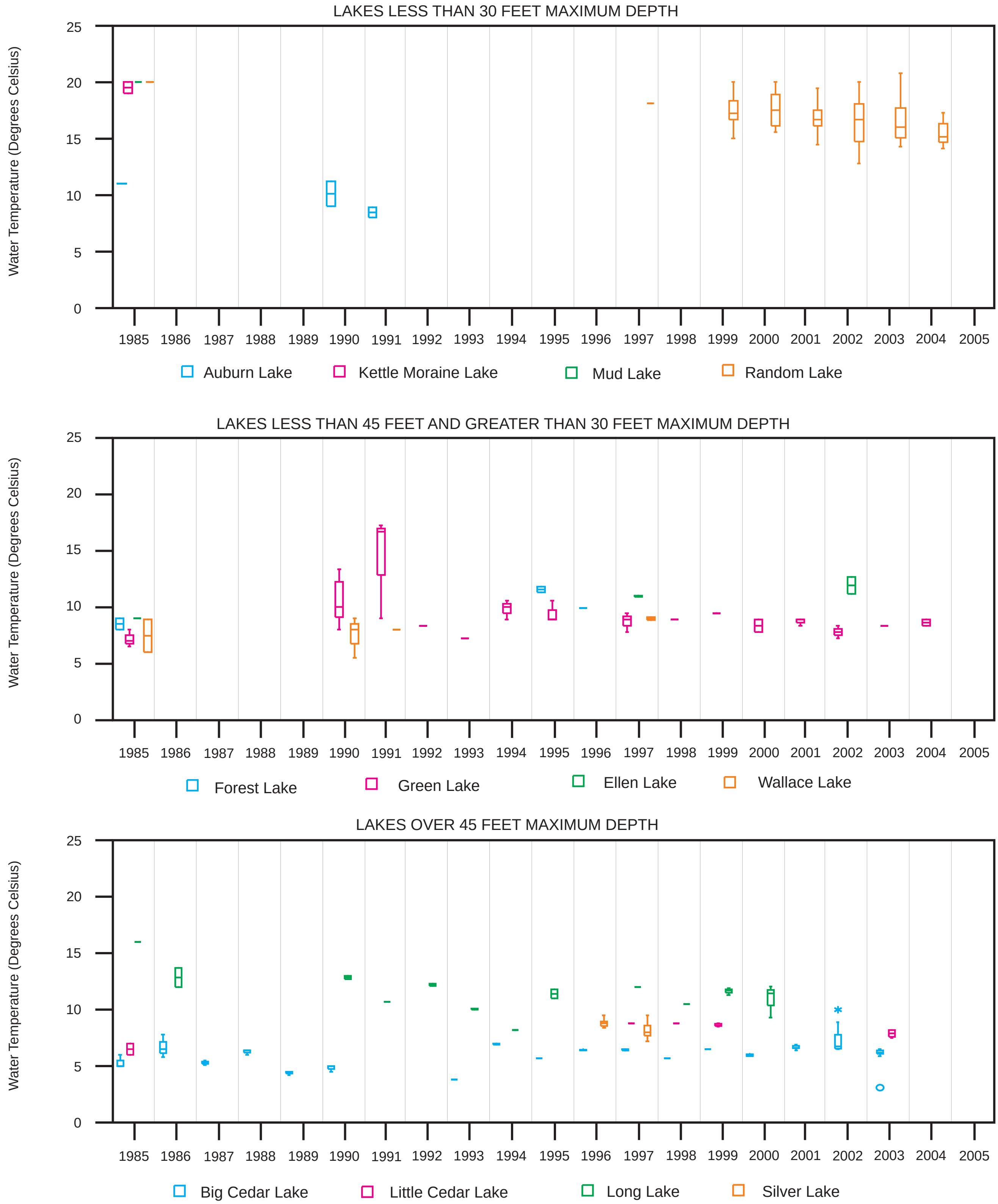


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 145

DEEP (HYPOLIMNETIC) WATER TEMPERATURES IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

gradient than the deeper lakes. During thermal stratification, a layer of relatively warm water floats on top of a layer of cooler water. Thermal stratification is a result of the differential heating of the lake water, and the resulting water temperature-density relationships at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit of volume, at about 4°C. During stratification, the top layer, or epilimnion, of the waterbody is cut off from nutrient inputs from the sediment. At the same time, the bottom layer, or hypolimnion, is cut off from the atmosphere and sunlight penetration. Over the course of the summer, water chemistry conditions can become different between the layers of a stratified waterbody. In southeastern Wisconsin, the development of summer thermal stratification begins in late spring or early summer when surface waters begin to heat up, reaches its maximum in late summer, and disappears in the fall when surface waters cool.

Average surface water temperatures ranged between about 20°C and 30°C, with the warmer surface water temperatures being reported from the lakes with a maximum depth of less than 30 feet, as shown in Figure 144. The deeper water lakes, with maximum depths greater than 45 feet, tended to have slightly cooler surface water temperatures during the period of record, ranging between 20°C and 25°C, during most years. Likewise, average hypolimnetic water temperatures typically ranged between 10°C and 20°C in the shallower lakes with maximum depths of less than 30 feet, and between 5°C and 15°C in the deeper water lakes. These temperature differences were sufficient to set up stable stratification within these lakes during most years.

Variations in surface water temperatures can be discerned in the data for Big Cedar Lake, Green Lake, and Little Cedar Lake, shown in Figure 144, with a tendency toward a cyclical pattern of slightly warmer and slightly cooler water temperatures being observed. The early- to mid-1990s appeared to be a period of slightly cooler surface temperatures, while the late-1990s appeared to be slightly warmer. The early-2000s again appeared to be slightly cooler, suggesting an approximately decadal cycle corresponding to that indicated by the WTSI values. These surface water temperature variations were less pronounced than those observed in several major lakes outside of the Milwaukee River watershed in Waukesha County, where increases in surface water temperatures of up to 5°C to 10°C have been noted during this period.[12] Hypolimnetic water temperatures generally show less variation, especially since 1992.

Figures 146 and 147 show summer surface and hypolimnetic dissolved oxygen concentrations from the twelve lakes during the study period, from 1985 through 2004. During the summer, dissolved oxygen concentrations in the hypolimnia of the lakes tend to be substantially lower than dissolved oxygen concentrations at the surface. In the deeper lakes, with maximum depths of greater than 45 feet, the hypolimnia become anoxic during most summers. This is consistent with the characterization of these lakes as meso-eutrophic or eutrophic waterbodies. The lower oxygen concentration in the hypolimnion results from depletion of available oxygen through chemical oxidation and microbial degradation of organic material in water and sediment.

Hypolimnetic anoxia is common in many of the lakes in southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion cause fish to move upward, nearer to the surface of the lakes, where higher dissolved oxygen concentrations exist. This migration, when combined with temperature, can select against some fish species that prefer the cooler water temperatures that generally prevail in the lower portions of the lakes. When there is insufficient oxygen at these depths, these fish are susceptible to summer-kills, or, alternatively, are driven into the warmer water portions of the lake where their condition and competitive success may be severely impaired.

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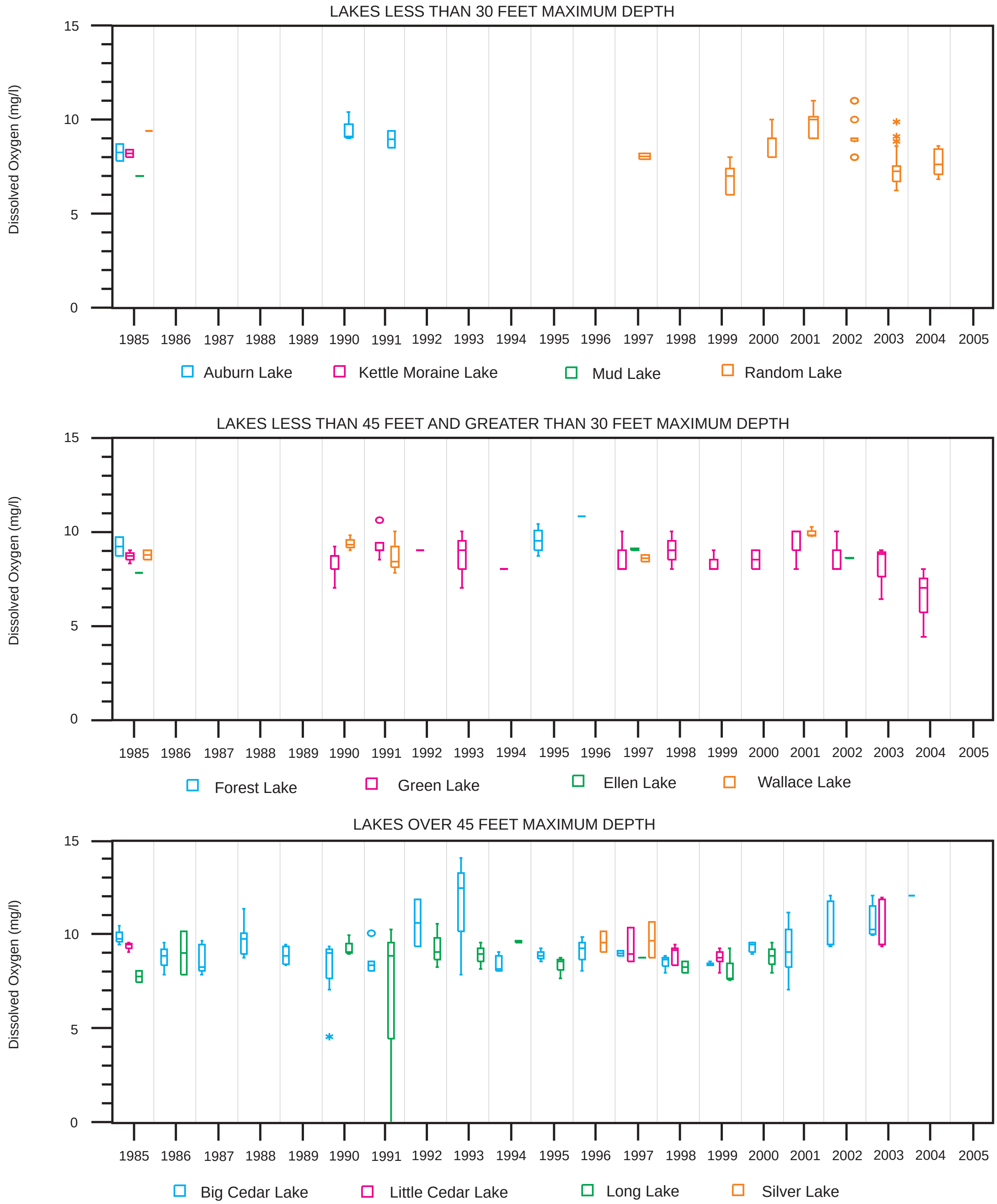
[12]*See, for example, SEWRPC Community Assistance Planning Report No. 58, 2nd Edition,* A Lake Management Plan for Pewaukee Lake, Waukesha County, Wisconsin, *May 2003; SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* A Lake Management Plan for Okauchee Lake, Waukesha County, Wisconsin, *December 2003; SEWRPC Community Assistance Planning Report No. 47, 2nd Edition,* A Lake Management Plan for Lac La Belle, Waukesha County, Wisconsin, *May 2007.*

Figure 146

SURFACE DISSOLVED OXYGEN IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004

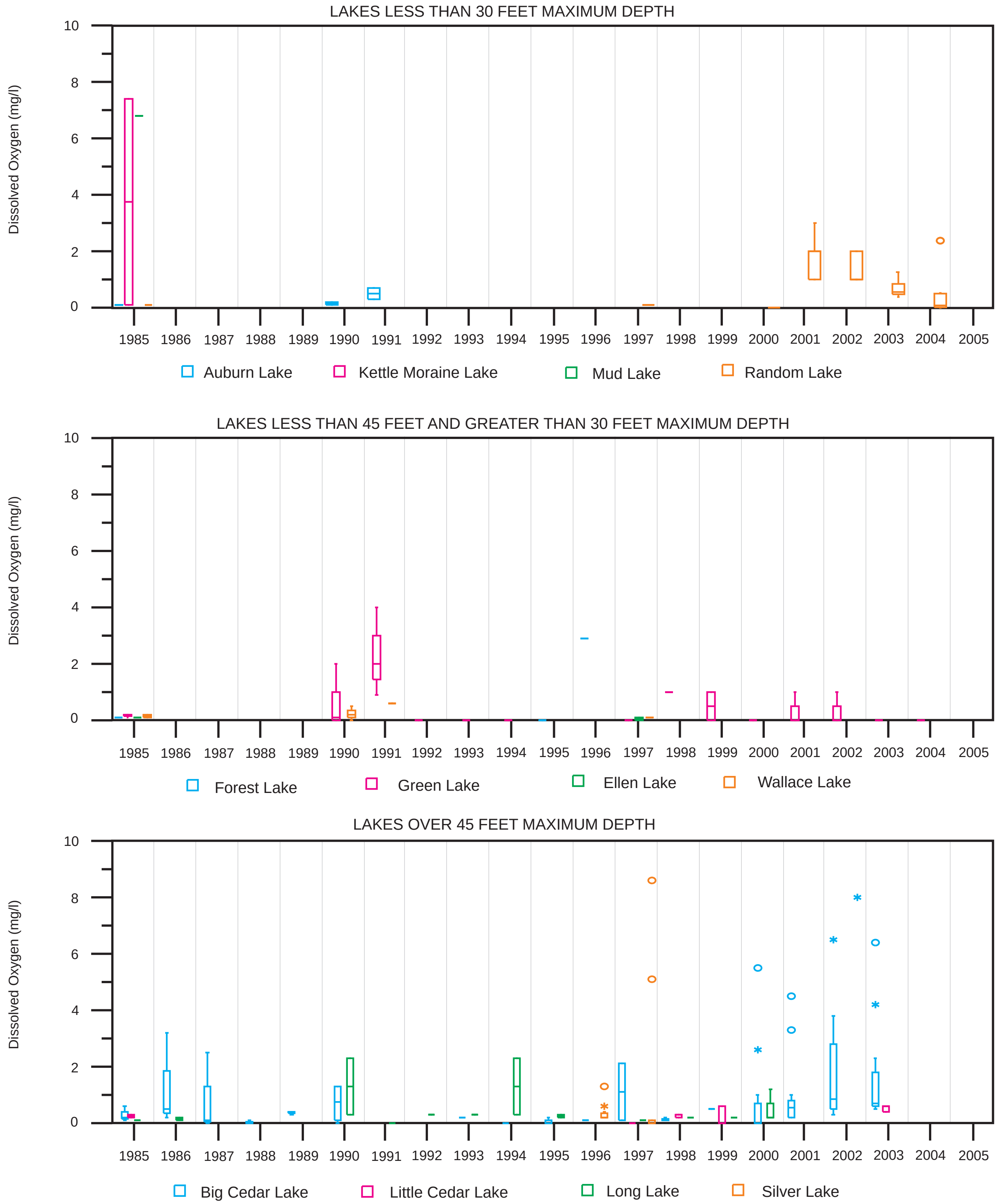


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 147

DEEP (HYPOLIMNETIC) DISSOLVED OXYGEN IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

In addition to these biological consequences, the lack of dissolved oxygen at depth can enhance the development of chemoclines, or chemical gradients, with an inverse relationship to the dissolved oxygen concentration. For example, the sediment-water exchange of elements such as phosphorus, iron, and manganese is increased under anaerobic conditions, resulting in higher hypolimnetic concentrations in these elements. Under anaerobic conditions, iron and manganese change oxidation states enabling the release of phosphorus from the iron and manganese complexes to which they are bound under aerobic conditions. This "internal loading" can affect water quality significantly if these nutrients and salts are mixed into the epilimnion, especially during early summer when these nutrients can become available for algal and rooted aquatic plant growth.

Limited other water chemistry data were available for several of the lakes in the Milwaukee River watershed. Data for chloride are summarized in Figure 148. As has been noted in other lakes in southeastern Wisconsin, most lakes for which data were available in the Milwaukee River watershed show an increasing trend in chloride concentrations. This trend is most discernable in those lakes with longer term data sets. These trends suggest that most lakes within the watershed have increased chloride levels over the period of record. During the 1970s, Lillie and Mason reported chloride concentrations of between 5.0 and 10 milligrams per liter (mg/l) in Milwaukee River watershed lakes.[13] Since that time, concentrations in most lakes for which data are available have increased to between 20 and 50 mg/l. Sources of these chlorides include road salts applied to area roadways during the winter months, and water softener salts utilized in home water softeners year round. The relative proportions of these sources vary with proximity to major human settlements and road systems; however, geological sources of chloride in southeastern Wisconsin are few, leading to the conclusion that the rapid increase in chloride concentrations is of anthropogenic origin. Threshold concentrations for chloride, above which instream and in-lake biological impacts may be expected to be observed, are on the order of about 250 mg/l.[14] Consequently, while the lakes of the Milwaukee River watershed are well below this threshold, salination of these lakes may be considered as an emerging issue of concern.

TOXICITY CONDITIONS OF THE MILWAUKEE RIVER

Much, though not all, of the data on toxic contaminants in the Milwaukee River watershed is related to two sites with PCB-contaminated sediments: the Cedar Creek USEPA Superfund site and Estabrook Impoundment on the Milwaukee River.

The Cedar Creek Superfund site consists of the Mercury Marine Plant 2 on St. John Avenue, the Amcast Facility on Hamilton Road, and Zeunert Pond, all in the City of Cedarburg, and a 5.1 mile segment of Cedar Creek from below the Ruck Pond dam in the City of Cedarburg downstream to the confluence with the Milwaukee River in the Town of Grafton. PCBs from two sources have contaminated Cedar Creek. Mercury Marine, a boat engine manufacturer, operated a plant on St. John Avenue from 1951 to 1982. Fluids containing PCBs leaked from equipment in this plant and were washed into floor drains, which emptied into storm sewers. Those sewers emptied into Ruck Pond and ultimately flowed into the Milwaukee River. Amcast, an automotive industry supplier, operated an aluminum and magnesium die-cast plant on Hamilton Road that discharged PCBs into the Creek via storm sewers. One of those sewers emptied into Hamilton Pond, an impoundment on Cedar Creek. In 1996, as a result of heavy rains and high stream flow, the Hamilton dam failed and was removed. The pond was drained, leaving behind several acres of mud flats containing PCBs. Several remediation efforts have been undertaken at this site. In 1994, storm sewer lines near Ruck Pond were cleaned and sealed to reduce PCB movement. In 1994 and 1995, Mercury Marine removed about 7,700 cubic yards of contaminated sediment and soil from Ruck Pond. While this removed about 96 percent of the PCB mass from the pond, samples from residual

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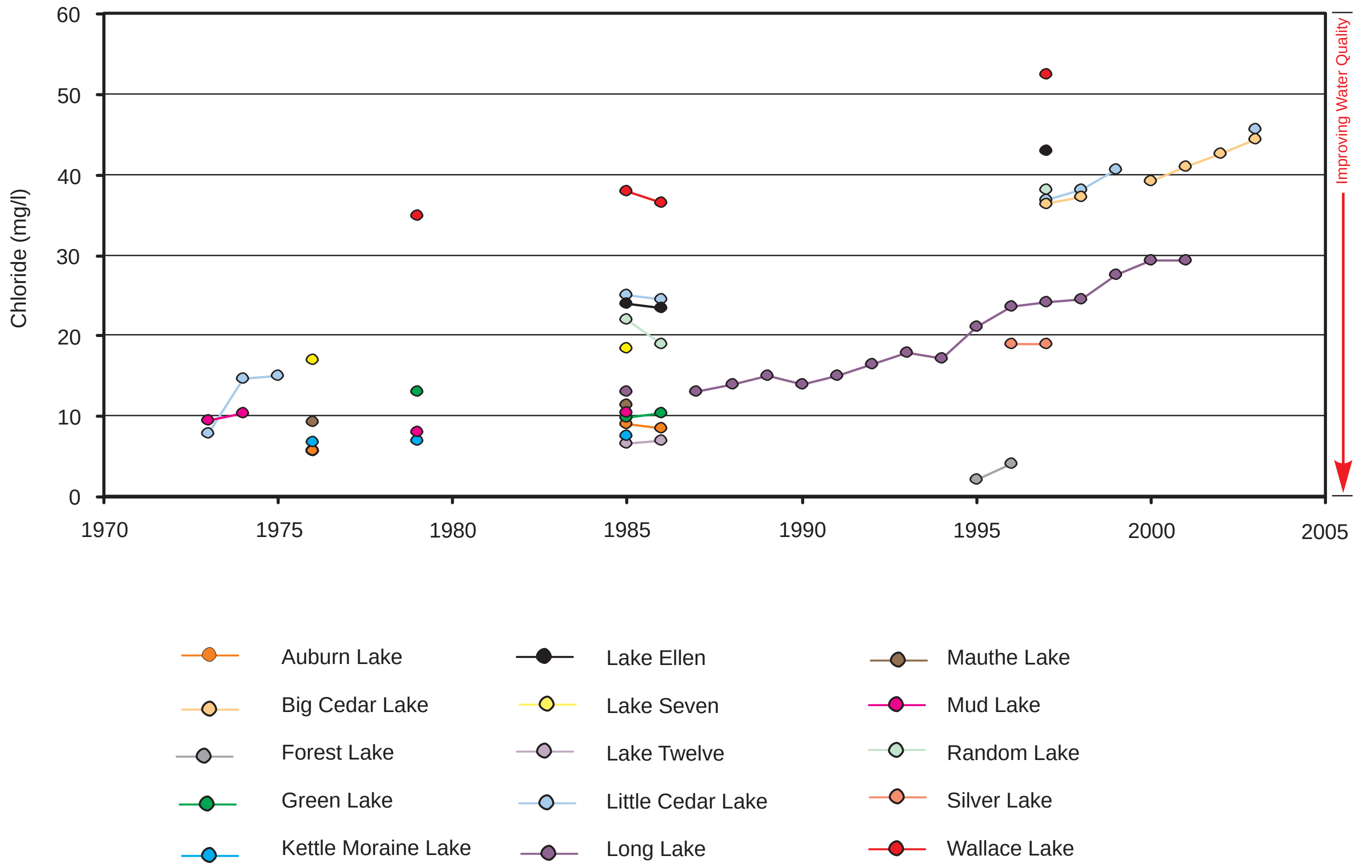
[13]*R.A. Lillie and J.W. Mason,* Limnological Characteristics of Wisconsin Lakes*, Wisconsin Department of Natural Resources Technical Bulletin No. 138, 1983.*

[14]*Fritz van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia*, Lewis Publishers, 1990.*

Figure 148

CHLORIDE CONCENTRATIONS IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1973-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

sediment remaining in the pond exhibited an average PCB concentration of 76 mg/kg.[15] After the removal, the area was restored through bank reconstruction and landscaping. In 2000 and 2001, Mercury Marine removed about 14,000 tons of contaminated soils from the banks of the former Hamilton Pond. These banks were restored by backfilling, revegetation, and wetland construction. Mercury Marine has been conducting studies on PCBs in Cedar Creek and soil along the banks of Cedar Creek, and Amcast has been conducting studies on soil and ground water at its facility and sediment in Zeunert Pond.

Estabrook Impoundment is formed by the Estabrook dam on the Milwaukee River. This site contains about 100,000 cubic yards of sediment contaminated with about 5,200 kg of PCBs.[16] The site includes the western channel of the Milwaukee River, sections of the mainstem of the Milwaukee River from the confluence with the western channel downstream to Estabrook dam, and Lincoln Creek from Green Bay Road to the confluence with the Milwaukee River. A study of PCB transport in the Milwaukee River watershed estimated that, through resuspension of sediment and dissolution of PCBs stored in sediment, this impoundment increases annual mass

[15]*Baird and Associates,* Final Report, Milwaukee PCB Mass Balance Project, *September 1997.*

[16]Ibid.

transport of PCBs in the Milwaukee River from about 5 kg to about 15 kg.[17] The source of the PCBs in this impoundment is not known; however, the mixture of PCB congeners found at this site contains a greater proportion of lighter, less chlorinated congeners than those found at sites along Cedar Creek or at upstream sites along the mainstem of the Milwaukee River, suggesting that these contaminants may have entered the watershed through Lincoln Creek.

Toxic Substances in Water

Pesticides

Since the 1970s, the Milwaukee River has been sampled for the presence of pesticides in water on several occasions. There have been four periods of sampling: 1975-1976, 1982, 1993-2002, and 2004. It is important to note that the results from the samples taken during 1993-2002 and 2004 are not directly comparable to those from the earlier periods. The data from the earlier periods were derived from unfiltered samples which included both pesticides dissolved in water and pesticides contained in and adsorbed to particulates suspended in the water. The data from 1993-2002 and 2004 were derived from filtered samples and measure only the fraction of pesticides dissolved in water. Since most pesticides are poorly soluble in water, the data from 1993-2002 and 2004 may underestimate ambient pesticide concentrations relative to the earlier data. During 1975 and 1976, water samples from six sites along the mainstem of the Milwaukee River in Milwaukee County were examined for the presence of the insecticides DDT, dieldrin, and lindane and for the DDT metabolites DDD and DDE. In all samples the concentrations of these substances were below the limit of detection. In 1982, three samples collected from the Milwaukee River at Estabrook Park were examined for presence of the herbicide atrazine. Atrazine was detected in all samples at a mean concentration of 0.33 μg/l. During the period 1993-2002, samples collected from the Milwaukee River at Estabrook Park were examined for the presence of several pesticides. The herbicide atrazine and its metabolite deethylatrazine were detected in all samples at mean concentrations of 0.10 μg/l and 0.03 μg/l, respectively. In addition, the atrazine metabolite deisopropylatrazine was detected in all samples that were screened for it. The mean concentration of this compound was 0.02 μg/l. The insecticides carbaryl and diazinon were frequently detected at mean concentrations of 0.014 μg/l and 0.010 μg/l, respectively. The insecticides dieldrin, lindane, and malathion and the DDT metabolite DDE were detected in a few samples at concentrations of 0.011 μg/l, 0.06 μg/l, 0.018 μg/l, and 0.014 μg/l, respectively. In 2004, samples were collected from the mainstem of the Milwaukee River at Pioneer Road, Estabrook Park, and Jones Island and examined for the presence of several pesticides. Atrazine and deethylatrazine were detected in all samples that were screened for these compounds at mean concentrations of 0.190 μg/l. and 0.055 μg/l, respectively. Carbaryl and diazinon were occasionally detected with mean concentrations of 0.008 μg/l and 0.007 μg/l, respectively. When they were detected in the Milwaukee River, the concentrations of atrazine and diazinon reported were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

Since the 1970s, Lincoln Creek has been sampled for the presence of pesticides in water on several occasions. There have been four periods of sampling: 1975, 1993-1994, 2001 and 2004. The results from the samples taken during 2001 and 2004 are not directly comparable to those from the earlier periods for the reasons given above. During 1975, water samples from three sites along Lincoln Creek were examined for the presence of the insecticides DDT, dieldrin, and lindane and for the DDT metabolites DDD and DDE. In all samples the concentrations of these substances were below the limit of detection. During the period 1993-1994, water samples were collected from Lincoln Creek at N. 47th Street and examined for the presence of several pesticides. Atrazine was occasionally detected with a mean concentration of 0.20 μg/l. The insecticide chlordane was detected in one sample at a concentration of 0.08 μg/l. In 2001, water samples collected from Lincoln Creek at N. 47th Street were examined for the presence of several pesticides. Atrazine was detected in most of the samples, with a mean concentration of 0.040 μg/l. Deethylatrazine was detected in all samples with a mean concentration of 0.016 μg/l. Diazinon was frequently detected and had a mean concentration of 0.203 μg/l. Carbaryl, deisopropylatrazine, and

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[17] *Jeffrey S. Steuer, Sharon A. Fitzgerald, and David W. Hall,* Distribution and Transport of Polychlorinated Biphenyls and Associated Particulates in the Milwaukee River System, Wisconsin, 1993-1995, *U.S. Geological Survey Water-Resources Investigations Report 99-4100, 1999.*

malathion were each detected in one sample at concentrations of 0.035 μg/l, 0.008 μg/l, and 0.127 μg/l, respectively. In 2004, water samples collected from Lincoln Creek at N. 47th Street were examined for the presence of several pesticides. Atrazine, carbaryl, deethylatrazine, and diazinon were each detected in one sample at concentrations of 0.148 μg/l, 0.004 μg/l, 0.046 μg/l, and 0.009 μg/l. When they were detected in Lincoln Creek, the concentrations of atrazine and diazinon reported were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

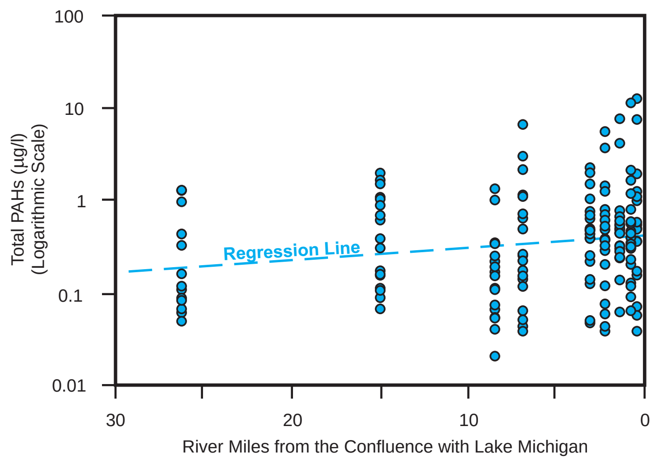
Relatively few data are available on concentrations of pesticides in water in other tributaries to the Milwaukee River. In 1993, samples were collected from Batavia Creek, Chambers Creek, Gooseville Creek, the Lake Ellen Outlet, Melius Creek, Nichols Creek, and the North Branch of the Milwaukee River and examined for the presence of atrazine and deethylatrazine. Both of these compounds were found in all of the samples. Concentrations of atrazine in these streams ranged between 0.07 μg/l and 0.043 μg/l, with a mean of 0.023 μg/l. Concentrations of deethylatrazine ranged between 0.011 μg/l and 0.041 μg/l, with a mean of 0.022 μg/l. During the period 1993-1994, the North Branch of the Milwaukee River was sampled extensively at a site near Random Lake for the presence of several pesticides. Atrazine and deethylatrazine were found in all samples with mean concentrations of 0.060 μg/l and 0.031 μg/l, respectively. Carbaryl, diazinon, and malathion were also occasionally detected. In 2001, additional sampling was conducted at this site. Atrazine and deethylatrazine were found in all samples with mean concentrations of 0.080 μg/l and 0.021 μg/l, respectively. The concentrations of atrazine and diazinon reported in tributary streams in the Milwaukee River watershed were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

Polycyclic Aromatic Hydrocarbons (PAHs)
Between 1995 and 2001, MMSD conducted extensive sampling for 15 PAH compounds in unfiltered water at its nine long-term water quality sampling stations along the mainstem of the Milwaukee River. Measurable concentrations of PAHs were detected in about 85 percent of the samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 12.83 μg/l, with a mean concentration of 0.85 μg/l. The frequency at which PAHs were detected changed along the length of the River. At the farthest upstream MMSD station at Pioneer Road, PAHs were detected in about 60 percent of the samples. The frequency of detection increased from upstream to downstream, reaching 100 percent at the two stations farthest downstream, the stations at Water Street and the Union Pacific Railway. Figure 149 shows that while there was considerable variation in the concentrations of total PAHs detected among samples taken at individual sites on different dates, concentrations of total PAHs tended to increase from upstream to downstream. Regression analysis indicates that this represents a statistically significant trend which accounts for about 3 percent of the variation in the data. Some PAH compounds were more commonly detected in water from the Milwaukee River than other PAH compounds. The compounds fluoranthene, chrysene, pyrene, benzo(a)pyrene, benzo(b)fluoranthene, and phenanthrene were frequently detected. The compounds acenaphthalene, acenaphthene, fluorene, and anthracene were rarely detected. In 2004, the USGS sampled three sites along the mainstem of the River on three dates for six PAH compounds dissolved in water. At the Pioneer Road and Estabrook Park stations, dissolved PAHs were detected in one sample each at a concentration of 0.1 μg/l. At Jones Island, dissolved PAHs were detected in each sample with a mean concentration of 0.17 μg/l. It is important to note that the results from the samples taken in 2004 are not directly comparable to those from the earlier period. The samples collected in 2004 were screened for six compounds as opposed to the 15 compounds that were screened for in the earlier samples. In addition, the data from the earlier period were derived from unfiltered samples which included both PAHs dissolved in water and PAHs contained in and adsorbed to particulates suspended in the water. The data from 2004 were derived from filtered samples and measured only the fraction of PAHs dissolved in water. Since PAHs are poorly soluble in water and tend to adsorb to suspended material, the data from 2004 may underestimate ambient PAH concentrations relative to the earlier data.

Few tributary streams in the Milwaukee River watershed have been examined for the presence of PAHs in water. Between 1997 and 2001, MMSD conducted extensive sampling for 15 PAH compounds in unfiltered water at its five long-term water quality sampling stations along Lincoln Creek in the City of Milwaukee. In addition, during the period 1993-2001 the USGS and WDNR each conducted sampling in Lincoln Creek for 16 PAH compounds in unfiltered water at N. 47th Street. Measurable concentrations of PAHs were detected in about 80 percent of the

Figure 149

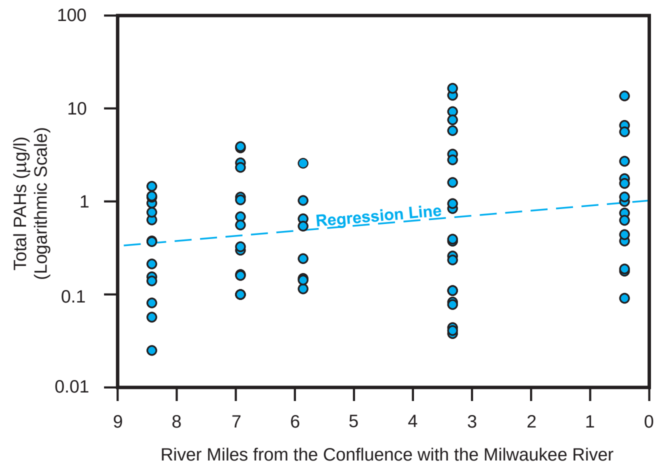
CONCENTRATIONS OF TOTAL PAHs IN WATER IN THE MILWAUKEE RIVER: 1995-2001



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 150

CONCENTRATIONS OF TOTAL PAHs IN WATER IN LINCOLN CREEK: 1997-2001



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 40.16 μg/l, with a mean concentration of 2.68 μg/l. Figure 150 shows that while there was considerable variation in the concentrations of total PAHs detected among samples taken at individual sites on different dates, concentrations of total PAHs tended to increase from upstream to downstream. This did not represent a statistically significant trend. Some PAH compounds were more commonly detected in water from Lincoln Creek than other PAH compounds. The compounds fluoranthene, pyrene, benzo(b)fluoranthene, benzo(a)pyrene, and benz(a)anthracene were frequently detected. The compounds acenaphthalene, acenaphthene, fluorene, and anthracene were rarely detected. This pattern is very similar to the pattern observed in the mainstem of the Milwaukee River, suggesting that inputs of PAHs from Lincoln Creek may represent a major source of PAHs entering the River. In 1997, the USGS sampled Lincoln Creek at N. 47th Street on seven dates for 14 PAH compounds dissolved in water. Dissolved PAHs were detected in five of these samples. Concentrations of total dissolved PAHs in these samples ranged from below the limit of detection to 0.31 μg/l, with a mean concentration of 0.12 μg/l. In 2004, the USGS sampled Lincoln Creek at N. 47th Street on three dates for six PAH compounds dissolved in water. Dissolved PAHs were detected in each of these samples. Concentrations of total dissolved PAHs in these samples ranged from 0.10 μg/l to 0.70 μg/l, with a mean concentration of 0.43 μg/l. It is important to note that the results of the 1997 and 2004 samplings for dissolved PAHs are not directly comparable to the results from the samplings of Lincoln Creek for total PAHs for the reasons given above.

Between 1999 and 2001, MMSD sampled four locations along Southbranch Creek in the Village of Brown Deer for 15 PAH compounds in unfiltered water. PAHs were detected in about 56 percent of the samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 1.26 μg/l, with a mean concentration of 0.42 μg/l. During the period 1996-1997, the USGS conducted extensive sampling for 16 PAH compounds in unfiltered water samples collected from Parnell Creek in the headwaters of the East Branch of the Milwaukee River. Additional unfiltered water samples were collected from this stream in 2002 and examined for the presence of 17 PAH compounds. In all samples, concentrations of PAHs were below the limit of detection. No other data on the concentrations of PAHs in water were available for streams in the Milwaukee River watershed.

Polychlorinated Biphenyls (PCBs)

Between 1993 and 1995, the USGS collected samples at four sites along the mainstem of the Milwaukee River which were analyzed for the presence of polychlorinated biphenyls (PCBs) in water. These samples were divided by filtration into two portions: one portion consisting of PCBs dissolved in water and another portion consisting of PCBs associated with suspended sediment particles. These portions were analyzed on a congener-specific basis that examined 62 fractions representing 85 of the 209 individual PCB compounds.[18] Because only some congeners were analyzed, the results should be considered to represent minimum concentrations. In all of the samples collected, the sum of the PCB concentrations in the dissolved and suspended portions of the samples exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l). Table 93 summarizes congener-specific PCB data for the dissolved portion of the samples. Several trends are apparent in this summary. The number of PCB fractions detected, the number of potential congeners represented, and concentration of PCBs increased between the CTH T station and the Pioneer Road station. Increases in these quantities also occurred between the stations at STH 167 and Estabrook Park. Similar trends are apparent in the summary of the suspended sediment portion of the samples shown in Table 94. Higher average numbers of fractions and potential congeners and higher average concentrations of PCBs were detected in the suspended portion of the samples than in the dissolved portion (compare Tables 93 and 94). This reflects the facts that PCBs are poorly soluble in water and tend to adsorb to sediment particles. The congener composition of the samples was examined to estimate what proportion of each sample consisted of PCB congeners that are considered to be of greatest environmental concern due to toxicity. Toxicity was judged by the ability of the congeners to induce toxic effects through mechanisms similar to those involved in the toxicity of dioxins.[19] It is important to note that toxic effects unrelated to dioxin-like toxicity have been reported; however, less information is available on nondioxin-like PCB congeners and their toxicology is not well understood.[20] The results of this assessment are presented in Table 95. The data have several notable features. First, there was considerable variation among samples in the percentage of PCBs in the sample consisting of congeners considered to be of greatest environmental concern. Second, the portion of the PCB samples associated with suspended sediment contains a higher percentage of congeners considered to be of greatest environmental concern than the dissolved portion. This was the case at all four sites. Third, samples collected at the Pioneer Road and STH 167 stations contain a higher percentage of congeners considered to be of greatest environmental concern than samples collected at the CTH T and Estabrook Park stations. This may reflect contributions of PCBs to the Milwaukee River from Cedar Creek (see the *PCB Transport* section below).

Between 1995 and 2001, the MMSD long-term sampling stations along the mainstem of the Milwaukee River were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners were examined, the results of this sampling should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 ng/l.

Three tributary streams in the Milwaukee River watershed have been examined for the presence and concentrations of PCBs in water: Cedar Creek, Lincoln Creek, and Southbranch Creek.

Between 1991 and 2001, the USGS collected samples at four sites along Cedar Creek which were analyzed for the presence of PCBs in water. These samples were divided into portions, and analyzed on a congener-specific basis using the same methods described above for the samples the USGS collected from the mainstem of the

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[18]*In several cases, the analytical method used is not able to distinguish between two or more specific congeners.*

[19]*Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992*

[20]*Tala R. Henry and Michael J. DeVito, "Non-dioxin-like PCBs: Effects and Consideration in Ecological Risk Assessment", U.S. Environmental Protection Agency Ecological Risk Assessment Support Center, June 2003.*

Table 93

DISSOLVED PCB CONGENERS IN THE MILWAUKEE RIVER: 1993-1995

Sample Site	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
CTH T	5	2	22	12.2	3	35	19.6	0.09	1.86	0.94
Pioneer Road	27	11	50	27.3	16	70	40.4	0.54	17.97	3.36
STH 167	16	17	42	28.3	28	58	42.4	1.13	25.83	4.09
Estabrook Park	32	18	47	34.5	30	66	49.9	1.24	14.92	8.09

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 94

PCB CONGENERS ASSOCIATED WITH SUSPENDED SEDIMENT IN THE MILWAUKEE RIVER: 1993-1995

Sample Site	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
CTH T	5	2	29	17.0	3	41	24.8	0.07	6.74	2.38
Pioneer Road	27	16	53	33.6	22	74	47.5	1.13	76.36	11.48
STH 167	16	19	49	37.9	25	69	53.8	1.06	23.88	9.31
Estabrook Park	32	26	58	51.3	36	81	72.3	1.47	101.37	23.45

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Geological Survey and SEWRPC.

Table 95

PERCENT OF PCB MASS REPRESENTED BY CONGENERS OF GREATEST ENVIRONMENTAL CONCERN IN THE MILWAUKEE RIVER: 1994-1995[a]

Sample Site	Dissolved PCBs (percent[b])			PCBs Associated with Suspended Sediment (percent[b])		
	Minimum	Maximum	Average	Minimum	Maximum	Average
CTH T Grafton	0	32	10	11	57	34
Pioneer Road	7	27	18	36	50	42
STH 167	8	32	18	37	46	40
Estabrook Park	2	20	7	15	39	26

[a]*Congeners of greatest environmental concern are as described in Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992.*

[b]*Percent by weight.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Milwaukee River. Because only some congeners were analyzed, the results should be considered to represent minimum concentrations. At two of the sites, samples were collected during three periods: 1990-1991, 1994-1995, and 2000-2001. In all but one of the samples collected, the sum of the PCB concentrations in the dissolved and suspended portions of the samples exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l).

Table 96 summarizes congener-specific PCB data for the dissolved portion of the samples. Several trends are apparent in this summary. During the 1990-1991 sampling, the number of PCB fractions detected, the number of potential congeners represented, and concentration of PCBs increased between the stations at Columbia Road and below Wire and Nail Pond. Concentrations then decreased between the stations at Wire and Nail Pond and Green Bay Road. At the Columbia Road and Highland Road sites, the number of PCB fractions detected, the number of potential congeners represented, and concentration of PCBs in the samples collected during 2000-2001 were considerably lower than those in the samples collected during the previous two periods. This reflects the effects of the remediation efforts in and around Ruck Pond.

Similar trends are apparent in the summary of the suspended sediment portion of the samples shown in Table 97. Higher average numbers of fractions and potential congeners and higher average concentrations of PCBs were detected in the suspended portion of the samples than in the dissolved portion (compare Tables 96 and 97). This reflects the facts that PCBs are poorly soluble in water and tend to adsorb to sediment particles.

The congener composition of the samples was examined to estimate what proportion of each sample consisted of PCB congeners that are considered to be of greatest environmental concern due to toxicity using the approach described above. The results of this assessment are presented in Table 98. The data have several notable features. First, there was considerable variation among samples in the percentage of PCBs in the sample consisting of congeners considered to be of greatest environmental concern. Second, the portion of the PCB samples associated with suspended sediment contains a higher percentage of congeners considered to be of greatest environmental concern than the dissolved portion. This was the case at all four sites. Third, in samples collected at the Columbia Road site, the percentage of PCBs in the sample consisting of congeners considered to be of greatest environmental concern appears to be lower in the samples collected during 2000-2001 than the percentage in samples collected during the previous two periods. This may be a result of the remediation efforts in and around Ruck Pond. It does not appear that this change has occurred at the Highland Road site.

Between 1997 and 2001, the MMSD long-term sampling stations along Lincoln Creek were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners were examined, the results of this sampling should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 ng/l.

Between 1999 and 2001, the MMSD long-term sampling stations along Southbranch Creek were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners were examined, the results of this sampling should be considered minimum values. None of the 14 congeners sampled for were detected in any of these samples.

PCB Transport

During the period 1993-1995, the USGS studied the transport of PCBs in Cedar Creek and the Milwaukee River.[21] This study found that dissolved phase PCB congener distributions in water showed higher abundances of lighter, more soluble, less chlorinated congeners than PCB congener distributions in suspended particles or surface sediments. In addition, concentrations of PCBs associated with suspended particles increased with algal growth during spring and summer and with episodic resuspension of bed sediments during storms. Estimated

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[21] Ibid.

Table 96

DISSOLVED PCB CONGENERS IN CEDAR CREEK: 1990-2001

Sample Site	Period	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
			Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Columbia Road	1990-1991	12	7	40	23.7	10	56	33.7	0.53	16.90	4.67
	1994-1995	11	9	51	25.5	13	74	38.1	0.67	17.06	4.73
	2000-2001	8	1	33	15.3	1	47	21.0	0.05	2.37	0.93
	Total	31	1	51	22.2	1	74	31.7	0.05	17.06	3.72
Highland Road	1990-1991	13	19	57	38.9	28	80	55.7	2.40	50.82	16.83
	1994-1995	13	19	59	36.7	27	82	61.4	1.13	48.74	22.39
	2000-2001	14	3	53	28.3	3	74	39.2	0.11	9.71	3.04
	Total	40	3	59	36.7	3	82	51.8	0.11	50.82	13.81
Below Wire and Nail Pond	1991	7	25	56	46.3	39	79	68.0	4.28	40.71	25.31
Green Bay Road	1990-1991	13	24	52	40.4	38	73	57.7	4.07	24.12	12.66

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Geological Survey and SEWRPC.

Table 97

PCB CONGENERS ASSOCIATED WITH SUSPENDED SEDIMENT IN CEDAR CREEK: 1990-2001

Sample Site	Period	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
			Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Columbia Road	1990-1991	11	4	52	34.6	6	72	48.9	0.27	75.31	17.73
	1994-1995	11	18	44	28.8	25	64	38.8	1.54	44.83	12.07
	2000-2001	8	0	37	23.5	0	50	32.3	0.00	1.73	0.82
	Total	30	0	52	29.5	0	72	41.4	0.00	75.31	11.15
Highland Road	1990-1991	12	29	58	45.4	41	81	64.3	6.16	167.74	50.86
	1994-1995	13	23	57	47.5	33	79	66.7	1.91	288.93	84.06
	2000-2001	14	12	53	38.6	16	74	53.9	0.26	31.49	12.00
	Total	39	12	58	43.7	16	81	61.4	0.26	288.93	47.98
Below Wire and Nail Pond	1991	7	44	57	50.6	61	80	71.7	24.21	126.27	74.92
Green Bay Road	1990-1991	13	32	57	47.5	45	80	66.8	8.47	113.00	44.04

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Geological Survey and SEWRPC.

daily loads of PCBs at two sites along Cedar Creek and four sites along the Milwaukee River are given in Table 99. The estimated loads of PCBs in the Milwaukee River increase sharply between CTH T and Pioneer Road. Given that the confluence with Cedar Creek is between these two stations, it suggests that Cedar Creek is a major source of dissolved and suspended PCBs to the Milwaukee River. The daily PCB loads at Highland Road on Cedar Creek suggest that during 1993-1995, Cedar Creek contributed between 0.1 and 7.3 kg per year of PCBs to the Milwaukee River. These estimates are consistent with the results of the Cedar Creek Mass Balance Study, which concluded that Cedar Creek transported between 4 and 38 kg of PCBs per year to the Milwaukee River.[22] The USGS study also concluded that Estabrook Impoundment increases annual mass transport of PCBs in the Milwaukee River from about 5 kg to about 15 kg and that some PCB deposition may have occurred between the Highland Road and Pioneer Road sites, possibly in the impoundments of lower Cedar Creek.[23]

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[22]*S. Westenbroek,* Cedar Creek Polychlorinated Biphenyls Mass Balance, Phase I – Data Summary and Analysis, Final Draft, *Wisconsin Department of Natural Resources, 1993.*

[23]*Steuer,* et al., *1999,* op cit.

Table 98

PERCENT OF PCB MASS REPRESENTED BY CONGENERS OF GREATEST ENVIRONMENTAL CONCERN IN CEDAR CREEK: 1990-2001[a]

Sample Site	Period	Dissolved PCBs (percent[b])			PCBs Associated with Suspended Sediment (percent[b])		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Columbia Road	1990-1991	5	24	13	33	59	39
	1994-1995	9	23	16	37	52	44
	2000-2001	0	13	6	26	36	32
	Total	0	24	12	26	59	39
Highland Road	1990-1991	10	21	15	36	39	37
	1994-1995	15	24	19	35	51	38
	2000-2001	0	28	14	32	48	35
	Total	0	28	16	32	51	37
Below Wire and Nail Pond	1991	10	21	16	36	39	38
Green Bay Road	1990-1991	9	21	17	33	39	37

[a]*Congeners of greatest environmental concern are as described in Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992.*

[b]*Percent by weight.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 99

ESTIMATED LOADS OF PCBs TRANSPORTED IN THE MILWAUKEE RIVER WATERSHED: 1993-1995

Stream	PCB Loads (g/day)				Percent of Load Associated with Particulates	Samples
	Minimum	Maximum	Median	Mean		
Cedar Creek						
Columbia Avenue	0.2	2.8	1.5	1.3	36.7	11
Highland Road	0.3	20.2	6.5	9.4	67.1	13
Milwaukee River						
CTH T	0.2	3.9	0.8	1.3	55.3	5
Pioneer Road	0.6	105.9	4.8	20.1	61.0	26
Thiensville	2.6	208.6	9.6	25.0	74.7	16
Estabrook Park	1.1	221.1	26.1	51.4	64.1	31

Source: U.S. Geological Survey and SEWRPC.

Toxic Contaminants in Aquatic Organisms

The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the Milwaukee River watershed between 1977 and 2002. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Milwaukee River. The statewide fish consumption advisory for mercury applies to fish in the Milwaukee River watershed. In addition, special consumption advice has been issued for several species taken from portions of the Milwaukee River and from Cedar Creek, Lincoln Creek, and Zeunert Pond due to tissue concentrations of PCBs (see Table 100).

Table 100

FISH CONSUMPTION ADVISORIES FOR THE MILWAUKEE RIVER WATERSHED[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Cedar Creek from the Milwaukee River to Bridge Road in Cedarburg				
All Species	- -	- -	- -	All sizes
Lincoln Creek				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	- -	All sizes	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	- -	All sizes	- -
Walleyed Pike	- -	Less than 18 inches	Larger than 18 inches	- -
White Sucker	- -	- -	All sizes	- -
Yellow Perch	All sizes	- -	- -	- -
Milwaukee River Up to the First Dam				
Chubs	- -	All sizes	- -	- -
Chinook Salmon	- -	Less than 32 inches	Larger than 32 inches	- -
Coho Salmon	- -	All sizes	- -	- -
Brown Trout	- -	Less than 22 inches	Larger than 22 inches	- -
Lake Trout	- -	Less than 23 inches	23-27 inches	Larger than 27 inches
Rainbow Trout	Less than 22 inches	Larger than 22 inches	- -	- -
Smelt	All sizes	- -	- -	- -
Whitefish	- -	All sizes	- -	- -
Yellow Perch	All sizes	- -	- -	- -
Milwaukee River Estuary to Estabrook Falls				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	- -	All sizes	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	- -	All sizes	- -
Walleyed Pike	- -	Less than 18 inches	Larger than 18 inches	- -
White Sucker	- -	- -	All sizes	- -
Yellow Perch	All sizes	- -	- -	- -
Milwaukee River above Estabrook Falls to Grafton				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Largemouth Bass	- -	All sizes	- -	- -
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	All sizes	- -	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	All sizes	- -	- -
Milwaukee River above Grafton				
Carp	- -	- -	- -	All sizes
Zeunert Pond in Cedarburg				
All Species	- -	- -	- -	All sizes

[a]*The statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

It is important to note that some samples collected from the Milwaukee River consisted of whole organism homogenates while other consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisories are based on fillet samples. In both types of samples, a single sample may represent tissue from several fish of the same species.

It is also important to note that dams fragment the Milwaukee River fishery by preventing both upstream and downstream migration of fishes to and from Lake Michigan as well as from the mainstem of the Milwaukee River to tributary streams and between reaches of the mainstem of the Milwaukee River. Because of the limits on fish migration imposed by dams, the body burdens of some toxic substances found in aquatic organisms, especially those substances that are poorly soluble in water, may differ substantially among different portions of the watershed. In general, organisms inhabiting those reaches of the River that contain legacy deposits of toxic substances in the sediment may be expected to have high body burdens of the toxic substances, while organisms inhabiting reaches that are upstream from any legacy sediment deposits may be expected to have lower body burdens.

To reflect these factors, the presence and concentrations of toxic contaminants in aquatic organisms was analyzed within the framework of the fragmentation of the fishery imposed by the presence of dams and drop structures. Map 53 shows the extent of the fragmentation of reaches from downstream to upstream within the Milwaukee River watershed as defined by the location of dams and drop structures. As shown on Map 53, some reaches are very short, such as Reaches 4a and 5, while some reaches are much longer. In addition, some reaches have no tributary streams, such as Reaches 4d and 6c. In contrast, other reaches are both extensive and well connected to many tributary streams, such as Reaches 6 and 10.

Mercury

Between 1978 and 2002 the WDNR sampled tissue from fish and other aquatic organisms collected from the Milwaukee River watershed for mercury contamination. Figures 151 and 152 show concentrations of mercury in the tissue of aquatic organisms in fillet samples and whole organism samples, respectively, from stream reaches defined by the location of dams and drop structures. Tissue concentrations of mercury in fillet samples in organisms collected from the watershed ranged from below the limit of detection to 1.2 micrograms per gram tissue (μg per g tissue) (see Figure 151). Average tissue concentrations of mercury in fillet samples ranged from 0.14 μg per g tissue in Reach 4b along Cedar Creek to 0.38 μg per g tissue in Reach 9a along the East Branch Milwaukee River. It is important to note that Reach 9a includes Mauthe Lake, and that this average largely reflects tissue concentrations of mercury in fish collected from this lake. Tissue concentrations of mercury in whole organism samples collected from the watershed ranged from below the limit of detection to 0.28 μg per g tissue (see Figure 152). Average tissue concentrations of mercury in whole organism samples ranged from 0.03 μg per g tissue in Reach 2 along the mainstem of the Milwaukee River and Lincoln Creek to 0.20 μg per g tissue in Reach 7 along the mainstem of the Milwaukee River between Newburg and West Bend. The highest tissue concentrations tended to be detected in fillet samples. This reflects the fact that mercury tends to accumulate in muscle tissue in fish. Figure 153 shows tissue concentrations of mercury from fillet samples of fish collected from several lakes in the Milwaukee River watershed. Tissue concentrations of mercury in fillet samples from fish collected from lakes ranged between 0.04 μg per g tissue and 1.10 μg per g tissue. The average tissue concentration of mercury in fillet samples from fish collected from lakes in the watershed was 0.40 μg per g tissue. Within lake averages ranged between 0.23 μg per g tissue in Kettle Moraine Lake and 0.58 μg per g tissue in Big Cedar Lake. Tissue concentrations of mercury tended to be higher in gamefish than in panfish, but this is based upon a small number of samples.

The statewide consumption advisory for mercury applies to fish from the Milwaukee River watershed. In addition, Forest Lake, Long Lake, and Mauthe Lake are considered impaired due to fish consumption advisories related to atmospheric deposition of mercury.

It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury contamination are quite small. Because of this, these data may not be completely representative of current body burdens of mercury carried by aquatic organisms in the River and its tributaries.

PCBs

Between 1977 and 2002 the WDNR examined fillet and whole organism samples from several species of fish collected from the Milwaukee River watershed for PCB contamination. Over this time period, tissue concentrations

Map 53

STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES WITHIN THE MILWAUKEE RIVER WATERSHED: 2004

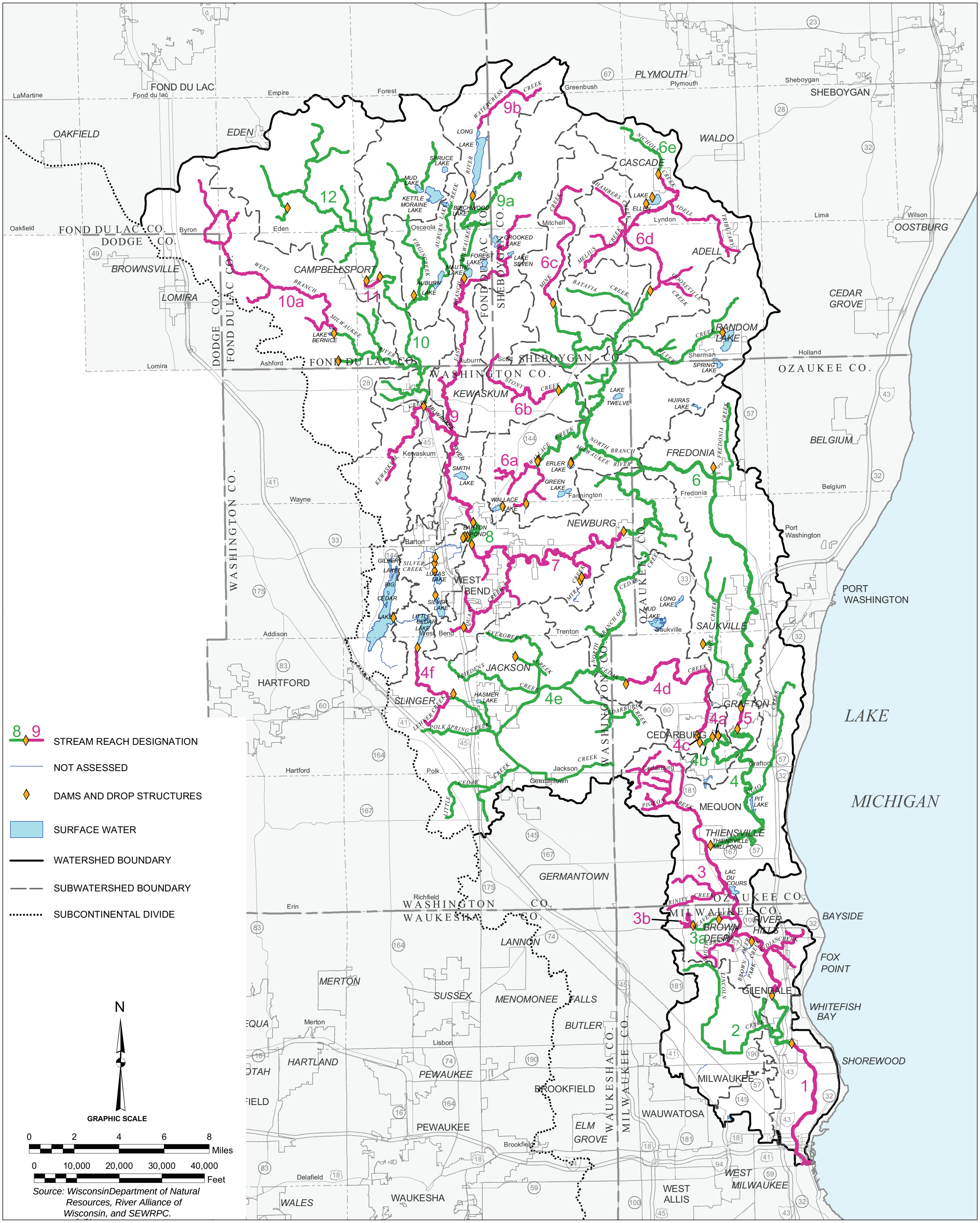
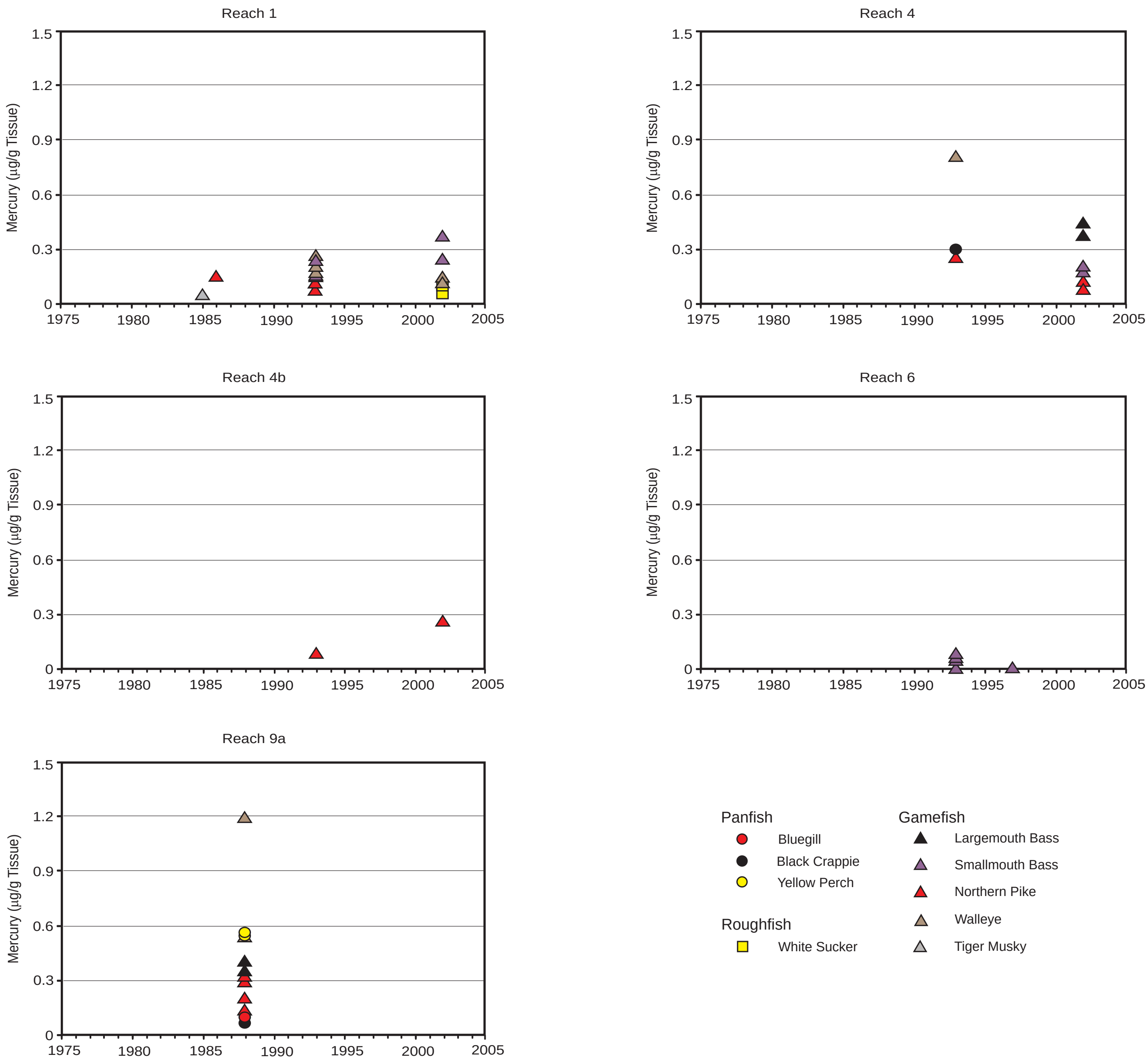


Figure 151

TISSUE CONCENTRATIONS OF MERCURY IN FILLETS FROM FISH SAMPLES COLLECTED FROM STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



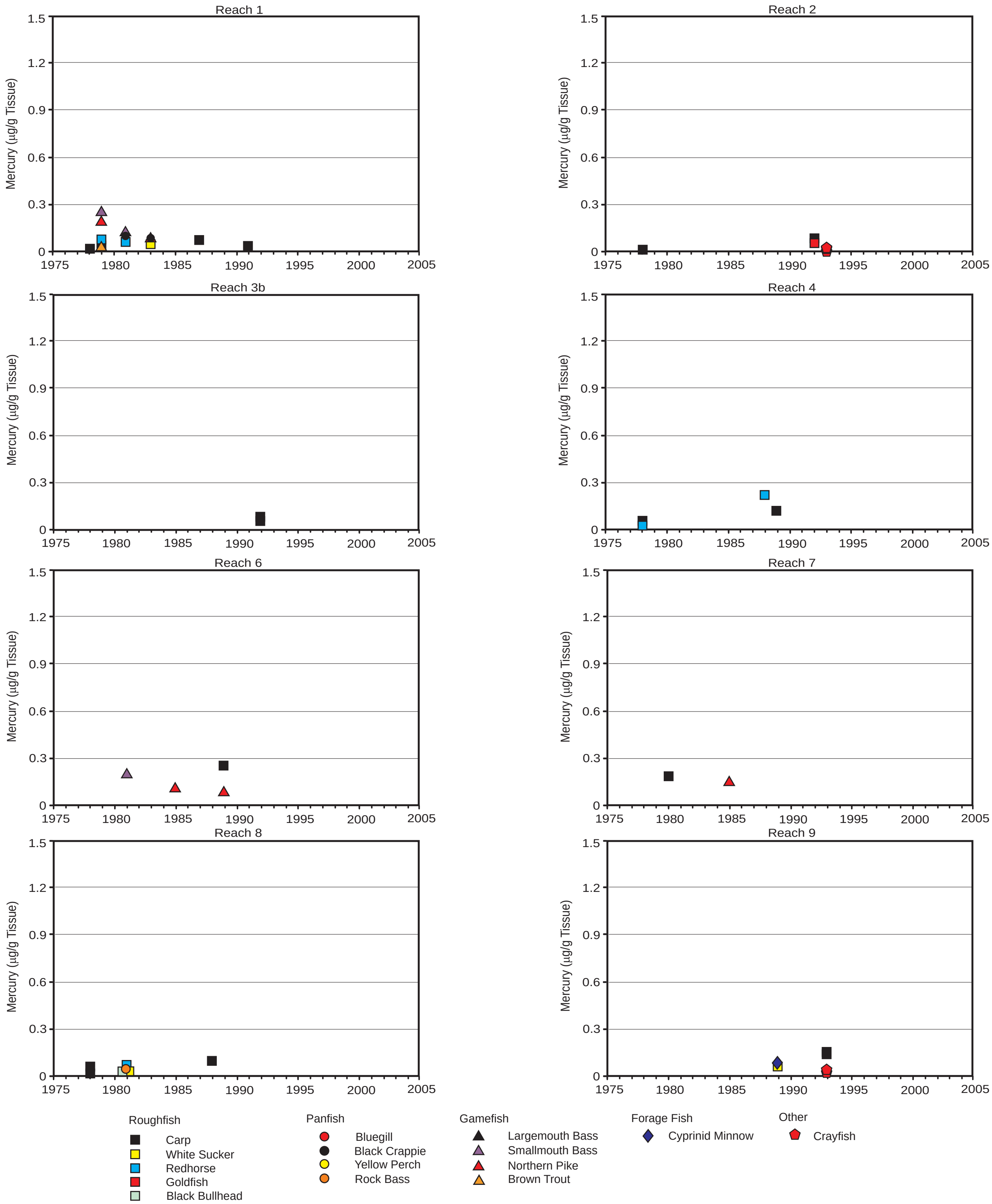
NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

of PCBs in whole organism samples ranged from below the limit of detection to 110 μg per g tissue. Tissue concentrations in fillet samples ranged from below the limit of detection to 160 μg per g tissue. Figure 154 shows concentrations of PCBs in the tissue from both whole organism samples and fillet sample of fish collected from stream reaches separated by dams and drop structures in the Milwaukee River watershed. Two trends are apparent. First, tissue concentrations in whole fish samples tend to be higher in whole organism samples than in fillet samples. This may reflect the fact that PCBs are more soluble in lipids than in water and consequently tend

Figure 152

TISSUE CONCENTRATIONS OF MERCURY IN WHOLE FISH SAMPLES COLLECTED FROM STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1977-2002

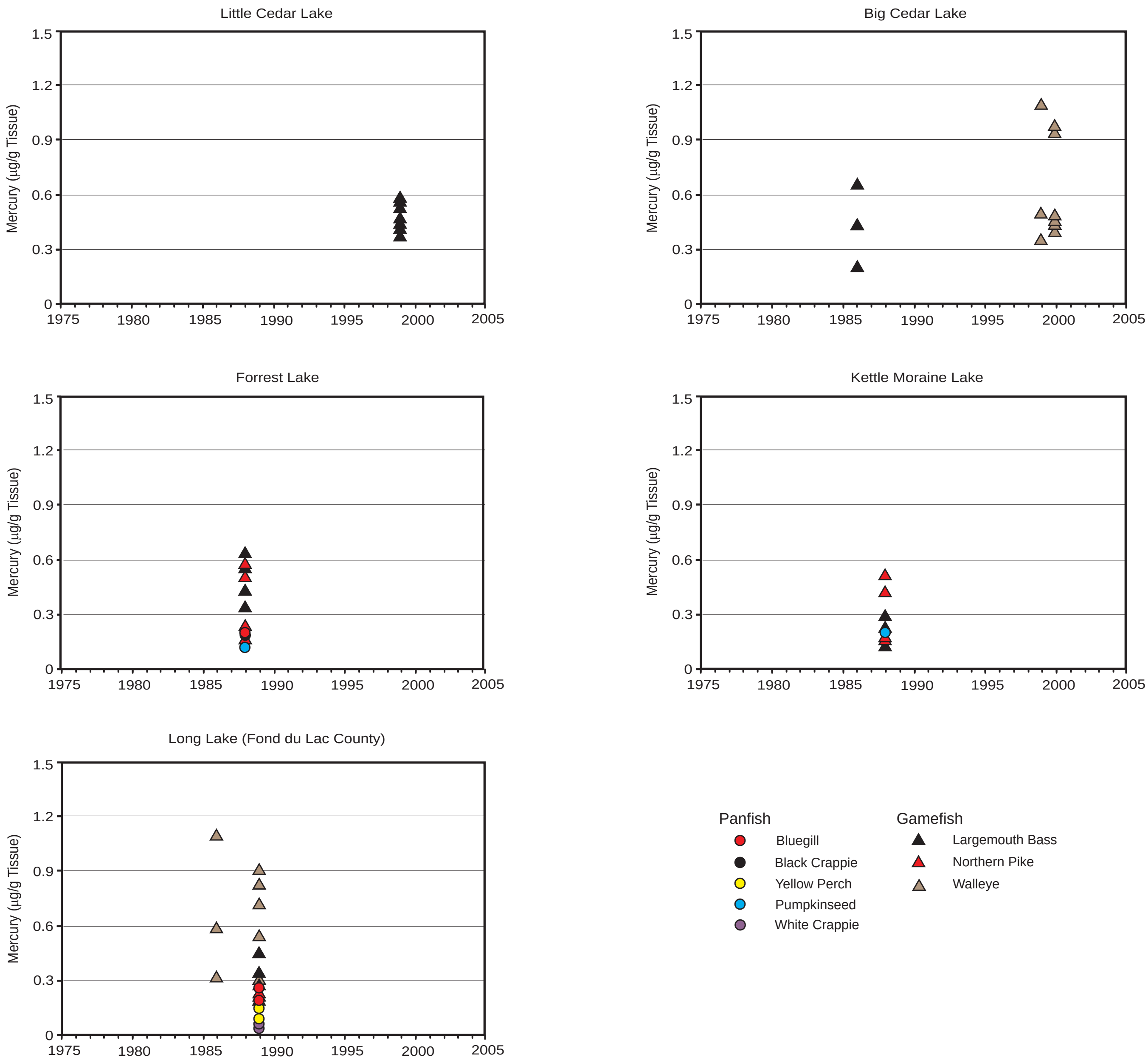


NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 153

TISSUE CONCENTRATIONS OF MERCURY IN FILLETS FROM FISH SAMPLES COLLECTED FROM LAKES IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



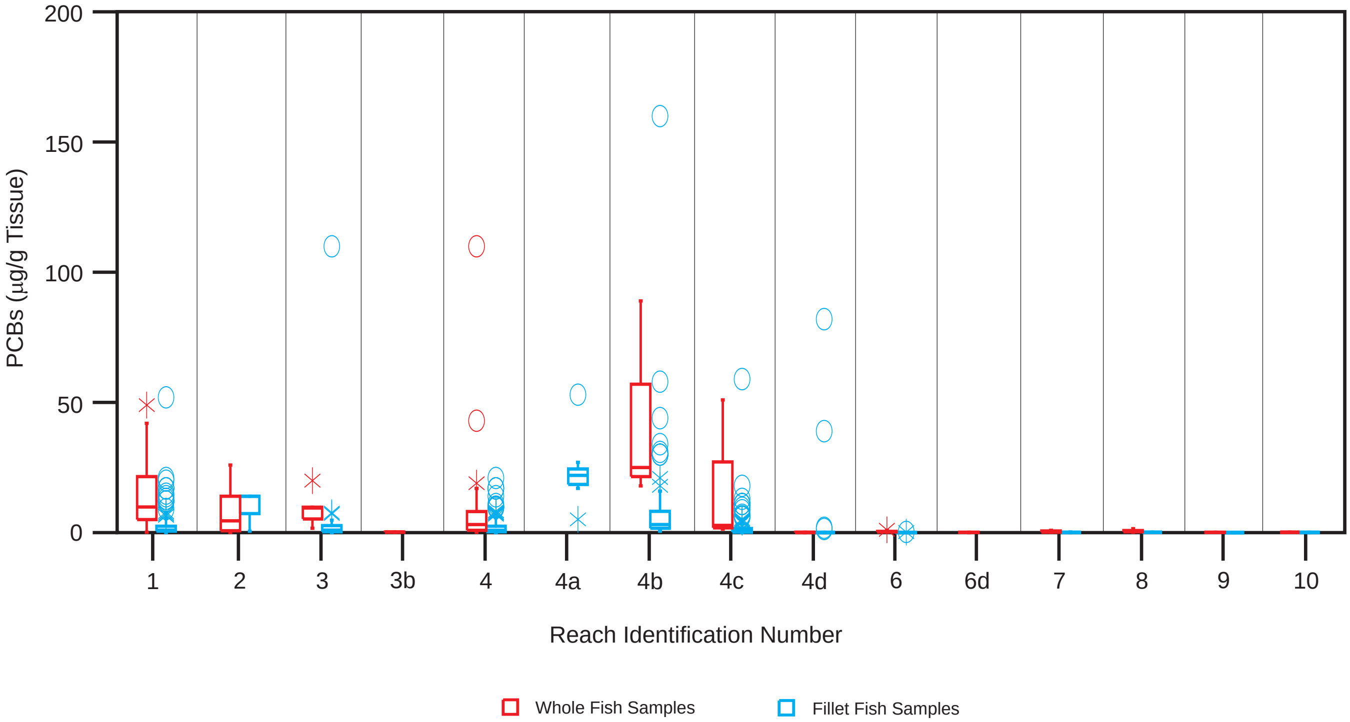
Source: Wisconsin Department of Natural Resources and SEWRPC.

to accumulate in fatty tissue. Second, higher tissue concentrations of PCBs are detected in fish collected from stream reaches along Cedar Creek in and downstream from Cedarburg and in the mainstem of the Milwaukee River below the confluence with Cedar Creek than from other locations in the watershed. These are stream reaches that either contain deposits of PCB-contaminated sediment or are downstream of reaches containing deposits of PCB-contaminated sediment (see the following subsection on Toxic Contaminants in Sediment).

Figures 155 through 158 show tissue concentrations of PCBs from aquatic organisms from stream reaches separated by dams and drop structures in the Milwaukee River watershed for reaches downstream from Thiensville Millpond (see Figure 155), between the Villages of Grafton and Thiensville (see Figure 156), and

Figure 154

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



NOTES: See Figure 109 for description of symbols.

Reaches correspond to those shown on Map 53.

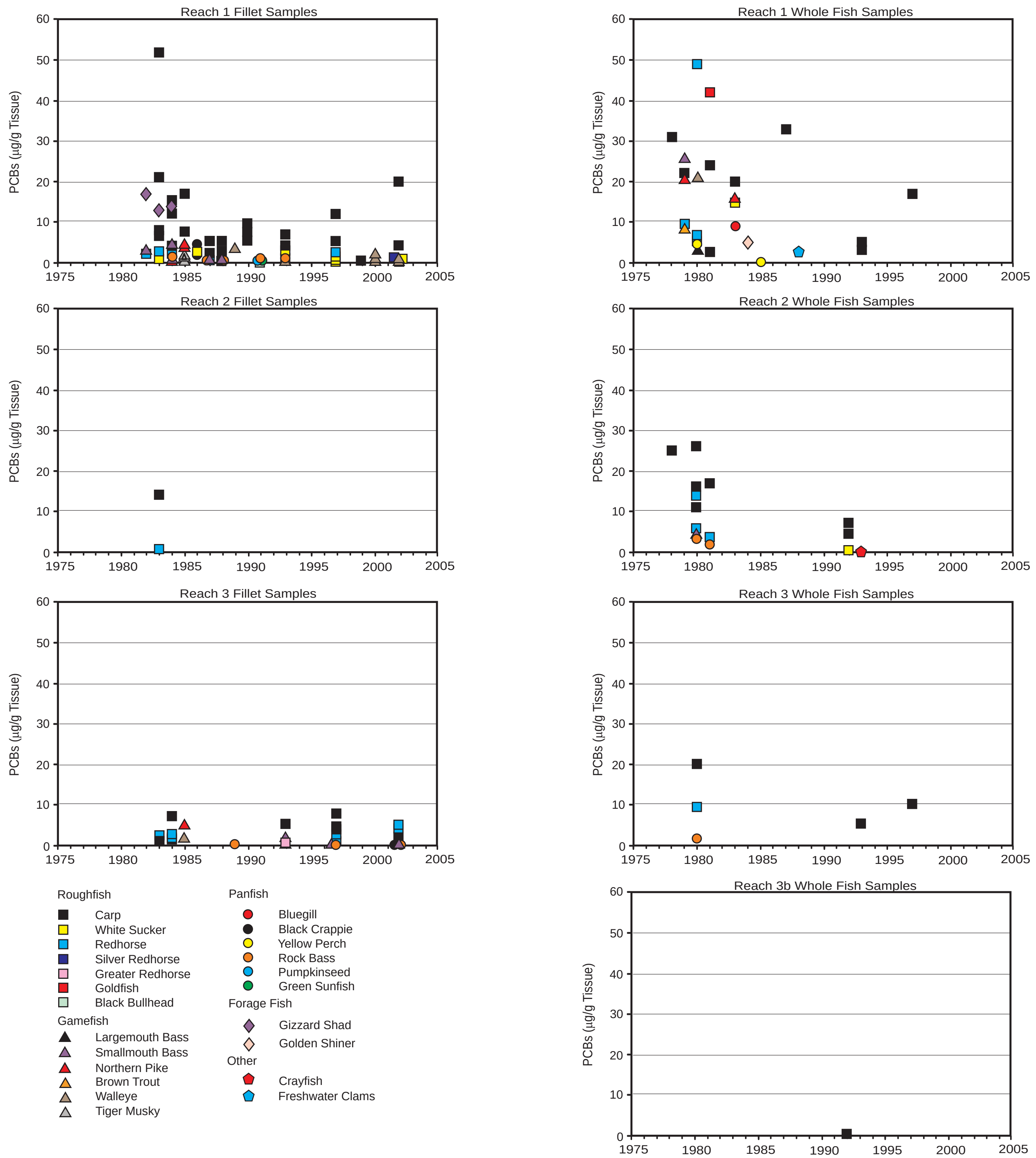
Source: Wisconsin Department of Natural Resources and SEWRPC.

upstream from the Village of Grafton (see Figure 157). In some stream reaches, tissue concentrations of PCBs appear to be decreasing with time, for example tissue concentrations in whole organism samples in Reaches 2 and 3 (see Figure 155). These apparent trends must be interpreted with caution, both because of the small number of samples that they are based upon, and because in many reaches different fish species were examined at different dates. In most of the stream reaches where data are available, no trend is apparent in tissue concentrations of PCBs. Among species, the body burdens of PCBs detected often reflected trophic mechanisms. Piscivorous fish tended to have larger body burdens than fish that feed primarily or largely on invertebrates. Highest body burdens were detected in omnivorous, bottom-dwelling species. For example, in fillet samples of fish collected from Reach 1, the mean tissue concentration of PCBs in northern pike, a primarily piscivorous species, was 1.92 μg per g tissue. Mean tissue concentrations of PCBs in this reach in black crappie and rock bass, two species that feed largely on invertebrates, were 1.69 μg per g tissue and 0.69 μg per g tissue, respectively. The mean tissue concentration in this reach in carp, an omnivorous, bottom-dwelling species, was 8.36 μg per g tissue. Similar relationships were detected in other stream reaches.

The WDNR measured tissue concentrations of PCB congeners in whole-fish samples in caged fathead minnows prior to and after the removal of contaminated sediment from Ruck Pond along Cedar Creek. These studies were designed to indicate the amount of bioaccumulation of PCBs in fish tissue during a fixed period of exposure. Cages were placed at three locations: in Cedarburg Pond upstream from Ruck Pond, within Ruck Pond, and in Columbia Pond downstream from Ruck Pond. In experiments conducted in July 1994, prior to the remediation, the average tissue concentration of PCBs was 0.12 μg per g tissue at the upstream site, 24 μg per g tissue at the Ruck Pond site, and 12 μg per g tissue at the downstream site. The average tissue concentration of PCBs detected

Figure 155

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM THE MILWAUKEE RIVER WATERSHED BELOW THIENSVILLE MILLPOND: 1977-2002

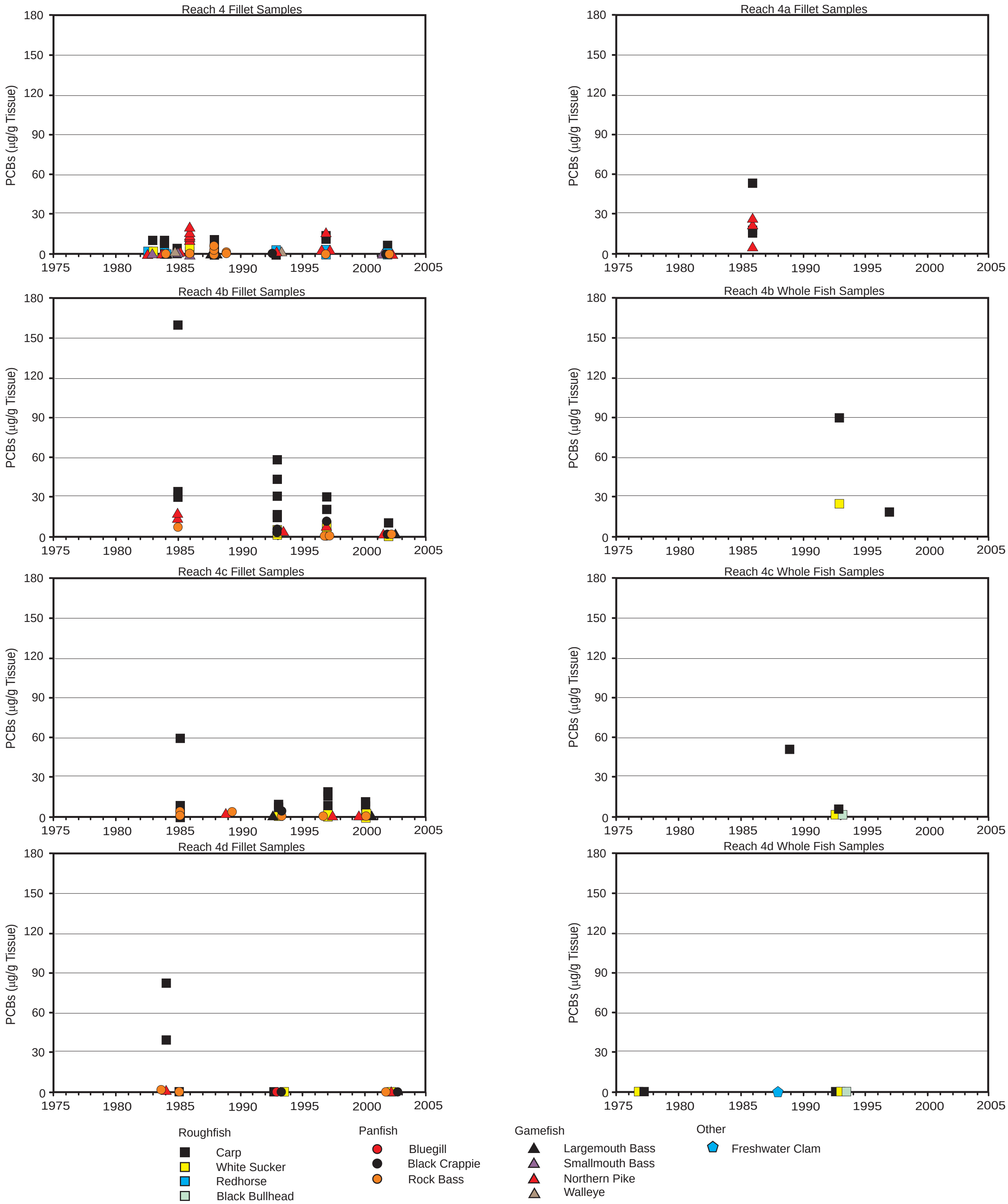


NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 156

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM CEDAR CREEK AND THE MILWAUKEE RIVER BETWEEN THE VILLAGES OF GRAFTON AND THIENSVILLE: 1977-2002



NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 157

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM THE MILWAUKEE RIVER WATERSHED ABOVE THE VILLAGE OF GRAFTON: 1977-2002

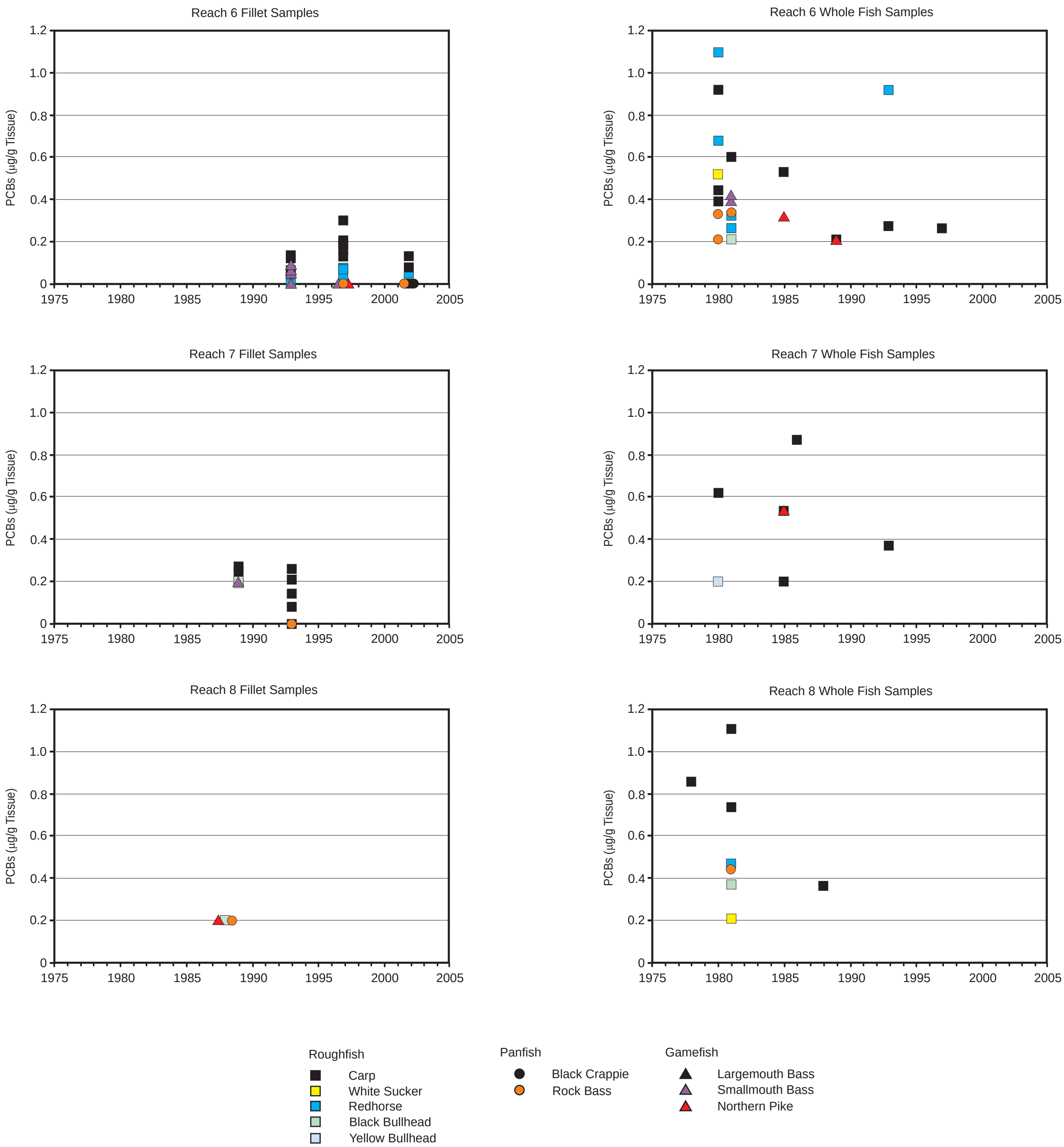
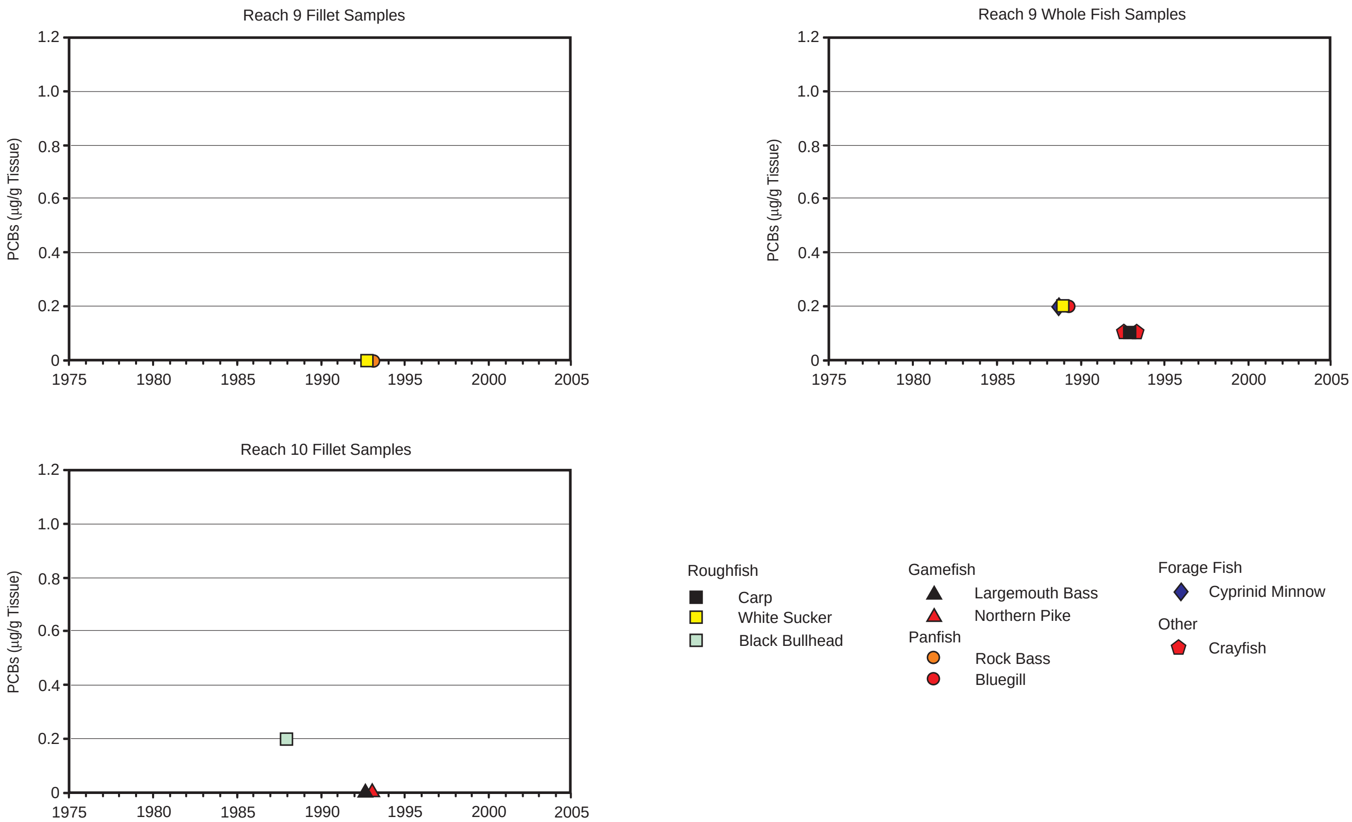


Figure 157 (continued)



NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

in experiments conducted in July and August of 1995, one year after the remediation, was 0.09 µg per g tissue at the upstream site, 4.2 µg per g tissue at the Ruck Pond site, and 11 µg per g tissue at the downstream site. In Ruck Pond, this represents about an 82 percent reduction in PCB bioaccumulation in caged fish experiments. In similar studies conducted in 2001, the average tissue concentration of PCBs in caged fathead minnows in Ruck Pond was about 0.36 µg per g tissue. It is important to note that this reduction may not entirely reflect the results of the remediation. Between 1994 and 1995, tissue concentrations of PCBs at the upstream site also decreased by about 25 percent and tissue concentrations at the downstream site decreased by about 10 percent. In addition, disturbance of the Ruck Pond site may be a factor in the concentrations detected. During the experiments prior to the remediation, in-water construction preparations and disturbances were occurring in Ruck Pond. This may have resulted in greater exposure of the caged minnows to PCBs than would have occurred under undisturbed conditions.

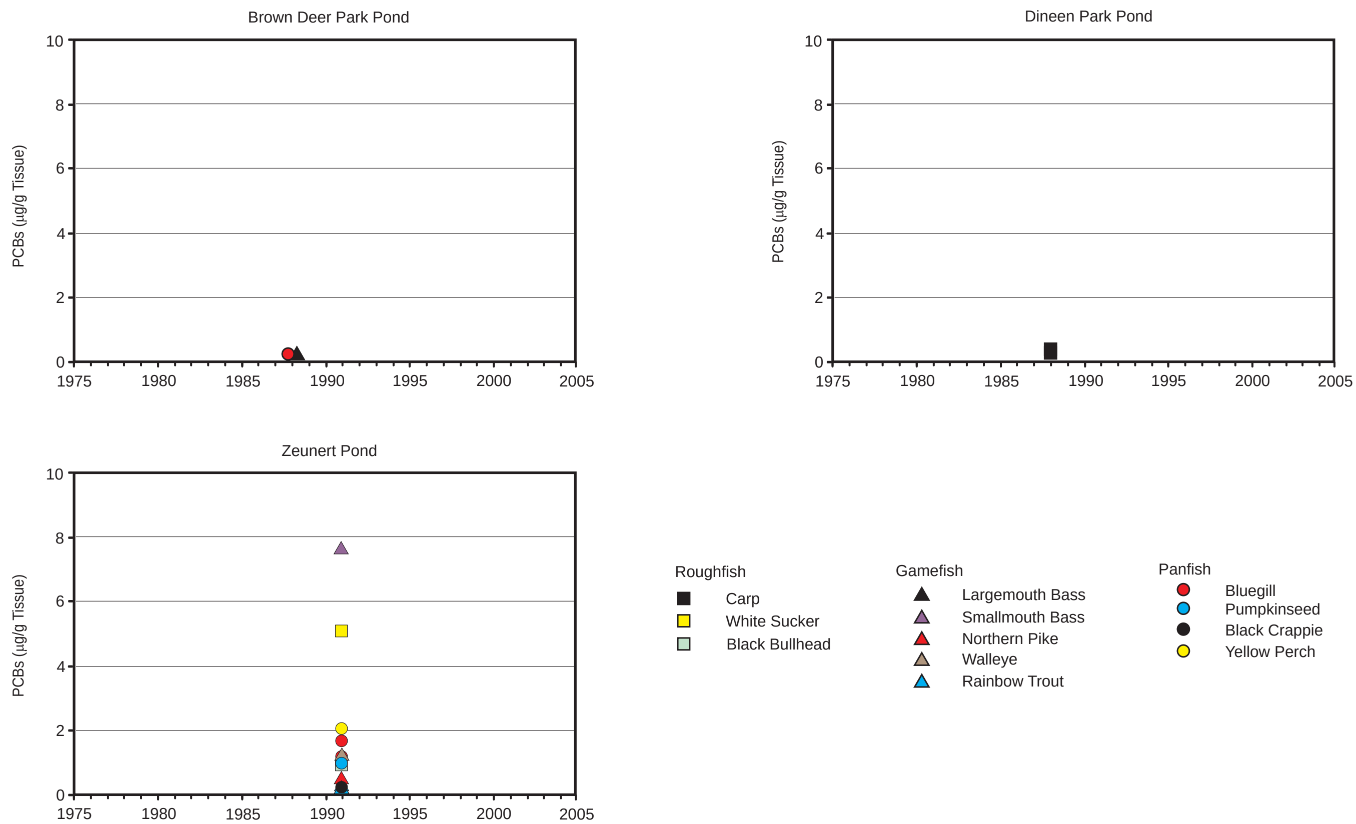
It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of PCB contamination are quite small. Because of this, these data may not be completely representative of current body burdens of PCBs carried by aquatic organisms in the River and its tributaries.

Pesticides

Between 1977 and 1993 the WDNR examined whole fish samples from several species of aquatic organisms from the Milwaukee River watershed for contamination by historically used, bioaccumulative pesticides and their

Figure 158

TISSUE CONCENTRATIONS OF PCBs IN FILLETS FROM FISH SAMPLES COLLECTED FROM PONDS IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



Source: Wisconsin Department of Natural Resources and SEWRPC.

breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out.

During the early 1980s, measurable concentrations of o,p'-DDT and p,p'-DDT were occasionally detected in tissue of fish from several species collected from stream reaches in the Milwaukee River watershed downstream from Kletzsch Park Dam (Reaches 1 and 2). These compounds were not detected in tissue samples collected in subsequent sampling. Between 1977 and 1993, measurable concentrations of the DDT breakdown products p,p'-DDD and p,p'-DDE were detected in the tissue of fish from several species in most of the stream reaches separated by dams and drop structures in the watershed that were sampled. There were no detections in Reaches 9 and 10. In addition, the DDT breakdown products o,p'-DDD and o,p'-DDE were occasionally detected in tissue samples of fish collected in Reach 1, downstream from Estabrook Park Dam.

During the same period, tissue from fish collected in the Milwaukee River watershed was analyzed for the presence of several other pesticides. Measurable concentrations of the chlordane isomers α-chlordane and γ-chlordane and of the insecticide methoxychlor were occasionally detected in fish tissue samples collected from Reaches 1, 2, 4, and 8. Similarly, measurable concentrations of the chlordane isomer trans-nonachlor and of the insecticides aldrin and pentachlorophenol were occasionally detected in the tissue of fish collected from Reach 1. Measurable concentrations of dieldrin were occasionally detected in tissue from carp and goldfish. Measurable concentrations of α-BHC, γ-BHC, endrin, hexachlorobenzene, toxaphene, and the chlordane isomer cis-nonachlor were not detected in the tissue of aquatic organisms collected from the Milwaukee River watershed during the period 1977-1993.

It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of pesticide body burdens of pesticides carried by aquatic organisms in the River and its tributaries.

Toxic Contaminants in Sediment

Between 1973 and 2000 the WDNR sampled sediment from streams in the Milwaukee River watershed for the presence and concentrations of toxic substances. Sampling sites and dates of sampling are shown in Table 101. Sediment samples collected from the Milwaukee River during the period 1989 to 2003 show detectable concentrations of arsenic, barium, cadmium, chromium, copper, cobalt, iron, lead, manganese mercury, nickel, selenium, and zinc. Summary statistics for concentrations of selected metals are shown in Table 102. The mean concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and zinc in these samples were between the Threshold Effect Concentrations (TEC) and the Probable Effect Concentrations (PECs), indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms (see Table 13 in Chapter III of this report).

The amount of organic carbon in sediment can exert considerable influence on the toxicity of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[24] Because of this, the concentrations of PAHs, PCBs, and pesticides were normalized to 1 percent organic carbon prior to analysis.

Concentrations of PAHs in 37 sediment samples collected between 1989 and 1999 ranged between about 146 micrograms PAH per kilogram sediment (μg PAH/kg sediment) and about 84,500 μg PAH/kg sediment with a mean value of 19,500 μg PAH/kg sediment (see Table 103). Total organic carbon data were not available for 25 of the samples. For the two samples collected from the Milwaukee River that had associated total organic carbon data, the concentrations of PAHs were between the TEC and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. In one sample collected from Lincoln Creek that had associated total organic carbon data, the concentrations of PAHs exceed the PEC for total PAHs and are high enough to pose substantial risk of toxicity to benthic organisms. In a second sample collected from this stream, the concentrations of PAHs were between the TEC and the PEC. In five samples collected from the North Branch Milwaukee River and three samples collected from Gooseville Creek that had associated total organic carbon data, the concentrations of PAHs were below the TEC. During the period 2003-2004, the WDNR examined 15 sediment cores collected from Estabrook Impoundment in the Milwaukee River and Lincoln Creek near the confluence with the Milwaukee River for the presence of PAHs.[25] Concentrations of total PAHs detected in these samples ranged from 318 μg PAH/kg sediment to 333,800 μg PAH/kg sediment. In most of these samples, individual PAH concentrations normalized to 1 percent total organic carbon were between the TEC and the PEC. In three samples, individual PAH concentrations exceeded the PEC. Areas with the highest concentrations of PAHs tended to be from Lincoln Creek sediments.

Concentrations of PCBs in 311 sediment samples collected from the Milwaukee River watershed between 1980 and 2000 ranged from below the limit of detection to about 870 milligrams PCB per kilogram sediment (mg PCB/kg sediment) with a mean value of 21.0 mg PCB/kg sediment. Total organic carbon data were not available

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[24]*U.S. Environmental Protection Agency*, Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics, *USEPA Office of Science and Technology, Washington, D.C., 2000.*

[25]*Wisconsin Department of Natural Resources*, Estabrook Impoundment Sediment Remediation Pre-Design Study Project Completion Report to USEPA, *PUBL-WT 826, August 2005.*

Table 101

SEDIMENT SAMPLING IN THE MILWAUKEE RIVER WATERSHED: 1973-2003

Location	Years	Contaminants Examined
East Branch Milwaukee River		
Two Sites near CTH S	1993	Metals, PCBs, Pesticides
New Fane Millpond	1999	Metals, PAHs, PCBs, Pesticides
Gooseville Creek		
Three Sites	1995	Metals, PAHs, PCBs
North Branch Milwaukee River		
One Site near CTH A	1995	Metals, PAHs, PCBs
Two Sites near Waubeka	1999	Metals, PAHs, PCBs, Pesticides
Cedar Creek		
Six Sites near CTH C	1999	Metals
Mayfield Pond	1998	Metals, PAHs, PCBs, Pesticides
Ruck Pond	1990	Metals, PCBs
	2000	PCBs
Columbia Pond	1995	PCBs
Wire and Nail Pond	2000	PCBs
CTH T	1995	PCBs
Hamilton Pond	1996	PCBs
Trinity Creek		
Confluence with the Milwaukee River	1995	PCBs
Indian Creek		
Bradley Road	1989	Metals, PAHs, PCBs
Crestwood Creek		
Above Confluence with Lincoln Creek	1995	PCBs
Wahl Creek		
47th Street	1989	Metals, PAHs, PCBs, Pesticides
Lincoln Creek		
N. 51st Street and W. Woolworth Avenue	1980	Pesticides
	1993	Pesticides
Havenwoods	1995	PCBs
N. 60th Street	1995	PCBs
N. 47th Street	1980	Pesticides
	1992-1993	Pesticides
	1995	PCBs
N. 46th Street	1995	PCBs
N. Teutonia Avenue	1995	PCBs
Below N. Green Bay Avenue	2001-2003	Metals, PAHs, PCBs, Pesticides
Meaux Park	1980	Pesticides
	1993	Pesticides
Confluence with Milwaukee River	1990	PAHs, PCBs, Pesticides
Milwaukee River Mainstem		
Chair Factory Impoundment-Grafton	1993	PAHs, PCBs
CTH T	1995	PCBs
Thiensville Millpond	1973	PCBs
	1993	PCBs
Kletzsch Park Impoundment	1993	PCBs
Estabrook Impoundment	1973	Metals
	1982	PCBs
	1993	PCBs
	1995	PCBs
	2001-2003	Metals, PAHs, PCBs, Pesticides
Multiple Locations Downstream from Thiensville	1984	Metals, PCBs, Pesticides
	1989	Metals, PAHs, PCBs, Pesticides
	1990-1991	PAHs, PCBs
Three Estuary Sites	1980	PCBs

Source: Wisconsin Department of Natural Resources.

Table 102

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM THE MILWAUKEE RIVER WATERSHED: 1989-2003[a]

Statistic	Metals							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Mean	13.2	1.61	92.1	43.5	83.2	0.67	16.0	180.8
Standard Deviation	13.9	1.65	134.3	39.8	88.5	0.98	17.6	174.6
Minimum	0.0	0.00	8.0	4.0	2.3	0.00	5.0	0.4
Maximum	52.0	6.10	540.0	160.0	350.0	3.35	40.0	680.0
Number of Samples	37	42	34	41	41	31	31	41
Date of Earliest Sample	1973	1973	1973	1973	1973	1973	1973	1973
Date of Latest Sample	1999	1999	1999	1999	1999	1999	1999	1999

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

Table 103

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SEDIMENT SAMPLES FROM THE MILWAUKEE RIVER WATERSHED: 1989-1999[a]

Parameter	Surface Sediment (0-30 cm)	Intermediate Sediment (31-60 cm)	Deep Sediment (60-152 cm)	All Sediment (0-152 cm)
Mean	21,110	1,518	- -	19,512
Standard Deviation	23,555	2,237	- -	23,200
Minimum	146	152	- -	146
Maximum	84,498	4,100	- -	84,498
Number of Samples	34	3	0	37

[a]*All concentrations expressed as µg/kg on a dry weight basis.*

Source: Wisconsin Department of Natural Resources.

for 52 of the samples. For 56 of the samples that had associated total organic carbon data, the concentrations of PCBs found in sediments from the Milwaukee River watershed were below the TEC for total PCBs, indicating that these concentrations are unlikely to be producing toxic effects in benthic organisms. The concentrations of PCBs in 102 samples were between the TEC and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. The concentrations of PCBs in 101 samples exceed the PEC for total PCBs and are high enough to pose substantial risk of toxicity to benthic organisms.

Much of the sediment sampling for PCBs in the Milwaukee River watershed is related to two sites known to contain sediment contaminated with PCBs: the lower reaches of Cedar Creek and Estabrook Impoundment. In addition, several sediment samples were collected from the Thiensville Millpond, an impoundment of the Milwaukee River in the Village of Thiensville and Zeunert Pond, a quarry pond in the City of Cedarburg.

Table 104 shows concentrations of PCBs in sediment collected at five sites along Cedar Creek between 1995 and 2000. The highest average concentrations of PCBs are in sediment collected from Columbia Pond and Wire and Nail Pond. The samples from Ruck Pond were collected about five years after the removal of about 7,700 cubic

Table 104

CONCENTRATIONS OF PCBs IN SEDIMENT SAMPLES FROM CEDAR CREEK: 1985-2000[a]

Statistic	Ruck Pond	Columbia Pond	Wire and Nail Pond	CTH T	Hamilton Pond[b]
Mean	7.11	27.03	11.14	2.14	1.70
Standard Deviation	24.40	41.64	12.20	1.64	1.75
Minimum	0.07	0.05	0.09	0.98	0.05
Maximum	120.00	190.00	49.00	3.30	4.30
Number of Samples	24	50	25	2	6
Date of Sample	2000	1995	2000	1995	1996

[a]*All concentrations in mg/kg based on dry weight.*

[b]*Samples from the former Hamilton Pond were collected during removal of the Hamilton dam.*

Source: Wisconsin Department of Natural Resources.

yards of contaminated sediment and still displayed high residual PCB levels. The samples collected from Hamilton Pond were collected during removal of the Hamilton dam following its failure.

Figure 159 shows PCB concentrations in 12 sediment cores collected from Thiensville Millpond in 1993. Concentrations of PCBs in sediment from this impoundment range from below the limit of detection to 4.9 mg PCB/kg sediment with a mean concentration of 0.53 mg PCB/kg sediment. The mean concentration of PCBs in surface sediments were 0.18 mg PCB/kg sediment, relatively low compared to deeper sediment. The highest concentrations of PCBs were detected at depths below the sediment surface between 30 cm and 40 cm. The mean concentration at this stratum was about 1.01 mg PCB/kg sediment. Below sediment depths of about 50 cm, PCB concentrations in this impoundment decrease sharply.

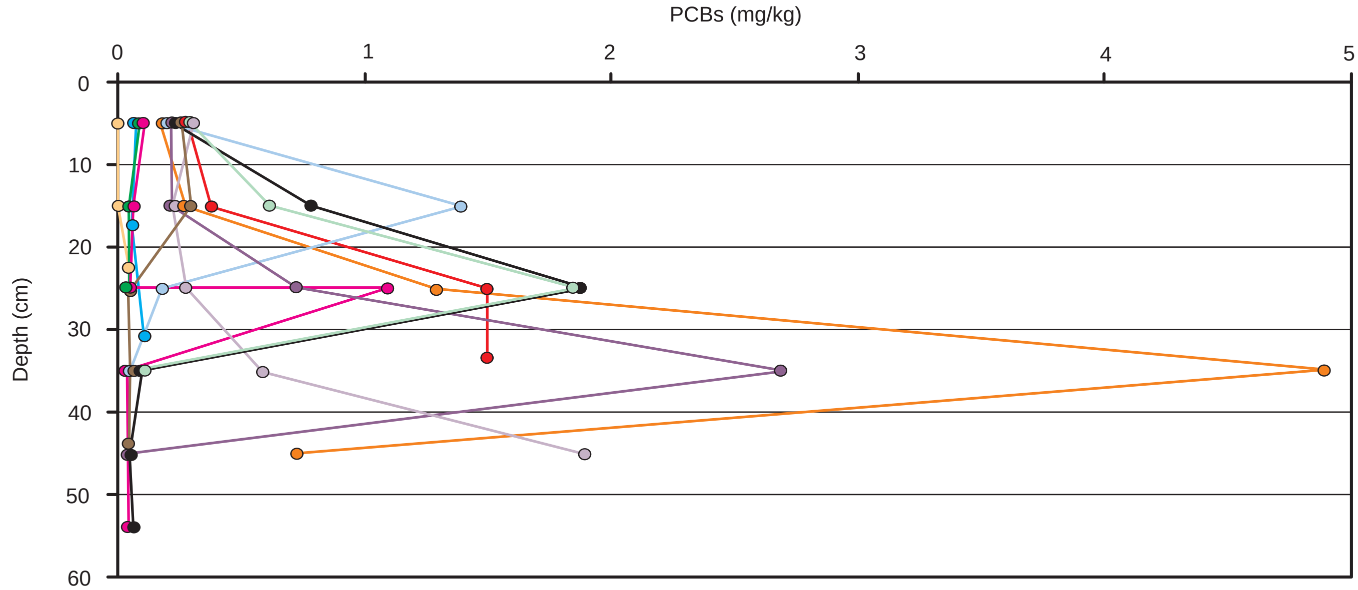
Figure 160 shows PCB concentrations in four sediment cores collected in 1993 and 14 sediment cores collected in 1995 from Estabrook Impoundment. In the 1993 samples, concentrations of PCBs in sediment ranged from 0.06 mg PCB/kg sediment to 380 mg PCB/kg sediment with a mean concentration of 49.2 mg PCB/kg sediment. The highest concentrations of PCBs were detected at depths below the sediment surface between 20 cm and 30 cm. In the 1995 samples, concentrations of PCBs in sediment ranged from 0.2 mg PCB/kg sediment to 870 mg PCB/kg sediment with a mean concentration of 51.5 mg PCB/kg sediment. The mean concentration of PCBs in surface sediments was 11.2 mg PCB/kg sediment, relatively low compared to deeper sediment. The highest concentrations of PCBs were detected at depths below the sediment surface between 30 cm and 40 cm. The mean concentration at this stratum was about 132 mg PCB/kg sediment. Below sediment depths of about 50 cm, PCB concentrations in this impoundment decrease sharply.

Between 2001 and 2003, the WDNR conducted additional sampling for PCBs in sediment in the Estabrook Impoundment and Lincoln Creek downstream from N. Green Bay Avenue.[26] Map 54 shows the depth of soft sediments in selected portions of Estabrook Impoundment. Sediment mapping was confined to areas of the impoundment where there is known sediment contamination. Accumulated soft sediment was thickest in the two side channels of the River, ranging up to 5.4 feet. Sediment depths in the main channel of the River were generally below about 1.6 feet, with some thicker deposits located near the Estabrook dam. The WDNR estimated the volume of soft sediments in the impoundment to be about 98,800 cubic yards. Map 55 shows the concentrations of PCBs in sediment in the Estabrook Impoundment and Lincoln Creek. Concentrations ranged from below the limit of detection to 460 mg PCB/kg sediment. The highest concentrations of PCBs were detected in sediments from the western channel of the River, nearshore deposits at the Blatz Pavilion inlet, and on the west

[26]*Wisconsin Department of Natural Resources,* PUBL-WT 826, op. cit.

Figure 159

CONCENTRATIONS OF PCBs IN SEDIMENT FROM THIENSVILLE MILL POND: 1993



Source: Wisconsin Department of Natural Resources and SEWRPC.

bank of the Milwaukee River below the side channels. The PCBs in the sediment were identified as a mixture of Aroclors 1242, 1248, and 1254. The WDNR estimated the mass of PCBs in the impoundment in sediments with PCBs at a concentration above 1.5 mg PCB/kg sediment to be about 2,400 kg.

Available information shows PCB concentrations in sediment in some samples collected from Zeunert Pond being as high as 11,000 mg/kg.[27] Shallow samples collected from locations near the present shoreline have PCB concentrations ranging between 0.85 mg/kg and 12 mg/kg. This suggests that the currently exposed shoreline of the pond may be contaminated. Shallow sediments collected in the center of the pond have PCB concentrations ranging between 12 mg/kg and 140 mg/kg. The highest PCB concentrations were reported from sediments taken between 22 and 28 inches below the sediment surface. Concentrations in several of these samples exceeded 1,300 mg/kg PCBs, with the maximum being 11,000 mg/kg.

The combined effects of several toxicants in sediment of the Milwaukee River were estimated using the methodology described in Chapter III of this report. Figure 161 shows overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, for streams in the Milwaukee River watershed. Figure 162 shows estimated incidences of toxicity to benthic organisms from sediment contaminants for the same streams. For sediments in the Milwaukee River, mean PEC-Q values range between 0.008 and 49.310. These mean PEC-Q levels suggest that benthic organisms in the Milwaukee River are experiencing moderate to high incidences of toxic effects. In these samples, the estimated incidence of toxicity ranges between about 0.8 and 100 percent. At sites upstream of the confluence with Cedar Creek, which is around River Mile 25, mean PEC-Q values are relatively low, ranging from 0.027-0.052. This suggests that benthic organisms at these sites are experiencing relatively low incidences of toxic effects, incidences less than or equal to about 5 percent. The mean PEC-Q values are higher at sites downstream from the confluence with Cedar Creek. The highest mean

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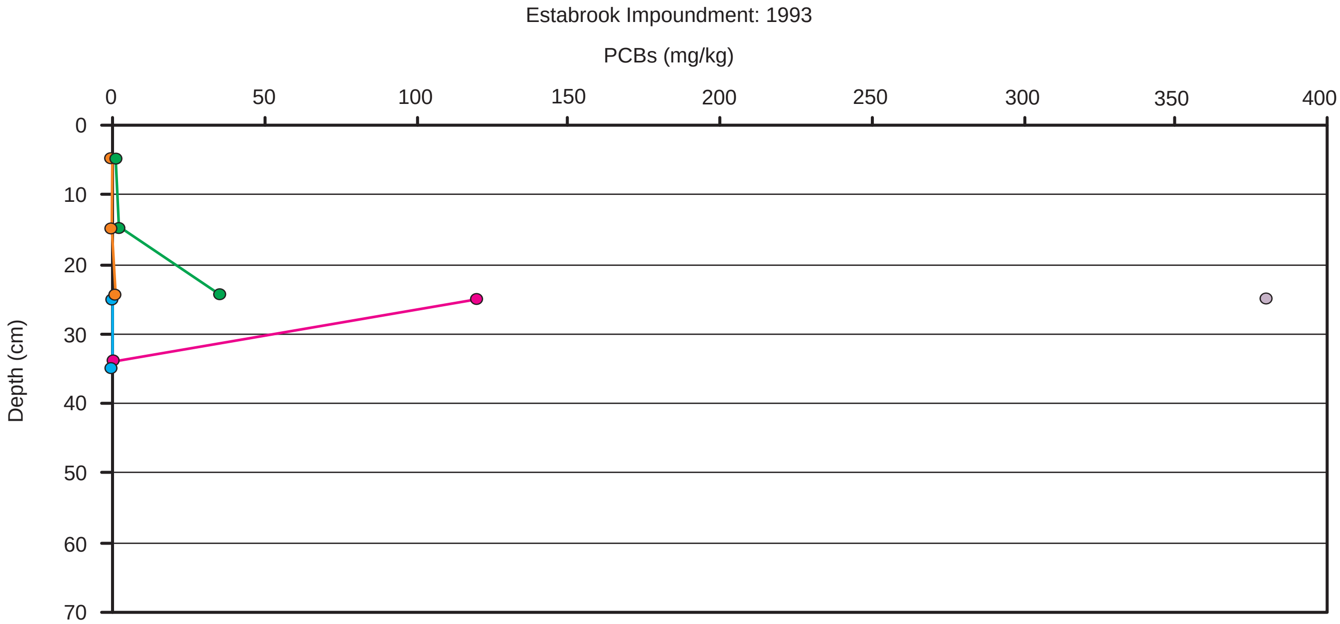
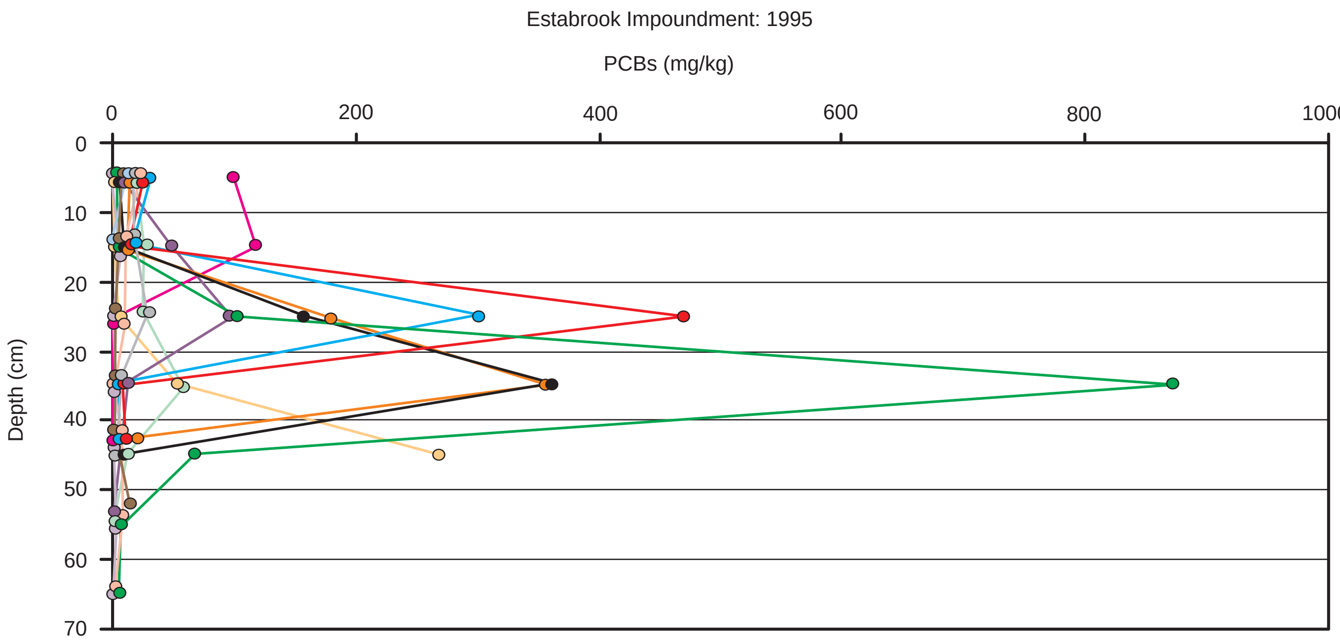
[27]*U.S. Department of Health and Family Services Agency for Toxic Substances and Disease Registry,* Health Consultation: Zeunert Quarry Pond Polychlorinated Biphenyl Site, City of Cedarburg, Ozaukee County, Wisconsin, *April 11, 2005.*

Figure 160

CONCENTRATIONS OF PCBs IN SEDIMENT FROM ESTABROOK IMPOUNDMENT: 1993-1995



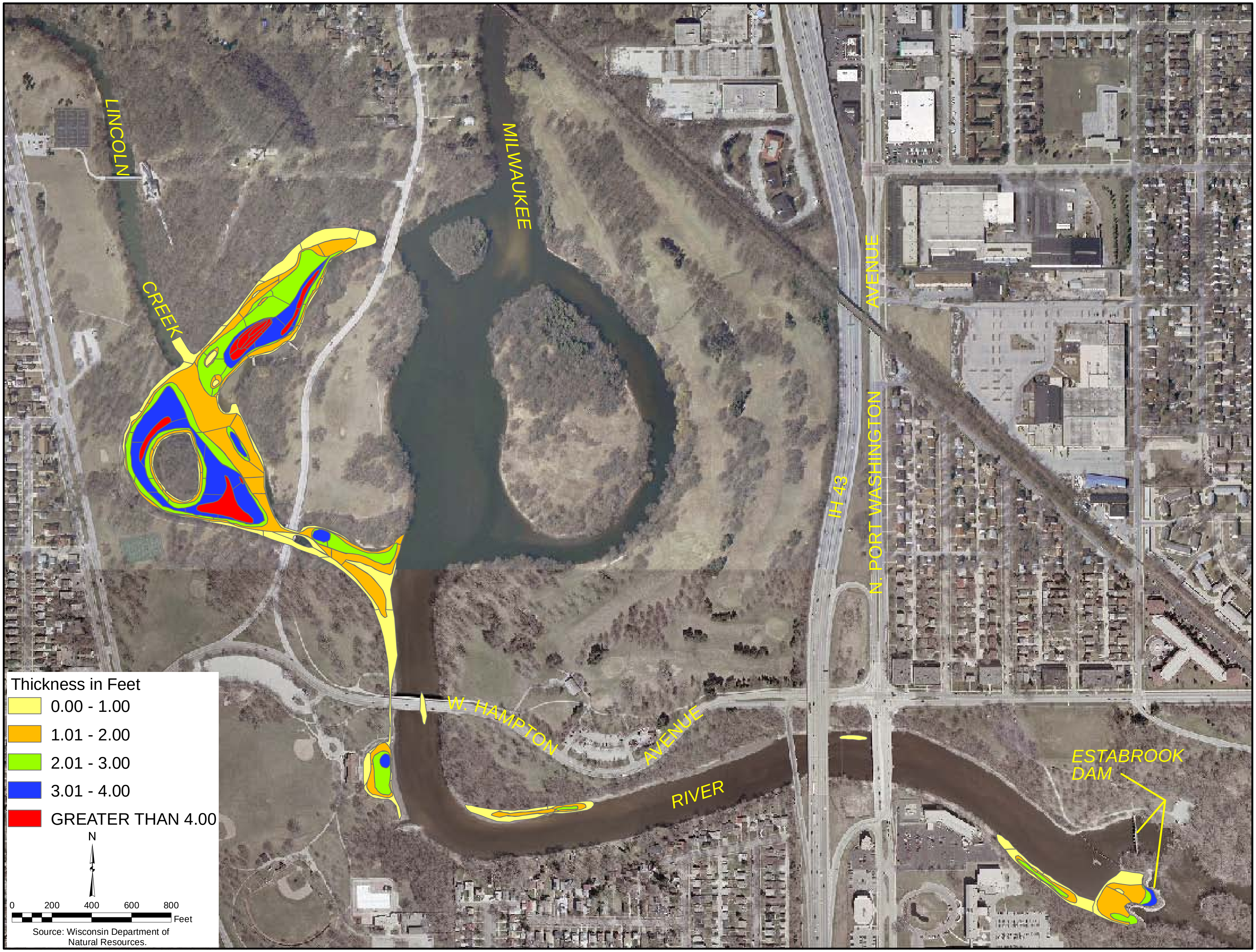


Source: Wisconsin Department of Natural Resources and SEWRPC.

PEC-Q values and the greatest range in mean PEC-Q values are observed at Estabrook impoundment. For sediments in Lincoln Creek, mean PEC-Q values range from about 0.22 to 5.34 (see Figure 161). These mean PEC-Q levels suggest that benthic organisms in Lincoln Creek are experiencing moderate to high incidences of toxic effects. In these samples the estimated incidences of toxicity range between about 20 and 100 percent. High mean PEC-Q values were also observed in sediment from Cedar Creek. Values of mean PEC-Q for this stream range from 0.01 to 81.43, with associated estimated incidences of toxic effects to benthic organisms ranging between about 9 and 100 percent. In upstream reaches, above River Mile 25, these high mean PEC-Q values are

Map 54

SEDIMENT DEPTH DISTRIBUTION IN SELECTED AREAS OF THE ESTABROOK IMPOUNDMENT WITHIN THE MILWAUKEE RIVER WATERSHED: 2001-2003



Map 55

PCB CONCENTRATION DISTRIBUTION WITHIN LINCOLN CREEK AND THE ESTABROOK IMPOUNDMENT WITHIN THE MILWAUKEE RIVER WATERSHED: 2001-2003

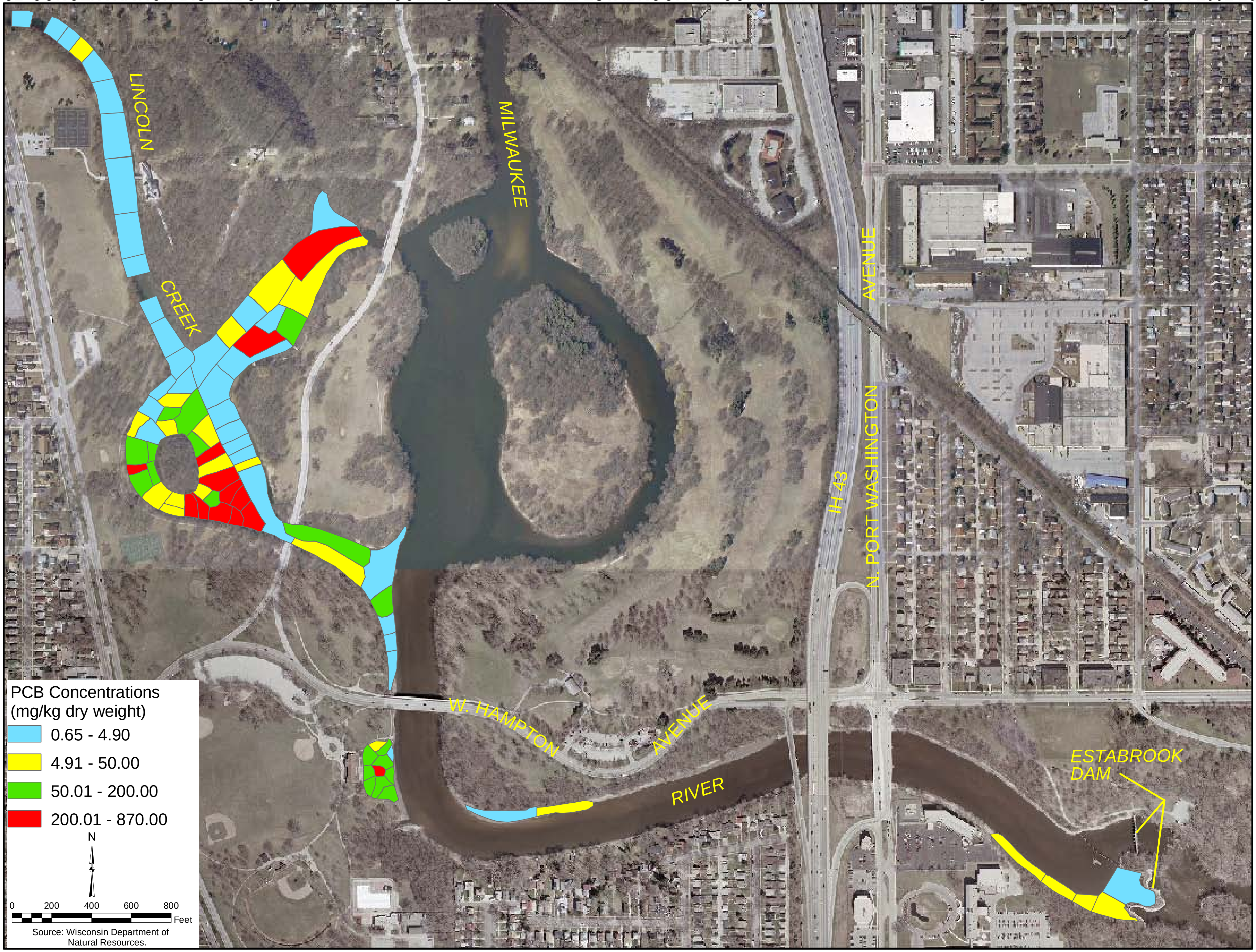
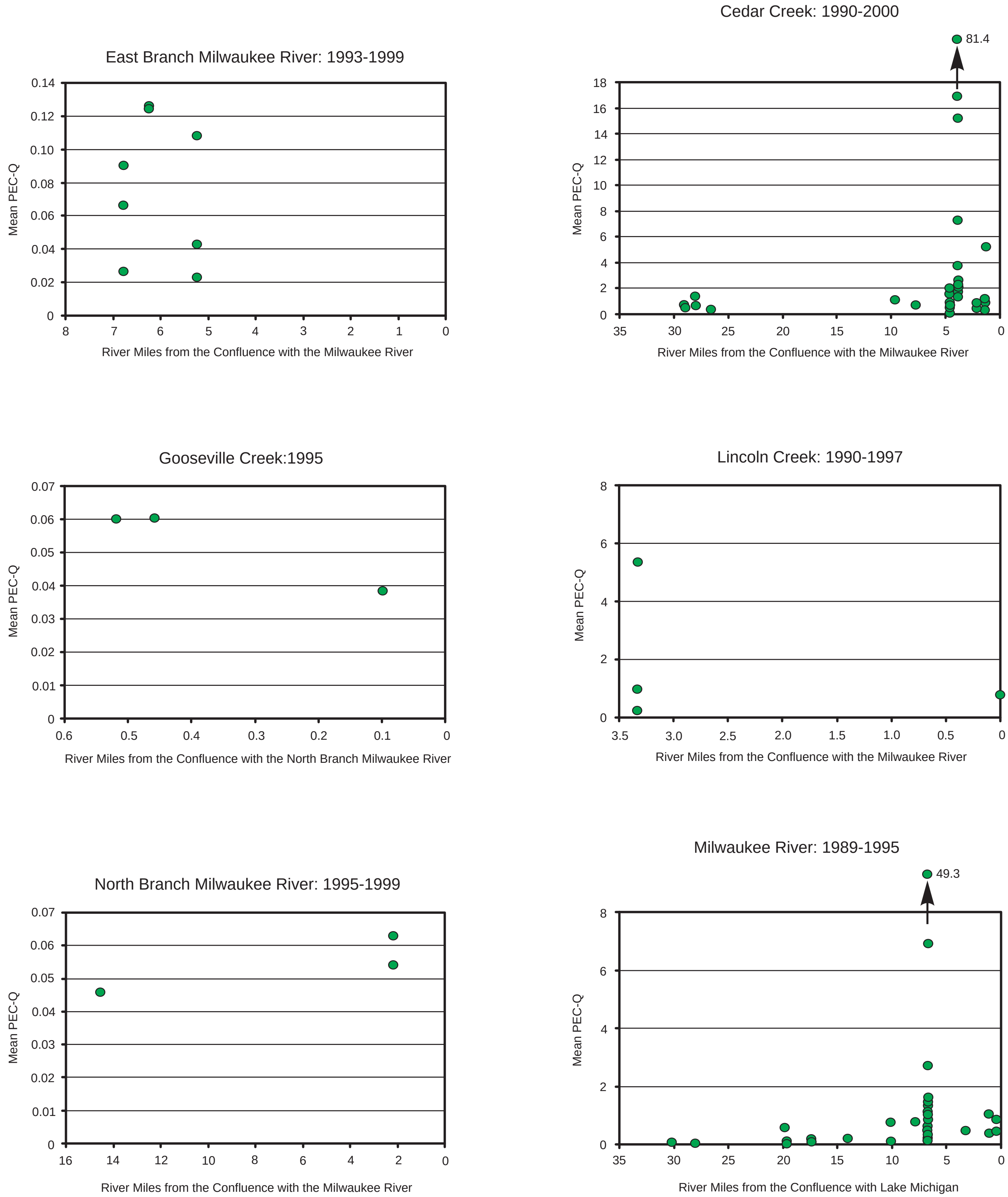


Figure 161

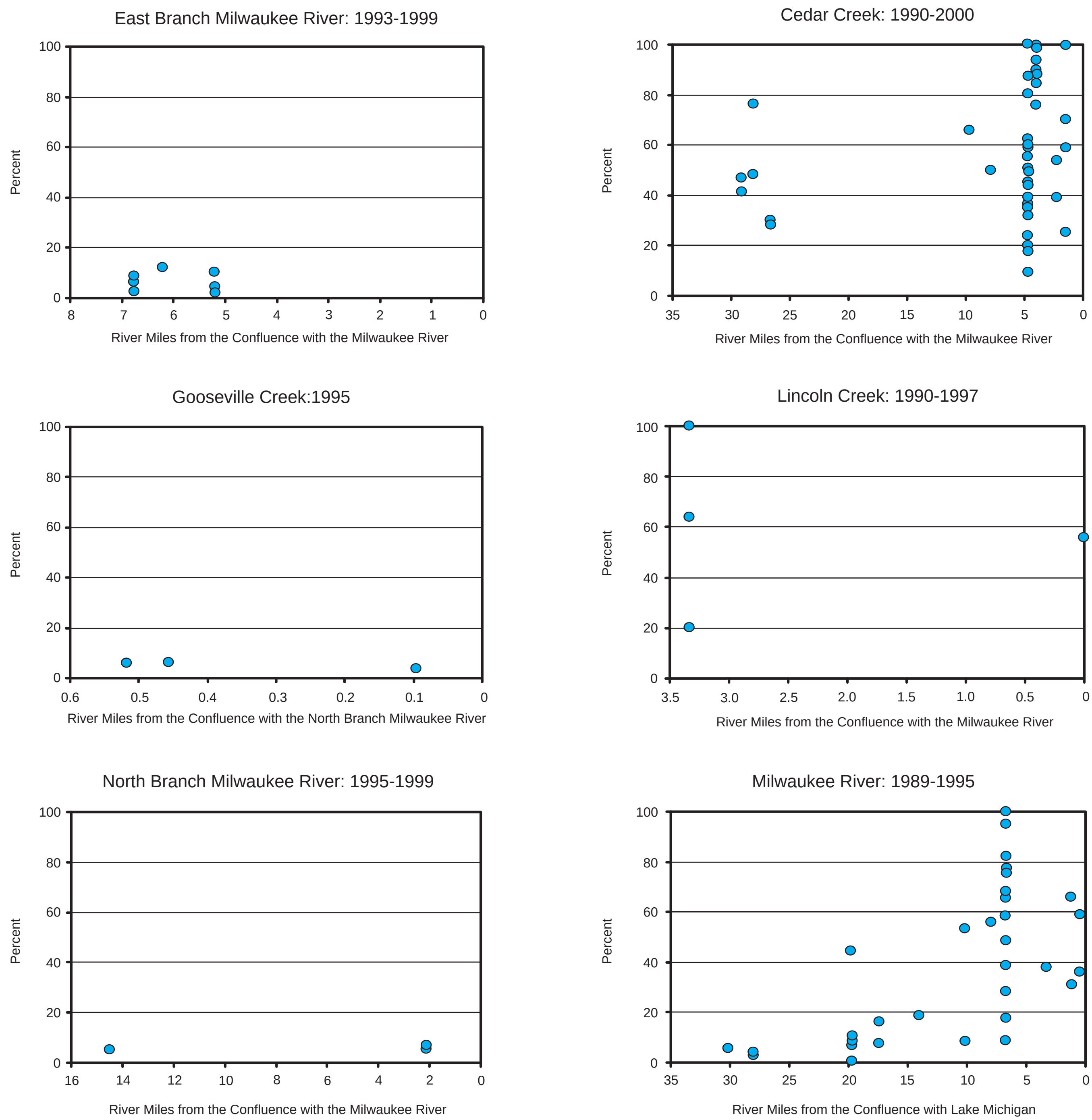
MEAN PROBABLE EFFECT QUOTIENTS (PEC-Q) FOR SEDIMENT IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1989-2000



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 162

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS IN THE MILWAUKEE RIVER WATERSHED: 1989-2000



Source: Wisconsin Department of Natural Resources and SEWRPC.

due to the presence of heavy metals in the sediment. In downstream reaches, the high values of mean PEC-Q result from PCB contamination. By comparison, mean PEC-Q values are lower in sediment from the East Branch of the Milwaukee River, Gooseville Creek, and the North Branch of the Milwaukee River. In these three streams, mean PEC-Q is below 0.14 in all samples. Estimated incidences of toxic effects to benthic organisms are below 20 percent for samples from the East Branch of the Milwaukee River and below 10 percent for samples from Gooseville Creek and the North Branch of the Milwaukee River.

BIOLOGICAL CONDITIONS OF THE MILWAUKEE RIVER AND ITS TRIBUTARIES

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristics of those areas are, therefore, important determinants of the overall quality of the environment in the Milwaukee River watershed.

Fisheries

Creeks and Rivers

Review of the fishery data collected in the Milwaukee River basin between 1900 and 2004 indicates an apparent net loss of about 10 total species throughout the watershed during this time period as shown in Table 105.[28] Table 105 indicates a loss of more than 20 species during the period of 1987 through 1997; however, this apparent decrease seems to be due, in part, to a decreased sampling effort. For example, the 1987-1993 time period contained about one-eighth the number of recorded total samples per year compared to the 1975-1986 time period. Table 105 also shows that the historical and current numbers of species have been, and continue to be, relatively high with a total of more than 60 different species, but the overall fish species composition has changed during this time period. The most recent fishery surveys in 1998-2004 indicated an apparent loss of about 12 species that have not been observed since 1986 that include the pugnose shiner, which is a threatened species in the State of Wisconsin; weed shiner and banded killifish, which are species of special concern in the State of Wisconsin; and the banded darter, northern hog sucker, pallid shiner, pugnose minnow, bullhead minnow, longnose dace, river shiner, warmouth, and yellow bass. Six of these species lost were intolerant fish species sensitive to degraded water quality conditions. The 1998-2004 surveys also indicate an apparent gain of two species that include the emerald shiner and gizzard shad, which are both intermediate tolerance species. It is important to note that these new fish species observations were found in the most downstream reach of the Milwaukee River between the confluence with Lake Michigan and the Estabrook Park dam, which indicates the potential influence of Lake Michigan fishes on the abundance and diversity of fishes within this lower reach of the Milwaukee River (see the "Influence of Dams/Dam Removal" subsection below). Stocking of a third species, lake sturgeon, has also begun in this lower section of the Milwaukee River as part of the Wisconsin Department of Natural Resources continued efforts to enhance this fishery community.

The Milwaukee River watershed contains a variety of both warmwater (maximum daily mean temperature greater than 24 degrees Celsius) and coldwater (maximum daily mean temperature less than 22 degrees Celsius) streams as well as lake and pond systems.[29] The majority of the streams and lakes in the Milwaukee River watershed are considered warmwater fisheries. However, there are several coldwater stream systems that are generally located in the upstream portions of the watershed and include Auburn Lake Creek, Chambers Creek, East Branch of the Milwaukee River, Gooseville Creek, Melius Creek, Mink Creek, Nichols Creek, North Branch of the Milwaukee River, Stony Creek, and Watercress Creek. In terms of the lake systems, only Big Cedar Lake is considered to contain a coldwater fishery (see the "Lakes and Ponds" subsection below). These coldwater systems are generally comprised of either brook trout or brown trout species, which require cold, well-oxygenated water to survive. These systems are rare in southeastern Wisconsin and persist due to a high proportion of groundwater discharge that helps maintain the physiological conditions necessary for these species to survive.

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[28]*Wisconsin Department of Natural Resources,* The State of the Milwaukee River Basin*, PUBL WT-704-2001, August 2001; Don Fago, Wisconsin Department of Natural Resources, "Distribution and Relative Abundance of Fishes in Wisconsin: VIII. Summary Report,"* Technical Bulletin No. 75*, 1992; Wisconsin Department of Natural Resources, "Distribution and Relative Abundance of Fishes in Wisconsin: IV. Root, Milwaukee, Des Plaines, and Fox River Basins,"* Technical Bulletin No. 147*, 1984; George Becker,* Fishes of Wisconsin*, University of Wisconsin Press, 1983; and M. Miller, J. Ball, and R. Kroner, Wisconsin Department of Natural Resources,* An Evaluation of Water Quality in the Milwaukee River Priority Watershed*, Publication WR-298-92, January 1992.*

[29]*John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management, Volume 16, May 1996.

Table 105

FISH SPECIES COMPOSITION IN THE MILWAUKEE RIVER WATERSHED: 1900-2004

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intolerant					
Banded Darter	0	1	0	0	0
Blackchin Shiner	2	4	2	0	1
Blacknose Shiner	6	6	10	0	1
Greater Redhorse[b]	5	9	57	12	14
Least Darter[c]	1	2	0	0	1
Longear Sunfish[b]	6	3	4	0	7
Iowa Darter	1	7	2	99	18
Mimic Shiner	41	1	0	0	7
Mottled Sculpin	3	10	2	4	29
Northern Hog Sucker	1	0	0	0	0
Pallid Shiner	0	<1	0	0	0
Pugnose Minnow	0	<1	0	0	0
Pugnose Shiner[b]	1	2	0	0	0
Rock Bass	22	30	65	9	30
Rosyface Shiner	8	1	0	0	1
Smallmouth Bass[d]	6	6	35	7	18
Spottail Shiner	2	2	0	0	2
Stonecat	7	15	31	7	29
Weed Shiner[c]	2	0	0	0	0
Tolerant					
Banded Killifish[c]	1	2	0	0	0
Black Bullhead	22	39	31	19	33
Blacknose Dace	9	15	10	10	34
Bluntnose Minnow	1	6	0	9	34
Brown Bullhead	8	4	0	3	0
Central Mudminnow	8	37	16	30	57
Common Carp	13	23	67	9	23
Creek Chub	20	37	24	22	74
Fathead Minnow	8	15	18	48	36
Golden Shiner	6	16	6	7	7
Goldfish	1	30	4	16	2
Green Sunfish	17	43	73	55	52
White Sucker	40	66	80	49	83
Yellow Bullhead	7	19	33	16	25
Intermediate					
Black Crappie	17	14	22	7	13
Blackside Darter	7	8	33	6	18
Blackstripe Topminnow	0	2	4	0	4
Bluegill	27	38	63	25	43
Bigmouth Shiner	0	0	2	0	2
Brassy Minnow	0	<1	2	0	0
Brook Stickleback	5	14	4	16	38
Brook Trout[d]	1	6	2	- -[d]	8
Brown Trout[d]	1	2	- -[d]	- -[d]	3
Bullhead Minnow	0	4	0	0	0
Central Stoneroller	1	11	12	12	13
Channel Catfish	1	1	0	0	3
Chinook Salmon[d]	- -[d]	<1	- -[d]	- -[d]	- -[d]
Coho Salmon[d]	- -[d]	<1	- -[d]	- -[d]	- -[d]
Common Shiner	24	42	51	36	63
Emerald Shiner	0	0	0	0	3
Fantail Darter	9	21	12	21	36
Gizzard Shad	0	0	0	1	1
Golden Redhorse	2	7	51	6	13

Table 105 (continued)

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1975	1975-1986	1987-1993	1994-1997	1998-2004
Intermediate (continued)					
Hornyhead Chub	22	25	51	21	45
Johnny Darter	41	28	33	99	42
Lake Chubsucker[c]	1	2	0	0	1
Lake Sturgeon[e]	0	0	0	0	- -[e]
Largemouth Bass	30	37	33	13	36
Largescale Stoneroller	13	3	20	9	4
Logperch	6	10	18	9	18
Longnose Dace	2	0	0	0	0
Northern Pike	29	39	51	25	25
Northern Redbelly Dace	1	6	0	0	5
Orangespotted Sunfish	0	1	0	0	1
Pearl Dace	1	7	0	0	8
Pumpkinseed	30	40	59	30	27
Rainbow Trout[d]	3	1	- -[d]	- -[d]	4
Redfin Shiner[b]	10	2	8	1	0
River Shiner	1	0	0	0	0
Sand Shiner	13	10	29	9	5
Shorthead Redhorse	1	3	2	1	3
Silver Redhorse	1	1	0	4	3
Southern Redbelly Dace	10	5	6	1	6
Spotfin Shiner	4	11	31	7	13
Striped Shiner[f]	8	3	0	1	0
Tadpole Madtom	7	6	12	7	13
Walleye[d]	9	4	8	- -[d]	- -[d]
Warmouth	3	1	0	0	0
White Bass	3	<1	2	0	0
White Crappie	0	1	2	0	0
Yellow Bass	3	<1	0	0	0
Yellow Perch	29	24	24	15	22
Total Number of Samples	143	446	49	67	119
Total Number of Samples per Year	1.9	40.5	4.9	22.3	19.8
Total Number of Species	69	73	53	50	63

NOTE: Data includes samples in both streams and lakes within the Milwaukee River watershed.

[a]*Values represent percent occurrence, which equals 100 times the number of sites where each species was found divided by the total number of sites within a given time period.*

[b]*Designated threatened species.*

[c]*Designated species of special concern.*

[d]*These species are stocked by Wisconsin Department of Natural Resources managers.*

[e]*Lake Sturgeon were stocked in 2004 in the Milwaukee River in Ozaukee County.*

[f]*Designated endangered species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

It is important to note that in order to provide quality recreational fishing opportunities throughout the Milwaukee River watershed, some of the warmwater and coldwater fisheries in both streams and lakes are supplemented by stocking to enhance the existing fishery where habitat, water quality, and/or overharvesting have led to decreased stocks (see Table 106). As shown in Table 106 stocking occurs in Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties. Largemouth bass, smallmouth bass, walleye, northern pike, walleye, and muskellunge tend to be stocked in warmwater areas. Brook trout, brown trout, and rainbow trout tend to be stocked in the coldwater areas.

Table 106

FISH STOCKING OF FRY, FINGERLING, AND JUVENILE FISHES IN STREAM REACHES AND LAKES/PONDS IN THE MILWAUKEE RIVER WATERSHED: 1982-2004

Stream/Pond	Species	Earliest Record	Recent	Annual Average Number Stocked
Milwaukee County				
Milwaukee River	Brook Trout Brown Trout Chinook Salmon Coho Salmon Rainbow Trout Walleye	1992 1992 1989 1992 1989 1986	- - 1998 1997 2004 2004 2004	9,200 20,834 149,375 14,137 17,485 7,758
Brown Deer Park Pond	Largemouth Bass Rainbow Trout	1991 1984	- - 2004	1,250 2,321
Dineen Park Pond	Rainbow Trout	1984	2004	989
Estabrook Park Pond	Largemouth Bass Rainbow Trout	1991 1984	- - 2004	50 458
Juneau Park Lagoon	Largemouth Bass Rainbow Trout	1991 1988	- - 2004	725 3,070
McGovern Park Pond	Largemouth Bass Rainbow Trout Centrarchid species	1987 1986 1986	1991 2004 1988	1,075 2,264 2,056
Fond du Lac County				
Auburn Lake	Walleye	1986	1987	400,000
Auburn Lake Creek	Brook Trout Brown Trout	1972 1988	2003 - -	488 500
Campbellsport Millpond	Northern Pike	1977	1978	78,500
Forest Lake	Largemouth Bass	1974	1984	6,500
Kettle Moraine Lake	Largemouth Bass Northern Pike Walleye	1976 1977 1986	- - - - 1992	10,000 20,000 262,225
Lake Bernice	Largemouth Bass	1972	1976	3,083
Long Lake	Northern Pike Walleye	- - 1983	2004 2003	240,000 76,171
Milwaukee River	Smallmouth Bass	1983	1985	4,593
Silver Creek	Brown Trout	1998	2001	10,805
Ozaukee County				
Cedarburg Pond	Centrarchid hybrid	1987	- -	4,860
Cedarburg Stone Quarry	Largemouth Bass Rainbow Trout Centrarchid hybrid	1988 1985 1986	- - 1991 - -	650
Hawthorne Hills Pond	Largemouth Bass	1982	1983	450
Milwaukee River	Lake Sturgeon	- -	2004	2,200
North Branch Milwaukee River	Catfishes	1973	- -	30,450

Table 106 (continued)

Stream/Pond	Species	Earliest Record	Recent	Annual Average Number Stocked
Sheboygan County				
Beechwood Lake	Largemouth Bass Northern Pike	1982 1982	1983 2001	1,750 10,815
Butler Lake	Brook Trout Rainbow Trout	1981 1972	1985 1992	1,017 1,090
Crooked Lake	Northern Pike	1980	1992	428
Lake Ellen	Northern Pike Walleye	1980 1975	1995 2004	640 8,035
Melius Creek	Brook Trout Brown Trout	1980 1972	1992 2003	640 764
Mink Creek	Brook Trout	1994	2002	335
Random Lake	Muskellunge Northern Pike Walleye	1991 1991 1991	2004 1996 2004	453 1,216 15,909
Watercress Creek	Brook Trout	1972	1997	828
Washington County				
Big Cedar Lake	Lake Trout Walleye	1985 1986	2004 2003	20,849 73,550
Green Lake	Northern Pike Walleye	1991 1984	1993 - -	39 5,605
Kewaskum Millpond	Rainbow Trout	1994	1999	1,200
Little Cedar Lake	Walleye	2001	2003	15,643
Milwaukee River	Northern Pike Smallmouth Bass Walleye	1983 1984 1982	- - - - 1984	2,015 2,079 10,284
Wallace Lake	Largemouth Bass	1988	- -	24,000

Source: Wisconsin Department of Natural Resources and SEWRPC.

In Wisconsin, high-quality warmwater streams are characterized by many native species including cyprinids, darters, suckers, sunfish, and percids that typically dominate the fish assemblage. Intolerant species (species that are particularly sensitive to water pollution and habitat degradation) are also common in high-quality warmwater systems.[30] Tolerant fish species (species that are capable of persisting under a wide range of degraded conditions) are also typically present within high-quality warmwater streams, but they do not dominate. Insectivores (fish that feed primarily on small invertebrates) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrates) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common.

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[30]*John Lyons, "Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin," United States Department of Agriculture*, General Technical Report NC-149, *1992.*

In contrast to warmwater streams, coldwater systems are characterized by few native species, with salmonids (trout) and cottids (sculpin) dominating, and they lack many of the taxonomic groups that are important in high-quality warmwater streams as summarized above. An increase in fish species richness in coldwater fish assemblages often indicates environmental degradation. When degradation occurs the small number of coldwater species are replaced by a larger number of more physiologically tolerant cool and warmwater species, which is the opposite of what tends to occur in warmwater fish assemblages. Due to the fundamental differences between warmwater versus coldwater streams a separate IBI was developed to assess the health of coldwater streams.[31] This coldwater IBI is based upon the following elements: number of intolerant species, percent of individuals that are tolerant, percent of all individuals that are top carnivore species, percent of all individuals that are native or exotic coldwater (coho salmon, chinook salmon, rainbow trout, brown trout) or coolwater species, and percent of salmonid individuals that are brook trout. Since brook trout are the only native stream dwelling salmonid in the State of Wisconsin, the presence and abundance of brook trout dramatically improves the coldwater IBI scores.

Both the warmwater IBI and coldwater IBI were used to assess the fishery among warmwater and coldwater streams as appropriate in the analyses of the fisheries abundance and distribution that are presented below.

When applying the Index of Biotic Integrity (IBI) that is used to measure environmental quality in warmwater and coldwater streams of Wisconsin, it is recommended that electrofishing gear be used as opposed to other techniques such as seining or fyke netting.[32] Table 105 summarizes all fish species found within both stream and lake systems by selected time periods throughout the entire Milwaukee River watershed from samples collected by a variety of gear types. Maps 56 and 57 show the location and quality of fisheries samples collected by all gear types for the Milwaukee River watershed from 1900 to 1997 and 1998 to 2004. Figure 163 shows the fisheries samples collected among rivers and creeks throughout the Milwaukee River watershed by selected time periods and their associated IBI scores among specific gear types that include the backpack electrofisher (generator carried on a backpack), long line electrofisher, stream electrofisher (generator towed by hand in the stream), boom electrofisher (generator located on a boat), and net or any type of net or seine. Since different sampling gear types affect the type and amount of different fish species caught, samples collected with any net or seine and long line electrofisher methods were removed prior to computing IBI scores among each of the time periods. The backpack electrofishing, stream electrofishing, and boom shocking gear types are legitimate gear types when applying the fisheries IBI and these are the only gear types sampled most consistently among the selected time periods as shown in Figure 164. Therefore, only samples using backpack, stream electrofishing, and boom electrofishing gear types were used to assess the fisheries community in the Milwaukee River watershed as summarized below.

Index of Biotic Integrity (IBI) results indicate that there has been an improvement in the quality of the fishery of the Milwaukee River watershed compared to the historical conditions moving from the very poor (IBI score 0-20) to a fair community IBI rating score of 30 to 49 based on mean IBI scores for each time period as shown in Figure 163. In addition, 25 percent of the current 1998-2004 time period samples were classified as good to excellent. However, 25 percent of the samples in the current time period still remain classified within the very poor categories, which indicate that the majority of the watershed contains a high abundance and diversity of fishes.

The Milwaukee River watershed fishery has consistently had about 25 percent of samples that are dominated by a high proportion of low dissolved oxygen tolerant fishes as shown in Figure 165 and Table 105, which is supported by dissolved oxygen problems identified in the water quality analysis above for the North Branch Milwaukee River, Lincoln Creek, and Lower Milwaukee River subwatersheds. Tolerant fish species tend to become dominant when water quality conditions become degraded, potentially leading to low levels of dissolved oxygen

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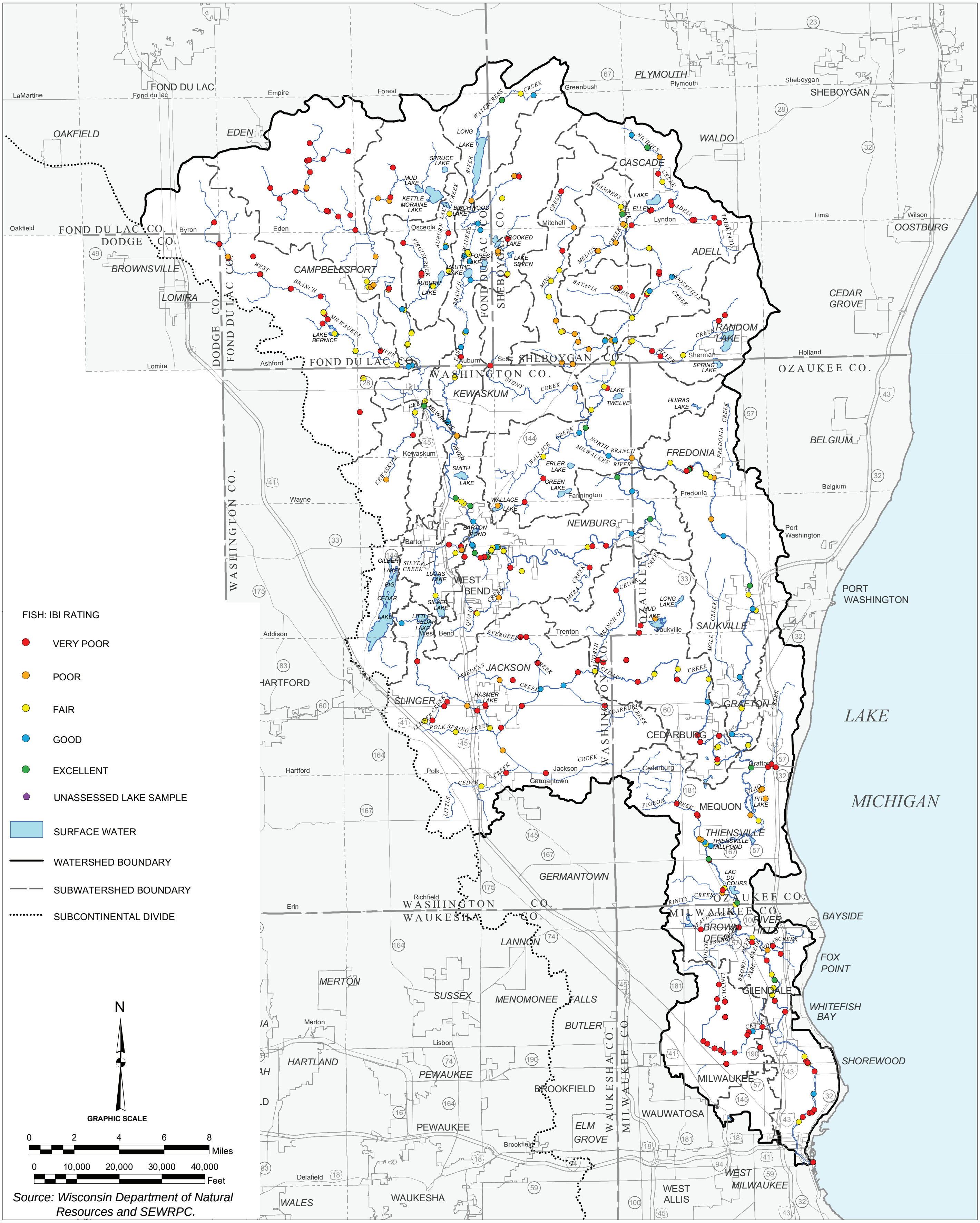
[31]*John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management, Volume 16, May 1996.

[32]*John Lyons,* General Technical Report NC-149, op. cit.

Map 56

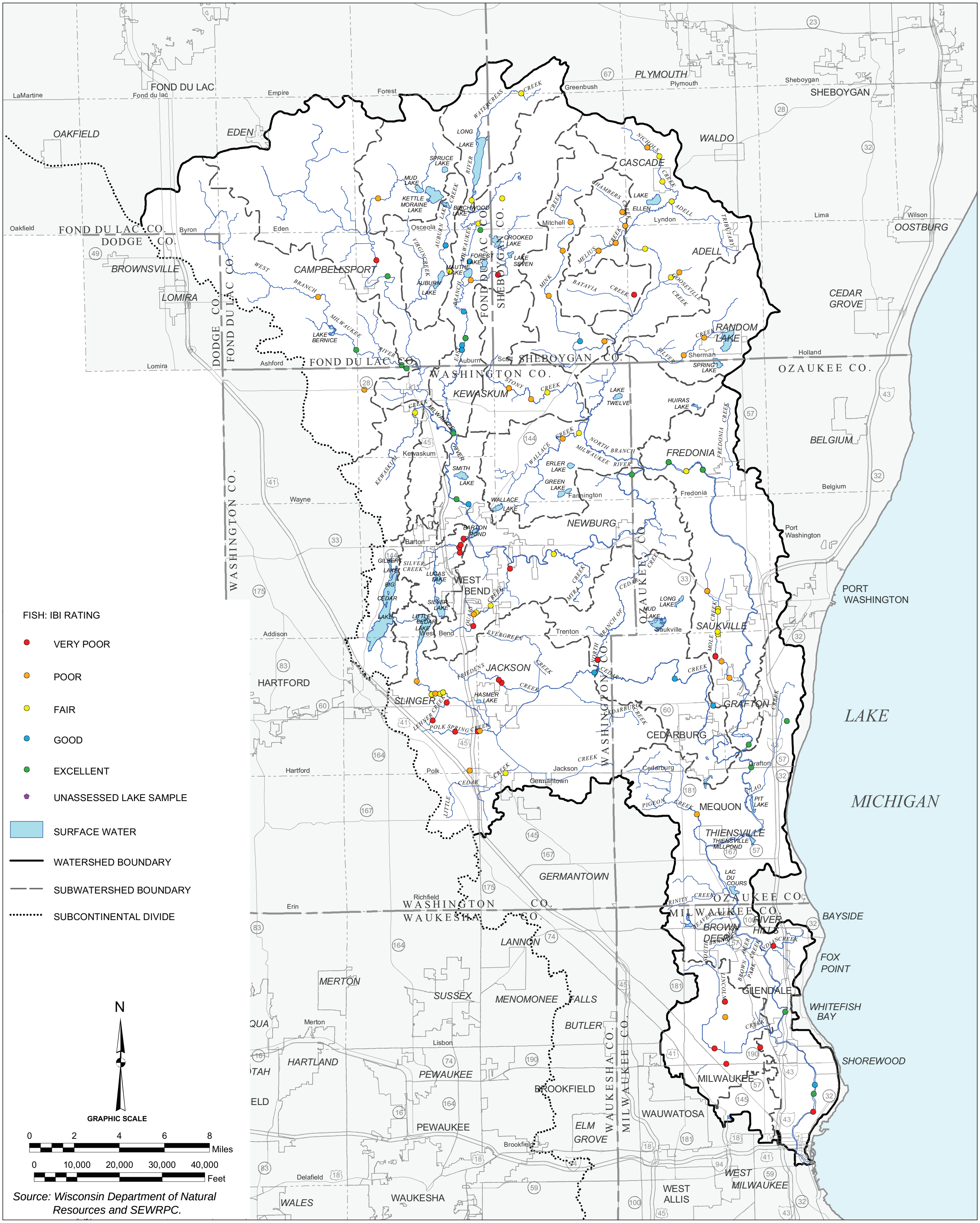
FISHERIES SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1900-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 57

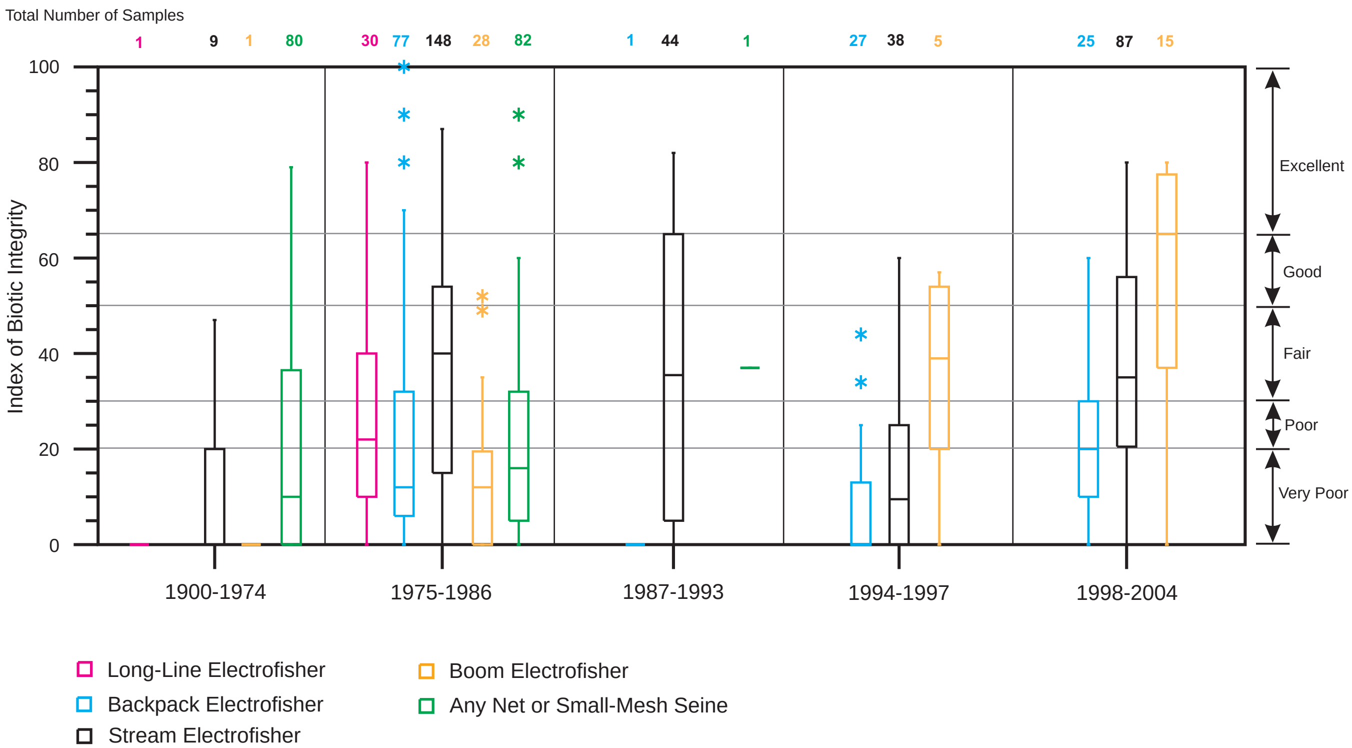
FISHERIES SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1998-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 163

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION BY GEAR TYPE IN THE MILWAUKEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

concentrations, increased levels of ammonia and other toxic substances, and/or high turbidity levels.[33] However, as shown in Figure 165 and Table 105 the proportions of dissolved oxygen tolerant fishes in the majority of the samples from 1975 to present have not exceeded 40 percent, which is consistent with a healthy and diverse fish community. Low dissolved oxygen concentrations and extreme high or low temperature fluctuations have been identified to be one of the major factors negatively impacting the warm and coldwater fishery on this system.[34] Carp, an exotic invasive species, are present but are not a dominant component of the fishery in this watershed. They continue to threaten the overall quality of this fishery by destroying habitat and competing for food and spawning areas of native fish species.

In addition to the relatively consistent low proportions of tolerant species in this watershed over time, there has also been a sustained good proportion of top carnivore fish species, which is indicative of a good balance of predator fishes to forage fishes ratio in this system as shown in Figure 166. The top carnivore species also tend to be highly sought after gamefish species by anglers, which indicate that recreational fishing opportunities may be increasing. The top carnivore species responsible for this shift include the largemouth bass, northern pike, and rock bass. (see Table 105).

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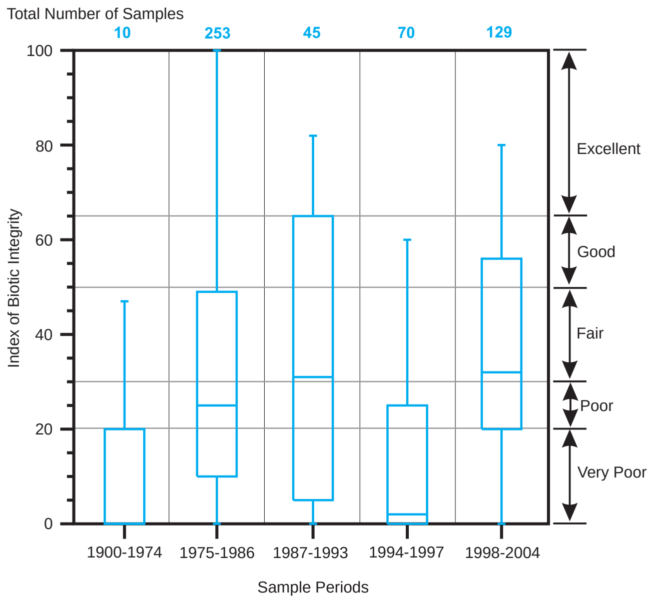
[33]*George Becker*, op. cit.

[34]*Wisconsin Department of Natural Resources, PUBL WT-704-2001*, op. cit.

Figure 164

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

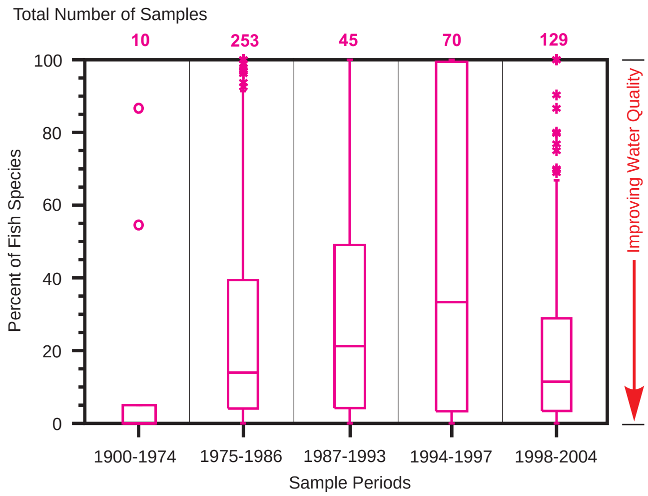
There are adequate data to assess the current fishery conditions within most of the subwatersheds during the 1998 through 2004 period as shown in Figure 167. For example, only the Kettle Moraine Lake, Kewaskum Creek, and Batavia Creek subwatersheds have only one survey record in the current time period. However, the results for these subwatersheds generally indicate that there has been an improvement in the fishery community quality from the historic very poor IBI rating, with the possible exception of the Batavia Creek subwatershed that shows a very poor IBI classification. Figure 167 also shows that nearly all of the subwatersheds either remained the same quality—as demonstrated in the Middle Milwaukee, North Branch Milwaukee River, Mink Creek, Silver Creek (Sheboygan County), Upper Lower Milwaukee River, Stony Creek, Cedar Creek, and Lincoln Creek subwatersheds—or improved in quality—as demonstrated in the Upper Milwaukee River, Kettle Moraine Lake, Lake Fifteen Creek, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Lower Cedar Creek, and Lower Milwaukee River subwatersheds. However, several subwatersheds including Watercress Creek, Silver Creek (West Bend), and Chambers Creek have decreased in quality.

In general, most of the subwatersheds indicating an improvement in the abundance and diversity of fishes are located in the upper portions of the Milwaukee River watershed (see Figure 167), with the exception of the Lower Cedar Creek and Lower Milwaukee River subwatersheds in the downstream areas (see the "Influence of Dams/Dam Removal" subsection below). The poorest quality subwatersheds include Silver Creek (West Bend), Chambers Creek, Batavia Creek, and Lincoln Creek, each of which achieved a classification of very poor (HBI score 0-20). Samples within the Mink, Silver (Sheboygan County), and Stony Creek subwatersheds are classified as poor, which indicates that these subwatersheds are also on the lower end of the fishery quality spectrum. The Chambers Creek, Mink Creek, Silver Creek (Sheboygan County), and Stony Creek subwatersheds include Melius Creek, Chambers Creek, Mink Creek, and Stony Creek, which are coldwater streams. That indicates that these trout streams contain degraded fisheries. In addition, the Watercress Creek subwatershed, which is also a coldwater system, moved from an excellent fishery to a fair classification, further indicating that many of the coldwater streams have become, or are becoming, degraded. The Silver Creek (West Bend), Batavia Creek, and Lincoln Creek subwatersheds are degraded warmwater systems.

The fishery IBI quality among subwatersheds within the Milwaukee River watershed spans the entire range in quality from very poor (IBI score 0-19) to excellent (IBI score 65-100). The majority of the subwatersheds ranged from a poor to fair (IBI score 20-49) classification. However, 10 subwatersheds, or about 50 percent, also achieved scores within the good (IBI score 50-64) classification and six subwatersheds, or about 30 percent, achieved scores within the excellent range. The highest quality subwatersheds include the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, and Middle Milwaukee River, which comprise state designated exceptional resource waters, coldwater, and warmwater systems. The Upper Lower Milwaukee River and Lower Milwaukee River subwatersheds also contain selected areas of high quality warmwater fisheries. Figure 167 demonstrates that, except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper

Figure 165

PROPORTIONS OF DISSOLVED OXYGEN TOLERANT FISHES FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004

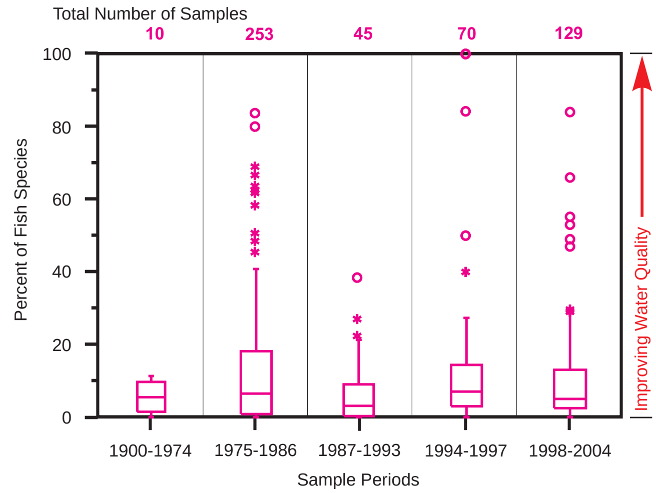


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 166

PROPORTIONS OF TOP CARNIVORES FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good, and in some cases, excellent fishery quality, the majority of the samples throughout the Milwaukee River watershed indicate only a poor to fair fishery.

Further analysis of both the East Branch of the Milwaukee River and Lower Milwaukee River subwatersheds indicates that the proportions of insectivorous fishes have generally remained consistently high from 1975 to 2004 as shown in Figure 168. This demonstrates that these communities are fairly balanced trophically and implies that the diversity and abundance of the food base throughout most of the areas in each of these subwatersheds has remained high. This result also agrees with the high quality macroinvertebrate communities found in the East Branch of the Milwaukee River and Lower Milwaukee River subwatersheds as summarized below. However, as previously mentioned, these subwatersheds contain areas with some of the highest quality fisheries in the Milwaukee River watershed and most of the areas in the rest of the watershed have only poor to fair diversity and abundance of fishes.

Although a small portion of the fishery is of high quality, the majority of these areas are located either in tributary streams in the northern portions of the Milwaukee River watershed, or in the lower portions in proximity to Lake Michigan, where recruitment from the lake has enriched the fishery. There are many areas throughout the watershed where the fishery quality has remained poor to fair or where the fishery quality has declined. The apparent stagnation of the majority of the fishery community within the Milwaukee River watershed can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historic and current agricultural and urban land use development that has occurred within the watershed. Agricultural and/or urban development can cause numerous changes to streams that have the potential to alter aquatic biodiversity that include but are not limited to the following factors which have been observed to varying degrees in the Milwaukee River watershed:[35]

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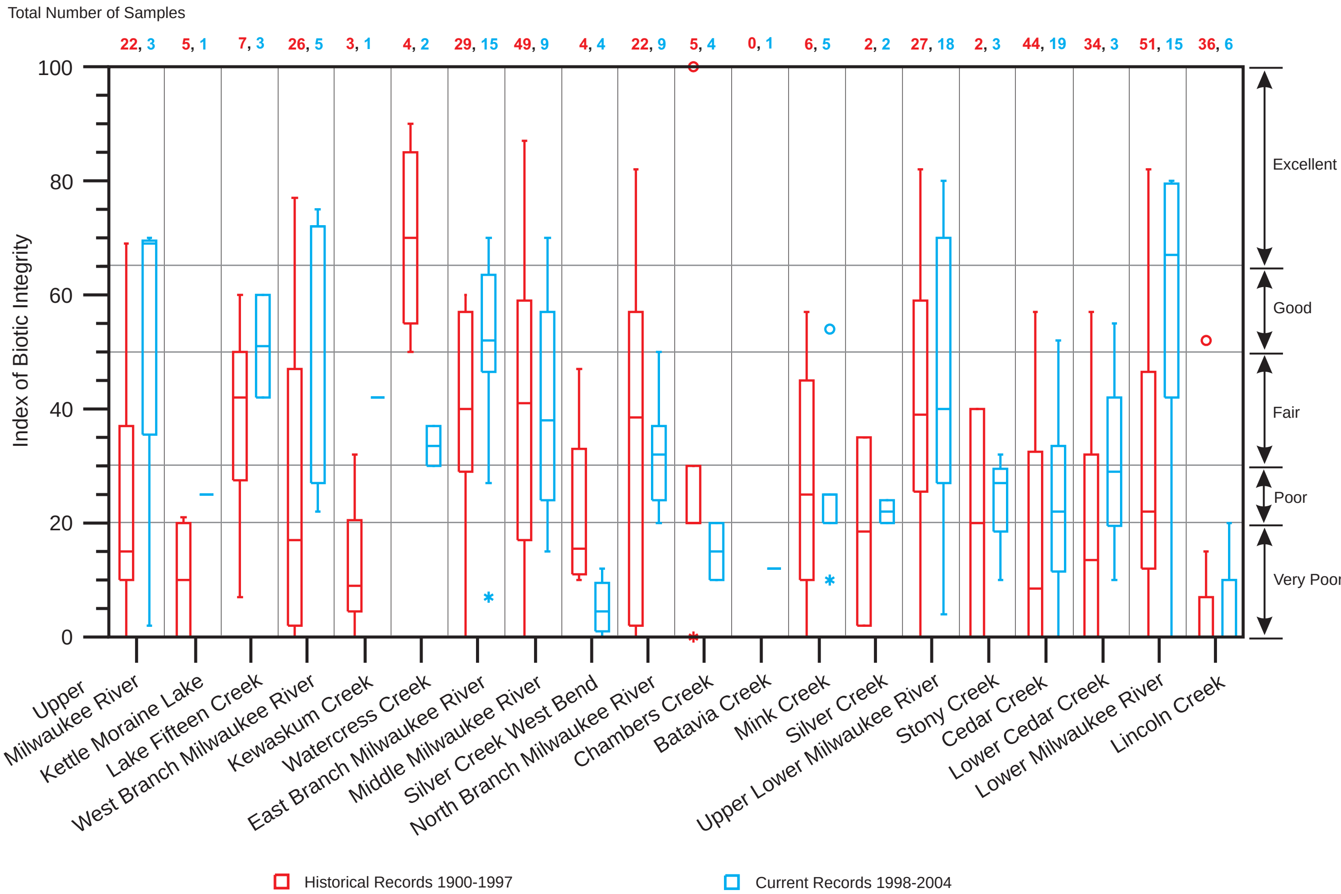
[35]*Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems,"* Watershed Protection Research Monograph No. 1, *March 2003.*

Figure 167

HISTORICAL AND BASE PERIOD FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004

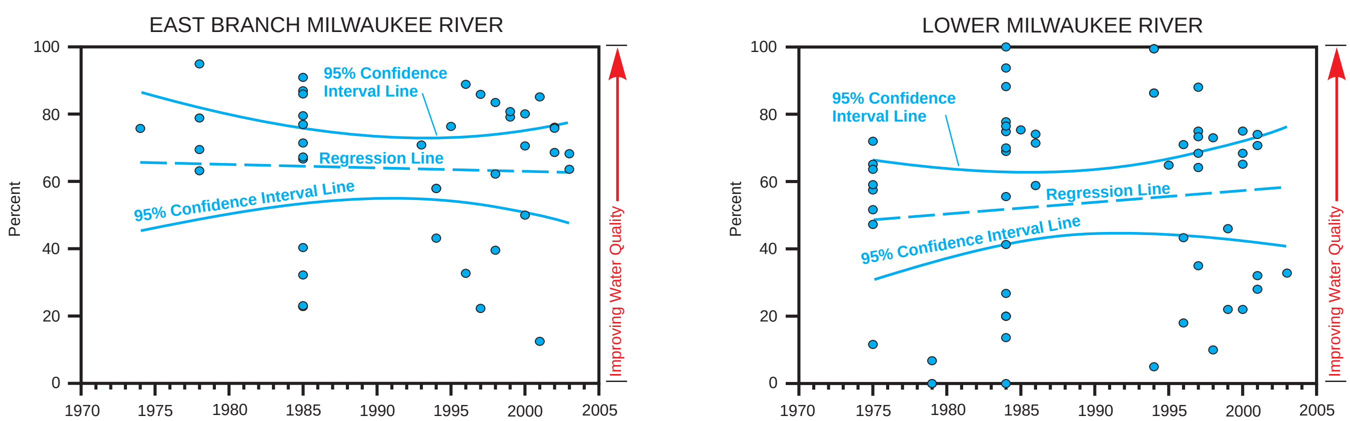


NOTE: See Figure 109 for description of symbols.

Source: *Wisconsin Department of Natural Resources and SEWRPC.*

Figure 168

PROPORTIONS OF INSECTIVOROUS FISHES AMONG SUBWATERSHEDS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: *Wisconsin Department of Natural Resources and SEWRPC.*

- Increased flow volumes and channel-forming storms—These alter habitat complexity, change availability of food organisms related to timing of emergence and recovery after disturbance, reduce prey availability, increase scour related mortality, deplete large woody debris for cover in the channel, and accelerate streambank erosion;

- Decreased base flows—These lead to increased crowding and competition for food and space, increased vulnerability to predation, decrease in habitat quality, and increased sediment deposition;

- Increased sediment load from cultivated agricultural lands and urban lands during and after construction of urban facilities, resulting in sediment transport and deposition in streams—This leads to reduced survival of eggs, loss of habitat due to deposition, siltation of pool areas, and reduced macroinvertebrate reproduction;

- Loss of pools and riffles—This leads to a loss of deep water cover and feeding areas causing a shift in balance of species due to habitat changes;

- Changed substrate composition—This leads to reduced survival of eggs, loss of inter-gravel cover refuges for early life stages for fishes, and reduced macroinvertebrate production;

- Loss of large woody debris—This leads to loss of cover from large predators and high flows, reduced sediment and organic matter storage, reduced pool formation, and reduced organic substrate for macroinvertebrates;

- Increased temperatures due to loss of riparian buffers as well as runoff from pavement–This leads to changes in migration patterns, increased metabolic activity, increased disease and parasite susceptibility, and increased mortality of sensitive fishes and macroinvertebrates;

- Creation of fish blockages by road crossings, culverts, drop structures, and dams—This leads to loss of spawning habitat, inability to reach feeding areas and/or overwintering sites, loss of summer rearing habitat, and increased vulnerability to predation;

- Loss of vegetative rooting systems—This leads to decreased channel stability, loss of undercut banks, and reduced streambank integrity;

- Channel straightening or hardening—This leads to increased stream scour and loss of habitat quality and complexity (i.e. width, depth, velocity, and substrate diversity) through disruption of sediment transport ability;

- Reduced water quality—This leads to reduced survival of eggs and juvenile fishes, acute and chronic toxicity to juveniles and adult fishes, and increased physiological stress;

- Increased turbidity—This leads to reduced survival of eggs, reduced plant productivity, and increased physiological stress on aquatic organisms; and

- Increased algae blooms due to increased nutrient loading—Chronic algae blooms, resulting from increased nutrient loading, lead to oxygen depletion, causing fish kills, and to increased eutrophication of standing waters. These effects can be worsened through encroachment into the riparian buffer adjacent to the waterbody and loss of riparian canopy which increases light penetration.

Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. The Milwaukee River watershed included about 10 percent urban land use by 1970, which approximately corresponds to less than 5 percent directly connected imperviousness in the watershed, and, as of 2000, it has about 21 percent urban land overall (approximately 7 percent directly connected imperviousness). That level of imperviousness is just below the threshold level of 10 percent at which previously cited studies indicate that negative biological impacts have been observed.

However, given the pattern of development in the lower portions of this watershed the Lower Milwaukee River, Lincoln Creek, and the Milwaukee/Menomonee River Combined Sewer Service Area subwatersheds are predominantly in urban land uses, and approach 50 to 60 percent directly connected imperviousness. These downstream areas are well above the threshold level of 10 percent where negative biological impacts are expected. As also described in Chapter II of this report, studies have indicated that the amount of agricultural land in a watershed can also be correlated with negative instream biological conditions. The Milwaukee River watershed was comprised of about 70 percent agricultural land use by 1970 and it currently has about 50 percent agricultural land. Agricultural land use has dominated the upper and middle portions of the Milwaukee River watershed, whereas the lower portions of the watershed have been dominated by urban development. Based upon the amount of agricultural and urban lands in the watershed and, in the past, a lack of measures to mitigate the adverse effects of those land uses, the resultant poor to fair IBI scores observed throughout this watershed are not surprising.[36] Consequently, the Wisconsin Department of Natural Resources has recently concluded that the quality of the fishery remains impaired throughout the Milwaukee River watershed primarily due to the impacts of instream habitat loss, undesirable rooted aquatic plants, fish migration interference, eutrophication, flow modifications, temperature extremes, dissolved oxygen, turbidity, and bacteriological contamination. In addition, the fishery in the lower portions of the Milwaukee River watershed are also impaired by general toxicity problems, PCB bioaccumulation, sediment contamination, and heavy metal toxicity.[37]

As shown on Map 58, habitat data for 100 sites have been collected as part of the WDNR baseline monitoring program and by the WDNR Fish and Habitat Research Section in the Milwaukee River watershed. The baseline monitoring program data were analyzed using the Qualitative Habitat Evaluation Index (QHEI),[38] which integrates the physical parameters of the stream and adjacent riparian features to assess potential habitat quality. This index is designed to provide a measure of habitat that generally corresponds to those physical factors that affect fish communities and which are important to other aquatic life (i.e. macroinvertebrates). This index has been shown to correlate well with fishery IBI scores. The habitat data from the WDNR Research Section evaluated the quality of fish habitat at sites based upon the guidelines developed from several publications.[39] Based upon the data collected, the results suggest that fisheries habitat is generally fair to good throughout the Milwaukee River watershed as shown on Map 58. Specifically, about 6 percent of the sites were classified as very

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[36]*The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the* Wisconsin Administrative Code *are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.*

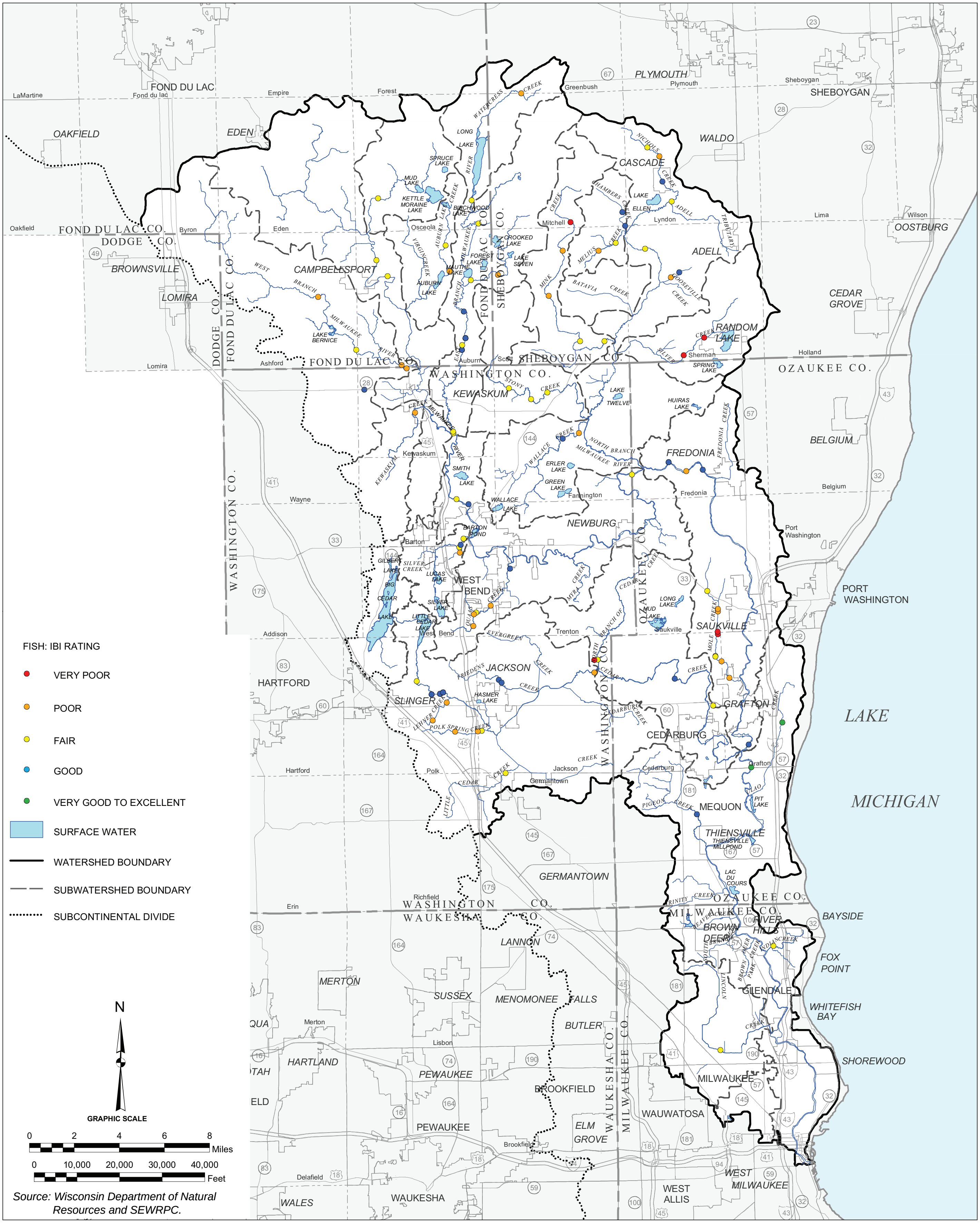
[37]*Wisconsin Department of Natural Resources, PUBL WT-704-2001,* op. cit.

[38]*Edward T. Rankin,* The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application, *State of Ohio Environmental Protection Agency, November 1989.*

[39]*Timothy Simonson, John Lyons, and Paul Kanehl, "Guidelines for Evaluating Fish Habitat in Wisconsin Streams,"* General Technical Report NC-164, *1995; and Lihzu Wang, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management, *Vol. 18, 1998.*

Map 58

STREAM HABITAT SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1998-2004



poor, 27 percent were poor, 35 percent were fair, 28 percent were good, and 4 percent were ranked as very good-excellent. The main limiting factors to habitat quality were siltation among many sites, both at sites with adjacent agricultural and urban lands, as well as reduced amounts and quality of instream cover. Since there are no data available to compare specific locations over time it is not possible to definitively assess changes in habitat conditions over time. It is important to note that significant lengths of streams have been channelized within the Milwaukee River watershed. Such channelization impacts habitat quality by reducing instream and riparian vegetative cover, increasing sedimentation, decreasing diversity of flow, decreasing water depths, and decreasing substrate diversity. Consequently, despite the habitat classification of fair to good, the WDNR has recently concluded that instream habitat is impaired in nearly every reach of the Milwaukee River watershed, primarily due to the impacts of hydrologic modification, stream flow fluctuations caused by unnatural conditions, stream bank erosion, urban storm water runoff, cropland erosion, and roadside erosion emanating from both agricultural and urban land use areas of this watershed.[40]

Influence of Dams/Dam Removal

Dams limit the Milwaukee River fishery by preventing both upstream and downstream immigration and emigration of fishes to and from Lake Michigan, as well as the mainstem of the Milwaukee River to headwater tributaries and/or vice versa; preventing the ability of fishes to reach feeding areas, spawning areas, juvenile rearing habitat, and/or overwintering sites; and increasing the vulnerability of fishes to predation, especially in the downstream area spillways. Limits on fish migration imposed by dams potentially contribute to the reduced abundance and diversity of the fishery over time. Therefore, the fishery was analyzed within the framework of the fragmentation to better understand the abundance and diversity of fishes within this watershed.

It is important to note that drop structures and even culverts can also obstruct fish migration. Map 53 shows the extent of the fragmentation of reaches from downstream to upstream within the Milwaukee River watershed as defined by the location of both dams and drop structures. As shown on Map 53, some reaches are very short, such as Reaches 6 and 10, while some reaches are much longer. In addition, some reaches are completely separated from tributary streams, such as Reaches 4 and 8c, or only connected to one tributary as for Reach 7. In contrast, some reaches are both extensive and well connected to many tributary streams, such as Reaches 8 and 12.

Figure 169 shows the total number of native fishes within the 1975-1986 time period versus the 1998-2004 time period among reaches as identified on Map 53. The mainstem reaches of the Milwaukee River are numbered in increasing order from downstream to upstream. The headwater tributary reaches are labeled according to which reach they flow into on the mainstem (e.g. 8a and 8b flow into Reach 8 on the mainstem). Both time periods on Figure 169 generally show the upstream headwater reaches, including Reaches 8a, 8b, 8c, 8d, 8e, 11b, 12a, and 14 as being much less diverse than the reaches on the mainstem. This is expected given that the smaller, upstream tributaries have much less volume of discharge, tend to be much flashier and shallower, tend to be more likely to go dry, and contain fewer types of available habitat than larger streams. In addition, headwater tributaries are typically coldwater streams, which naturally contain fewer species of fishes compared to the warmwater mainstem streams. Reaches 8b, 8c, 8d, 8e, and 11b are coldwater stream systems, which explain the low number of native species in 1975-1986 and 1998-2004. Although headwater tributaries do not generally contain many species of fishes on an annual basis, these resources are key spawning areas for fishes usually in the spring or fall time periods and they serve as key habitats for maintenance of forage fishes year round. Both of those functions help sustain fishery stocks on the mainstem into which the tributaries flow.

In comparing the 1975-1986 time period to the 1998-2004 time period, Figure 169 shows that some reaches have improved in diversity, some have decreased, and some have stayed the same. Reaches 1, 2, and possibly 5 seem to have increased in diversity. Most notably, Reach 1 increased from an average of five to nearly 25 species, which is due to the removal of the North Avenue dam as described below. In contrast, Reaches 3 and 7 lost species diversity, but this may be a function of sampling efforts on the tributary versus the mainstem of the Milwaukee

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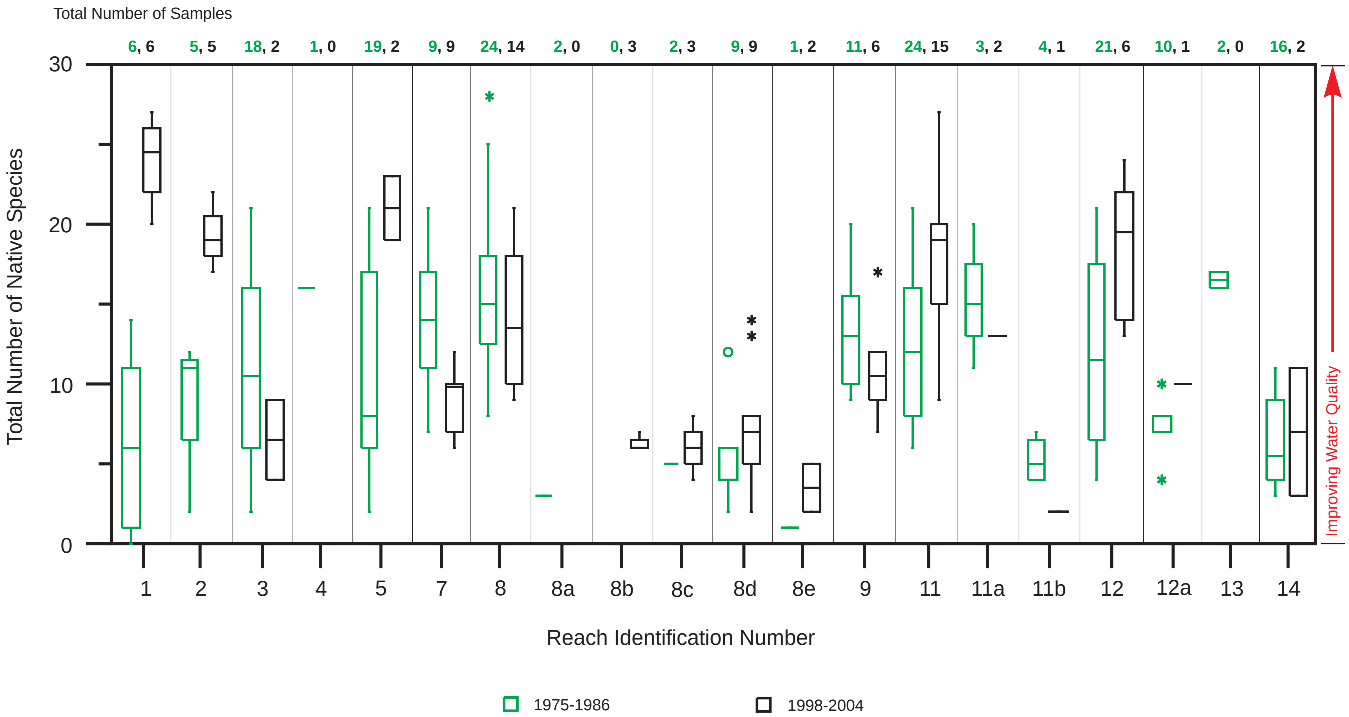
[40]*Wisconsin Department of Natural Resources, PUBL WT-704-2001,* op. cit.

Figure 169

TOTAL NUMBER OF NATIVE FISH SPECIES FROM ELECTROFISHING EFFORT AMONG STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1975-1986 AND 1998-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

River. However, the most consistently diverse fish communities within the Milwaukee River watershed are found within Reaches 8, 9, 11, and 12, which are the longest mainstem reaches and the ones with the greatest number of tributaries connected to them.

Besides blocking the upstream passage of fish, some dams as well as culverts could disrupt the normal, within-stream movements of some macroinvertebrates.[41] Aquatic macroinvertebrates are key components of these stream ecosystems. They are an important food source for fish, as well as amphibians, birds, bats, and other mammals. They also are important herbivores and detritivores, as well as predators of other invertebrates; therefore, they play a critical role in the cycling of energy and nutrients through stream ecosystems. Disruptions to the movement and dispersal of stream macroinvertebrates could reduce available habitat and lead to genetic isolation of some populations. The range size of most stream macroinvertebrates (e.g. insects) is unlikely to be affected, but dams and certain culvert types could pose problems for some mollusks and crustaceans. The separation of populations and subsequent reduction in genetic diversity may be especially important for relatively long-lived and highly threatened taxa such as the freshwater mussels. The Hilsenhoff Biotic Index[42] (HBI) was used to compare the

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[41]*D. Mace Vaughan,* Potential Impact of Road-Stream Crossings (Culverts) on the Upstream Passage of Aquatic Macroinvertebrates, *The Xerces Society, Portland, OR, Report submitted to the United States Forest Service, San Dimas Technology and Development Center, March, 2002.*

[42]*William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index, *University of Wisconsin-Madison, 1988.*

abundance and diversity of macroinvertebrates among streams in the Milwaukee River watershed. The results indicated that the majority of the reaches contained a good to very good community in both 1975-1986 and 1998-2004, with the exception of a fair community in headwater Reach 14 as shown in Figure 170. This indicates that the fisheries in these areas are not food-limited and the changes in the fish community diversity are most likely due to other factors.

Figure 171 shows the fisheries IBI scores among reaches that contained the best available data to assess changes in the fishery community over time in the Milwaukee River watershed. In general, the shorter reaches and the reaches with fewer tributaries tended to show much larger fluctuations in fishery quality from year to year than the larger reaches with many tributaries (see Figure 171). A second pattern that seems to be evident is that several of the reaches have some of the lowest IBI scores in the most recent years of record including Reaches 3, 7, 8, and 8d. In addition, the fishery in the downstream reaches seems to be improving.

Removal of the North Avenue dam and major habitat improvements near the dam site were completed in 1996 on the Milwaukee River. Figure 172 shows that the total number of native fish species dramatically improved after dam removal.[43] Removal of this dam reconnected a section of the Milwaukee River from the former dam site upstream to the Estabrook dam, creating an unimpeded connection to Lake Michigan. The area below the Estabrook dam changed from a very poor to excellent fishery within a few years and the data collected by the Wisconsin Department of Natural Resources also indicates that the number of exotic fish species did not change significantly in the areas above the North Avenue dam after this reach was reconnected to Lake Michigan. The smallmouth bass, which is an intolerant fish species, has also dramatically increased in abundance within the Milwaukee River and Harbor area.

Walleye abundances have also increased, but this increase is probably indicative of the WDNR stocking efforts conducted pursuant to walleye population restoration efforts in the Lower Milwaukee River and Harbor since 1995. Radiotelemetry technology was used to track the movements of stocked walleye and it was found that there was a distinct seasonal movement pattern by the adult walleye according to water temperature and food availability. During the summer, they moved from the rivers to cooler and deeper harbor waters. In winter they moved to the warmer waters of the Menomonee River canals which receive warmwater discharges from a nearby power plant. This was also associated with a significant increase in angling effort targeted towards walleye in recent years along the Menomonee River canals, Summerfest Lagoon, and the Milwaukee River upstream of the former North Avenue dam to Kletzsch Park. In a continued effort to restore the overall fishery community in the Milwaukee River, the WDNR has also begun stocking and tracking lake sturgeon in this system. Lake sturgeons were historically an integral part of the Milwaukee River and Lake Michigan fishery.

This dam removal project demonstrates how the potential of the fishery can be enhanced through removal of a dam, as well as the dependence of the fishery on the connection with Lake Michigan and the Estuary.

Lakes and Ponds

There are 20 major lakes (i.e. lakes greater than 50 acres in size) within the Milwaukee River watershed, but there are more than 80 lakes and ponds less than 50 acres in size within the watershed as listed in Table 92.

The last recorded fishery surveys for many of the lakes and ponds were completed in the late 1970s and early 1980s. The surveys indicate that that these waterbodies contained a typical urban fish species mixture mostly dominated by tolerant species of green sunfish, black bullhead, carp, and white sucker. However, largemouth bass, northern pike, and yellow perch were also recorded to occur in several of these waterbodies. Additional information from WDNR staff indicate that the majority of the lakes and ponds listed in Table 107 provide various recreational fishing opportunities for gamefish and/or panfish species, however, some of these waterbodies are stocked to supplement these fisheries (see Table 106).

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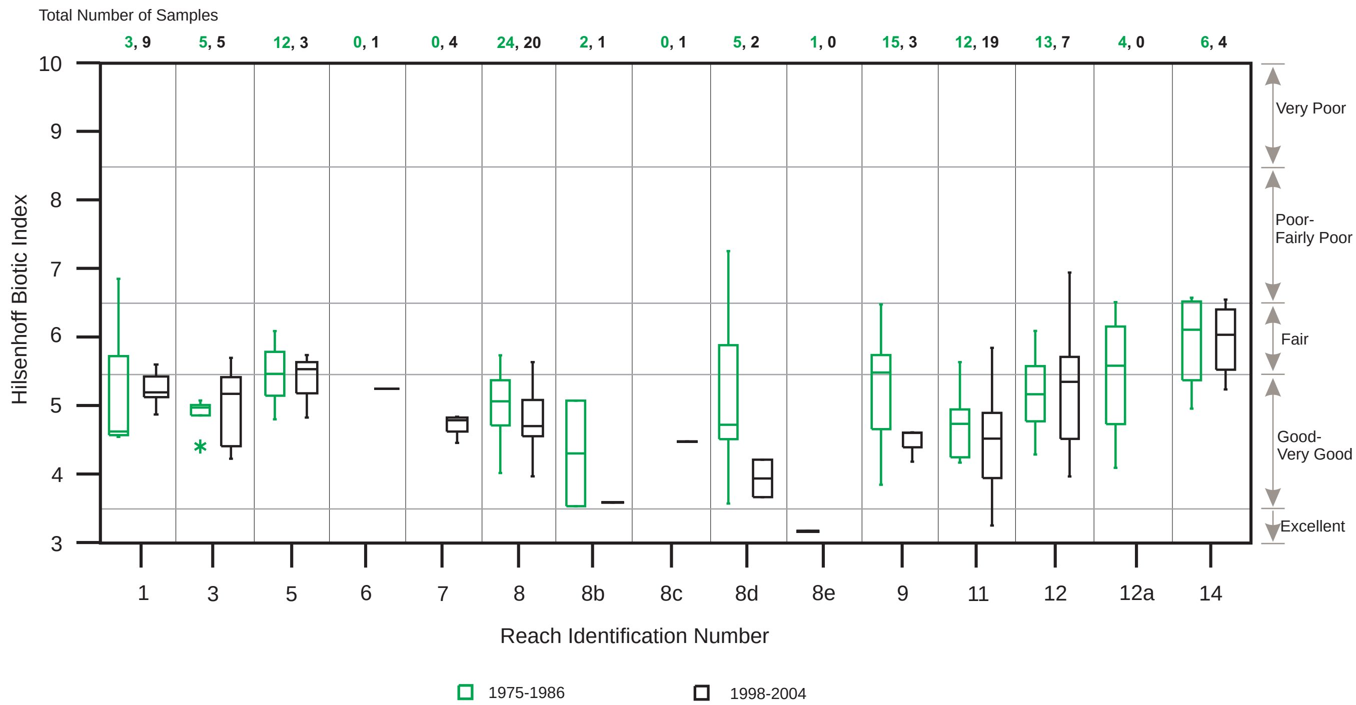
[43] *Pradeep S. Hirethota, Thomas E. Burzynski, and Bradley T. Eggold,* Changing Habitat and Biodiversity of the Lower Milwaukee River and Estuary, *PUB-FH-511-2005, August 2005.*

Figure 170

HILSENHOFF BIOTIC INDEX IN RIFFLE HABITAT AMONG STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1975-1986 AND 1998-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

More-recent comprehensive fisheries surveys completed by the WDNR for Erler, Little Cedar, Long (Fond du Lac County), and Random Lakes are summarized below.[44]

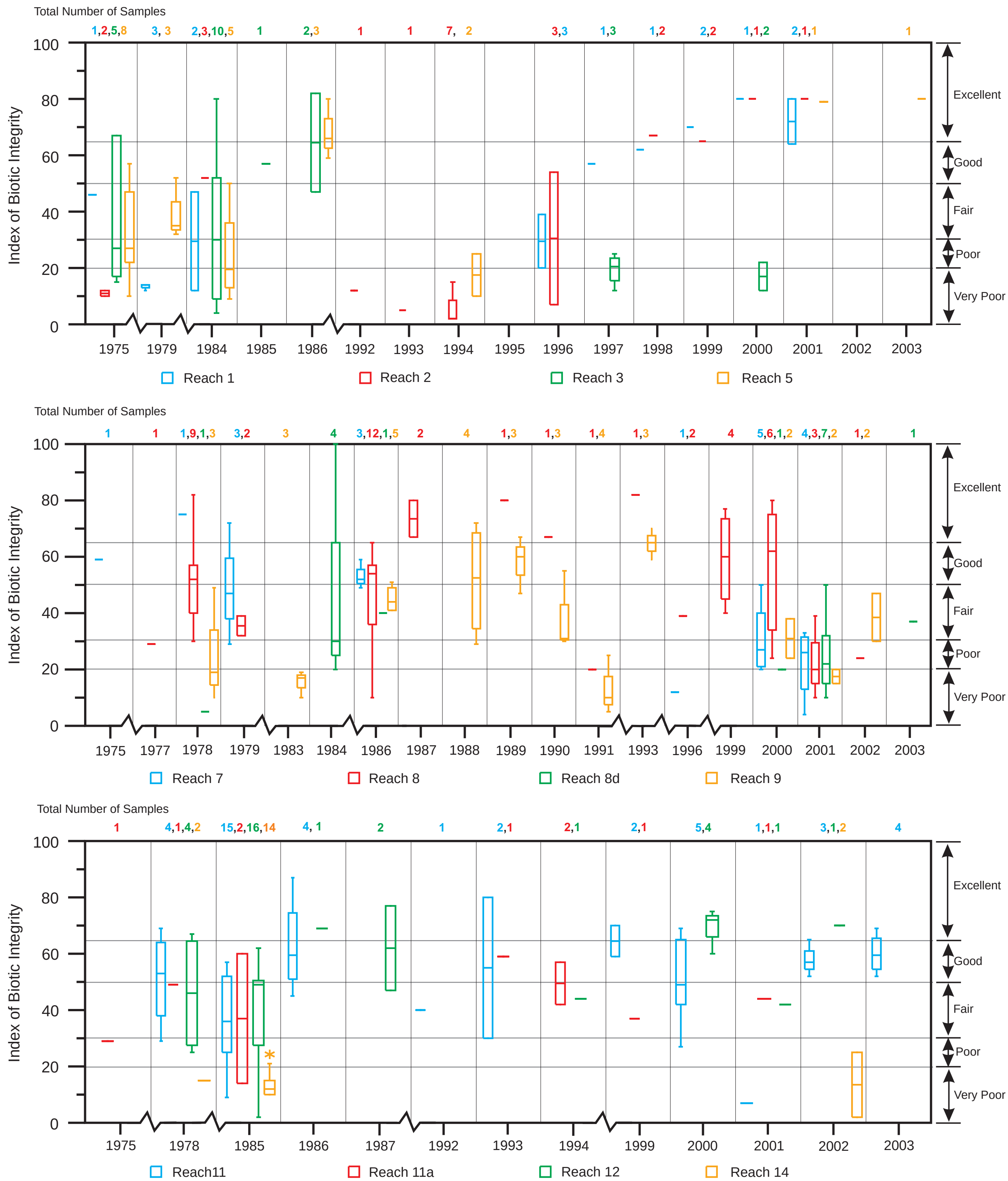
A comprehensive fish population survey of the 37-acre Erler Lake was conducted in the spring and fall of 2003. Fyke nets and electrofishing were used to collect fish samples. Eleven fish species were captured, with bluegill and largemouth bass being the predominant species. Bluegills exhibited an unusually high average size, length-frequency distribution and growth rate. Largemouth bass were generally small with an average length of 10 inches despite an average growth rate. Yellow perch were fairly common and had above average growth rates. Carp were present but, not abundant. More restrictive fishing regulations on panfish and bass were proposed to protect the populations from collapse when public access is developed.

In general, fish habitat conditions in Little Cedar Lake were good to very good during 1999. Natural shoreline is found in several areas, most of which front large wetlands. Those areas are primarily located on the southern end and western ends of the lake. Water quality is generally good and healthy stands of vegetation are found throughout the lake. No recent fishery data are available for Little Cedar Lake due to the fact that it had no public access until 1998 when Washington County bought the former Ackerman Resort located at the southeastern part

[44] *John Nelson, Senior Fisheries Biologist, Wisconsin Department of Natural Resources,* Long Lake, Comprehensive Fish Community Survey, Fond Du Lac County, 2004; Random Lake Electrofishing Report, 2004; Comprehensive Fish Community Survey, Little Cedar Lake, Washington County, 1999, *and;* Erler Lake Fish Community Survey, Washington County, 2003.

Figure 171

FISHERIES INDEX OF BIOTIC INTEGRITY AMONG STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1975-2003



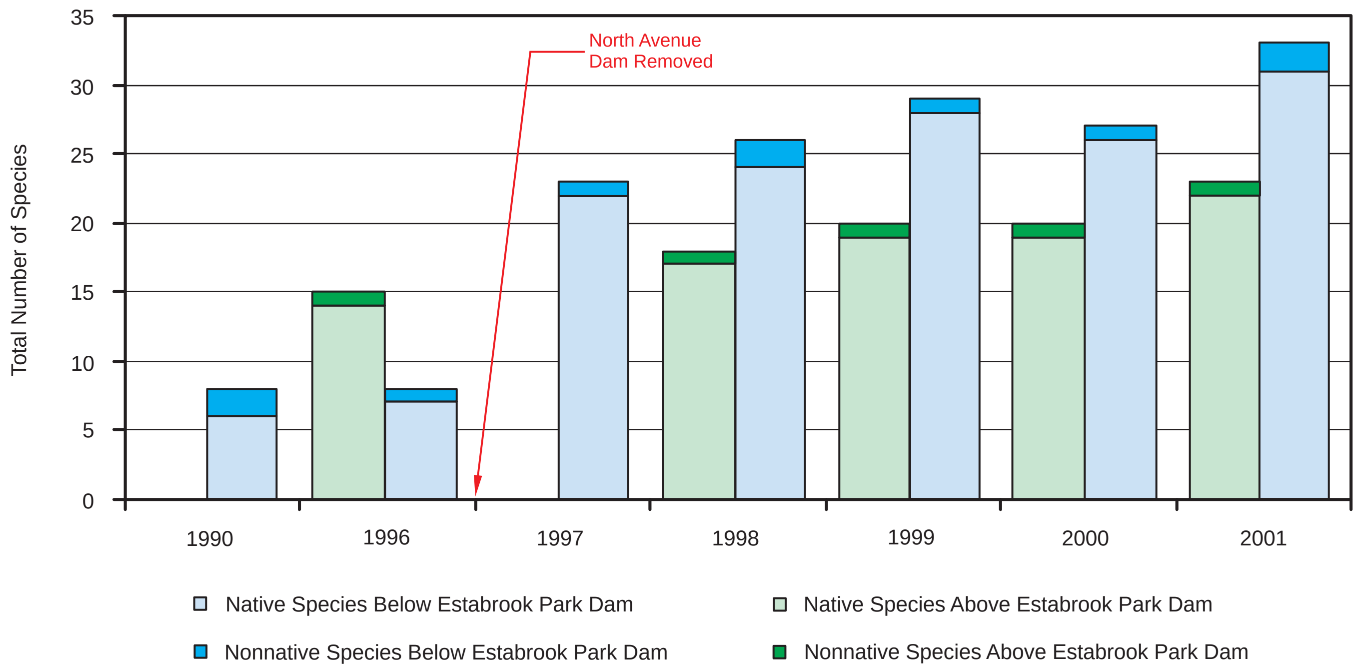
NOTES: See Figure 109 for description of symbols.

Years are not plotted on a continuous scale.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 172

COMPARISON OF THE NUMBER OF SPECIES RECORDED AT TWO SITES BEFORE AND AFTER THE REMOVAL OF THE NORTH AVENUE DAM



Source: Wisconsin Department of Natural Resources and SEWRPC.

of the lake. The lake was historically noted for fairly good northern pike, largemouth bass, and panfish fishing. The WDNR used fyke nets, mini-fyke nets, electrofishing, and seines to collect data on the fish community. Northern pike appeared to be abundant, with few legal sized fish present. Largemouth bass were abundant and had a very good size structure. Bluegills were abundant, but generally small in size. Small crappies were present. Yellow perch did not appear to be abundant and bluntnose minnow were common. Walleye were present and produced a natural population until recently when natural reproduction apparently failed to sustain healthy numbers of fish. Carp are present and concern some residents, especially in spring when they congregate at the shallow southern end of the lake to spawn. The Department tried several times around 1960 to reduce carp numbers by trapping and removing carp, but that effort was soon abandoned.

A comprehensive fish community survey of the 417-acre Long Lake in eastern Fond du Lac County was conducted during 2004. Northern pike, largemouth bass, bluegill and yellow perch were the most common fish found during the survey. Only a remnant population of walleye was present. The northern pike population estimate of 3,563 in 2004 was much reduced compared to an estimate of 8,075 in 1986. The walleye population was small with no signs of natural reproduction. A naturally reproducing population was present in the 1960s and 1970s with a 1974 estimate of 4.8 walleye/acre. The Long Lake largemouth bass population was in exceptional condition and was likely the best overall population in Fond du Lac and surrounding counties. Bluegills were abundant and had a very good size structure; however, total annual mortality estimates were high indicating excessive harvest once the fish reached six inches in size. Yellow perch were common. Yellow bullhead were abundant and had a very good size structure. Seining at four locations found 15 native species.

An electrofishing survey of the shoreline of Random Lake in Sheboygan County was conducted during the fall of 2004. The most abundant gamefish captured during the electrofishing survey was largemouth bass, however, size structure was poor and growth rates of bass in the lake were generally below the statewide average for the species. Bluegills were the most abundant panfish species caught. The population of bluegill has always been dominated

Table 107

FISH AND EXOTIC SPECIES IN LAKES AND PONDS IN THE MILWAUKEE RIVER WATERSHED

Name	Muskellunge	Northern Pike	Walleye	Largemouth Bass	Smallmouth Bass	Panfish	Trout	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Allis Lake	- -	Present	- -	Present	Present	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Auburn Lake (Lake Fifteen)	- -	Common	Present	Common	- -	Common	- -	Present	Present	- -	- -[a]	- -[a]
Barton Pond	- -	Common	--	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Batavia Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Beechwood Lake	- -	Common	- -	Common	- -	Common	- -	Present	- -	- -	Present	- -[a]
Big Cedar Lake	- -	Common	Present	Abundant	- -	Common	Present	- -	Present	Present	Present	- -[a]
Birchwood Lake	- -	- -	- -	- -	- -	Present	- -	- -	Present	- -	- -[a]	- -[a]
Boltonville Pond	Present	- -	Present	- -	Common	Present	- -	- -	- -	- -	- -[a]	- -[a]
Brickyard Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Brown Deer Park Pond[b]	- -	- -	- -	Present	- -	Present	Common	- -	- -	- -	- -[a]	- -[a]
Butler Lake	- -	Present	- -	Common	- -	Present	Common	Present	- -	- -	- -[a]	- -[a]
Buttermilk Lake	- -	- -	- -	- -	-	Present	- -	- -	- -	- -	- -[a]	- -[a]
Butzke Lake	- -	- -	- -	- -	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Cambellsport Millpond	- -	Present	- -	- -	- -	Present	- -	Present	- -	- -	- -[a]	- -[a]
Cascade Millpond	- -	Present	- -	Common	- -	Present	Common	- -	- -	- -	- -[a]	- -[a]
Cedar Lake (Fond du Lac County)	- -	Present	- -	Common	- -	Common	- -	Present	- -	- -	- -[a]	- -[a]
Cedar Lake (Sheboygan County)	- -	- -	- -	Abundant	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Cedarburg Pond	- -	Present	- -	Common	- -	Common	- -	Present	- -	- -	- -[a]	- -[a]
Cedarburg Stone Quarry	- -	- -	- -	Present	- -	Common	Present	- -	- -	- -	- -[a]	- -[a]
Chair Factory Millpond	- -	Present	- -	- -	Present	Present	- -	- -	- -	- -	- -[a]	- -[a]
Columbia Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Crooked Lake	- -	Common	- -	Common	- -	Common	Present	Present	Present	- -	Present	- -[a]
Daly Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Dickman Lake	- -	- -	- -	- -	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Dineen Park Pond[b]	- -	Present	- -	- -	- -	Present	Common	- -	Present	- -	- -[a]	- -[a]
Donut Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Drzewiceki Lake	- -	- -	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Ehne Lake	- -	- -	- -	Common	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Erler Lake	- -	- -	- -	Common	- -	Common	- -	- -	- -	- -	Present	- -[a]
Estabrook Park Lagoon[b]	- -	- -	- -	Present	- -	Common	Present	- -	- -	- -	- -[a]	- -[a]
Forest Lake	- -	Present	Present	Common	- -	Abundant	- -	Present	Present	- -	Present	- -[a]
Fromm Pit	- -	- -	- -	Present	- -	Abundant	Present	- -	- -	- -	- -[a]	- -[a]
Gilbert Lake	- -	Common	- -	Common	- -	Common	- -	- -	Present	- -	Present	- -[a]
Gooseville Millpond	- -	Abundant	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Gough Lake	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Grafton Millpond	- -	Present	Present	Common	Abundant	Common	- -	Present	Present	- -	- -[a]	- -[a]
Green Lake	- -	Present	Present	Common	- -	Common	- -	Present	Present	- -	Present	- -[a]
Haack Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Hamilton Pond	- -	- -	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Hanneman Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Hansen Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Hasmer Lake		Common	- -	Abundant	- -	Present	- -	- -	Present	- -	- -[a]	- -[a]

Table 107 (continued)

Name	Muskellunge	Northern Pike	Walleye	Largemouth Bass	Smallmouth Bass	Panfish	Trout	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Hawthorn Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Hawthorne Hills Pond	- -	- -	- -	Present	- -	Present	- -	Present	- -	- -	- -[a]	- -[a]
Horn Lake	- -	Common	- -	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Huiras Lake	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Juneau Park Lagoon[b]	- -	- -	- -	Common	- -	Present	Common	- -	- -	- -	Present	- -[a]
Kelling Lakes #1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Kelling Lakes #2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Kelling Lakes #3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Keowns Pond	- -	- -	- -	Present	- -	Present	Present	- -	- -	- -	- -[a]	- -[a]
Kettle Moraine Lake	- -	Common	Present	Common	- -	Abundant	- -	Present	- -	- -	Present	- -[a]
Kewaskum Millpond	- -	Present	- -	Present	- -	Present	Present	Present	Present	- -	- -[a]	- -[a]
Kilbourn Lake Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Lake Bernice	- -	Abundant	- -	Common	- -	Common	- -	Present	Present	- -	- -[a]	- -[a]
Lake Ellen	- -	Common	Common	Common	- -	Common	Present	Present	Present	Present	- -[a]	- -[a]
Lake Lenwood	- -	Present	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lake Seven	- -	Present	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lake Sixteen	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Lake Twelve	- -	Present	- -	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Lehner Lake	- -	- -	- -	Common	- -	Abundant	Present	- -	- -	- -	- -[a]	- -[a]
Lent Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lime Kiln Millpond	- -	Present	Present	Present	Abundant	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lincoln Park Lagoon	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Linden Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Little Cedar Lake	- -	Present	Common	Abundant	- -	Common	- -	Present	- -	Present	Present	- -[a]
Little Drickens Lake	- -	Present	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Little Mud Lake	- -	Present	- -	- -	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Long Lake (Ozaukee County)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Long Lake (Fond du Lac County)	- -	Common	Common	Common	- -	Abundant	- -	Present	Present	Present	Present	- -[a]
Lucas Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	Present	- -[a]
Mallard Hole Lake	- -	- -	- -	- -	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Mauthe Lake	- -	Present	Present	Common	- -	Common	- -	Present	Present	- -	Present	- -[a]
McGovern Park Pond[b]	- -	- -	- -	Common	- -	Present	Common	- -	Present	- -	- -[a]	- -[a]
Mee-Quon Park Pond	- -	- -	Present	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Miller Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Moldenhauer Lake	- -	- -	- -	Common	- -	Abundant	Present	- -	- -	- -	- -[a]	- -[a]
Mud Lake (Ozaukee County)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Mud Lake (Fond du Lac County)	- -	- -	- -	- -	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
New Fane Millpond	- -	Present	Present	Present	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Newburg Pond	- -	Present	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Paradise Valley Lake	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Pit Lake	- -	Present	- -	Present	Present	Common	- -	- -	- -	- -	Present	- -[a]
Proschinger Lake	- -	Present	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Quaas Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Radtke Lake	- -	- -	- -	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]

Table 107 (continued)

Name	Muskellunge	Northern Pike	Walleye	Largemouth Bass	Smallmouth Bass	Panfish	Trout	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Random Lake	Common	Common	Present	Common	- -	Common	- -	Present	Present	- -	Present	- -[a]
Roeckl Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Ruck Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Schwietzer Pond	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Senn Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Silver Lake	- -	Abundant	Present	Abundant	- -	- -	- -	- -	- -	- -	Present	- -[a]
Smith Lake	- -	Common	- -	Abundant	- -	Abundant	- -	- -	Present	- -	- -[a]	- -[a]
Spring Lake (Fond du Lac County)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Spring Lake (Ozaukee County)	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Spruce Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Thiensville Millpond	- -	Present	Present	Present	Present	Common	- -	Present	Present	- -	- -[a]	- -[a]
Tilly Lake	- -	Present	- -	Common	- -	Abundant	Common	- -	Present	- -	- -[a]	- -[a]
Tittle Lake	- -	Common	Common	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Uihlein Pond	- -	- -	- -	- -	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Unnamed Lake (T11 R21 E17)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Wallace Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Washington Park Pond	- -	Present	- -	Common	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Wire and Nail Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Zeunert Pond	- -	- -	- -	- -	- -		- -	- -	- -	- -	- -[a]	- -[a]

[a]*These aquatic exotic, invasive plant species are known to occur in the counties that these lakes are found, but there is no data to confirm their presence in the waterbody.*

[b]*These ponds are stocked by Wisconsin Department of Natural Resources and Milwaukee County as part of the Urban Fishing Program.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

by small fish that are slow growing. Scale samples from the bluegills confirmed the slow growth rate, as the rates were well below the state average rate for bluegills. Black crappies and yellow perch were also fairly abundant in the catch. The perch catch indicated that a few quality size perch were present. The crappies were generally small. WDNR also caught four muskellunge, and this species continues to be the most popular fishery in the lake. The walleye fishery of Random Lake has continued to improve in recent years. The walleye in the lake are generally plump, an indication that they are feeding well on the abundant panfish in the lake.

Brown Deer Park Pond, Dineen Park Pond, Estabrook Park Lagoon, Juneau Park Lagoon, and McGovern Park Pond are enrolled in the WDNR Urban Fishing Program in partnership with Milwaukee County (see Table 107). That program was initiated in 1983 for the metropolitan Milwaukee area and is still active today. The program provides fishing in urban ponds for anglers who do not have opportunities to leave the urban environment. The program stocks rainbow trout and other species to provide seasonal and year-round fishing (see Table 106).

Table 107 also shows that exotic invasive species have been recorded in 28, or nearly 30 percent, of the lakes and ponds within the Milwaukee River watershed. Carp are found in Barton Pond, Big Cedar Lake, Birchwood Lake, Crooked Lake, Dineen Park Pond, Estabrook Park Pond, Forest Lake, Gilbert Lake, Green Lake, Grafton Millpond, Hasmer Lake, Kettle Moraine Lake, Kewaskum Millpond, Lake Bernice, Lake Ellen, Long Lake (Fond du Lac County), Mauthe Lake, McGovern Park Pond, Random Lake, Smith Lake, Thiensville Millpond, Tilly Lake, and West Bend Pond. Zebra mussels have only been recorded in Big Cedar Lake, Lake Ellen, Little Cedar Lake, and Long Lake (Fond du Lac County). While data on aquatic plant communities are limited (see Table 108), Eurasian water milfoil is known to exist in Beechwood Lake, Big Cedar Lake, Crooked Lake, Erler Lake, Estabrook Park Pond, Forest Lake, Gilbert Lake, Green Lake, Juneau Park Lagoon, Kettle Moraine Lake, Little Cedar Lake, Long Lake (Fond du Lac County), Lucas Lake, Mauthe Lake, Pit Lake, Random Lake, and Silver Lake. Curly-leaf pondweed is known to exist in each of the Counties within the Milwaukee River watershed, but there is no data to confirm its presence in any particular waterbody.

Macroinvertebrates

The Hilsenhoff Biotic Index[45] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations in the Milwaukee River watershed.

When applying the HBI that is used to measure the amount of organic pollution in warmwater streams of Wisconsin, it is recommended that a similar type of gear be used as well as similar type of habitat be sampled. Analysis of the macroinvertebrate data in the Milwaukee River watershed indicates that a D-Frame kick net was the only gear type used to sample these organisms, which indicates that there is sampling consistency among all sites. There have been a variety of habitat types sampled within the Milwaukee River watershed as shown in Figure 173. Figure 173 shows that riffle habitats contain the highest quality macroinvertebrate communities compared to pool, run, snag, or lake habitats in the Milwaukee River watershed. Habitat types such as lakes, pools, riffles, and runs generally contain very different compositions of substrates, water depths, and flows, which greatly affects the abundance and diversity of the associated macroinvertebrate community. Hence, the HBI procedures recommend that macroinvertebrate communities be sampled from shallow fast flowing riffle habitats, and that samples from pools or under the stream banks should not be used.[46] Therefore, only samples from riffle habitats were used to assess the macroinvertebrate community in the Milwaukee River watershed as summarized below.

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[45]*William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin-Madison, 1988.*

[46]*William L. Hilsenhoff, "An Improved Biotic Index of Organic Stream Pollution,"* The Great Lakes Entomologist*, Volume 20, 19887.*

Table 108

FREQUENCY OF OCCURRENCE OF AQUATIC PLANT SPECIES IN BIG AND LITTLE CEDAR LAKES, AND SILVER LAKE: 2005

Plant Genus and Species	Plant Common Name	Relative Frequency of Occurrence (percent)[a] Big Cedar Lake	Relative Frequency of Occurrence (percent) Little Cedar Lake	Relative Frequency of Occurrence (percent) Silver Lake	Ecological Significance[b]
Ceratophyllum demersum	Coontail	- -	31.1	- -	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris	Muskgrass	Present	63.3	95.5	Excellent producer of fish food, especially for young trout, bluegills, small and largemouth bass, stabilizes bottom sediments, and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis	Waterweed	- -	18.9	1.5	Provides shelter and support for insects which are valuable as fish food
Lemna minor	Lesser duckweed[c]	Present	Present	Present	A nutritious food source for ducks and geese, also provides food for muskrat, beaver, and fish, while rafts of duckweed provide shade and cover for insects; in addition, extensive mats of duckweed can inhibit mosquito breeding
Lythrum salicaria	Purple loosestrife[c,d]	- -	- -	Present	Exotic invasive plant species that can lead to a decrease in native aquatic plant community abundance and diversity
Myriophyllum spicatum	Eurasian water milfoil[d]	Present	81.1	33.3	Exotic invasive plant species that can lead to a decrease in native aquatic plant community abundance and diversity, but it can provide cover for invertebrates and forage fish species
Myriophyllum sp.	Native milfoil	- -	13.3	- -	Provides valuable food and shelter for fish; fruits eaten by many wildfowl
Najas flexilis	Bushy Pondweed	Present	12.2	0.5	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Najas marina	Spiny naiad	- -	10.0	- -	Provides good food and shelter for fish and food for ducks
Nuphar sp.	Yellow water lily[c]	Present	Present	Present	Leaves, stems, and flowers are eaten by deer; roots eaten by beaver and porcupine; seeds eaten by wildfowl; leaves provide harbor to insects, in addition to shade and shelter for fish
Nymphaea tuberosa	White water lily[c]	Present	Present	Present	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrat; roots eaten by beaver, deer, moose, and porcupine
Potamogeton americanus	Long-leaf pondweed	- -	- -	4.6	Offers shade, shelter, and foraging for fish; valuable food for waterfowl
Potamogeton amplifolius	Large-leaf pondweed	Present	5.6	Present	Provides cover for panfish, largemouth bass, muskellunge, and northern pike; nesting grounds for bluegill; supports insects valuable as food for fish and ducklings
Potamogeton crispus	Curly-leaf pondweed[d]	- -	13.3	- -	Provides food, shelter, and shade for some fish and food for waterfowl
Potamogeton foliosus	Leafy pondweed	- -	- -	- -	Provides valuable food for geese and ducks; grazed by muskrat, deer, beaver, and moose; good surface area for invertebrates and cover for young fish
Potamogeton gramineus	Variable pondweed	- -	5.6	12.1	Provides habitat for fish and food for waterfowl, muskrat, beaver, and deer
Potamogeton natans	Floating-leaf pondweed	- -	- -	- -	Provides valuable grazing for ducks and geese. Portions eaten by muskrat, beaver, deer, and moose; provides shade and food for fish
Potamogeton pectinatus	Sago pondweed	Present	8.9	10.6	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton richardsonii	Clasping-leaf pondweed	Present	3.3	- -	Provides good food and cover for fish and supports insects eaten by fish

Table 108 (continued)

Plant Genus and Species	Plant Common Name	Relative Frequency of Occurrence (percent)[a] Big Cedar Lake	Relative Frequency of Occurrence (percent) Little Cedar Lake	Relative Frequency of Occurrence (percent) Silver Lake	Ecological Significance[b]
Potamogeton robbinsii	Robbins pondweed	- -	1.1	- -	Provides habitat for invertebrates, in addition to providing food and shelter for young fish
Potamogeton zosteriformis	Flat-stemmed pondweed	- -	22.2	10.6	Provides some cover for bluegills, perch, northern pike, and muskellunge; food for waterfowl; supports insects valuable as food for fish and ducklings
Ranunculus longirostris	Stiff water crowfoot	- -	7.8	- -	Provides food for trout, upland game birds, and wildfowl
Scirpus subterminalis	Water bulrush	- -	2.2	- -	Supports insects; provides food for a variety of ducks and muskrats and provides cover for wildfowl
Typha augustafolia	Cattail[c]	- -	- -	- -	Supports insects; stalks and roots important food for muskrat and beaver; attracts marsh birds, wildfowl, and songbirds, in addition to being used as spawning grounds by sunfish and shelter for young fish
Utricularia vulgaris	Common bladderwort	Present	- -	30.3	Free floating plant that can provide needed fish habitat in areas not easily colonized by rooted plants; provides food and cover for fish
Vallisneria americana	Eel grass	- -	16.7	19.7	Provides good shade and shelter, supports insects, and is valuable fish food
Zosterella dubia	Water stargrass	- -	18.9	Present	Provides food and shelter for fish, locally important food for waterfowl

[a]*Maximum equals 100 percent.*

[b]*Information obtained from Norman C. Fassett, A Manual of Aquatic Plants, Wisconsin Department of Natural Resources,* Guide to Wisconsin Aquatic Plants, *and Wisconsin Lakes Partnership,* Through the Looking Glass…A Field Guide to Aquatic Plants*, 1997.*

[c]*Not measurable using the Jesson and Lound Survey Technique for Submersed Aquatic Plants.*

[d]*Section NR 109.07, "Designated Invasive and Nonnative Aquatic Plant."*

Source: SEWRPC.

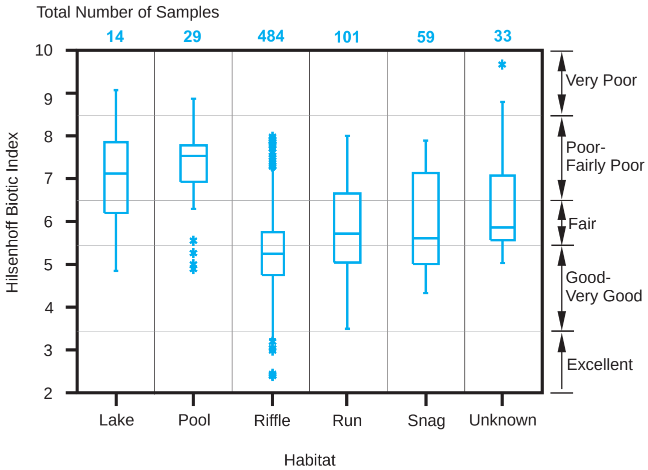
Macroinvertebrate surveys conducted by the WDNR from 1975 through 2004 show that HBI scores generally range from fair (HBI score 5.51-6.5) to good-very good (HBI score 3.51-5.5) in the Milwaukee River watershed (see Figure 174 and Maps 59 and 60). Figure 174 also shows that, based on 117 samples that were collected from 1998 through 2004 and were well distributed throughout the Milwaukee River watershed, the macroinvertebrate community quality has generally remained fairly constant from 1975 to 2004. Results generally indicate that current macroinvertebrate diversity and abundances are indicative of fair to good-very good water quality in the watershed. From 1975 to the present, the average total number of genera has increased, and the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) genera has slightly increased, as shown in Figure 175. This indicates that the diversity of macroinvertebrates has been improved by the addition of organisms not within the EPT genera. In addition, over the long term, percent dominance of the top five families has been decreasing as shown in Figure 176. This is another indication that there is a long-term improvement in the abundance and diversity of macroinvertebrates.[47]

Results of the proportions of EPT genera and HBI scores by individual subwatersheds in the Milwaukee River indicate that the data are limited to assess the current macroinvertebrate community conditions within seven of the

[47]*M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling,* Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, *Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

Figure 173

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES AMONG HABITAT TYPES IN THE MILWAUKEE RIVER WATERSHED: 1975-2004

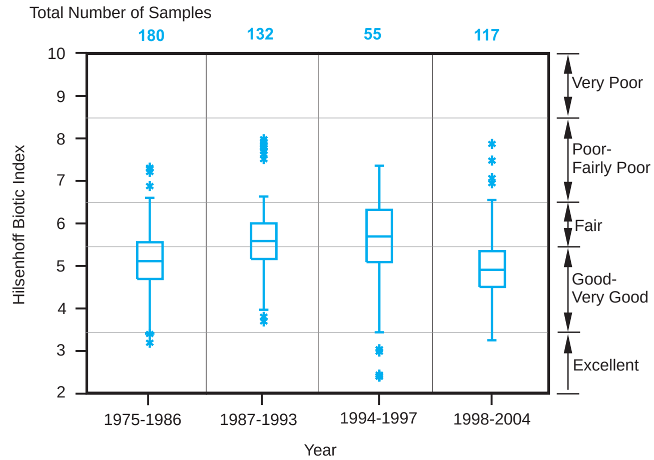


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 174

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES WITHIN RIFFLE HABITATS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

Sorted by riffle habitat and gear type (D-Frame Net).

Source: Wisconsin Department of Natural Resources and SEWRPC.

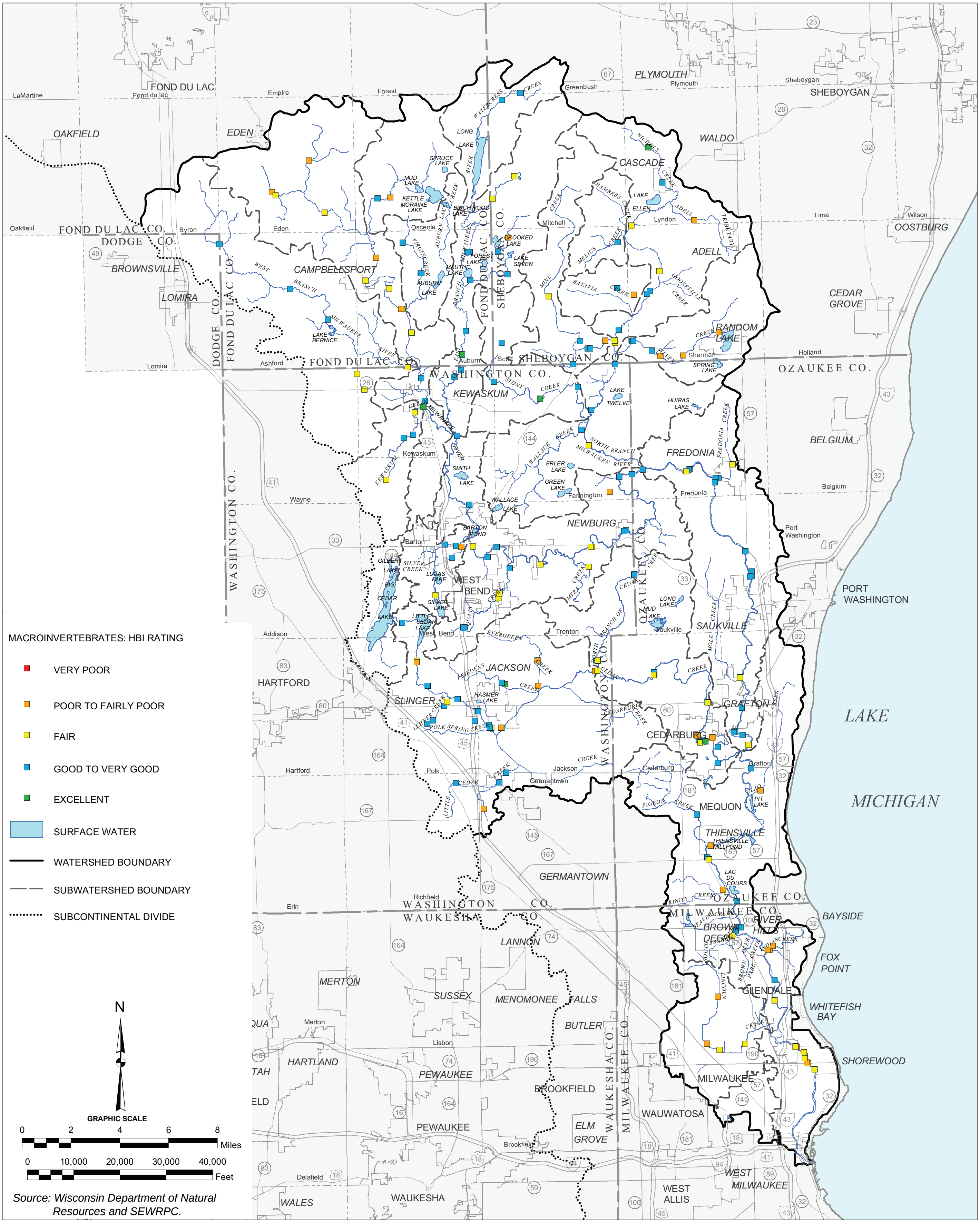
subwatersheds during the 1998 through 2004 period, as shown in Figures 177 and 178. For example, the Lake Fifteen, Watercress Creek, Chambers Creek, Lower Cedar Creek, Lincoln Creek, and Silver Creek (West Bend) subwatersheds either have only one survey record or no data in that time period. The EPT results as shown in Figure 177 for the remaining subwatersheds generally indicate that the majority of sites have a relatively moderate to high proportion of EPT genera, which is indicative of fair to good water quality conditions. In addition, most of the subwatersheds do not seem to have changed appreciably in the proportion of EPT genera from the historical records, which is supported by the HBI results in Figure 178. Figure 178 shows that the macroinvertebrate community quality has generally remained in the good-very good HBI rating from 1975 to the present within most of the subwatersheds. However, eight, or nearly 40 percent, of the subwatersheds contained sites that ranked in the fair HBI classification, which indicates some level of potential impairment to the macroinvertebrate abundance and diversity. Figure 178 demonstrates that, except for the Lincoln Creek subwatershed, most of the subwatersheds throughout the Milwaukee River watershed continue to sustain a fair to good-very good macroinvertebrate community. It should be noted that any effects on macroinvertebrates from the recently completed MMSD Lincoln Creek environmental restoration and flood control project would not be reflected in the data, which only extend through 2004.

Further analysis of the East Branch of the Milwaukee River and Lower Milwaukee River subwatersheds indicates that the proportions of collectors have not changed significantly from 1979 to 2004, as shown in Figure 179.[48] The proportion of collectors in the East Branch of the Milwaukee River subwatershed is significantly less than the Lower Milwaukee River subwatershed. This difference in the trophic structure between these subwatersheds implies that streams in the East Branch of the Milwaukee River subwatershed are potentially less disturbed or have better water quality than streams in the Lower Milwaukee River subwatershed. Similarly, as shown in

[48]*A description of the collectors, scrapers, and shredders can be found in Chapter II of this report.*

Map 59

MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1979-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 60

MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1998-2004

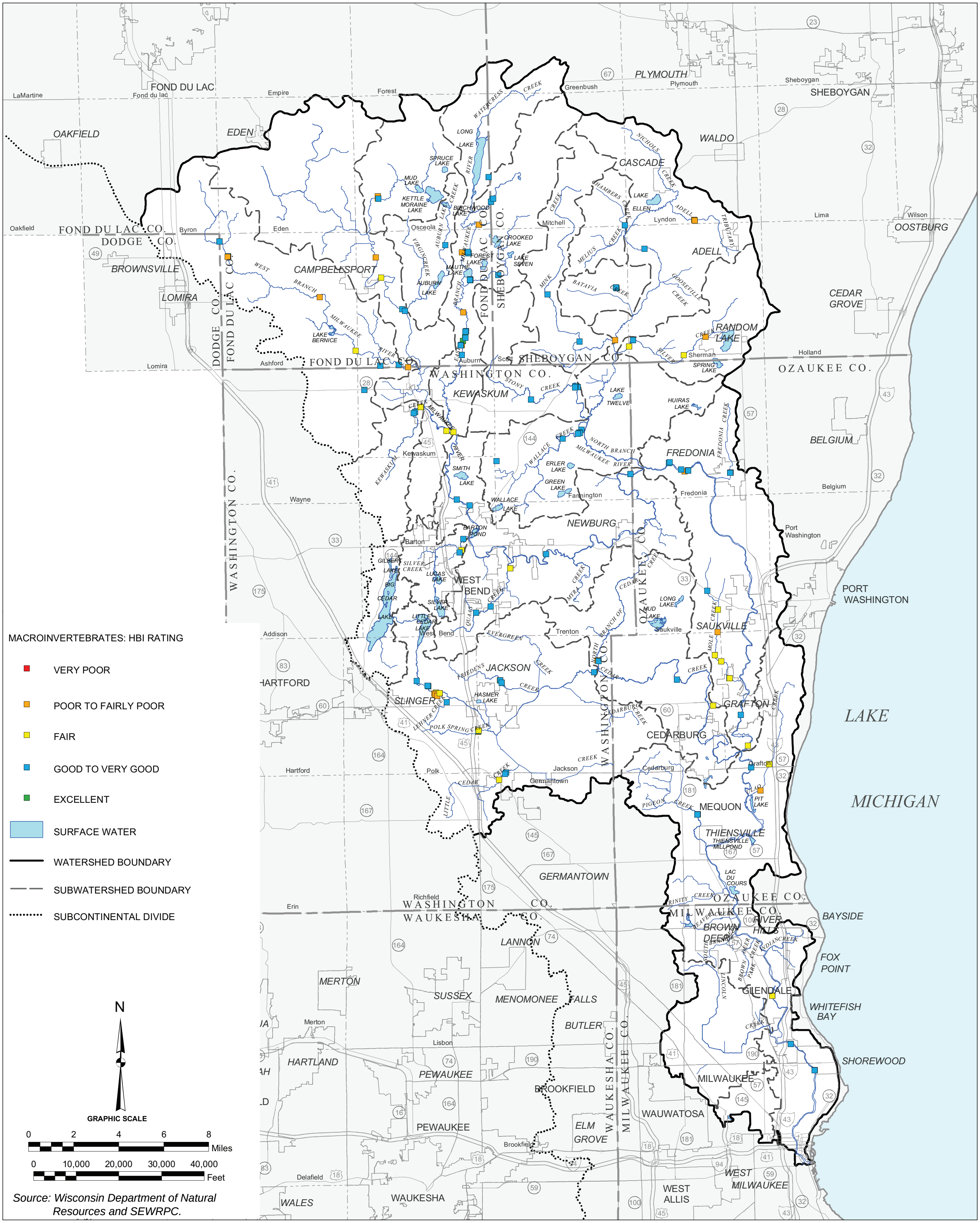
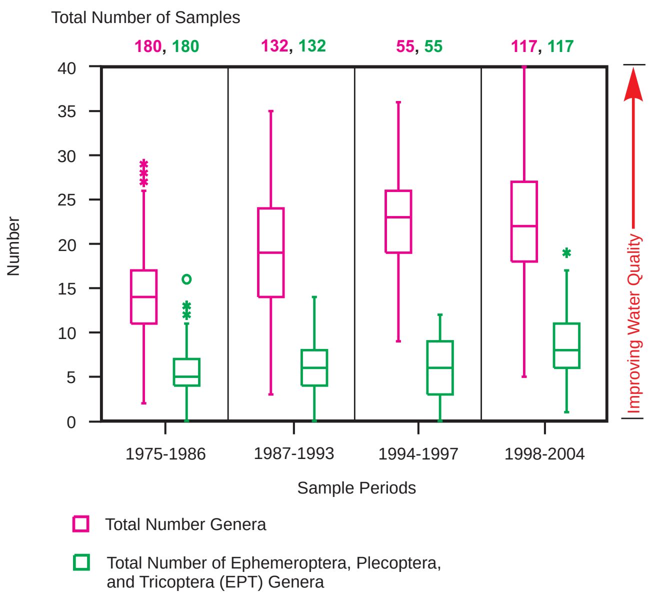


Figure 175

TOTAL NUMBER OF GENERA AND EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) GENERA IN RIFFLE HABITAT IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 180, the high proportion of scrapers in the East Branch of the Milwaukee River subwatershed and the loss of scrapers in the Lower Milwaukee River subwatershed from 1979 to the present also indicates that the former subwatershed contains a higher quality macroinvertebrate community trophic structure. Each of these patterns are consistent with improvement in water quality in the East Branch of the Milwaukee River subwatershed and a decline in water quality in the Lower Milwaukee River subwatershed. Water quality improvement may be related to a decrease in organic or inorganic pollution, decrease in nutrients, improvements in dissolved oxygen concentrations, decreases in heavy metals or other toxic contaminants. This trophic difference between the East Branch of the Milwaukee River subwatershed and the Lower Milwaukee River subwatershed is also consistent with the fishery community differences and water quality differences between these subwatersheds as summarized above.

Wisconsin researchers have generally found that as the amount of human land disturbance increases, such as in the Milwaukee River watershed, the subsequent macroinvertebrate community diversity and abundance decreases, which is generally supported by the data for this watershed.[49] In addition, this fairly high quality of macroinvertebrates found throughout most of the Milwaukee River watershed may also be a function of the integrity and continuity of riparian buffers greater than 75 feet adjacent to the streams and lake systems (see the "Habitat and Riparian Corridor Conditions" section below). Effective buffers help reduce pollutant loadings and other human disturbances.

Synthesis

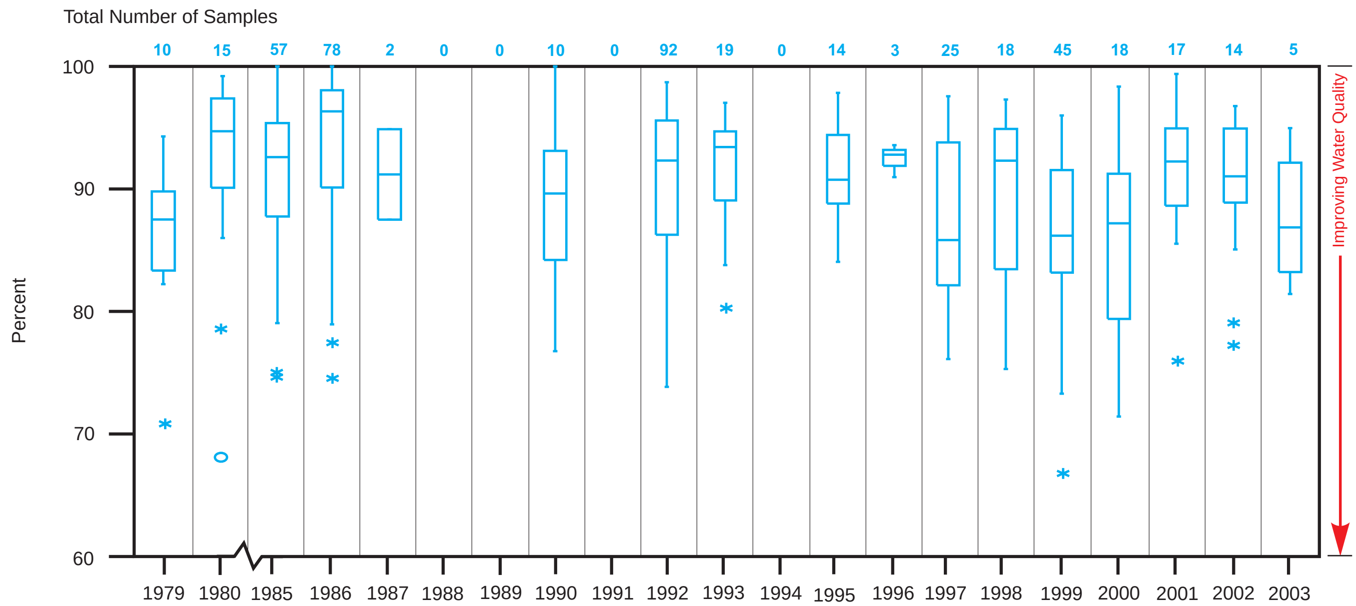
Except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good and in some cases excellent fishery quality, the watershed of the Milwaukee River in general contains a poor to fair fishery. The fish community contains a high abundance of both warmwater and coldwater species of fishes, seems trophically balanced in the highest quality areas, contains a good percentage of top carnivores (except for those species stocked), and is not dominated by tolerant fishes. Macroinvertebrate communities are classified as fair to good-very good at present. The macroinvertebrate community is also generally trophically balanced and not dominated by tolerant taxa. Overall, the fish and macroinvertebrate communities in the Milwaukee River watershed are of a better quality than those communities in the other watersheds in the study area.

The habitat quality was shown to largely be limited by siltation, as well as reduced amounts and quality of instream cover throughout the watershed. In addition, although there have been some water quality improvements in the downstream areas in the watershed, those areas also continue to be impaired due to sediment toxicity

[49]*J. Masterson and R. Bannerman,* Impact of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin, *Wisconsin Department of Natural Resources, Madison, Wisconsin, 1994.*

Figure 176

PERCENT DOMINANCE OF TOP FIVE MACROINVERTEBRATE FAMILIES IN RIFFLE HABITAT IN THE MILWAUKEE RIVER WATERSHED: 1975-2003



NOTES: See Figure 109 for description of symbols.

Years are not plotted on a continuous scale.

Source: Wisconsin Department of Natural Resources and SEWRPC.

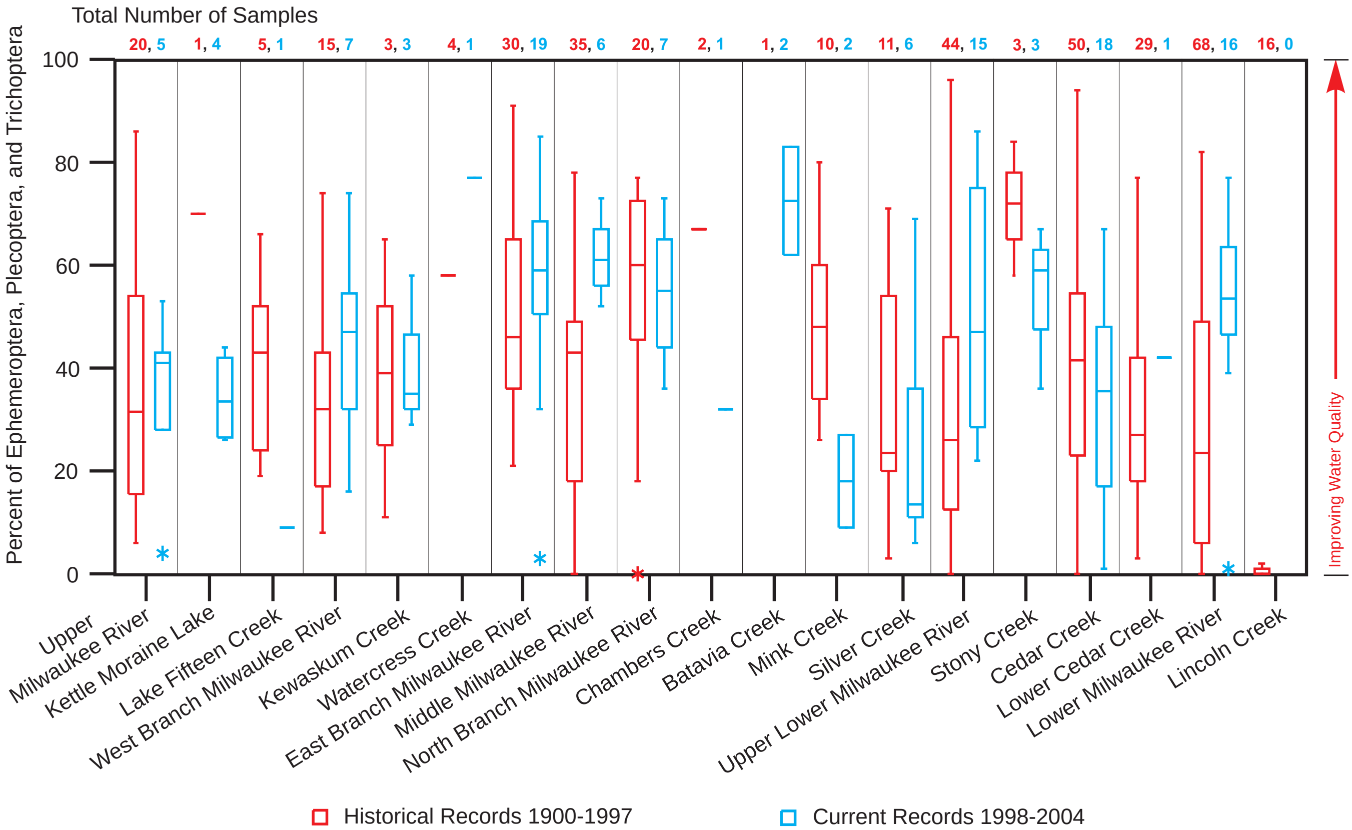
problems. Therefore, in differing degrees throughout the watershed, water, sediment, and habitat quality are important factors limiting both the fishery and macroinvertebrate community. There are several other factors that are likely to be limiting the aquatic community, including, but not limited to, 1) periodic stormwater loads and sediment toxicity; 2) decreased base flows; 3) continued fragmentation due to dams, drop structures, culverts, concrete lined channels, and enclosed conduits; 4) past channelization; 5) cropland erosion, and/or 5) increased water temperatures due to urbanization.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Milwaukee River watershed area, associating these lists with the historic and remaining habitat areas in the area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed area. The net result of the application of this technique is a listing of those species which were probably once present in the watershed area, those species which may be expected to still be present under currently prevailing conditions, and those species which may be expected to be lost or gained as a result of agricultural and urban land development within the area. It is important to note that this inventory was conducted on a countywide basis for each of the aforementioned major groups of organisms. Some of the organisms listed as occurring in Milwaukee, Washington, Ozaukee, Fond du Lac, Sheboygan and Dodge Counties may only infrequently occur within the Milwaukee River watershed.

Figure 177

HISTORICAL AND BASE PERIOD PERCENT EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) MACROINVERTEBRATE GENERA IN RIFFLE HABITAT IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTES: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

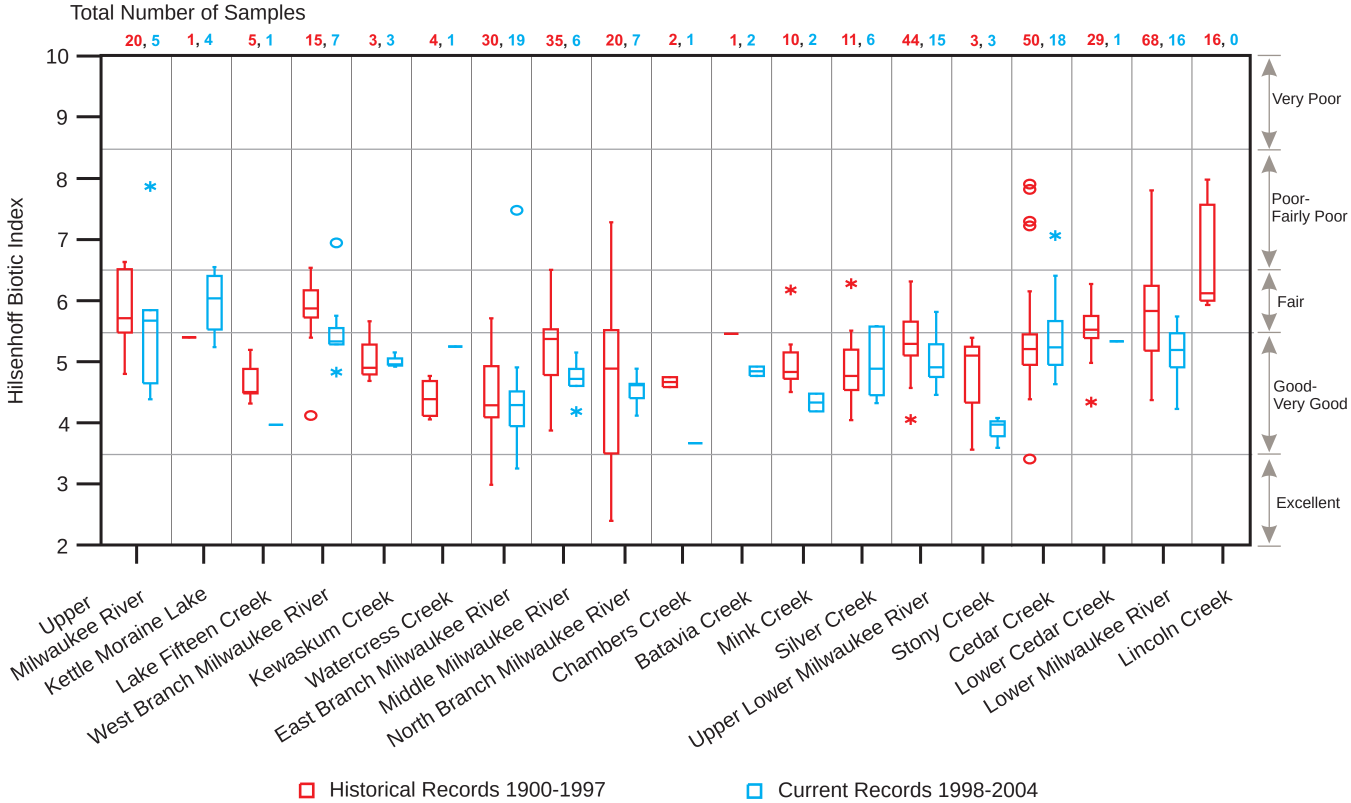
A variety of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are likely to be found in the vicinity of the Milwaukee River watershed. Muskrat, white-tailed deer, gray squirrel, and cottontail rabbit are mammals reported to occur in the area. Appendix D lists the mammals whose ranges historically extended into the watershed.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Milwaukee River watershed. Appendix E lists those birds that normally occur in the watershed. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Milwaukee River watershed also supports a significant population of waterfowl, including mallards and Canada geese. Larger numbers of various waterfowl likely move through the watershed area during the annual migrations when most of the regional species may also be present. Many game birds, songbirds, waders, and raptors also reside or visit the watershed.

Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the Milwaukee River watershed. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Milwaukee River area. Appendix F lists the amphibian and reptile species normally expected to be present in the Milwaukee River watershed under present conditions. Most amphibians and reptiles have specific habitat requirements that are adversely affected by agricultural

Figure 178

HISTORICAL AND BASE PERIOD HILSENHOFF BIOTIC INDEX (HBI) SCORES IN RIFFLE HABITAT IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTES: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

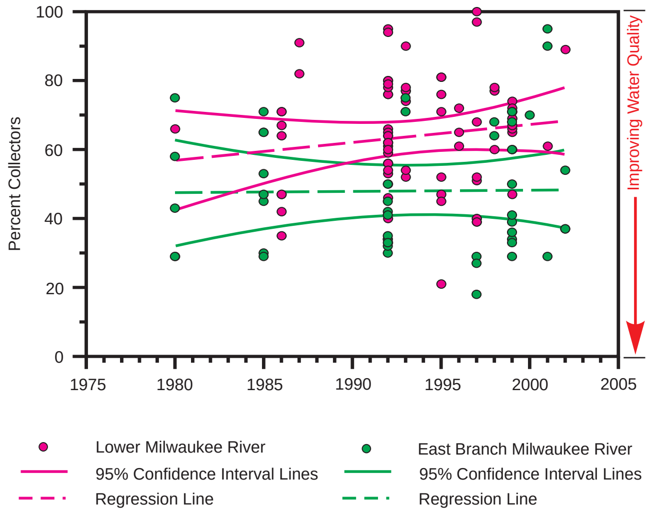
disturbances and advancing urban development. The major detrimental factors affecting the maintenance of amphibians in a changing environment is the draining or destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

A total of 88 Endangered and threatened species and species of special concern were identified to be present within the vicinity of the Milwaukee River watershed, including 47 species of plants, 10 species of birds, 11 species of fish, four species of herptiles, and 16 species of invertebrates from Wisconsin Department of Natural Resources records dating back to the late 1800s (see Table 109). Since 1975, there have been observed 24 species of plants, 10 species of birds, 10 species of fish, three species of herptiles, and 15 species of invertebrates, totaling to an apparent loss of 26 total species.

The complete spectrum of wildlife species originally native to the watershed, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of urban land in some areas. Successive cultural uses and attendant management practices, primarily urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

Figure 179

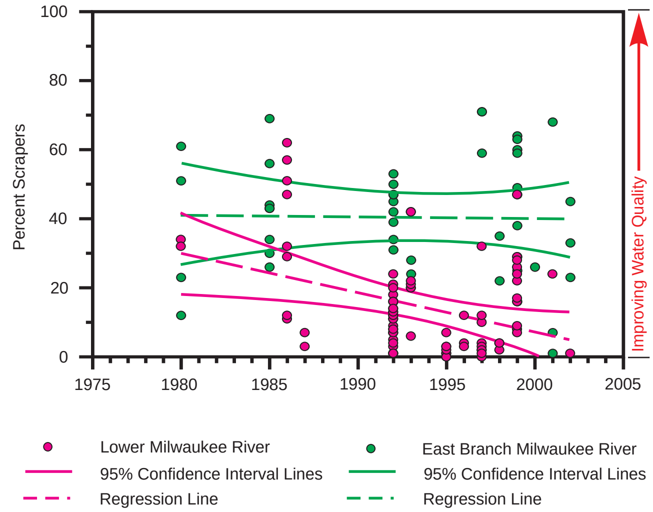
PERCENT COLLECTOR MACROINVERTEBRATE TROPHIC GROUPS IN THE EAST BRANCH MILWAUKEE RIVER AND LOWER MILWAUKEE RIVER SUBWATERSHEDS: 1979-2003



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 180

PERCENT SCRAPER MACROINVERTEBRATE TROPHIC GROUPS IN THE EAST BRANCH MILWAUKEE RIVER AND LOWER MILWAUKEE RIVER SUBWATERSHEDS: 1979-2003



Source: Wisconsin Department of Natural Resources and SEWRPC.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as particle traps or filters. On an annual basis or a long-term basis, streams may exhibit net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may be contributed by streambank erosion.[50] In the absence of mitigative measures, increased urbanization in a watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. In many of the communities in the downstream portion of the Milwaukee River watershed, the requirements of MMSD Chapter 13, “Surface Water and Storm Water,” are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. In communities outside of the MMSD service area, local ordinances provide for varying degrees of control of runoff from new development. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, “Runoff Management,” of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development.

Milwaukee County commissioned an assessment of stability and fluvial geomorphic character of streams within four watersheds in the County including the Milwaukee River watershed.[51] This study, conducted in fall 2003,

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[50]*SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975, *September 1978.*

[51]*Inter-Fluve, Inc.,* op. cit.

Table 109

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE MILWAUKEE RIVER WATERSHED: 2004

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Insects			
A Common Netspinner Caddisfly	*Hydropsyche bidens*	Not listed	Special concern
A Side-Swimmer	*Crangonyx gracilis*	Not listed	Special concern
Amber-Winged Spreadwing	*Lestes eurinus*	Not listed	Special concern
Aurora Damselfly	*Chromagrion conditum*	Not listed	Special concern
Broad-Winged Skipper	*Poanes viator*	Not listed	Special concern
Dion Skipper	*Euphyes dion*	Not listed	Special concern
Elegant Spreadwing	*Lestes inaequalis*	Not listed	Special concern
Ellipse	*Venustaconcha ellipsiformis*	Not listed	Threatened
Green-Striped Darner	*Aeshna verticalis*	Not listed	Special concern
Mulberry Wing	*Poanes massasoit*	Not listed	Special concern
Prairie Crayfish[a]	*Procambarus gracilis*	Not listed	Special concern
Slaty Skimmer	*Libellula incesta*	Not listed	Special concern
Slender Bluet	*Enallagma traviatum*	Not listed	Special concern
Swamp Metalmark	*Calephelis muticum*	Not listed	Endangered
Swamp Spreadwing	*Lestes vigilax*	Not listed	Special concern
Unicorn Clubtail	*Arigomphus villosipes*	Not listed	Special concern
Fish			
American Eel[a]	*Anguilla rostrata*	Not listed	Special concern
Banded Killifish	*Fundulus diaphanus*	Not listed	Special concern
Bloater[b]	*Coregonus hoyi*	Not listed	Special concern
Greater Redhorse	*Moxostoma valenciennesi*	Not listed	Threatened
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Least Darter	*Etheostoma microperca*	Not listed	Special concern
Longear Sunfish	*Lepomis megalotis*	Not listed	Threatened
Pugnose Shiner	*Notropis anogenus*	Not listed	Threatened
Redfin Shiner	*Lythrurus umbratilis*	Not listed	Threatened
Striped Shiner	*Luxilus chrysocephalus*	Not listed	Endangered
Weed Shiner	*Notropis Texanus*	Not listed	Special concern
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Blanchard's Cricket Frog[a]	*Acris crepitans blanchardi*	Not listed	Endangered
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Threatened
Queen Snake	*Regina septemvittata*	Not listed	Endangered
Birds			
Acadian Flycatcher	*Empidonax virescens*	Not listed	Threatened
Cerulean Warbler	*Dendroica cerulea*	Not listed	Threatened
Common Tern	*Sterna hirundo*	Not listed	Endangered
Dickcissel	*Spiza americana*	Not listed	Special concern
Hooded Warbler	*Wilsonia citrina*	Not listed	Threatened
Kentucky Warbler	*Oporornis formosis*	Not listed	Threatened
Northern Pintail	*Anas acuta*	Not listed	Special concern
Orchard Oriole	*Icterus spurius*	Not listed	Special concern
Red-Shouldered Hawk	*Buteo lineatus*	Not listed	Threatened
White-Eyed Vireo	*Vireo griseus*	Not listed	Special concern
Plants			
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
American Sea-Rocket	*Cakile edentula*	Not listed	Special concern
Autumn Coral-Root	*Corallorhiza odontorhiza*	Not listed	Special concern
Christmas Fern	*Polystichum acrostichoides*	Not listed	Special concern
Clustered Broomrape[a]	*Orobanche fasciculata*	Not listed	Threatened
Common Bog Arrow-Grass[a]	*Triglochim maritima*	Not listed	Special concern
Cooper's Milkvetch[a]	*Astragalus neglectus*	Not listed	Endangered
Cuckooflower	*Cardamine pratensis*	Not listed	Special concern
Downy Willow-Herb	*Epilobium strictum*	Not listed	Special concern

Table 109 (continued)

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Plants (continued)			
Forked Aster	*Aster furcatus*	Not listed	Threatened
Giant Pinedrops	*Pterospora andromedea*	Not listed	Endangered
Great Indian-Plantain[a]	*Cacalia muehlenbergii*	Not listed	Special concern
Hairy Beardtongue[a]	*Penstemon hirsutus*	Not listed	Special concern
Handsome Sedge	*Carex formosa*	Not listed	Threatened
Harbinger-of-Spring[a]	*Erigenia bulbosa*	Not listed	Endangered
Hemlock Parsley[a]	*Conioselinum chinense*	Not listed	Endangered
Heart-Leaved Plantain	*Plantago cordata*	Not listed	Endangered
Hooker Orchis[a]	*Platanthera hookeri*	Not listed	Special concern
Large Roundleaf Orchid	*Platanthera orbiculata*	Not listed	Special concern
Lesser Fringed Gentain	*Gentianopsis procera*	Not listed	Special concern
Marsh Blazing Star[a]	*Liatris spicata*	Not listed	Special concern
Many-Headed Sedge	*Carex sychnocephala*	Not listed	Special concern
Marbleseed[a]	*Onosmodium molle*	Not listed	Special concern
Narrow-Leaved Vervain[a]	*Verbena simplex*	Not listed	Special concern
Ohio Goldenrod	*Solidago ohioensis*	Not listed	Special concern
One-Flowered Broomrape[a]	*Orobanche uniflora*	Not listed	Special concern
Pale-Green Orchid[a]	*Platanthera flava var. herbiola*	Not listed	Threatened
Purple Milkweed[a]	*Asclepias purpurascens*	Not listed	Endangered
Ram's-Head Lady's Slipper[a]	*Cypripedium arietinum*	Not listed	Threatened
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Round-Leaved Orchis[a]	*Amerorchis rotundifolia*	Not listed	Threatened
Seaside Spurge[a]	*Euphorbia polygonifolia*	Not listed	Special concern
Showy Lady's Slipper[a]	*Cypripedium reginae*	Not listed	Special concern
Slender Sedge[a]	*Carex gracilescens*	Not listed	Special concern
Slim-Stem Small Reedgrass	*Calamagrostis stricta*	Not listed	Special concern
Small White Lady's Slipper[a]	*Cypripedium candidum*	Not listed	Threatened
Small Yellow Lady's Slipper	*Cypripedium calceolus*	Not listed	Special concern
Snow Trillium	*Trillium nivale*	Not listed	Threatened
Sparse-Flowered Sedge	*Carex tenuiflora*	Not listed	Special concern
Sticky False Asphodel	*Tofieldia glutinosa*	Not listed	Threatened
Twinleaf	*Jeffersonia diphylla*	Not listed	Special concern
Tufted Hairgrass[a]	*Deschampsia cespitosa*	Not listed	Special concern
Variegated Horsetail[a]	*Equisetum variegatum*	Not listed	Special concern
Wafer-Ash	*Ptelea trifoliata*	Not listed	Special concern
Waxleaf Meadowrue	*Thalictrum revolutum*	Not listed	Special concern
White Adder's-Mouth[a]	*Malaxis brachypoda*	Not listed	Special concern
Yellow Gentain	*Gentiana alba*	Not listed	Threatened

[a] *Species observed prior to year 1975.*

[b]*Unknown when species was observed.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, Wisconsin Society of Ornithology, and SEWRPC.

examined channel stability in about 24 miles of stream channel along the mainstem of the Milwaukee River and several of its tributaries. A major goal of this study was to create a prioritized list of potential project sites related to mitigation of streambank erosion and channel incision, responses to channelization, and maintenance of infrastructure integrity. In addition, the SEWRPC staff has evaluated the condition of the streambanks and associated erosion 1) along an unnamed Tributary to the Milwaukee River as part of the reconstruction of the USH 45 roadway improvement project in cooperation with the Wisconsin Department of Transportation and 2) in the Quaas Creek subwatershed as part of the development of a watershed protection plan in cooperation with Washington County Land Conservation Department.[52]

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[52]*Wisconsin Department of Transportation and SEWRPC Letter Agreement, USH 45—Stream Relocation Project (Project ID# 4070-01-02), August 2001; SEWRPC Memorandum Report No. 151,* Stream Channel Stability and Biological Assessment of Quaas Creek: 2002, *Washington County Wisconsin, July 2002.*

Map 61 shows the types of channel bed lining in streams within the Milwaukee River watershed. Reaches within Polk Spring Creek, Beaver Creek, Southbranch Creek, an unnamed tributary to Southbranch Creek, Brown Deer Park Creek, and an unnamed tributary to Indian Creek in the lower portions of the Milwaukee River watershed are enclosed in approximately 3.3 miles of underground conduit. Enclosed channel represents less than 1 percent of the stream length assessed. Reaches within Beaver Creek, Lincoln Creek, Southbranch Creek, Brown Deer Park Creek, and Indian Creek are lined with concrete over a total length of approximately 3.7 miles. The stream network has been substantially modified over much of the watershed, with many stretches having been channelized. However, there are some areas within the upper portions of the watershed where stream channel modification has not been as significant, such as the designated exceptional water resources areas in the East Branch of the Milwaukee River and Lake Fifteen Creek subwatersheds.

Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious surfaces increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become “flashier,” with flows increasing rapidly in response to rainfall events. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[53] Lowering of the downstream channel bed increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

It is also important to note that most of the agricultural lands in the Milwaukee River watershed contain drain tiles that are designed specifically to convey water out of the soils and into the adjacent streams that have generally been channelized. As a result of runoff being conveyed via drain tiles, relative to undrained conditions, peak flows become somewhat higher and more frequent with flows increasing more rapidly in response to rainfall events. Similar to urban development conditions, agricultural activities in a watershed can also lead to localized bank scour, channel incision, and bank failure.

Map 62 summarizes bank stability for the Milwaukee River and several of its tributaries.[54] Photographs of typical bank stability conditions throughout the watershed are shown in Figure 181. About 43 miles of channel were inventoried for stability as shown on Map 62, including about 31 miles of channel in Milwaukee County and about 2.4 miles of channel in the unnamed tributary to the Milwaukee River and Quaas Creek systems. Approximately half of the alluvial reaches that were examined appeared to be degrading and actively eroding. About 9.5 percent of the stream length assessed was observed to be stable. The stable reaches are located in Lincoln Creek, Lower Milwaukee River, an unnamed tributary to the Milwaukee River, and portions of the Brown Deer Park Creek and Quaas Creek systems (see Map 62). These assessments represent about 9 percent of the approximately 511 total miles of stream length that exist throughout the Milwaukee River watershed area. It should be noted that the assessment of Lincoln Creek was conducted prior to the completion of the MMSD environmental restoration and flood control project. That project was designed to promote bank stability and the conclusion of stable banks along Lincoln Creek is still valid under post-project conditions.

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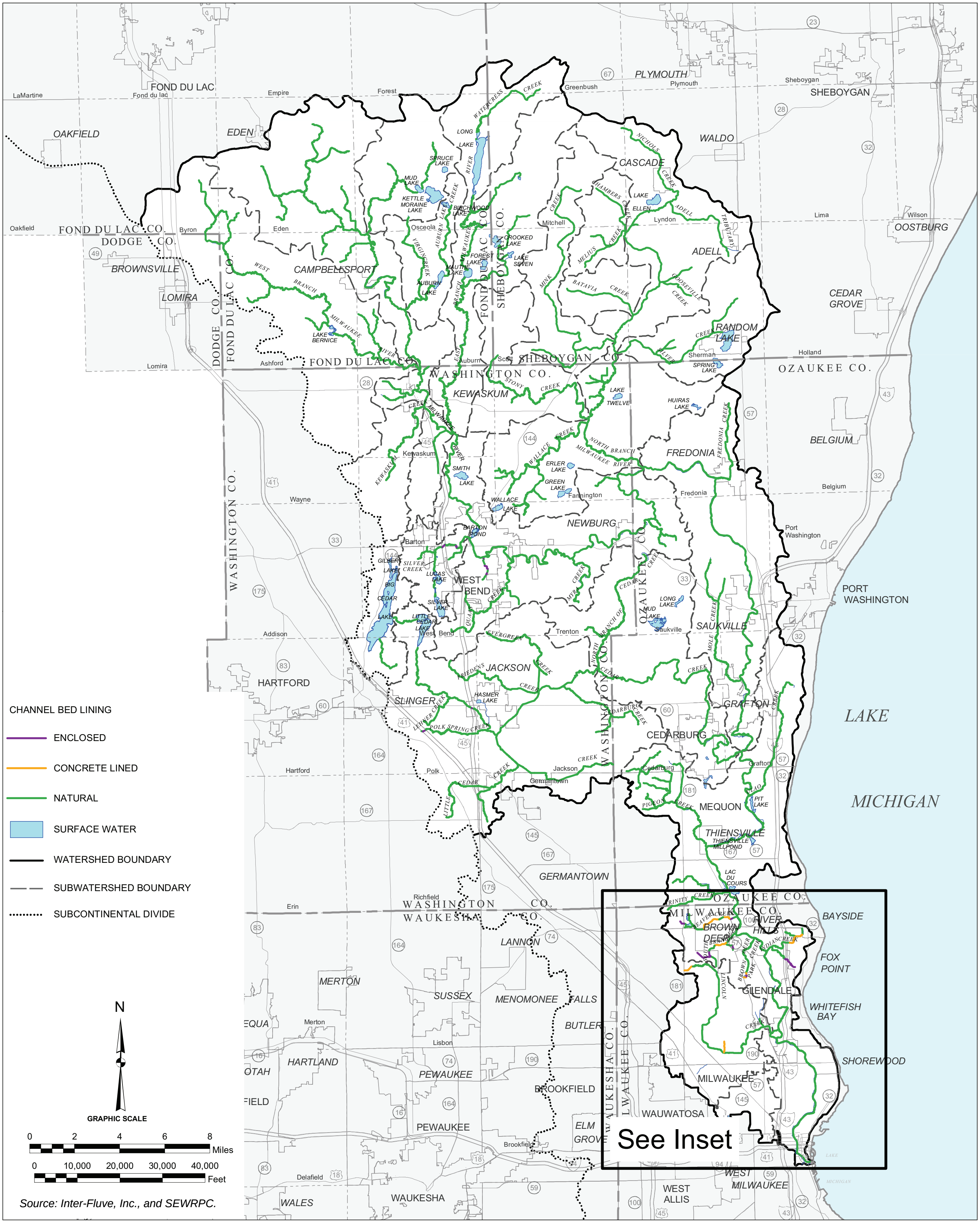
[53]*S.A. Schumm, “Causes and Controls of Channel Incision,” In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

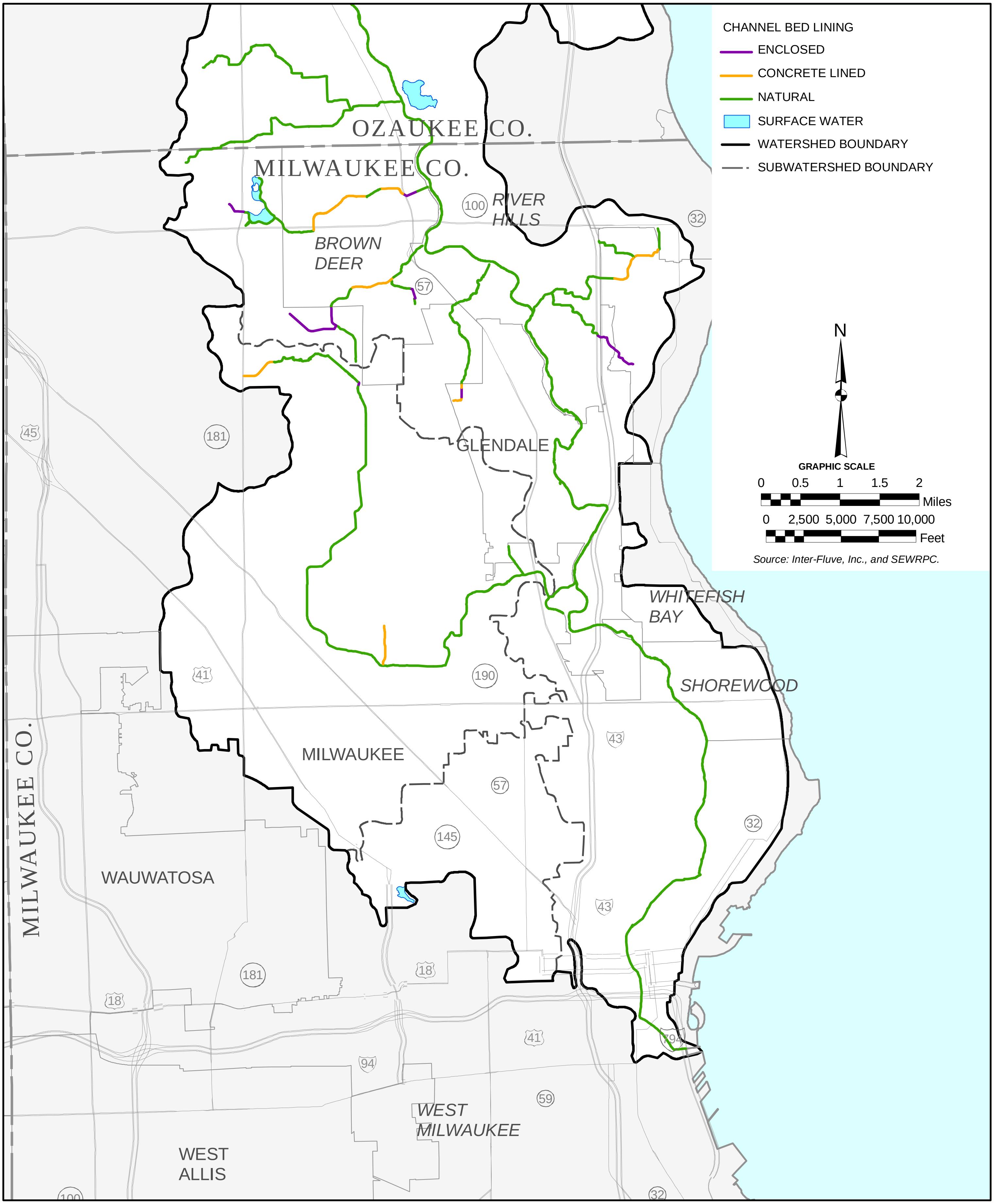
[54]*Inter-Fluve, Inc.,* op. cit.; *Wisconsin Department of Transportation and SEWRPC Letter Agreement,* op. cit.; *SEWRPC Memorandum Report No. 151,* op. cit.

Map 61

CHANNEL BED CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



INSET to Map 61



Map 62

STREAMBANK STABILITY CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

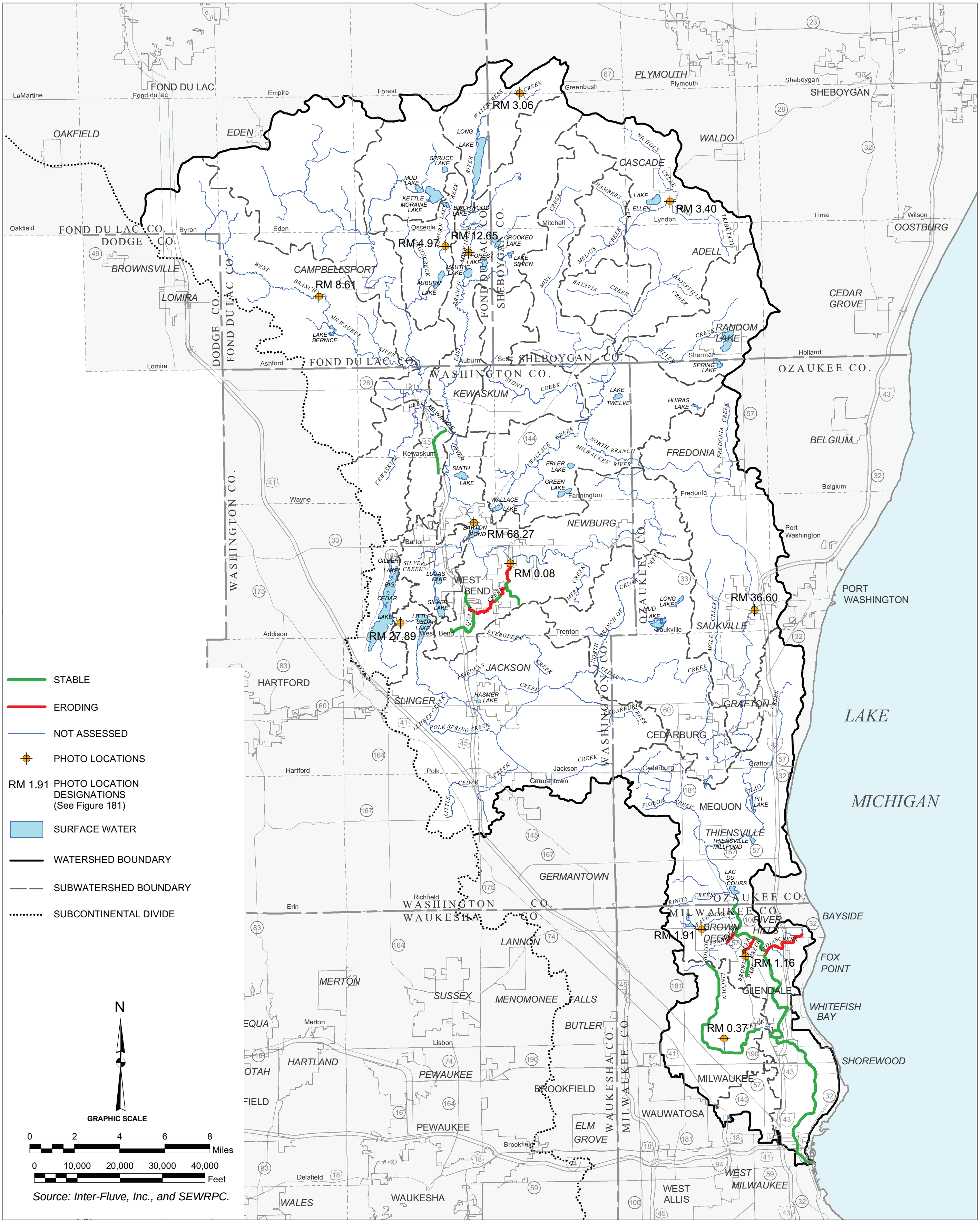
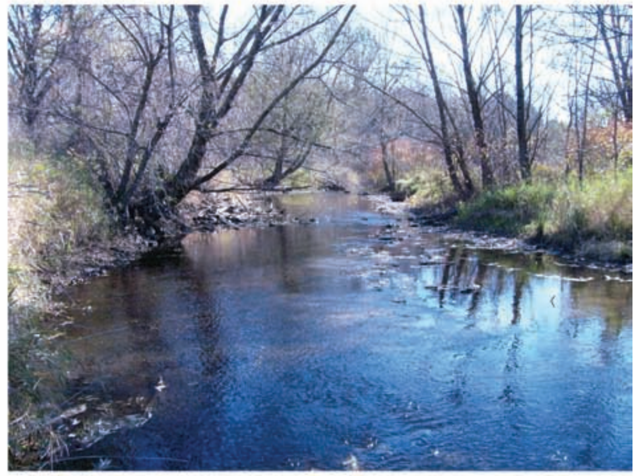


Figure 181

STREAMBANK STABILITY CONDITIONS AMONG REACHES WITHIN THE MILWAUKEE RIVER WATERSHED: 2003, 2005

WATERCRESS CREEK AT RIVER MILE 3.06

EAST BRANCH MILWAUKEE RIVER AT RIVER MILE 12.65



NICHOLS CREEK AT RIVER MILE 3.40

WEST BRANCH MILWAUKEE RIVER AT RIVER MILE 8.61

AUBURN LAKE CREEK AT RIVER MILE 4.97

MILWAUKEE RIVER AT RIVER MILE 68.27

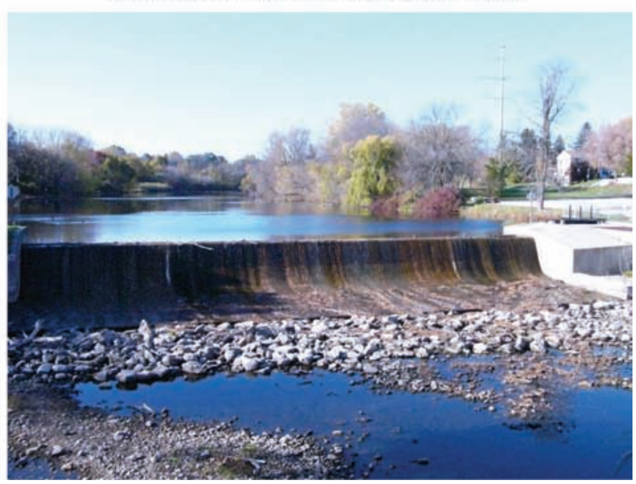


Figure 181 (continued)

QUAAS CREEK AT RIVER MILE 0.08

BEAVER CREEK AT RIVER MILE 1.91

CEDAR CREEK AT RIVER MILE 27.89

BROWN DEER CREEK AT RIVER MILE 1.16

MILWAUKEE RIVER AT RIVER MILE 36.60

WAHL CREEK AT RIVER MILE 0.37

Source: Inter-Fluve, Inc., and SEWRPC.

Dams
There are currently about 70 dams and about 6 drop structures within the Milwaukee River watershed. As shown on Map 63, the dams are located throughout the watershed, along the mainstem and tributaries of the Milwaukee River. Most of these dams form impoundments. In addition, a small number of drop structures are located in Beaver Creek and Brown Deer Park Creek. Dams and drop structures can disrupt sediment transport and limit aquatic organism passage, fragmenting populations in the reaches shown on Map 53. Those factors can lead to a reduction in overall abundance and diversity of aquatic organisms as summarized in the "Influence of Dams/Dam Removal" subsection above.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

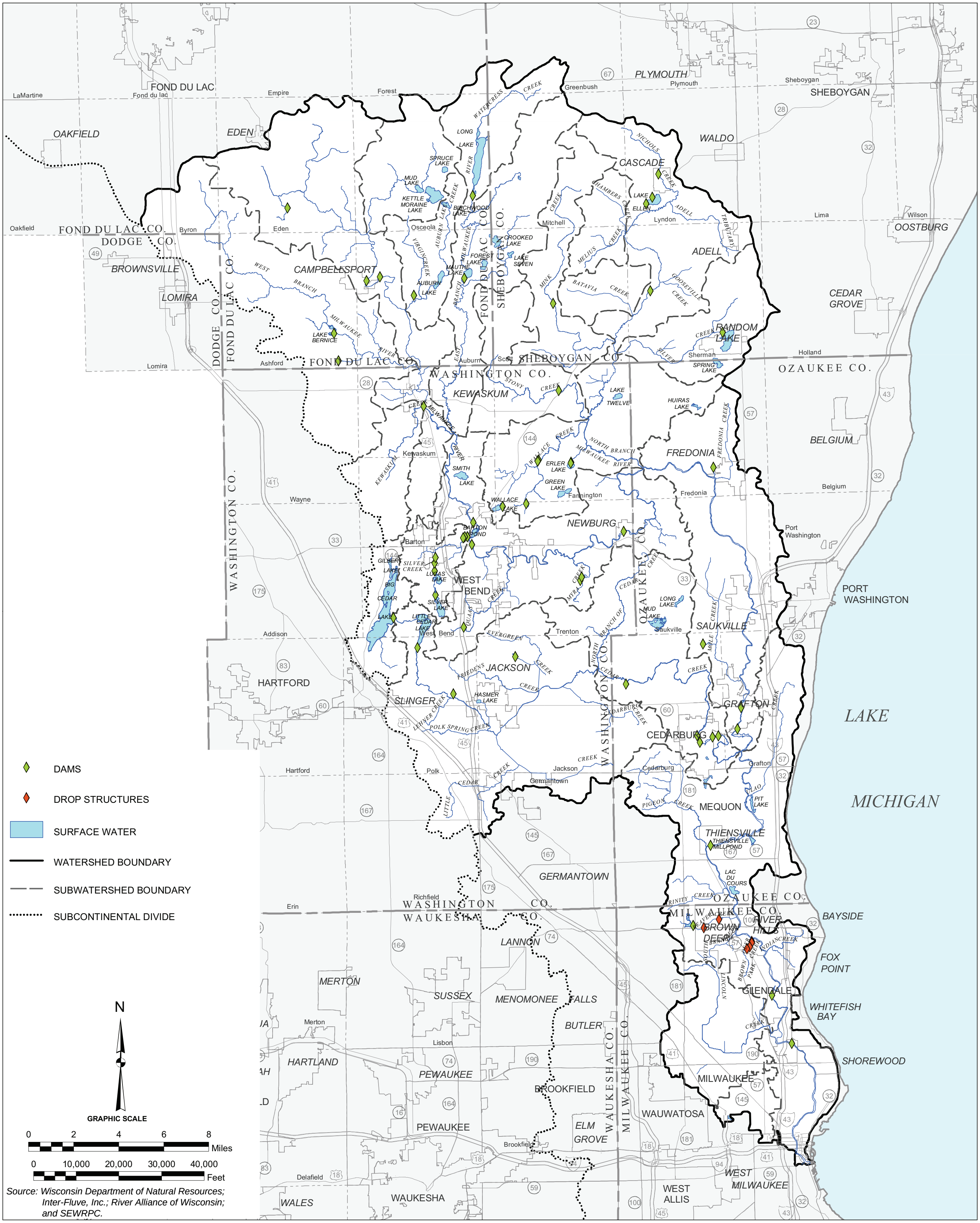
The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one-mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the watershed area directly tributary to the Milwaukee River system thus becomes apparent.

Primary Environmental Corridors
The primary environmental corridors in southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat

Map 63

DAMS AND DROP STRUCTURES WITHIN THE MILWAUKEE RIVER WATERSHED: 2005



areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 64, in the year 2000 primary environmental corridors in the Milwaukee River watershed area encompassed about 94,500 acres, or about 21 percent of the watershed area. The major environmental corridor lands within the watershed lie along the Kettle Moraine and trend in a north-south direction in the west central portions of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of primary environmental corridors within the watershed. Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 64, secondary environmental corridors in the Milwaukee River watershed area encompassed about 9,500 acres, or about 2 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of secondary environmental corridors within the watershed. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain “pockets” of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to the primary and secondary environmental corridors, other small concentrations of natural resource base elements exist within the watershed area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource area features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource area features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the Milwaukee River watershed area also are shown on Map 64 and total about 11,200 acres, or about 3 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of isolated natural resource areas within the watershed.

Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[55] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Milwaukee River watershed area, as shown on Map 65 and Table 110, 113 such sites were identified, 26 of which were identified as critical species habitat sites. Eight sites totaling about 2,600 acres were identified as being of statewide or great significance (NA-1), about 75 percent of which are already in public ownership. There were 29 sites identified as natural areas of countywide or regional significance (NA-2) totaling 6,860 acres; about 2,315 acres or about 35 percent of which are already in public ownership and the remaining lands are proposed to be acquired. A further approximately 55 sites, totaling about 5,345 acres of natural area of local significance (NA-3), were identified. Of the approximately 5,340 acres of

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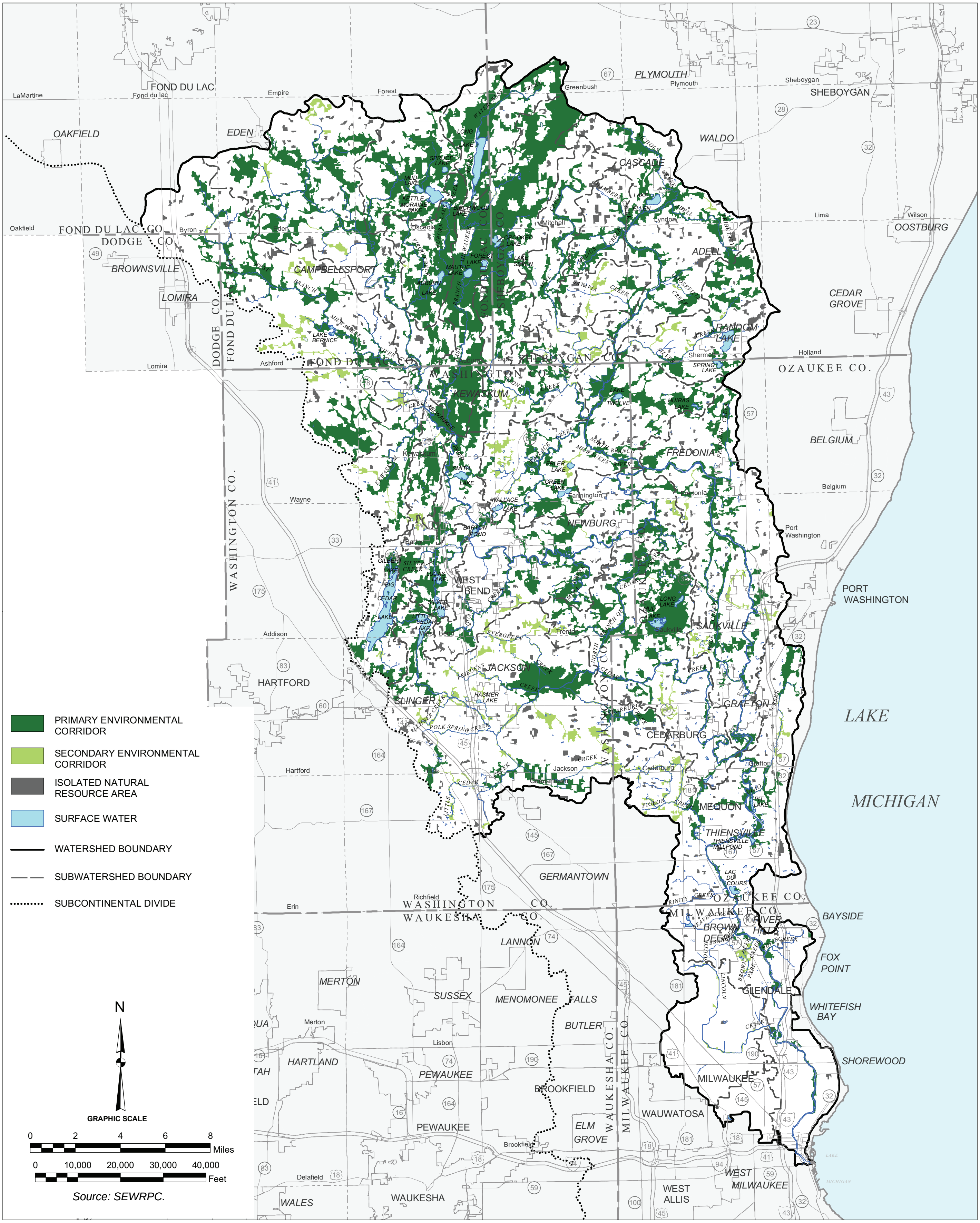
[55]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

Map 64

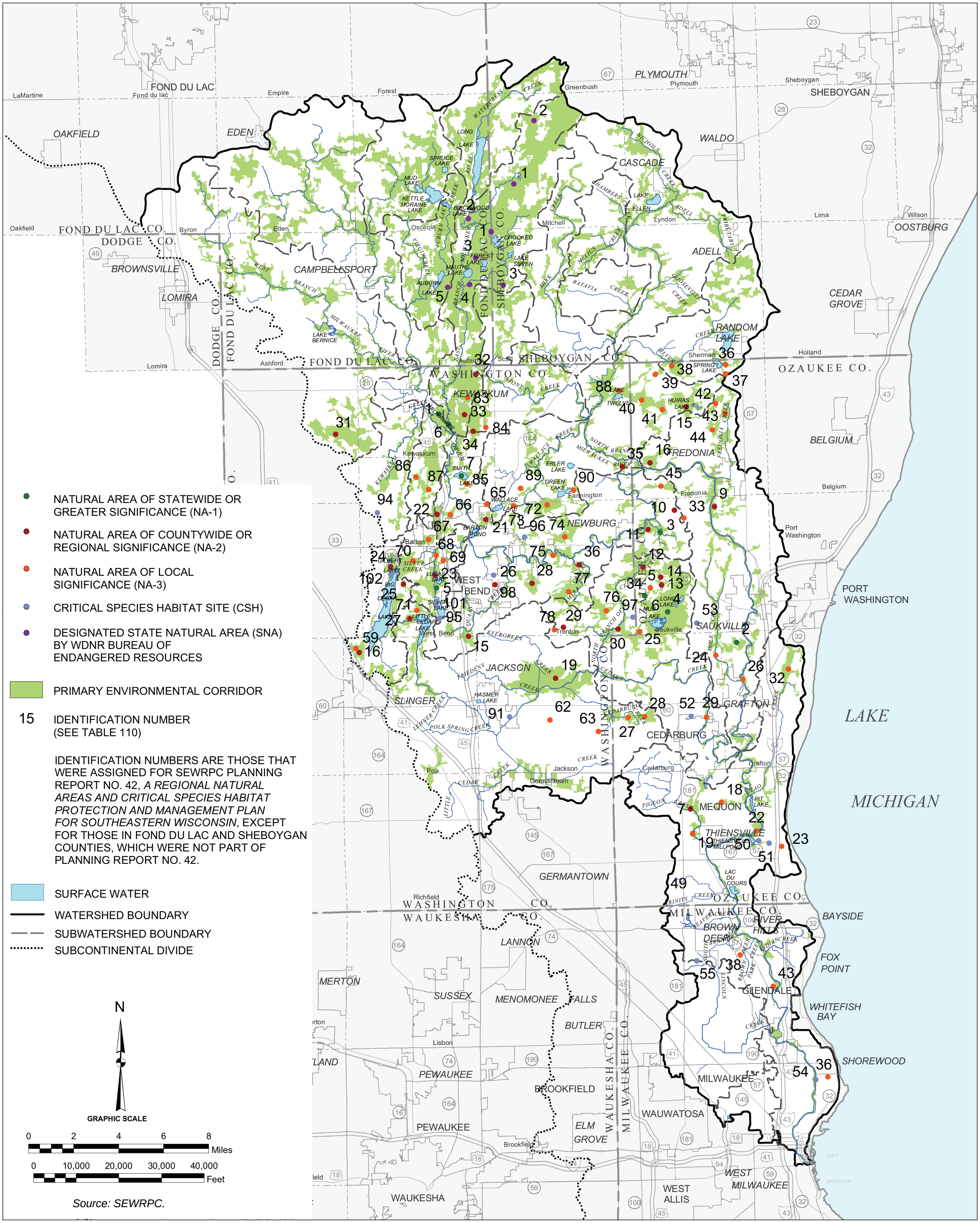
ENVIRONMENTAL CORRIDORS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Source: SEWRPC.

Map 65

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE MILWAUKEE RIVER WATERSHED: 1994



Source: SEWRPC.

Table 110

NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES IN THE MILWAUKEE RIVER WATERSHED

Number on Map 65	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas						
1	Crooked Lake Wetlands	SNA	Fond du Lac County	- -[b]	- -	- -	- -
1	Kewaskum Maple-Oak Woods State Natural Area	NA-1, CSH	Town of Kewaskum	46	40	86	Wisconsin Department of Natural Resources
1	Butler Lake Flynn's Spring	SNA	Sheboygan County	- -[c]	- -	- -	- -
2	Milwaukee River Tamarack Lowlands & Dundee Kame	SNA	Fond du Lac County	- -	- -	- -	- -
2	Kurtz Woods State Natural Area	NA-1	Town of Grafton	31	39	70	The Nature Conservancy
2	Johnson Hill Kame	SNA	Sheboygan County	- -[c]	- -	- -	- -
3	Kettle Hole Woods	SNA	Sheboygan County	- -[c]	- -	- -	- -
3	Haskell Noyes Woods	SNA	Fond du Lac County	- -[b]	- -	- -	- -
3	Riveredge Creek and Ephemeral Pond State Natural Area	NA-1, CSH	Town of Saukville	75	22	97	Riveredge Nature Center
4	Milwaukee River and Swamp	SNA	Fond du Lac County	- -[b]	- -	- -	- -
4	Cedarburg Bog State Natural Area	NA-1, CSH	Town of Saukville	1,572	437	2,009	Wisconsin Department of Natural Resources
5	Spring Lake	SNA	Fond du Lac County	- -[b]	- -	- -	- -
5	Sapa Spruce Bog State Natural Area	NA-1	Town of Saukville	22	37	59	University of Wisconsin-Milwaukee
5	Paradise Lake Fen	NA-1	Town of West Bend	11	11	22	Wisconsin Department of Natural Resources
6	Cedarburg Beech Woods State Natural Area	NA-2, CSH	Town of Saukville	87	43	130	University of Wisconsin-Milwaukee
6	Milwaukee River Floodplain Forest State Natural Area	NA-1	Town of Kewaskum	130	5	135	Wisconsin Department of Natural Resources
7	Pigeon Creek Low and Mesic Woods	NA-2	City of Mequon	- -	81	81	Ozaukee County
7	Smith Lake and Wetlands	NA-1	Town of Barton	85	45	130	Wisconsin Department of Natural Resources
9	Milwaukee River Mesic Woods	NA-2	Village of Fredonia, Town of Saukville, Town of Fredonia	67	315	382	Ozaukee County
10	Duck's Limited Bog	NA-2	Town of Saukville	13	8	21	Ducks Limited
11	Riveredge Mesic Woods	NA-2, CSH	Town of Saukville	158	54	212	Riveredge Nature Center
12	Kinnamon Conifer Swamp	NA-2	Town of Saukville	- -	382	382	Ozaukee County
13	South Conifer Swamp	NA-2	Town of Saukville	3	49	52	Wisconsin Department of Natural Resources
14	Max's Bog	NA-2	Town of Saukville	5	8	13	Private conservancy organization
15	Mud Lake Swamp	NA-2	Town of Polk, Town of West Bend	7[d]	179	188	Washington County
15	Huiras Lake Woods and Bog	NA-2	Town of Fredonia	22	413	435	Ozaukee County
16	Janik's Woods	NA-2	Town of Fredonia	- -	163	163	Ozaukee County
16	Big Cedar Lake Bog	NA-2	Town of Polk	- -	89	89	Washington County
18	Highland Road Woods	NA-3	City of Mequon	- -	83	83	City of Mequon
19	Pigeon Creek Maple Woods	NA-3	City of Mequon	- -	13	13	Ozaukee County
19	Jackson Swamp	NA-2, CSH	Town of Jackson	1,221	350	1,571	Wisconsin Department of Natural Resources
21	Lac Lawrann Conservancy Upland Woods and Wetlands	NA-2	City of West Bend	78	23	101	City of West Bend
22	Blue Hills Woods	NA-2, CSH	City of West Bend, Town of Barton	105	161	266	City of West Bend
22	Ville de Parc Riverine Forest	NA-3	City of Mequon	49	62	111	City of Mequon
23	Mequon Wetland	NA-3	City of Mequon	- -[e]	- -[e]	77	- -
23	Silverbrook Lake Woods	NA-2	Town of West Bend	148	256	404	Wisconsin Department of Natural Resources
24	Mole Creek Swamp	NA-3	Town of Cedarburg	22	67	89	Town of Cedarburg
24	Gilbert Lake Tamarack Swamp	NA-2, CSH	Town of West Bend	54	76	130	Cedar Lakes Conservation Foundation
25	Cedar-Sauk Low Woods	NA-3	Town of Cedarburg, Town of Saukville, Town of Trenton	- -	218	218[f]	Private conservancy organization

Table 110 (continued)

Number on Map 65	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas (continued)						
25	Hacker Road Bog	NA-2	Town of West Bend	25	- -	25	Wisconsin Department of Natural Resources
26	Muth Woods	NA-2	City of West Bend	- -	30	30	City of West Bend
26	Grafton Woods	NA-3	Town of Grafton	- -	18	18	Ozaukee County
27	Little Cedar Lake Wetlands	NA-2	Town of West Bend	126	11	137	Cedar Lakes Conservation Foundation
27	Sherman Road Woods	NA-3	Town of Cedarburg	- -	72	72	Private conservancy organization
28	Schoenbeck Woods	NA-2	Town of Trenton	- -	195	195	Washington County
28	Five Corners Swamp	NA-3	Town of Cedarburg	19	154	173	Wisconsin Department of Natural Resources
29	Bellin Bog	NA-2	Town of Trenton	2	15	17	Washington County
29	Cedar Creek Forest	NA-3	Town of Cedarburg	- -	23	23	City of Cedarburg
30	Reinartz Cedar Swamp	NA-2	Town of Trenton	9	110	119	Washington County
31	Wayne Swamp	NA-2	Town of Wayne, Town of Kewaskum	- -	1,126	1,126	Washington County
32	Ulao Lowland Forest	NA-3	Town of Grafton	- -	347	347	Private conservancy organization
32	Kettle Moraine Drive Bog	NA-2	Town of Kewaskum	29	10	39	Wisconsin Department of Natural Resources
33	Hanson Lake Wetland	NA-3	Town of Saukville	5	8	13	Private conservancy organization
33	Glacial Trail Forest	NA-2, CSH	Town of Kewaskum	212	11	223	Wisconsin Department of Natural Resources
34	St. Michael's Woods	NA-2, CSH	Town of Kewaskum	81	3	84	Wisconsin Department of Natural Resources
34	Knollwood Road Bog	NA-3	Town of Saukville	4	5	9	Private conservancy organization
35	Hawthorne Drive Forest	NA-3	Town of Port Washington	- -[e]	- -	54	- -
35	North Branch Woods	NA-2	Town of Farmington	- -	96	96	Washington County
36	Spring Lake Marsh	NA-3	Town of Fredonia	3	16	19	Private conservancy organization
36	Myra Wetlands	NA-2	Town of Trenton	- -	69	69	Washington County
36	Downer Woods	NA-3	City of Milwaukee	13	- -	13	University of Wisconsin-Milwaukee
37	Spring Lake Beech Forest	NA-3	Town of Fredonia	- -	65	65	Private conservancy organization
38	County Line Low Woods	NA-3	Sheboygan County	- -[c]	- -	- -	- -
38	Brown Deer Park Woods	NA-3	Village of Brown Deer	40	- -	40	Milwaukee County
39	Beekeeper Bog	NA-3	Town of Fredonia	9	6	15	Ozaukee County
40	Department of Natural Resources Lowlands	NA-3	Town of Fredonia	45	141	186	Wisconsin Department of Natural Resources
41	Pioneer Road Lowlands	NA-3	Town of Fredonia	- -	94	94	Private conservancy organization
42	Cedar Valley Swamp	NA-3	Town of Fredonia	- -	141	141	Private conservancy organization
43	Kletzsch Park Woods	NA-3	City of Glendale	13	- -	13	Milwaukee County
43	Evergreen Road Bog	NA-3	Town of Fredonia	5	39	44	Private conservancy organization
44	Kohler Road Woods	NA-3	Town of Fredonia	- -	124	124	Private conservancy organization
45	Waubeka Low Woods	NA-3	Town of Fredonia	21	140	161	Ozaukee County
59	Mueller Woods	NA-3, CSH	Town of Polk	4	93	97	Private conservancy organization
60	Slinger Upland Woods	NA-3	Town of Polk	- -	196	196	Wisconsin Department of Natural Resources
62	Kowalske Swamp	NA-3	Town of Jackson	- -[e]	- -	83	- -
63	Sherman Road Swamp	NA-3	Town of Jackson	- -[e]	- -	96	- -
65	Newark Road Wetland	NA-3	Town of Barton	- -[e]	- -	9	- -
66	Sunset Park Wetlands	NA-3	City of West Bend	- -	85	85	City of West Bend
67	Albecker Park Wetlands	NA-3	City of West Bend	31	60	91	City of West Bend
68	Silver Creek Marsh	NA-3	City of West Bend	10	17	27	Washington County
69	University Fen	NA-3	City of West Bend	1	- -	1	City of West Bend
70	CTH Z Upland Woods and Wetlands	NA-3	Town of West Bend	41	240	281	Cedar Lakes Conservation Foundation
71	Ziegler Woods	NA-3	Town of West Bend	- -	170	170	Wisconsin Department of Natural Resources
72	Sandy Knoll Swamp	NA-3	Town of Trenton, Town of Farmington	70	269	339	Washington County

Table 110 (continued)

Number on Map 65	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas (continued)						
73	Sandy Knoll Wetlands	NA-3	Town of Trenton	17	30	47	Washington County
74	Poplar Road Lacustrine Forest	NA-3	Town of Trenton	- -	177	177	Private conservancy organization
75	Fellenz Hardwood Swamp	NA-3	Town of Trenton	- -	58	58	Washington County
76	Paradise Drive Tamarack Swamp	NA-3	Town of Trenton	- -	81	81	Private conservancy organization
77	Camp Wowitan Wetlands	NA-3	Town of Trenton	10	99	109	Private conservancy organization
78	Schalla Tamarack Swamp	NA-3	Town of Trenton	- -	- -[e]	16	- -
81	Stockcar Swamp	NA-3, CSH	Town of Wayne	- -	240	240	Private conservancy organization
83	Kettle Moraine Driver Woods	NA-3	Fond du Lac County	- -[b]	- -	- -	- -
84	STH 28 Woods	NA-3	Town of Kewaskum	- -	145	145	Private conservancy organization
85	Smith Lake Swamp	NA-3	Town of Barton	- -	38	38	Wisconsin Department of Natural Resources
86	Lange Hardwoods	NA-3	Town of Barton	- -	53	53	Wisconsin Department of Natural Resources
87	Wildwood Hardwood Swamp	NA-3	Town of Barton	- -	98	98	Wisconsin Department of Natural Resources
88	Milwaukee River Swamp	NA-3	Town of Farmington	72	474	546	Private conservancy organization
89	Lizard Mound Woods	NA-3	Town of Farmington	22	6	28	Washington County
90	Green Lake Bog	NA-3	Town of Farmington	- -	19	19	Green Lake Association
	Critical Species Habitat						
54	Cambridge Bluff Woods	CSH	City of Milwaukee	12	- -	12	Milwaukee County
55	Brynwood Country Club Woods	CSH	City of Milwaukee	- -[e]	- -	7	- -
50	Pecard Sedge Meadow	CSH	City of Mequon	- -	13	13	City of Mequon
51	Eastbrook Road Woods	CSH	City of Mequon	- -	8	8	City of Mequon
52	Cedarburg Road West	CSH	Town of Cedarburg	- -[e]	- -	6	- -
53	Cedar-Sauk Upland Woods	CSH	Town of Saukville	- -[e]	- -	38	- -
91	Jackson Woods	CSH	Village of Jackson	3	21	24	Village of Jackson
94	Riesch Woods	CSH	Town of Barton	- -[e]	- -	34	- -
95	Silver Lake Swamp	CSH	Town of West Bend	- -	10	10	City of West Bend
96	Cameron Property	CSH	Town of Trenton	- -	12	12	City of West Bend
97	Fechters Woods	CSH	Town of Trenton	- -[e]	- -	6	- -
98	High School Woods	CSH	City of West Bend	7	- -	7	West Bend School District
101	Silver Lake	CSH	Town of West Bend	- -	7	7	City of West Bend
102	Gilbert Lake	CSH	Town of West Bend	- -[g]	10[g]	10[g]	Cedar Lake Conservation Foundation

[a]*Acquisition is recommended in SEWRPC Planning Report No. 42 (PR No. 42),* Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

[b]*Fond du Lac County.*

[c]*Sheboygan County.*

[d]*The seven acres of this Natural Area in existing protective ownership are within the right-of-way of USH 41 and owned by the Wisconsin Department of Transportation.*

[e]*Not proposed for acquisition.*

[f]*Includes 204 acres in Ozaukee County and 14 acres in Washington County. SEWRPC PR No. 42 recommends that the entire Natural Area be acquired by a private conservancy organization.*

[g]*Does not include 100 acres of this Critical Species Habitat site located within the Gilbert Lake Tamarack Swamp Natural Area.*

Source: SEWRPC.

critical species habitat identified in the regional natural areas and critical species habitat protection and management plan, about 3,640 acres at 14 sites are already in public ownership and the remaining lands are proposed to be acquired, as shown in Table 110.

In addition to these lands within the Southeastern Wisconsin Region, certain lands inside of the Milwaukee River watershed, but outside of the Region have been acquired by the State of Wisconsin and designated as State Natural Areas. Eight such areas are identified on Map 65 and tabulated in Table 110.

Endangered and threatened species and species of special concern present within the Milwaukee River drainage area include: 47 species of plants, 10 species of birds, 11 species of fish, four species of herptiles, one invertebrate, and 15 species of insect, as shown in Table 109.

Measures for Habitat Protection

Varying approaches to the protection of stream corridor have been adopted within the Milwaukee River basin. In Milwaukee County, stream corridor protection has been focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas. In Washington County, the City of West Bend has also acquired some lands adjacent to the mainstem of the Milwaukee River, at the site of the former Woolen Mills dam site, and has preserved it as a park. The Washington County comprehensive shoreland and floodland protection ordinance requires setbacks of principal structures and places limits upon removal of shoreland vegetative cover, excavation of shoreland, and encroachment into shorelands by structures based upon a lake and stream classification system designed to protect those waters most sensitive to human encroachment. While most of the Milwaukee River system within the County is classified as Class III waters, which are subject to statewide minima with respect to these parameters, the East and West Branch of the Milwaukee River, Silver Creek (West Bend), and Stony Creek within Washington County are classified as a Class I streams, and Kewaskum Creek within the County is classified as a Class II stream. These waterways are subjected to greater setbacks and other more stringent performance standards designed to protect and preserve sensitive instream habitat and water quality. Of the lakes within the Milwaukee River watershed in Washington County, most of the larger, historically developed lakes are classified as Class III waters, subject to statewide minimum standards for shoreland protection. Erler, Hasmer, Lucas, Mud (in the Village of Slinger and the Town of Polk), and Smith Lakes are classified as Class II waters and are subject to greater setbacks and other more stringent performance standards designed to protect and preserve sensitive habitat and water quality.

The provision of buffer strips around waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[56] Map 66 shows the current status of riparian buffers along the Milwaukee River and its major tributary streams. As noted above, Chapter 23 of the Washington County Code of Ordinances has established, among other provisions, buffer requirements and setback distances from both stream banks and lake shores based upon the likelihood of ecosystem disturbance from land-based human activities. These requirements provide for enhanced setbacks in excess of the statewide minima within three Classes, Class III of which is equal to the 75-foot statewide minimum standards for lakeshore setbacks. The enhanced setbacks are applicable to both lakes and streams. Buffers greater than 75 feet in width are often associated with adjacent recreational and park lands within the Milwaukee River watershed. This is especially the case in the portions of the watershed within Milwaukee County.

Enclosed conduits, which comprise less than three miles of the Milwaukee River watershed stream system, offer limited opportunity for installation of buffers. These enclosures are located largely within Beaver Creek, Brown Deer Park Creek, Southbranch Creek, an unnamed tributary to Southbranch Creek, and an unnamed tributary to Indian Creek, all in Milwaukee County.

Figure 182 shows the current status of buffer widths around streams among each of the major Milwaukee River subwatersheds, ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet. Buffers of greater than 75 feet in width were the most common category of buffer, accounting for between about 30 and 95 percent of the buffer widths observed in the subwatersheds. Buffer widths less than 25 feet were the next most common category of buffer, accounting for between about 5 and 55 percent of the buffer widths observed in the subwatersheds. Similarly, around the lakes within the Milwaukee River watershed, buffers of greater than 75 feet in width were observed on a majority of lakes studied, with the smaller waterbodies having a somewhat

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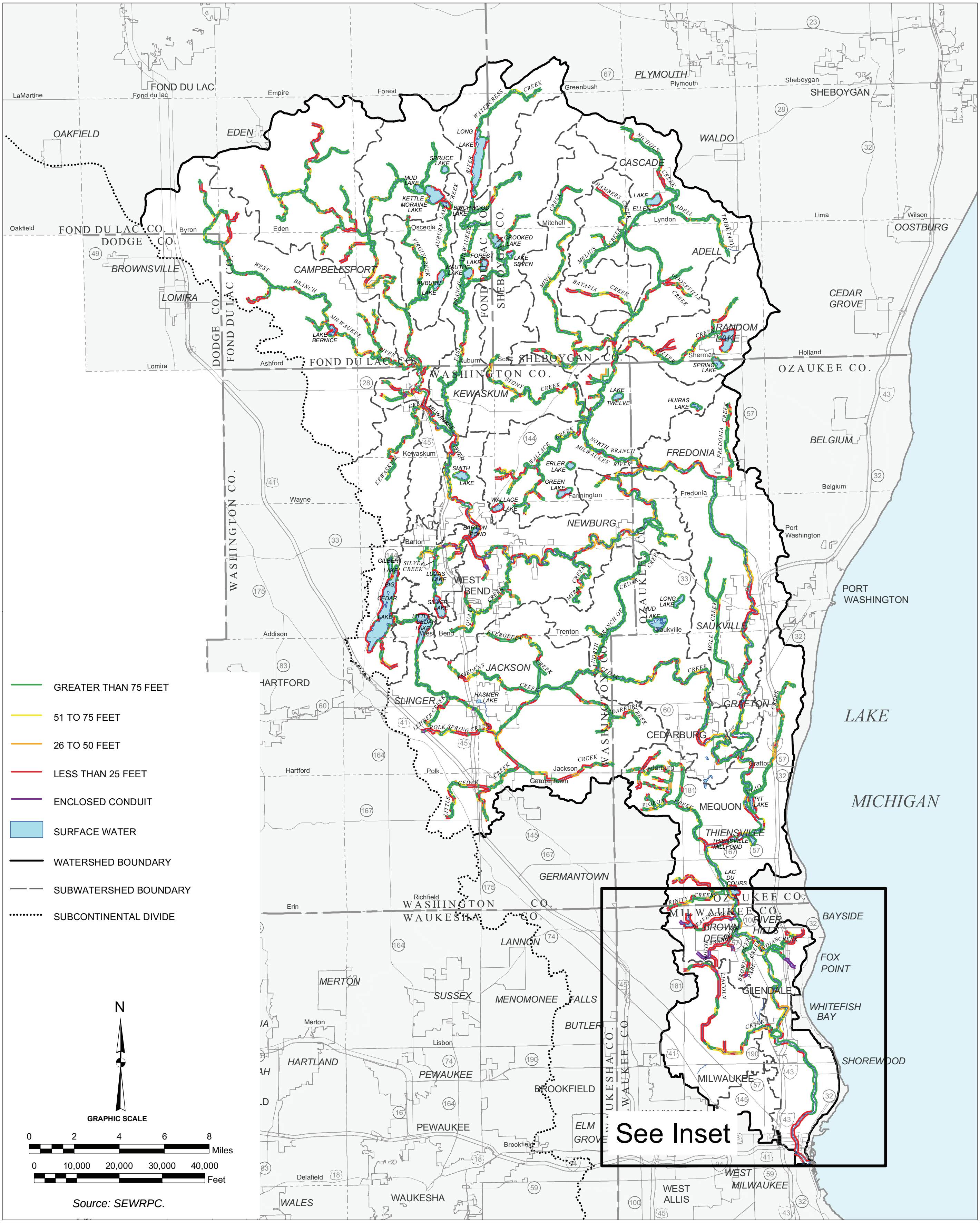
[56]*A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone – a Summary Review and Bibliography,"* CRC Technical Report No. 2064. *Coastal Resources Center, University of Rhode Island, 1994.*

Map 66

RIPARIAN CORRIDOR WIDTHS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



INSET to Map 66

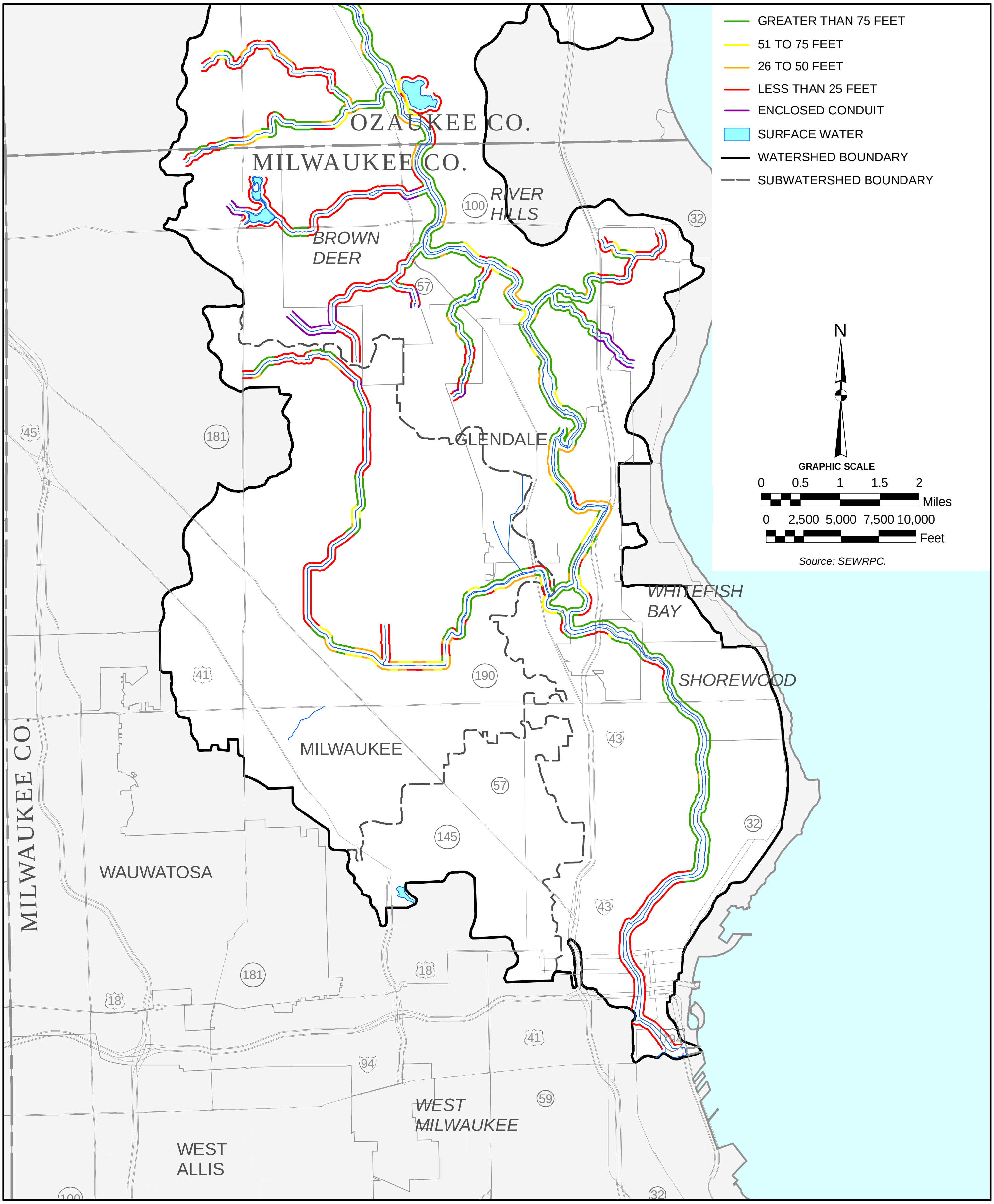


Figure 182

RIPARIAN CORRIDOR BUFFER WIDTHS IN STREAMS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

PERCENT OF BUFFER WIDTH CATEGORIES WITHIN EACH SUBWATERSHED

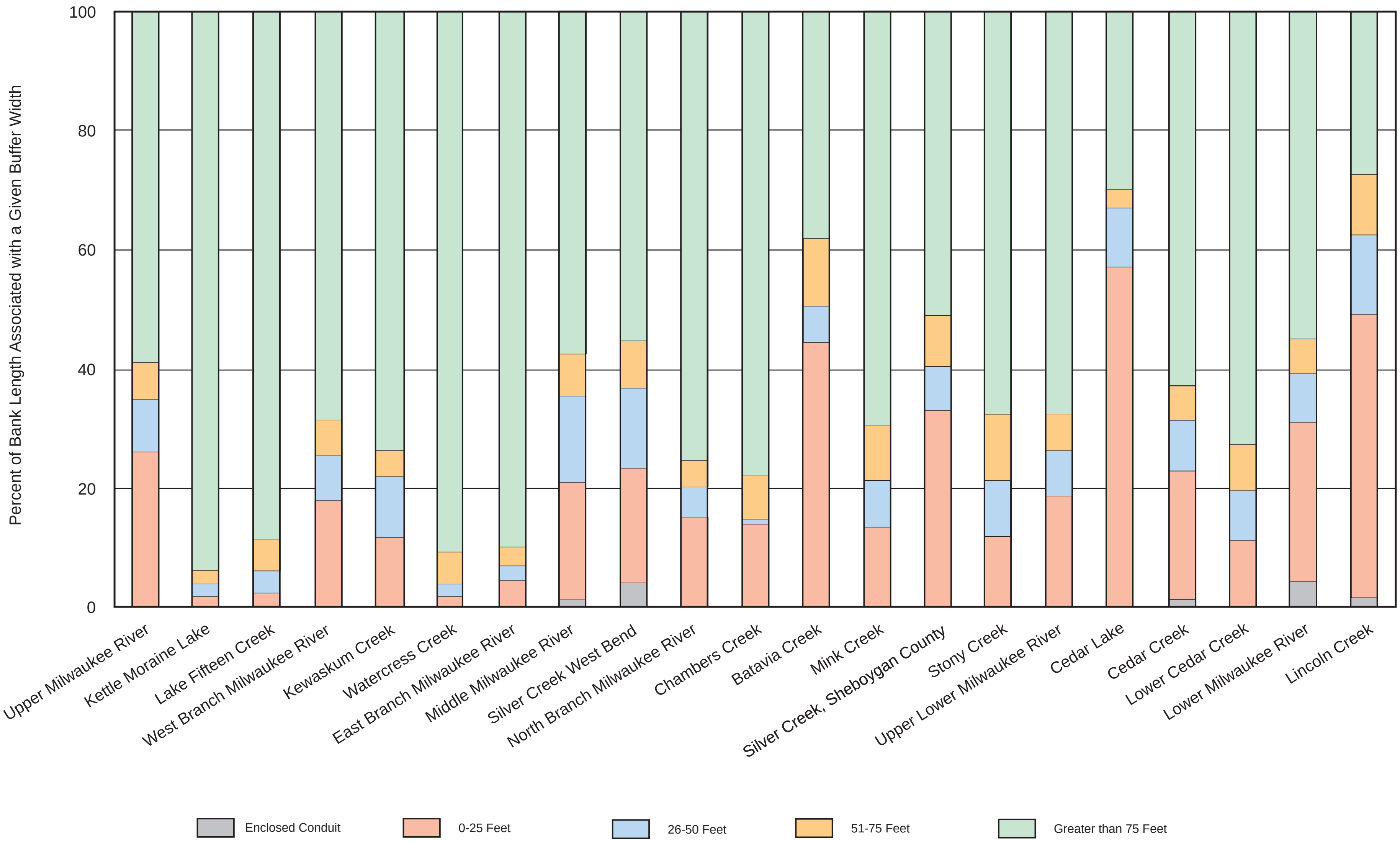
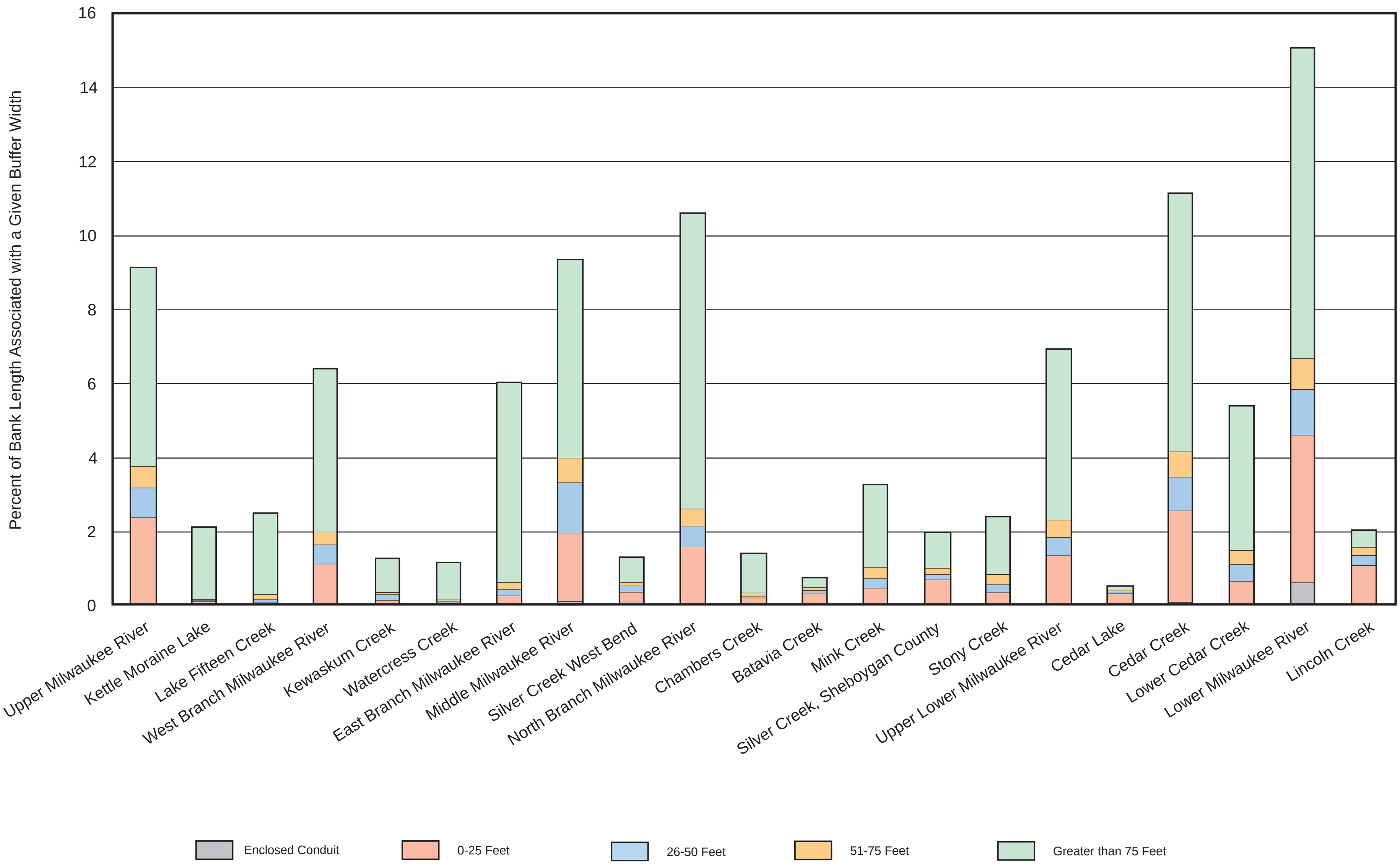


Figure 182 (continued)

PERCENT OF BUFFER WIDTH CATEGORIES WITHIN THE ENTIRE MILWAUKEE RIVER WATERSHED

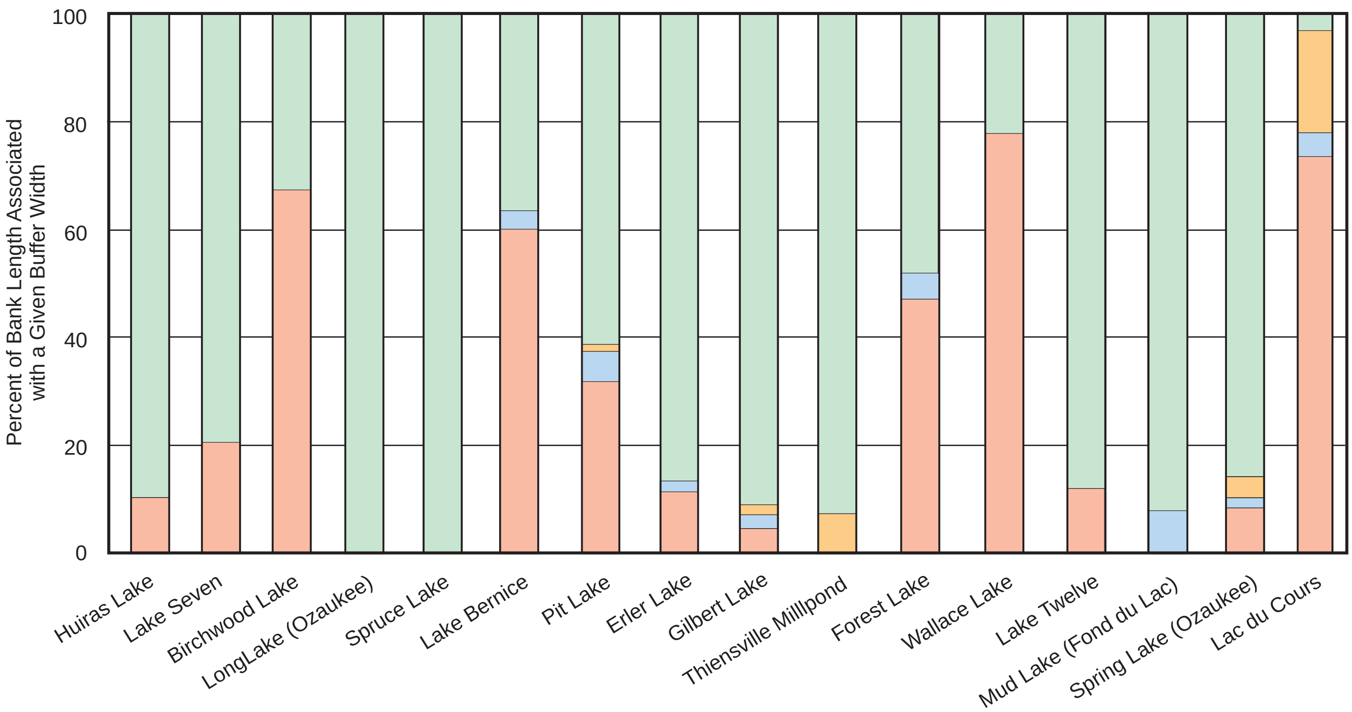


Source: SEWRPC.

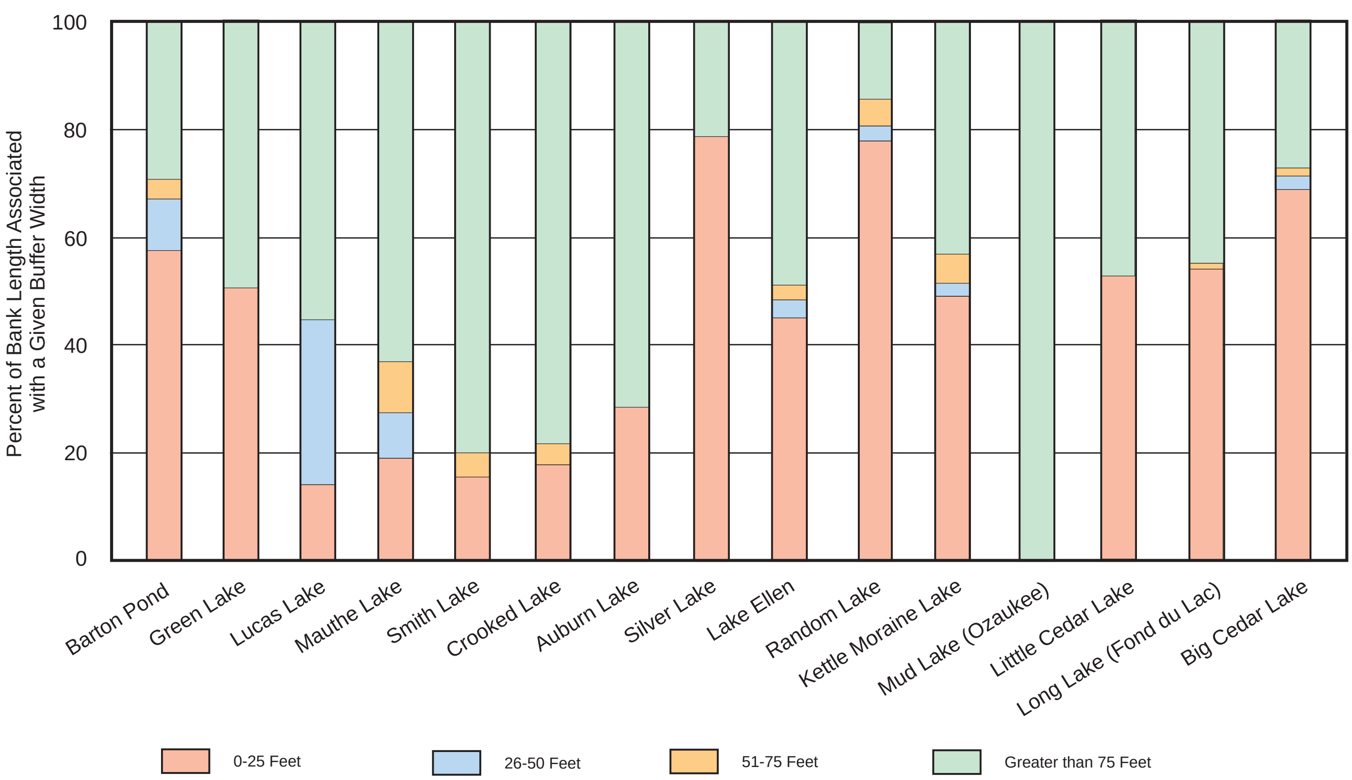
Figure 183

RIPARIAN CORRIDOR BUFFER WIDTH AROUND LAKES WITHIN THE MILWAUKEE RIVER WATERSHED: 2004

PERCENT OF BUFFER WIDTH CATEGORIES WITHIN LAKES UNDER 60 ACRES



PERCENT OF BUFFER WIDTH CATEGORIES WITHIN LAKES OVER 60 ACRES



Source: SEWRPC.

greater percentage of wider buffers than the larger lakes, as shown in Figure 183. This is consistent with the findings reported from Washington County, where the adoption of Ordinance provisions setting forth a 75 feet minimum shoreland buffer width for both lakes and streams was determined to create few additional nonconforming lots.[57]

SUMMARY AND STATUS OF IMPLEMENTATION OF ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE MILWAUKEE RIVER WATERSHED

The initial water quality management plan for the Southeastern Wisconsin Region, which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[58] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes actions taken to implement that plan. Those two specific elements of the plan as they relate to the Milwaukee River watershed and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element

The point source pollution abatement element of the initial plan made several recommendations regarding sewerage service in the Milwaukee River watershed. The plan recommended the abandonment of one public sewage treatment plant, located in the Village of Thiensville that was operating in the watershed in 1975. By 1987, this plant had been abandoned. The plan recommended that the attendant service area for this plant be connected to the Milwaukee Metropolitan Sewerage District's sewerage system for treatment purposes. The plan also recommended construction of a new sewage treatment plant for the Village of Jackson. The construction of that plant was complete by 1987. The initial plan also recommended upgrading or upgrading and expanding each of the remaining plants. These upgrades were subsequently completed. To facilitate connection of the Village of Thiensville sewer service area to MMSD's system, the plan recommended the construction of an intercommunity trunk sewer to connect the City of Mequon and the Village of Thiensville to MMSD's system. Construction of this trunk sewer was completed in 1987. In addition, the construction of four additional intercommunity trunk sewers within the MMSD service area was recommended to provide additional capacity to convey wastewater to MMSD's system. Three of these trunk sewers were completed over the period 1981-1994. The Northridge trunk sewer was not constructed. Outside of the area served by MMSD, the initial plan recommended the construction of two intercommunity trunk sewers. One of these was to facilitate the relocation of the Village of Jackson sewage treatment plant. This trunk sewer was completed in 1981. Another was to convey wastewater from the Waubeka sewer service area to the Village of Fredonia sewage treatment plant. This trunk sewer was not constructed. A recommendation for the construction of an additional intercommunity trunk sewer to convey sewage from the Silver Lake Sanitary District to the City of West Bend sewage treatment plant was added to the regional water quality management plan in a March 1992 plan amendment. Construction of this trunk sewer was completed in 1993.

A preliminary recommendation to abate separate sanitary sewer overflows and combined sewer overflows through the provision of large conveyance and storage facilities to contain separate and combined sewer peak flows in excess of sewerage system capacity was originally made in the comprehensive plan for the Milwaukee

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[57]*See SEWRPC Memorandum Report No. 139,* Surface Water Resources of Washington County, Wisconsin: Lake and Stream Classification Project: 2000*, September 2001.*

[58]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plan, *February 1979; Volume Three,* Recommended Plan, *June 1979.*

River watershed.[59] The initial regional water quality management plan deferred recommendation on adoption of this alternative pending completion of the facility planning related to MMSD's Water Pollution Abatement Program. This planning effort, documented in a series of reports by MMSD,[60] recommended construction of a deep tunnel inline storage system in conjunction with construction of a shallow relief sewer system. These recommendations were adopted as an amendment to the regional water quality management plan as part of the water resources management plan for the Milwaukee Harbor estuary.[61] This system was subsequently constructed and began operation in 1994.

The initial regional water quality management plan recommended that one private sewage treatment plant, the Cedar Lake Home Campus in the Town of West Bend, be maintained. A 1988 amendment to the plan recommended that this plant be abandoned. The plant was abandoned in 1988. Finally the initial plan recommended the refinement of sanitary sewer service areas for all sewer service areas in the watershed. As of 2005, the refinement of all service areas in the watershed had been completed, except for the MMSD area, which, in the Milwaukee River watershed, is almost entirely served by sewers.

In 1975, there were 61 combined sewer outfalls and 127 known sanitary sewer overflow relief devices located in the portion of the Milwaukee River watershed within the Southeastern Wisconsin Region. Overflows typically occurred over 50 times per year. Currently combined sewer overflows have been reduced to less than three per year. Likewise, the number of sanitary sewer overflows has been markedly reduced from the 1975 conditions.

In 1975, there were 68 point sources of wastewater other than public and private sewage treatment plants. These sources discharged industrial cooling, process, rinse, and wash waters through 118 outfalls directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of waste water be monitored, and discharges limited to levels determined on a case-by-case basis under the Wisconsin Pollutant Discharge Elimination System (WPDES) permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the watershed, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems. Many of the historical discharges are now connected to the public sanitary sewer system.

Nonpoint Source Pollution Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. It identified biochemical oxygen demand as a pollutant requiring nonpoint source control in the Milwaukee River watershed. For urban areas, it recommended septic system management, construction site erosion control, and implementation of urban land

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[59]*SEWRPC Planning Report No. 13,* A Comprehensive Plan for the Milwaukee River Watershed, *Volume One,* Inventory Findings and Forecasts, *December 1970; Volume Two,* Alternative Plans and Recommended Plan, *October 1971.*

[60]*Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows, *June 1980; Milwaukee Metropolitan Sewerage District,* Inline Storage Facilities Plan, *February 1982; Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflow Advanced Facilities Plan, *December 1983.*

[61]*SEWRPC Planning Report No. 37,* A Water Resources Management Plan for the Milwaukee Harbor Estuary, *Volume One,* Inventory Findings, *March 1987; Volume Two,* Alternative and Recommended Plans, *December 1987.*

practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. For rural areas in the watershed, it recommended livestock waste control and conservation practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. The plan also recommended that additional nonpoint source controls sufficient to produce a 75 percent reduction in pollutants be provided in the area tributary to Lake Twelve. No nonpoint source controls were recommended in the portions of the watershed served by combined sewers in the City of Milwaukee and the Village of Shorewood, since the plan assumed the provision of a deep tunnel conveyance, storage, and treatment system through which stormwater runoff would be treated.

In 1984, four portions of the Milwaukee River watershed comprising the entire watershed were designated priority watersheds under the Wisconsin Nonpoint Source Priority Watershed Pollution Abatement Program.[62] The priority watershed plans for these watersheds identified the need for reductions in total pollutant loadings, phosphorus loadings, and sediment loadings to the streams of the watersheds in order to meet water quality objectives. In addition, they recommended a number of management actions and practices to be implemented for both urban and rural lands and provided funding for a variety of activities related to abatement of nonpoint source pollution. In addition, these plans recommended that comprehensive stormwater management plans be prepared and adopted for urban areas in the priority watersheds. The implementation periods were 1989-1997 for the North Branch Milwaukee River and East and West Branch Milwaukee River Priority Watersheds, 1991-1999 for the Milwaukee River South Priority Watershed, and 1992-2000 for the Cedar Creek Priority Watershed. The plan recommendations for nonpoint source pollution control were partially implemented as of completion of the projects.[63]

During the 1980s and 1990s a stormwater management plan was developed for the City of West Bend.[64] This plan refined and detailed the recommendations of the initial regional water quality management plan. This plan recommended implementation of several measures related to water quality. The recommended measures included construction of 38 wet detentions basins, conversion of two dry detention basins to wet detention basins, maintenance of some existing basins, intensive street sweeping in selected portions of the City, catch basin cleaning, infiltration of runoff from parking lots in selected areas, leaf collection, and continued enforcement of the City’s construction site erosion control ordinances. As of 2007, the recommendations of the plan have been partially implemented. The City has constructed several of the recommended detention basins and has performed maintenance on existing basins. They have ongoing programs of street sweeping, catch basin cleaning, and leaf collection and continue to enforce their construction erosion control ordinance.

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[62]*Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the East and West Branches of the Milwaukee River Priority Watershed Project, *PUBL WR-255-90, February 1989; Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the North Branch Milwaukee River Priority Watershed Project, *PUBL WR-253-90, July 1989; Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Milwaukee River South Priority Watershed Project, *PUBL WR-246-91, December 1991; Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Cedar Creek Priority Watershed Project, *PUBL WR-336-93, August 1993.*

[63]*M. Miller, J. Ball, and R. Kroner,* An Evaluation of Water Quality in the Milwaukee River Priority Watershed, *Wisconsin Department of Natural Resources PUBL WR-298-92, 1992.*

[64]*SEWRPC Community Assistance Planning Report No. 173,* A Stormwater Management Plan for the City of West Bend, Washington County, Wisconsin, *Volume One,* Inventory Findings, Forecasts, Objectives, and Design Criteria, *October 1989; Volume Two,* Alternatives and Recommended Plan for the Silver Creek Subwatershed, *June, 1990; Volume Three,* Alternatives and Recommended Plan for the Milwaukee River Drainage Area, *June 1995; Volume Four,* Alternatives and Recommended Plan for the Quaas Creek Subwatershed, *July 1996.*

In 2001, a water quality protection plan and stormwater management plan for Big Cedar Lake was prepared.[65] This plan also refined and detailed the recommendations of the initial regional water quality management plan. As a part of this plan, the subbasin boundaries within the area tributary to Big Cedar Lake were delineated and stormwater management plans were prepared for three pilot subbasins. In addition, the plan recommended the preparation and implementation of stormwater management plans for the other 17 subbasins delineated in the tributary area. Specific recommendations in the stormwater management plans for the pilot subbasins included the construction of four wet detention basins, preservation of an existing wooded depression, installation of two culverts, raising the elevation of a road, and provision of grassed swales along road sides. With some modifications, the recommendations for the pilot subbasins have been largely implemented. As of 2007 stormwater management plans have not been prepared for any of the other subbasins.

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial regional water quality management plan. Facilities engaged in certain activities have been required to apply for and obtain stormwater discharge permits under the WPDES and to develop and follow stormwater pollution prevention plans. Many of the communities in the watershed have applied for WPDES discharge permits, and have adopted construction site erosion control ordinances. All of the communities, except the Towns of Cedarburg, Fredonia, Port Washington, and Saukville and the Villages of Adell, Campbellsport, Cascade, Eden, Lomira, Newburg, Random Lake, and Slinger, have adopted stormwater management plans or ordinances or are covered under stormwater management ordinances administered by their respective counties. The communities with permits will be required to develop new stormwater management ordinances, or update existing ordinances, to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code*. Stormwater management measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Milwaukee River watershed must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification are intended to aid in determining the probable causes of water pollution problems.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

The status of implementation in regard to the abandonment of public and private sewage treatment plants in the Milwaukee River watershed, as recommended in the initial regional water quality management plan, is summarized in Table 111. In 1975, there were nine public sewage treatment facilities located in or discharging to the portion of the Milwaukee River watershed within the Southeastern Wisconsin Region. The plants for the City of Cedarburg and the Village Jackson discharged effluent to Cedar Creek; the plants for the City of West Bend, the Village of Fredonia, the Village of Grafton, the Village of Kewaskum, the Village of Newburg, and the Village of Saukville discharged effluent to the mainstem of the Milwaukee River; and the Village of Thiensville plant discharged effluent to Pigeon Creek. One of these plants, the Village of Thiensville plant, was abandoned in 1987 and the attendant service area was connected to the MMSD system for treatment purposes, as recommended in the initial regional water quality management plan. As also recommended in the initial regional water quality

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[65] *SEWRPC Memorandum Report No. 137,* A Water Quality Protection and Stormwater Management Plan for Big Cedar Lake Washington County, Wisconsin, *Volume One,* Inventory Findings, Water Quality Analyses, and Recommended Management Measures, *August 2001; Volume 2,* Stormwater Management Plans for Three Pilot Subbasins, *August 2001.*

Table 111

IMPLEMENTATION STATUS OF THE INITIAL REGIONAL WATER QUALITY MANAGEMENT PLAN RECOMMENDATIONS FOR PUBLIC SEWAGE TREATMENT PLANTS IN THE MILWAUKEE RIVER WATERSHED: 2004

Plant	Receiving Water	Plan Recommendation	Implementation Status	Year of Implementation
Public				
Cedarburg	Cedar Creek	Upgrade and expand plant	Completed	1990
Fredonia	Milwaukee River	Upgrade and expand plant	Completed	1982
Grafton	Milwaukee River	Upgrade and expand plant	Completed	1984
Jackson	Cedar Creek	Construct new plant	Completed	1981
Kewaskum	Milwaukee River	Upgrade plant	Completed	After 1995
Newburg	Milwaukee River	Upgrade and expand plant	Completed	1997
Saukville	Milwaukee River	Upgrade and expand plant	Completed	1981
Thiensville	Pigeon Creek	Abandon plant	Plant abandoned	1987
West Bend	Milwaukee River	Upgrade and expand plant	Completed	1980
Private				
Cedar Lake Home Campus	Soil absorption	Maintain plant[a]	Plant abandoned	1988

[a]*The initial regional water quality management plan recommended maintaining the Cedar Lake Home Campus sewage treatment plant. A 1988 amendment to the plan recommended that this plant be abandoned and the area served be connected to the City of West Bend sewage treatment plant.*

Source: SEWRPC.

Table 112

WASTEWATER TREATMENT FACILITIES IN THE MILWAUKEE RIVER WATERSHED: 2004

Number on Map 68	Facility Name	Address	Municipality	Ownership
1	Campbellsport Wastewater Treatment Facility	110 Columbus Park Court	Campbellsport	Public
2	Cascade Wastewater Treatment Facility	N3191 Bates Road	Cascade	Public
3	Cedarburg Wastewater Treatment Facility	W54 N370 Park Lane	Cedarburg	Public
4	Fredonia Municipal Sewer and Water Utility	210 Park Avenue	Fredonia	Public
5	Grafton Water and Wastewater Utility	1900 9th Avenue	Grafton	Public
6	Jackson Wastewater Treatment Plant	W194 N16658 Eagle Drive	Jackson	Public
7	Kettle Moraine Correctional Institution	W9071 Forest Road	Mitchell	Private
8	Kewaskum	204 First Street	Kewaskum	Public
10	Long Lake Recreational Area	N1765 Highway G	Campbellsport	Private
11	Newburg	P.O. Box 50	Newburg	Public
12	Random Lake Sewage Treatment Plant	96 Russell Drive	Random Lake	Public
13	Saukville Village Sewer Utility	1600 Cottontail Lane	Saukville	Public
14	West Bend	512 Municipal Drive	West Bend	Public
15	Town of Scott Sanitary District No. 1	N1614 Highway 28	Adell	Public

Source: SEWRPC.

management plan, a new plant was constructed to serve the Village of Jackson. The initial plan recommended upgrading or upgrading and expanding each of the remaining plants. Dates of implementation of these recommendations are given in Table 111. In addition, two plants have received additional upgrades since the implementation of the initial plan. The Village of Jackson plant was subsequently expanded and upgraded, with modifications being completed around 1997. The Village of Saukville plant was subsequently expanded and upgraded, with modifications being completed in 2002 (see Table 112).

In 1975, there were four publicly owned sewage treatment plants located in or discharging to the portion of the Milwaukee River watershed outside of the Southeastern Wisconsin Region. The Village of Adell plant discharged to a soil absorption system, the Village of Campbellsport plant discharged to the mainstem of the Milwaukee

River, the Village of Cascade plant discharged to a tributary of the North Branch of the Milwaukee River, and the Village of Random Lake plant discharged to Silver Creek (Sheboygan County). One of these plants, the Village of Adell plant, was abandoned in 1992 and the attendant service area was connected to the Onion River Wastewater Commission sewage treatment plant. This plant discharges into the Onion River, outside of the Milwaukee River watershed. One additional public sewage treatment plant in the Milwaukee River watershed, serving the Town of Scott Sanitary District, was completed in 1985.

In 1975, there were two private sewage treatment facilities located in, or discharging to, the Milwaukee River watershed, the Cedar Lake Home Campus in the Town of West Bend and the Kettle Moraine Correctional Institution in the Town of Mitchell. Both of these plants discharged effluent to soil for absorption. The initial regional water quality management plan recommended that the Cedar Lake Home Campus plant be maintained. In 1988, an amendment to the plan recommended that this plant be abandoned. This plant was abandoned in 1988 and its service area connected to the City West Bend sewage treatment plant. One additional private plant, serving the Long Lake Recreational Area in the Town of Osceola was completed and began operation in 1998. Several other private wastewater treatment plants listed in the initial plan are either currently permitted and regulated as industrial dischargers and not as sewage treatment plants or are not in operation. These include plants belonging to the Federal Food Company, the Justo Feed Company, the Level Valley Dairy, the S & R Cheese Corporation, and the Seneca Food Company.

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. There were 12 sewer service areas identified within, or partially within, the Milwaukee River watershed: Cedarburg, Fredonia, Grafton, Jackson, Kewaskum, Mequon, the Milwaukee Metropolitan Sewerage District, Newburg, Saukville, Thiensville, Waubeka, and West Bend. As of 2005, all of these areas with the exception of the Milwaukee Metropolitan Sewerage District service area had undergone refinements as recommended. In addition, the Port Washington and Slinger sewer service areas, which initially did not extend into the Milwaukee River watershed, were subsequently refined to incorporate portions of the watershed. Also, six sanitary sewer service areas in portions of the Milwaukee River watershed outside of the Southeastern Wisconsin Region were refined by the relevant State and local authorities. Table 113 lists the plan amendment prepared for each initial refinement, the date the Commission adopted the document as an amendment to the regional water quality management plan, and the date the Commission adopted the most recent refinement to the sewer service area. Table 113 also identifies the original service area names and the relationship of these service areas to the service area names following the refinement process. The planned sewer service areas in the Milwaukee River watershed, as refined through June 2005, total about 86.7 square miles, or about 12 percent of the total watershed area. Planned sewer service areas in the Milwaukee River watershed are shown on Map 67.

Sanitary Sewer Overflow (SSO) Sites in the Watershed

By 1993, work was completed by MMSD on its Water Pollution Abatement Program, including construction of the Inline Storage System and major relief sewers. As a result of this project, many flow relief devices within the watershed were eliminated. Those which remain include combined sewer overflows and sanitary sewer overflows. During the period from August 1995 to August 2002, separate sanitary sewer overflows were reported at 54 locations in the Milwaukee River watershed. Table 114 gives the locations of sanitary sewer overflow locations in the Milwaukee River watershed for MMSD and 14 communities. Table 114 indicates the number of days during which overflows were reported as occurring at each location during the period from August 1995 to August 2002. The SSO sites which are being incorporated into the water quality model are indicated on Map 68.

Combined Sewer Overflows (CSOs)

Combined sewer overflows are potential sources of pollution within the watershed. MMSD has 65 combined sewer overflow outfalls that discharge to streams in the Milwaukee River watershed. These outfalls can convey diluted sewage from the combined sewer system to the surface water system of the watershed as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. This conveyance to surface waters occurs to prevent damage to buildings or the mechanical elements

Table 113

PLANNED SANITARY SEWER SERVICE AREAS IN THE MILWAUKEE RIVER WATERSHED: 2004

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area					
Adell	0.6	Adell	- -[a]	- -[a]	- -[a]
Batavia	0.5	Batavia	- -[a]	- -[a]	- -[a]
Campbellsport	1.1	Campbellsport	- -[a]	- -[a]	- -[a]
Cascade	0.8	Cascade	- -[a]	- -[a]	- -[a]
Cedarburg	8.3	Cedarburg	SEWRPC CAPR No. 91, *Sanitary Sewer Service Areas for the City of Cedarburg and the Village of Grafton, Ozaukee County Wisconsin*	June 15, 1987	June 19, 1996
Fredonia	1.9	Fredonia	SEWRPC CAPR No. 96, *Sanitary Sewer Service Area for the Village of Fredonia, Ozaukee County, Wisconsin*	September, 13, 1984	March 3, 2004
Grafton	8.6	Grafton	SEWRPC CAPR No. 91, *Sanitary Sewer Service Areas for the City of Cedarburg and the Village of Grafton, Ozaukee County Wisconsin*	June 15, 1987	June 19, 1996
Jackson	6.9	Jackson	SEWRPC CAPR No. 124, *Sanitary Sewer Service Area for the Village of Jackson and Environs, Washington County, Wisconsin*	June 17, 1984	June 16, 2004
Kewaskum	4.3	Kewaskum	SEWRPC CAPR No. 161, *Sanitary Sewer Service Area for the Village of Kewaskum, Washington County, Wisconsin*	March 7, 1988	December 7, 2005
Lomira	0.2	Lomira	- -[a]	- -[a]	- -[a]
Mequon	16.4	Mequon	SEWRPC CAPR No. 188, *Sanitary Sewer Service Area for the City of Mequon and the Village of Thiensville, Ozaukee County, Wisconsin*	January 15, 1992	June 21, 1995
Newburg	2.2	Newburg	SEWRPC CAPR No. 205, *Sanitary Sewer Service Area for the Village of Newburg, Ozaukee and Washington Counties, Wisconsin*	March 3, 1993	- -
Port Washington	0.3	Port Washington	SEWRPC CAPR No. 95, *Sanitary Sewer Service Area for the City of Port Washington, Ozaukee County, Wisconsin*	December 1, 1983	December 3, 2003
Random Lake	1.7	Random Lake	- -[a]	- -[a]	- -[a]
Saukville	4.7	Saukville	SEWRPC CAPR No. 90, *Sanitary Sewer Service Area for the Village of Saukville, Washington County, Wisconsin*	December 1, 1993	March 6, 2002
Slinger	1.0	Slinger	SEWRPC CAPR No. 128, *Sanitary Sewer Service Area for the Village of Slinger and Environs, Washington County, Wisconsin*	December 2, 1985	September 10, 2003
Thiensville	1.1	Thiensville	SEWRPC CAPR No. 188, *Sanitary Sewer Area for the City of Mequon and the Village of Thiensville, Ozaukee County, Wisconsin*	January 15, 1992	June 21, 1995

Table 113 (continued)

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area (continued)					
Waubeka	0.7	Waubeka	SEWRPC CAPR No. 96, *Sanitary Sewer Service Area for the Village of Fredonia, Ozaukee County, Wisconsin*	September, 13, 1984	- -
West Bend	25.5	West Bend	SEWRPC CAPR No. 35, *Sanitary Sewer Service Area for the City of West Bend and Environs, Washington County, Wisconsin*	December 2, 1982	June 17, 1998
Subtotal	86.7	- -	- -	- -	- -
Unrefined Sanitary Sewer Service Areas					
Milwaukee Metropolitan Sewerage District	57.7	- -	- -	- -	- -
Subtotal	57.7	- -	- -	- -	- -
Total	144.4	- -	- -	- -	- -

[a] *Adell, Batavia, Campbellsport, Cascade, Lomira, and Random Lake are outside of the Southeastern Wisconsin Region.*

Source: SEWRPC.

Map 67

PLANNED SANITARY SEWER SERVICE AREAS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

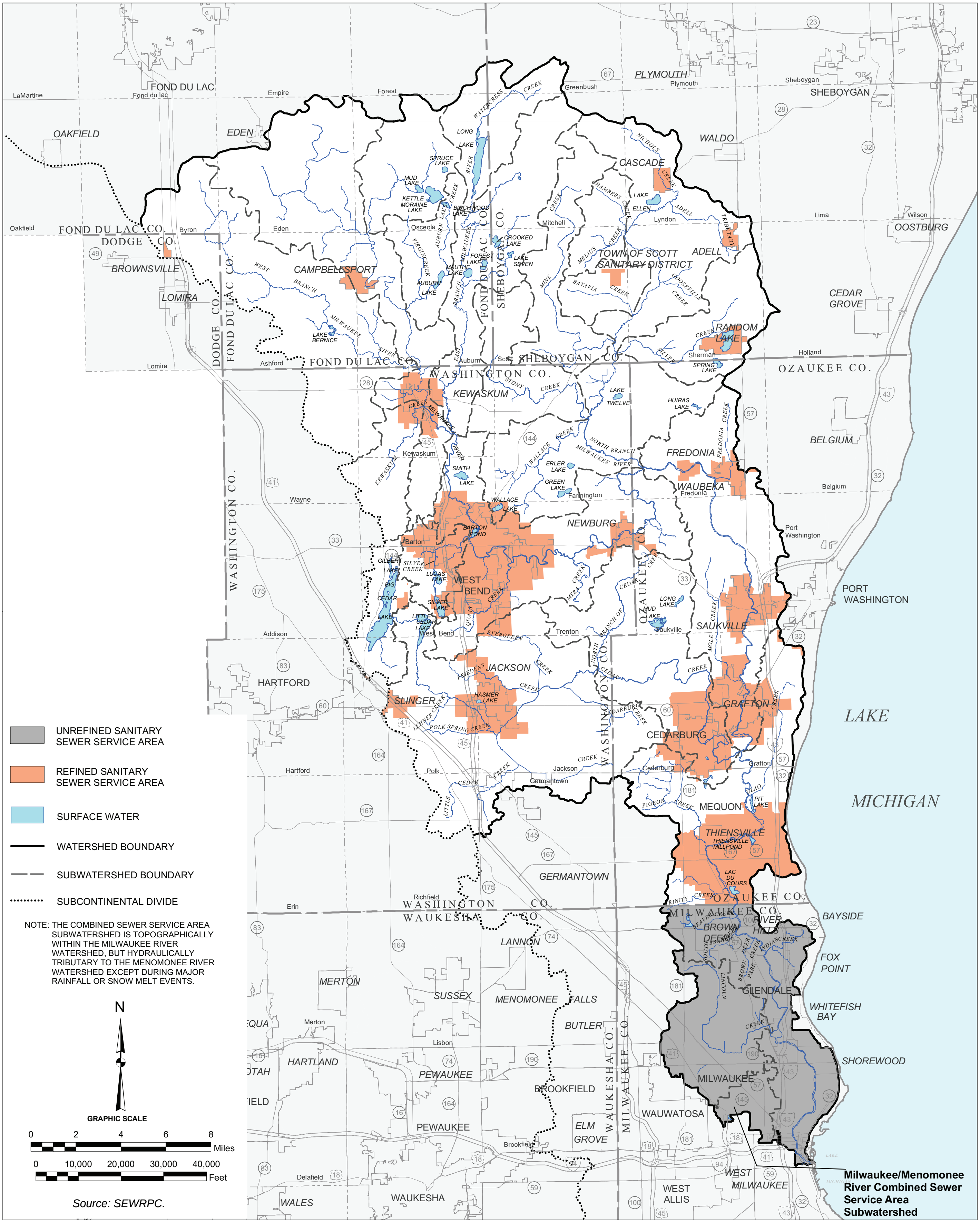


Table 114

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE MILWAUKEE RIVER WATERSHED

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
205	W. Roosevelt Drive and W. Scranton Place	MMSD	2
207	N. 31st Street and W. Fairmount Avenue	MMSD	18
208	N. 31st Street on north side of Lincoln Creek	MMSD	5
209	N. 27th Street and W. Silver Spring Drive	MMSD	8
212	W. Hampton Avenue and N. Green Bay Road, West	MMSD	6
213	W. Hampton Avenue and N. Green Bay Road, East	MMSD	6
214	N. Lydell Avenue and W. Hampton Avenue	MMSD	16
223	N. 27th Street and W. Villard Avenue	MMSD	6
224	W. Hampton Avenue and N. 32nd Street	MMSD	10
226	N. 35th Street and W. Marion Street	MMSD	17
230	N. Richards Street	MMSD	21
231	N. Range Line Road	MMSD	18
244	N. Lydell Avenue and W. Lancaster Avenue	MMSD	14
245	N. Lydell Avenue and W. Montclair Avenue	MMSD	4
250	S. Water Street and E. Bruce Street	MMSD	1
BD02	N. 61st Street and W. Darnel Avenue	Brown Deer	1
BD03	N. 61st Street and Arch Avenue	Brown Deer	2
BD04	N. 61st Street	Brown Deer	2
BD05	N. 61st Street and W. Tower Avenue	Brown Deer	2
BD06	S. 57th Street and Brown Deer Road	Brown Deer	1
FP01	N. Seneca Road and Indian Creek Parkway	Fox Point	2
FP02	E. Indian Court and Indian Creek Parkway	Fox Point	2
FP03	N. Mohawk Avenue and Indian Creek Parkway	Fox Point	1
FP04	N. Navajo Road and Cherokee Circle	Fox Point	1
MQ02	Center Drive at Island Drive Lift Station	Mequon	3
MQ03	11330 N. Oriole Lane	Mequon	1
MI01	N. 31st Street and W. Capitol Drive	Milwaukee	5
MI02	N. 31st Street and W. Capitol Drive	Milwaukee	1
MI04	5384 N. 60th Street	Milwaukee	2
MI08a	N. 20th Street and W. Hampton Avenue	Milwaukee	4
MI08b	N. 20th Street and W. Hampton Avenue	Milwaukee	9
MI09	N. 20th Street (680 feet South of W. Hampton Avenue)	Milwaukee	1
MI10	N. 21st Street and W. Hampton Avenue	Milwaukee	4
MI11	N. 24th Street and W. Villard Avenue	Milwaukee	2
MI12	N. 24th Place and W. Villard Avenue	Milwaukee	2
MI13	N. 27th Street and W. Villard Avenue	Milwaukee	2
MI14	N. 27th Street (300 feet North of Villard Avenue)	Milwaukee	2
MI15	N. 27th Street (South of Hope Avenue)	Milwaukee	1
MI16	N. 28th Street and W. Villard Avenue	Milwaukee	2
MI17	N. 30th Street and W. Hope Avenue	Milwaukee	6
MI18	N. 31st Street and W. Villard Avenue	Milwaukee	2
MI19	N. 35th Street and W. Oriole Drive	Milwaukee	2
MI20	N. 36th Street and W. Toronto Street	Milwaukee	6
MI21	N. 37th Street and W. Kiley Street	Milwaukee	1
MI22a	N. 41st Street and W. Congress Street	Milwaukee	2
MI22b	N. 41st Street and W. Congress Street	Milwaukee	3
MI23	N. 49th Street and W. Rohr Avenue	Milwaukee	2
MI24	N. 55th Street and W. Custer Avenue	Milwaukee	3
MI25	N. 56th Street and W. Villard Avenue	Milwaukee	2
MI26	N. 61st Street and W Lawn Avenue	Milwaukee	1
MI27	N. 61st Street and W. Sheridan Avenue	Milwaukee	2
MI28	N. 62nd and W. Fairmount Avenue	Milwaukee	4
MI29	N. 66th Street and W. Ruby Avenue	Milwaukee	1
MI31	N. 72nd Street and W. Capitol Drive	Milwaukee	5
MI32	N. 72nd Street and W. Hope Avenue	Milwaukee	2
MI34	N. 83rd Street and W. Hope Avenue	Milwaukee	2
MI46	N. Sherman Boulevard and W. Burleigh Street	Milwaukee	0
MI47	N. Sherman Boulevard and W. Congress Street	Milwaukee	1

Table 114 (continued)

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
MI48	W. Chapman Place and W. Potomac Avenue	Milwaukee	4
MI49	W. Fairmount Avenue and N. Green Bay Avenue	Milwaukee	2
MI51	W. Milwaukee River Parkway and W. Lawn Avenue	Milwaukee	1
MI52	W. Olive Street (South of Roosevelt Drive)	Milwaukee	2
MI53	W. Potomac Avenue (North of Glendale Avenue)	Milwaukee	2
RH04	7650 N. Pheasant Lane	River Hills	5
RH05	N. Pheasant Lane	River Hills	1
SH01	Glendale Avenue and Wildwood Avenue	Shorewood	3
TH01	Vernon Avenue and Sunny Lane	Thiensville	1
TH02	Riverview Drive and Green Bay Road	Thiensville	1
WB05	Hampton Avenue and Sheffield Avenue	Whitefish Bay	1
56	Lift Station at County Highway I and County Highway A	Adell	2
57	Lift Station at 608 Tower Avenue	Adell	3
58	State Highway 57 between CTH I and CTH W	Adell	1
34	Dorchester Lift Station	Cedarburg	1
35	Doerr Way Lift Station	Cedarburg	1
- -	Cedarburg sewage treatment plant	Cedarburg	2
50	Manhole at Park Avenue	Fredonia	1
49	Manhole at Wisconsin Street	Fredonia	3
48	Manhole at Wisconsin Street and Wenzel Avenue	Fredonia	3
42	11th Avenue lift station	Grafton	1
41	14th Avenue lift station	Grafton	1
40	Manhole at 11th Avenue and Meadowbrook Court	Grafton	2
39	17th Avenue lift station	Grafton	4
38	Bridge Street lift station	Grafton	2
43	Green Bay Road lift station	Grafton	1
44	Manhole at 10th Avenue and Power Street	Grafton	1
36	Manhole at 7th Avenue and North Street	Grafton	1
37	Manhole at 13th Avenue and Veteran's Park	Grafton	1
- -	Grafton sewage treatment plant	Grafton	1
52	Manhole at Glen Brooke Drive	Jackson	1
- -	Jackson sewage treatment plant	Jackson	2
59	Manhole at Roseland Drive	Kewaskum	1
53	Manhole preceding main lift station	Kewaskum	1
54	Lift Station No. 1, Main Street	Newburg	1
- -	Kettle Moraine Correctional Institution sewage treatment plant	Mitchell	1
45	North Mill Street lift station	Saukville	1
46	Manhole at STH 33 and N. Mill Street	Saukville	3
47	Bridge Lift Station	Saukville	0
- -	Saukville sewage treatment plant	Saukville	1
51	Manhole at Main Street	West Bend	1
55	Manhole at Gadow Lane	West Bend	1
- -	West Bend sewage treatment plant	West Bend	1

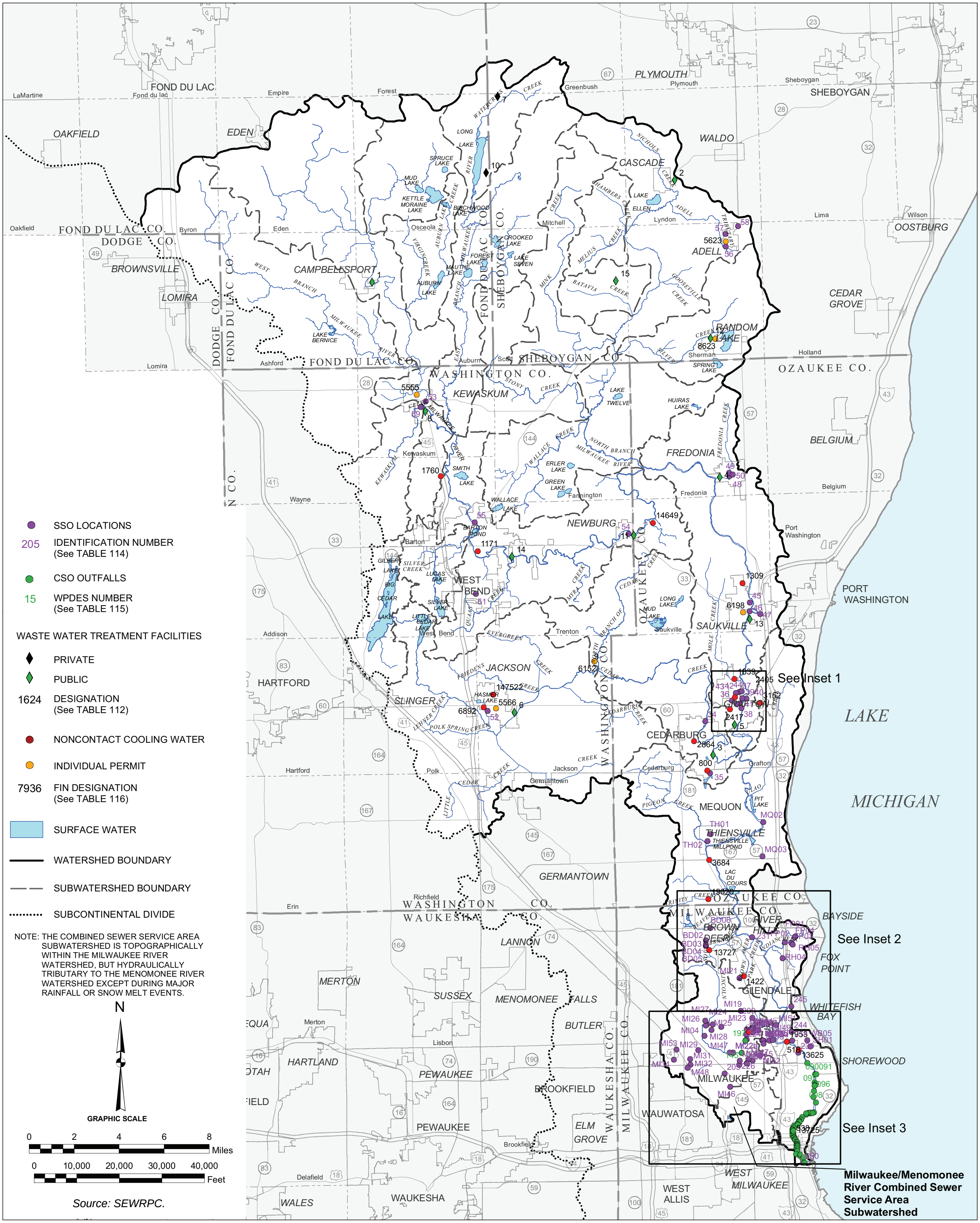
NOTE: For the MMSD Sanitary Sewer Overflow locations, the Identification Number corresponds to the WPDES permit number.

Source: Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, Triad Engineering, and SEWRPC.

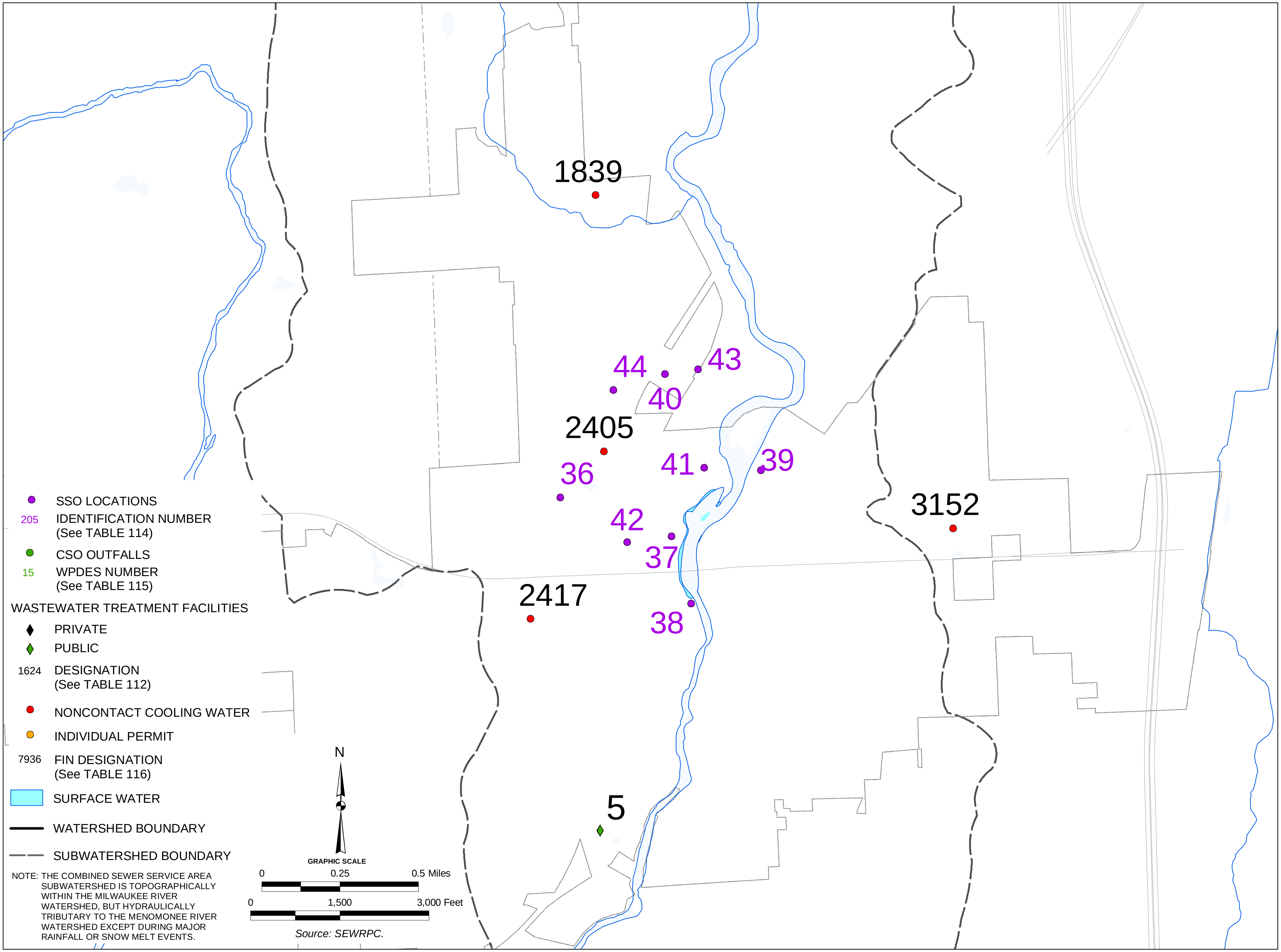
of the conveyance system during such events. The locations of these outfalls are shown on Map 68. Associated with these CSO outfalls is a set of sample collectors which obtain samples of effluent discharged during overflow events for chemical and bacteriological analysis. The assignment of collectors to outfalls is shown in Table 115. Over the period August 1995 to August 2002, the mean number of days during which individual outfalls discharged to streams in the watershed was 13.4. Associated with this mean was high variability among outfalls. There were no known discharges from several of these outfalls during this period. Other outfalls discharged over as many as 48 days. There was also variation in the number of outfalls involved in particular discharge events. Some CSO events were quite localized, consisting of discharge from only one outfall. Others occurred over a large portion of the CSO area, involving discharge from as many as 49 outfalls into the watershed. The mean number of outfalls discharging on any day that discharge occurred was 15.7.

Map 68

POINT SOURCES OF POLLUTION WITHIN THE MILWAUKEE RIVER WATERSHED: 2003

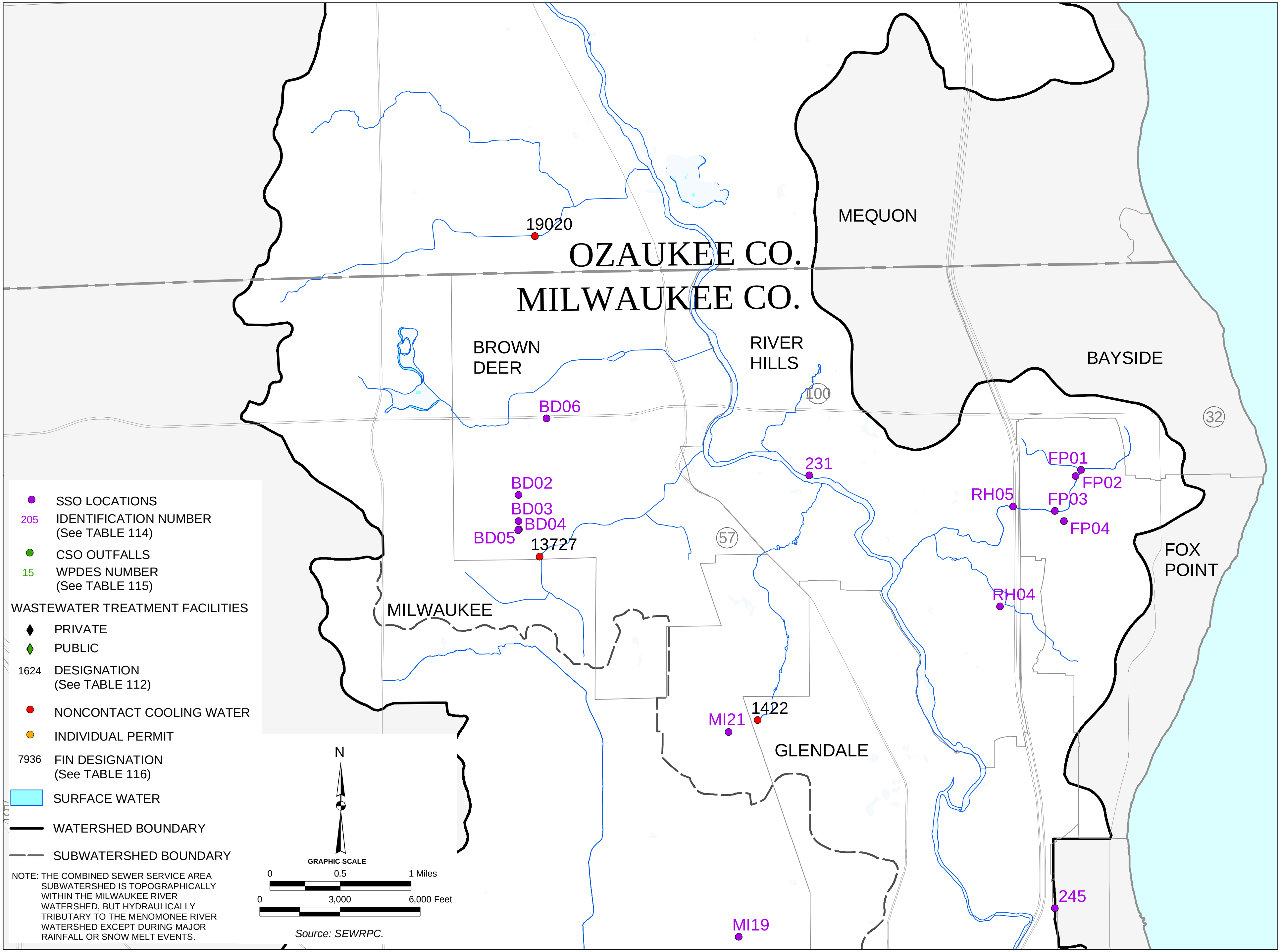


INSET 1 to Map 68



Source: SEWRPC.

INSET 2 to Map 68



Source: SEWRPC.

INSET 3 to Map 68

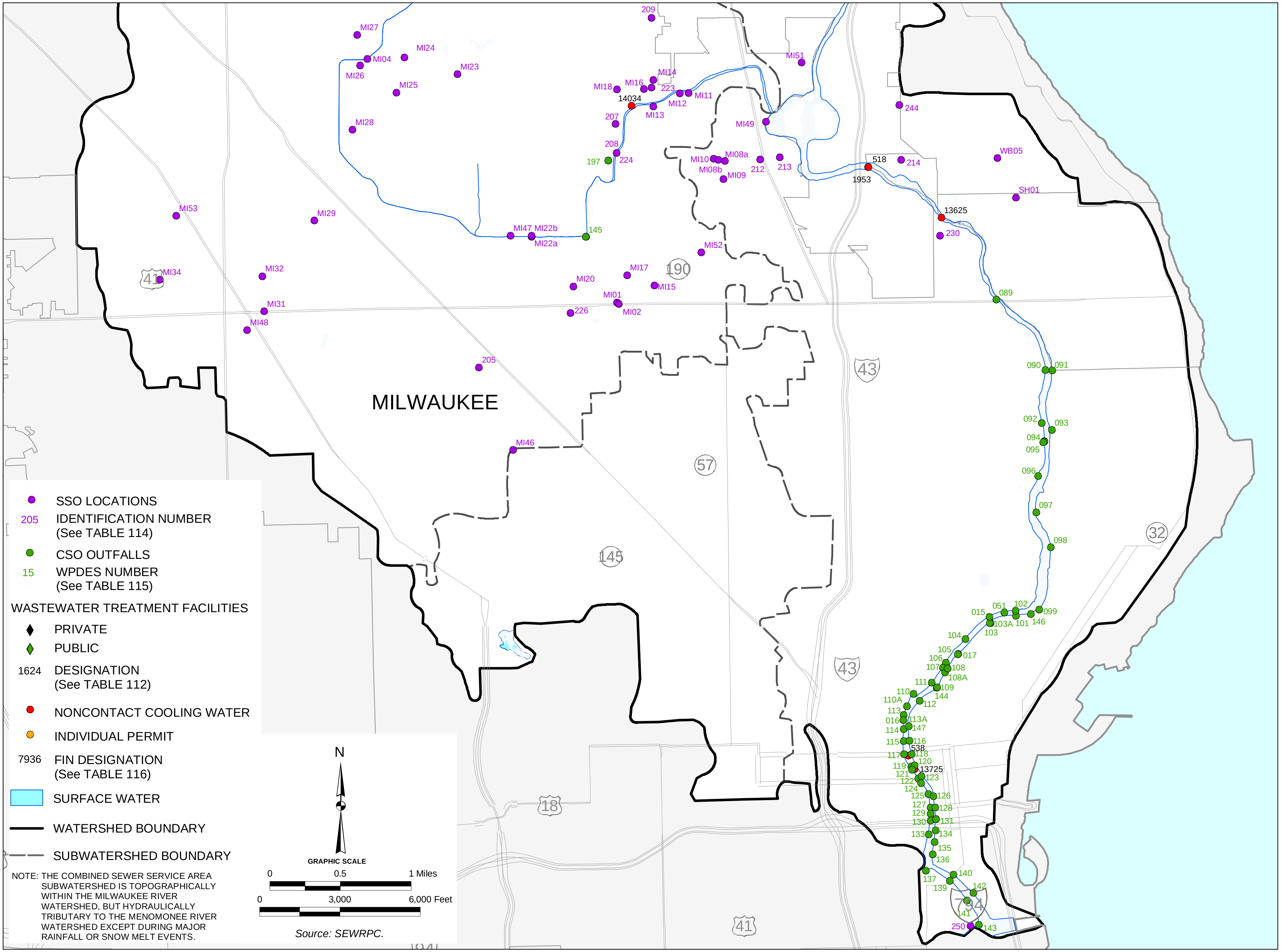


Table 115

COMBINED SEWER OVERFLOW OUTFALL LOCATIONS IN THE MILWAUKEE RIVER WATERSHED

WPDES Number	Location	Collector	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
15	N. Marshall Street	Unknown	30	1
16	W. Vliet Street east of N. 3rd Street	Unknown	36	6
17	N. Van Buren Street at E. Brady Street	NS 8	54	0
51	N. Commerce St. and N. Weil Street	NS 7	78	0
89	E. Capitol Drive	NS 11	72	34
90	E. Keefe Avenue	NS 4	54	42
91	E. Edgewood Avenue	NS 4	72	31
92	E. Auer Avenue	NS 5	84	6
94	E. Burleigh Street	NS 5	114 x 51[a]	20
95	E. Chambers Street	NS 5	30	22
96	E. Locust Street	NS 5	78	16
97	E. Park Place	NS 6	60	12
98	E. Park Place	NS 6	72	37
99	E. Boylston Street	NS 7	72	15
101	N. Pulaski Street	NS 7	72	3
102	N. Humboldt Avenue	NS 7	72	1
103	N. Marshall Street	NS 7	24	7
103A	N. Commerce Street	NS 7	96	48
104	N. Holton Street	NS 7	84 x 48	13
105	E. Brady Street	NS 8	30	0
106	North of E. Walnut Street	NS 8	96	31
107	E. Walnut Street	NS 8	42	0
108	E. Pleasant Street	NS 8	84 x 36	1
108A	N. Water Street and E. Pleasant Street	NS 8	96	30
109	North of W. Cherry Street	NS 8	60 x 48	0
110	W. Cherry Street	NS 8	90	0
110A	W. Cherry Street	NS 8	30	0
111	E. Lyon Street	NS 8	30	10
112	E. Ogden Avenue	NS 9	72 x 36	25
113	W. McKinley Avenue	NS 9	60	7
113A	W. Juneau Avenue	NS 9	84	10
114	W. Juneau Avenue	NS 9	52	6
115	W. Highland Avenue	NS 9	111 x 54	10
116	E. Highland Avenue	NS 9	36	11
117	W. State Street	NS 9	48	27
118	E. State Street	NS 9	60	24
119	W. Kilbourn Avenue	NS 9	54 x 72	25
120N	E. Kilbourn Avenue	NS 9	96 x 48	21
120S	E. Kilbourn Avenue	NS 9	96 x 48	20

Table 115 (continued)

WPDES Number	Location	Collector	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
121	North of W. Wells Street	NS 9	30	13
122	W. Wells Street	NS 9	48	14
123	E. Wells Street	NS 9	48	17
124	North of W. Wisconsin Avenue	NS 9	30	19
125	W. Wisconsin Avenue	NS 9	24	24
126	E. Wisconsin Avenue	NS 10	36	3
127	W. Michigan Street	NS 10	54	14
128	E. Michigan Street	NS 10	42	7
129	North of W. Clybourn Street	NS 10	30	13
130	W. Clybourn Street	NS 10	48	16
131	E. Clybourn Street	NS 10	48[a]	19
133	W. St. Paul Avenue	NS 10	72 X 36	15
134	E. St. Paul Avenue	NS 10	108 x 48	15
135	E. Buffalo Street	NS 10	42	13
136	E. Chicago Street	NS 10	72 x 48	9
137	S. 1st Street	CT 8	24	3
139	E. Pittsburgh Avenue	CT 8	24	14
140	N. Broadway	NS 10	30	5
141	E. Florida Street	CT 8	60	3
142	E. Polk Street	NS 10	54	16
143	E. Bruce Street	CT 8	36	5
144	E. Lyon Street	NS 8	36	0
145	N. 35th Street and W. Congress Street	NS 12	120 x 90[a]	22
146	N. Arlington Place	NS 7	120 x 48	0
147	E. Juneau Avenue	NS 9	42	21
197	W. Hampton Avenue at 32nd Street	- -	Pumps	0

[a]*Double outfall.*

Source: Milwaukee Metropolitan Sewerage District, Triad Engineering, and SEWRPC.

Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Milwaukee River watershed has increased over time. In 1975, there were a total of 68 known industrial wastewater permitted dischargers identified in the watershed. These permitted facilities discharged industrial cooling, process, rinse, and wash waters to surface waters.[66] In 1990, 120 permitted facilities discharged wastewater to the Milwaukee River, its tributaries, or the groundwater system.[67]

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[66]*SEWRPC Planning Report No. 30,* op. cit.

[67]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995.*

Table 116 lists the industrial discharge permits in effect through the WPDES during February 2003 in the Milwaukee River watershed. At that time, 130 WPDES industrial permits were in effect in the watershed. Individual permits represent 15 of these permits, the rest are spread among 11 categories of general permits. The most common category of general permit issued in this watershed was for noncontact cooling water which regulates the discharge of noncontact cooling water, boiler blowdown, and air conditioning condensate. There were 46 facilities in the watershed covered by permits in this category. Other common categories of permits were for the discharge from contaminated groundwater remedial actions and nonmetallic mining operations and the discharge of hydrostatic test water. These types of facilities represented 16, 13, and 15 permits, respectively. The other general permit categories were each represented by 10 or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water are being included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 68.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution

Urban Stormwater Runoff

As shown in Table 84, as of the year 2000, about 21.2 percent of land in the Milwaukee River watershed was in urban uses. Urban land uses within the watershed were primarily residential (10.2 percent); followed by transportation, communication, and utilities (6.4 percent) and industrial and extractive, and governmental and institutional, commercial, and recreational each of which comprised less than 1.5 percent of watershed area. Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program

Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits used to be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated stormwater. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 231 industrial stormwater permits were in effect in the Milwaukee River watershed in February 2003. A total of 121 of these were Tier 2 permits, representing slightly over half of the permitted facilities in the watershed. Tier 3 permits were the next most common in the watershed. In February 2003, 54 of these were in effect. There were 20 or fewer each of Tier 1, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at this time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan,

Table 116

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE MILWAUKEE RIVER WATERSHED: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Carriage/Interstitial Water from Dredging	Henschke Hillside County Lake Access to Silver Lake	5607 and 5630 Peters Drive	West Bend	0046558	- -	21763
Concrete Products Operations	Advance Cast Stone Company	W5104 Hwy. 144	Random Lake	0046507	460117460	16179
	Jackson Concrete Company	605 W. Pleasant Valley Road	Jackson	0046507	267115090	7936
	Schmitz Ready Mix	11050 N. Industrial Drive	Mequon	0046507	246090130	7444
	Schmitz Ready Mix	989 Ulao Road	Grafton	0046507	246106740	8027
	Schmitz Ready Mix	2707 Scenic Road	Town of Polk	0046507	267115530	10123
	Yahrs Ready Mix	1020 S. Indiana Avenue	West Bend	0046507	267115970	8186
Contaminated Groundwater Remedial Actions	Bank One Corporation	501 N. Water Street	Milwaukee	0046566	241433060	14494
	Carlson Marketing Group	3825 W. Green Tree Road	Milwaukee	0046566	241485860	14585
	Clark Station #0562	4751 N. Santa Monica Boulevard	Whitefish Bay	0046566	241574850	14470
	Deli-Food Xpress	1700 E. Washington Avenue	West Bend	0046566	267058500	14523
	Edison Street Parking Lot	1201 N. Edison Street	Milwaukee	0046566	241908370	17719
	Former Northbrook Hospital	4600 Schroeder Drive	Brown Deer	0046566	241645800	14609
	Moore Oil Company, Inc.	4033 W. Custer Avenue	Milwaukee	0046566	241174340	14591
	Pentler Property–Citgo Station	246 S. Main Street	Thiensville	0046566	246019290	14625
	Praefke Brake	133 Oak Street	West Bend	0046566	267004430	14493
	Stan and Sons Service	6030 N. Green Bay Road	Glendale	0046566	241102180	14620
	Stein Property	7425 W. Capitol Drive	Milwaukee	0046566	241581230	14619
	Superior Trucking Company	1319 Riverview Drive	Kewaskum	0046566	267122240	14497
	Teutonia Avenue Service	6811 N. Teutonia Avenue	Milwaukee	0046566	241179290	14600
	Tri Par Oil	1613 Washington Street	West Bend	0046566	246041730	14627
	University Car Wash, Inc.	4519 N. Green Bay Road	Milwaukee	0046566	241628310	14520
	Village of Shorewood	3801 N. Morris Boulevard	Shorewood	0046566	241218230	14597
Hydrostatic Test Water and Water Supply System	Adell Waterworks	P.O. Box 47	Adell	0057681	460043540	16178
	ANR Pipeline Kewaskum Loop	T11N R20E Sec 19 NE NE	Town of Trenton	0057681	- -	29927
	Brown Deer Waterworks	4800 W. Glen Brook Drive	Brown Deer	0057681	241055650	13370
	Cascade Waterworks	301 First Street	Cascade	0057681	460043650	15152
	Cedarburg Light and Water Commission	N30 W5926 Lincoln Boulevard	Cedarburg	0057681	246010820	14655
	Fredonia Water Utility	P.O. Box 159	Fredonia	0057681	246010930	18205
	Jackson Water Utility	N168 W20733 Main Street	Jackson	0057681	267011140	14673
	Kewaskum Waterworks	204 First Street	Kewaskum	0057681	267011250	14674
	Random Lake Waterworks	690 Wolf Road	Random Lake	0057681	460035510	15155
	Sanitaire Corporation	2320 Camden Road	Glendale	0057681	241522380	14102
	Saukville Water Utility	639 E. Green Bay Avenue	Saukville	0057681	246013460	14651
	Shorewood Waterworks	3930 N. Murray Avenue	Shorewood	0057681	241060710	14101
	Village of Grafton Water and Wastewater Utility	1900 9th Avenue	Grafton	0057681	246003010	5814
	West Bend Water Utility	251 Municipal Drive	West Bend	0057681	267012020	14676
	Wisconsin Gas Company	2000-4300 W. Donges Bay Road	Mequon	0057681	246013130	14653
Land Applying Liquid Industrial Wastes	Marigold Foods, Inc.	W55 N155 McKinley Boulevard	Cedarburg	0057657	246010270	12176
Landspreading Sludge	Kerry Ingredients, Inc.	N168 W21455 Main Street	Jackson	0057657	267074390	6892

Table 116 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Noncontact Cooling Water	3M Touch Systems	7025 W. Marcia Road	Milwaukee	0044938	241684630	13393
	Brady USA, Inc–Coated Products Division	2230 W. Florist Avenue	Glendale	0044938	241029030	3150
	Brewery Works, Inc.	1555 N. River Center Drive Suite 200	Milwaukee	0044938	241283350	6884
	Carlson Tool & Manufacturing Corporation	W57 N14386 Doerr Road	Cedarburg	0044938	246067580	800
	Cedarburg Nail Factory, Inc.	4811 Columbia Road	Cedarburg	0044938	246000480	17035
	Charter Steel Division of Charter Manufacturing	1658 Cold Springs Road	Saukville	0044938	246044700	1309
	DRS Power & Control Technologies, Inc.	4201 N. 27th Street	Milwaukee	0044938	241016710	7133
	E.R. Wagner	4611 N. 32nd Street	Milwaukee	0044938	241019790	847
	Electron Bean Fusion Corporation	6510 N. 40th Street	Milwaukee	0044938	241381910	13605
	First National Bank Building	735 N. Water Street	Milwaukee	0044938	241013630	13623
	Franchise Mailing Systems	4355 N. Richards Street	Milwaukee	0044938	241373440	13625
	Fred Usinger, Inc.	1030 N. Old World Third Street	Milwaukee	0044938	241006040	538
	Gateway Plastics	5650 W. County Line Road	Mequon	0044938	246002350	19020
	Gehl Company	143 Water Street	West Bend	0044938	267003880	1171
	Great Lakes REIT, Inc.	111 E. Kilbourn Avenue	Milwaukee	0044938	241341430	13725
	Hercules, Inc.	5228 N. Hopkins Street	Milwaukee	0044938	241041900	2263
	Hydrite Chemical Company	7300 W. Bradley Road	Milwaukee	0044938	241211630	13727
	Hydro Platers, Inc.	3525 W. Kiehnau Avenue	Milwaukee	0044938	241231760	969
	Johnson Controls Battery Group, Inc.	5400 N. Teutonia Avenue	Milwaukee	0044938	241033320	12482
	Kerry Ingredients	N168 W21455 Main Street	Jackson	0044938	267074390	6892
	Lallemand Biochem International	6120 W. Douglas Avenue	Milwaukee	0044938	241316350	16680
	Leeson Electric Corporation	2100 Washington Street	Grafton	0044938	246005100	3152
	Liphatech	3101 W. Custer Avenue	Menomonee Falls	0044938	241050700	14034
	Mid City Foundry–United Division	460 N. 9th Street	Grafton	0044938	246096290	1839
	Milwaukee Gear Company, Inc.	5150 N. Port Washington Road	Milwaukee	0044938	241167960	1953
	Molecular Biology Resources, Inc.	6143 N. 60th Street	Milwaukee	0044938	241294020	660
	Myers Manufacturing, Inc.–Plant 2	N172 W20950 Emery Way	Jackson	0044938	267063720	24277
	Norstar Aluminum Molds, Inc.	W66 N622 Madison Avenue	Cedarburg	0044938	246066150	2864
	Pechiney Plastic Packaging, Inc.	6161 N. 64th Street	Milwaukee	0044938	241334060	1046
	Pereles Brothers	5840 N. 60th Street	Milwaukee	0044938	241016490	269
	Rexnord--Stearns Division	120 N. Broadway	Milwaukee	0044938	241256840	12483
	Ritus Rubber Corporation	7901 W. Clinton Avenue	Milwaukee	0044938	241252990	2570
	Ritus Rubber Corporation	7201 W. Bradley Road	Milwaukee	0044938	241267180	13340
	Riveredge Nature Center	4438 W. Hawthorne Drive	Newburg	0044938	246032710	14649
	Signicast Corporation–Milwaukee	9000 N. 55th Street	Milwaukee	0044938	241025510	2242
	SPX Dock Products	6720 N. Teutonia Avenue	Milwaukee	0044938	241083590	1422
	Stainless Foundry Engineering, Inc.	5150 N. 35th Street	Milwaukee	0044938	241019350	8416
	Super Steel Products Corporation–Calumet	7100 W. Calumet Road	Milwaukee	0044938	241017040	2562
	Tecumseh Power–Grafton Operations	900 North Street	Grafton	0044938	246009170	2405
	Thermoset, Inc.	6411 W. Mequon Road	Mequon	0044938	246045250	3684
	Treat All Metals, Inc	5140 N. Port Washington Road	Milwaukee	0044938	241010770	518
	Universal Strap, Inc.	W209 N17500 Industrial Drive	Jackson	0044938	267080220	14722
	Vishay Cera Mite Grafton	1327 6th Avenue	Grafton	0044938	246043820	2417
	Weasler Engineering, Inc.	7801 North Hwy 45	Barton	0044938	267019610	1760
	West Bend Division of Regal Ware, Inc.	1100 Schmidt Road	West Bend	0044938	267067900	23790
	Wisconsin Color Press	5400 W. Good Hope Road	Milwaukee	0044938	241374980	2130
Nonmetallic Mining Operations[c]	B R Amon & Sons–Garbisch Pit	Boltonville Road	Scott	0046515	460071810	24654
	B R Amon & Sons–Kraemer Pit	W7055 CTH N and High View Road	Town of Mitchell	0046515	460001850	15190
	CRM Recycling Site	7460 N. 60th Street	Milwaukee	0046515	241049270	11086
	Hartman Sand & Gravel Company, Inc.–Home Pit	N6621 Pioneer Drive	Fredonia	0046515	246057020	23164
	Hartman Sand & Gravel Company, Inc.–Spring Lake Pit	North of Jay Road, East of Random Lake Road	Fredonia	0046515	- -	23165
	Jackson Quarry	607 Pleasant Valley Road	Jackson	0046515	267098810	16958
	James Cape and Sons Cedarburg Limestone Quarry	660 Susan Lane	Cedarburg	0046515	246105310	14399

Table 116 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Nonmetallic Mining Operations[c] (continued)	Lake Ellen Stone, Inc.	N2133 Hwy 28	Adell	0046515	460104370	867
	Ozaukee County Highway Department–Lakeland Pit	3601 Lakeland Road	Saukville	0046515	246005760	25115
	Payne & Dolan–Saukville Aggregate Site 81005	2892 Lakeland Drive	Saukville	0046515	999905280	2804
	Rowe Sand & Gravel, Inc.	1219 Hwy I	Grafton	0046515	246105750	3117
	Werner Johann & Son, Inc.	2021 W. Decorah Road	West Bend	0046515	267115750	2907
	West Bend Sand & Stone, Inc.	4246 Hwy 33	West Bend	0046515	267105960	2904
Petroleum Contaminated Water[a]	- -	- -	- -	- -	- -	- -
Pit/Trench Dredging	ANR Pipeline Kewaskum Loop	T11N R20E Sec 19 NE NE	Trenton	0049344	- -	29927
	Wondra Excavating, Inc.	- -	Washington Co.	0049344	- -	19633
Potable Water Treatment and Conditioning	Hays Brake LLC	5800 W. Donges Bay Road	Mequon	0046540	246021270	3617
	North Shore Water Commission	400 W. Bender Road	Glendale	0046540	241016820	13723
	Weasler Engineering, Inc.	7801 Hwy 45	Barton	0046540	267019610	1760
Swimming Pool Facilities	Cedaqua Swimming Pool	- -	Cedarburg	0046523	- -	1984
	Cedarburg Community Pool	W68 N851 Evergreen Boulevard	Cedarburg	0046523	246105420	14645
	Grafton High School Swimming Pool	1900 Washington Avenue	Grafton	0046523	246072200	14646
	Homestead High School	5000 W. Mequon Road	Mequon	0046523	246029190	13729
	Le Club	2001 W. Good Hope Road	Milwaukee	0046523	241519850	14033
	Mequon Public Pool	11333 Cedarburg Road	Mequon	0046523	246069550	14078
	Milwaukee County Parks and Recreation–Lincoln Park	1300 E. Glendale Avenue	Milwaukee	0046523	241520510	14059
	Milwaukee Country Club	8000 N. Range Line Road	River Hills	0046523	241088100	14079
	Ozaukee Country Club	10823 N. River Road	Mequon	0046523	246020610	14097
	Schroeder YMCA	9250 N. Green Bay Road	Brown Deer	0046523	241522600	14110
Individual Permits	Adell Corporation	627 Maine Street	Adell	- -	460032760	5623
	Badger Meter, Inc.	4545 W. Brown Deer Road	Milwaukee	0033529	241015500	6463
	Cook Composites & Polymers Company	340 Railroad Street	Saukville	0027731	246004330	6198
	ITW West Bend Company	400 Washington Street	West Bend	0027294	267004640	6178
	Johnson Controls, Inc.	5757 N. Green Bay Road	Glendale	0000108	241005160	5559
	Krier Foods, Inc.[b]	520 Wolf Road	Random Lake	0049204	460146280	10134
	Lakeside Foods, Inc.[b]	709 Allen Street	Random Lake	0032760	460034850	8623
	Level Valley Creamery, Inc.[c]	807 Pleasant Valley Road	West Bend	0026751	267030280	6152
	Milk Specialties Company, Inc.–Adell Ingredients	627 Maine Street	Adell	0001236	460032760	5623
	Northland Cranberries[d]	N168 W20701 Main Street	Jackson	- -	267003770	5566
	Osmonics Autotrol	5730 N. Glen Park Road	Milwaukee	0041351	241022210	6689
	Regal Ware, Inc.	1675 Reigle Drive	Kewaskum	0000060	267003660	5555
	Village of River Hills	7650 N. Pheasant Lane	River Hills	0032221	241088430	18595
	Wisconsin Thermoset Molding, Inc.	900 E. Vienna Avenue	Milwaukee	0042218	241440760	473
	Wisconsin Department of Natural Resources–Kettle Moraine Springs Fish Hatchery	N1929 Trout Springs Road	Adell	0026255	460033750	7297

[a] *There were no active WPDES general permits for Petroleum Contaminated Water in the Milwaukee River watershed during February 2003.*

[b] *The name of this facility has changed to Lakeside Foods, 709 Allen Street, Random Lake. Field checking indicates that this is the same building.*

[c] *Level Valley Creamery was purchased by Schreiber Foods in 2005.*

[d] *The Northland Cranberries bottling plant in Jackson closed on November 21, 2003, and was subsequently sold.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis and within 24 hours of a precipitation event of 0.5 inches or more. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the watershed are described below and are listed in Table G-3 in Appendix G.

Chapter NR 151 of the Wisconsin Administrative Code

Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004), that are specified under Chapter NR 151.

Stormwater Management Systems

Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Milwaukee River watershed, the stormwater drainage systems provide the means by which a significant portion of the nonpoint sources pollutants reach the surface water system.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 117 indicates the status of stormwater management activities in each of the communities in the watershed.

Table G-3 in Appendix G indicates that Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties; the Cities of Cedarburg, Glendale, Mequon, and Milwaukee; the Village of Bayside, Brown Deer, Fox Point, Germantown, Grafton, River Hills, Saukville, Shorewood, Thiensville, and Whitefish Bay; and the Towns of Cedarburg, Grafton, and Richfield have WPDES stormwater discharge permits. The remaining communities in the watershed do not currently have stormwater discharge permits. Thus, communities comprising 22 percent of the watershed area have been issued WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, the permitted communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*. As part of their

Table 117

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE MILWAUKEE RIVER WATERSHED

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Dodge County[a]	- -	X	- -
Town of Lomira	- -	X[a]	- -
Village of Lomira	- -	- -	- -
Fond du Lac County[b]	X	X	- -
Town of Ashford	X[b]	X[b]	- -
Town of Auburn	X[b]	X[b]	- -
Town of Byron	X[b]	X[b]	- -
Town of Eden	X[b]	X[b]	- -
Town of Empire	X[b]	X[b]	- -
Town of Forest	X[b]	X[b]	- -
Town of Osceola	X[b]	X[b]	- -
Village of Campbellsport	- -	X	- -
Village of Eden	- -	- -	- -
Milwaukee County			
City of Glendale	X	X	X
City of Milwaukee	X	X	X
Village of Bayside	X	X	- -
Village of Brown Deer	X	X	- -
Village of Fox Point	X	X	- -
Village of River Hills	X	X	- -
Village of Shorewood	X	X	- -
Village of Whitefish Bay	X	X	- -
Ozaukee County			
City of Cedarburg	X	X	- -
City of Mequon	X	X	- -
Town of Cedarburg	- -[c]	- -[c]	- -
Town of Fredonia	- -	- -	- -
Town of Grafton	X	X	- -
Town of Port Washington	- -	- -	- -
Town of Saukville	- -	- -	- -
Village of Fredonia	X	X	- -
Village of Grafton	X	X	- -
Village of Newburg	- -	X	- -
Village of Saukville	X	X	- -
Village of Thiensville	X	X	- -
Sheboygan County			
Town of Greenbush	X[d]	X[d]	- -
Town of Holland	X[d]	X[d]	- -
Town of Lyndon	X[d]	X[d]	- -
Town of Mitchell	X[d]	X[d]	- -
Town of Scott	X[d]	X[d]	- -
Town of Sherman	X[d]	X[d]	- -
Village of Adell	- -	- -	- -
Village of Cascade	- -	- -	- -
Village of Random Lake		X	

Table 117 (continued)

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Washington County	X	X	- -
City of West Bend	X	X	- -
Town of Addison	X[e]	X[e]	- -
Town of Barton	X[e]	X[e]	- -
Town of Farmington	X[e]	X[e]	- -
Town of Germantown	X[e]	X[e]	- -
Town of Jackson	X[e]	X[e]	- -
Town of Kewaskum	X	X	- -
Town of Polk	X[e]	X[e]	- -
Town of Richfield	X[e]	X[e]	- -
Town of Trenton	X[e]	X[e]	- -
Town of Wayne	X	X	- -
Town of West Bend	X	X	- -
Village of Germantown	X	X	- -
Village of Jackson	X	X	- -
Village of Kewaskum	X	X	- -
Village of Newburg	- -	X	- -
Village of Slinger	- -	- -	- -

[a]*The Town of Lomira is covered under the Dodge County construction erosion control ordinance.*

[b]*All towns are covered under Fond du Lac County's stormwater management and construction erosion control ordinances.*

[c]*Will adopt ordinances as required under WPDES stormwater discharge permit.*

[d]*All towns are covered under Sheboygan County's stormwater management and construction erosion control ordinances.*

[e]*In the indicated towns; Washington County administers either 1) the county stormwater management and construction erosion control (SWM & CEC) ordinance or 2) a SWM & CEC ordinance adopted by the town.*

Source: SEWRPC.

permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

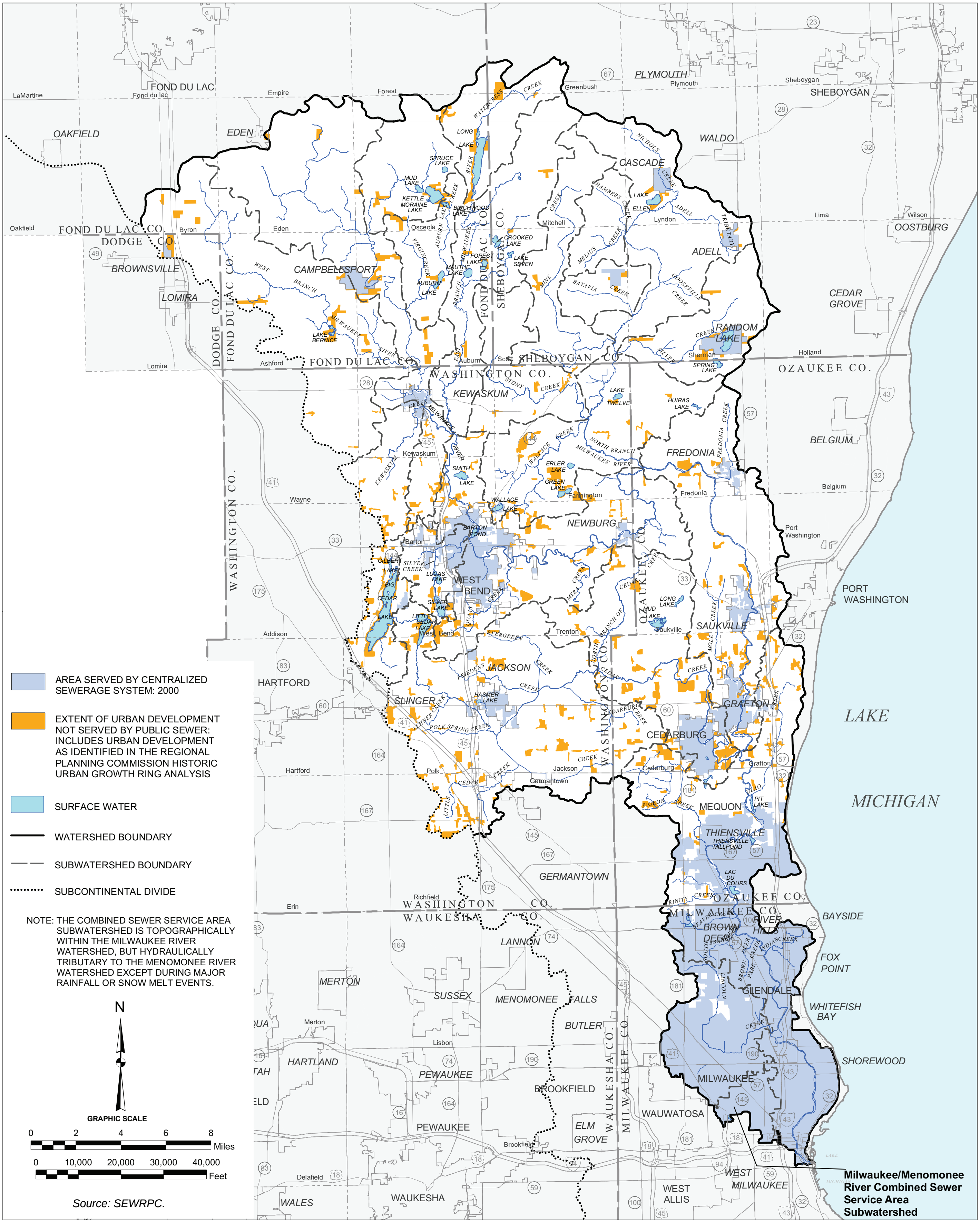
Urban Enclaves Outside Planned Sewer Service Areas

Map 69 shows areas served by centralized sanitary sewer systems in the Milwaukee River watershed in 2000. In that year, 59,932 acres of the watershed were served by sanitary sewer systems. In addition, there were about 18,105 acres of urban-density enclaves that were not served by public sanitary sewer systems. As shown on Map 70, about 11,935 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980. These older systems may be at particular risk for malfunctioning. As described in Chapter II of this report, failure of onsite disposal systems can contribute nonpoint source pollutants to streams and groundwater.

In 1978, the State of Wisconsin established the Private Onsite Wastewater Treatment System Replacement or Rehabilitation Financial Assistance Program under the Wisconsin Fund Program. That voluntary program annually awards grants to counties, Indian tribes, and municipalities to assist homeowners and small businesses in replacing or rehabilitating failing private, onsite systems. The program is administered by the Wisconsin Department of Commerce in cooperation with the counties and communities. Grant eligibility is subject to

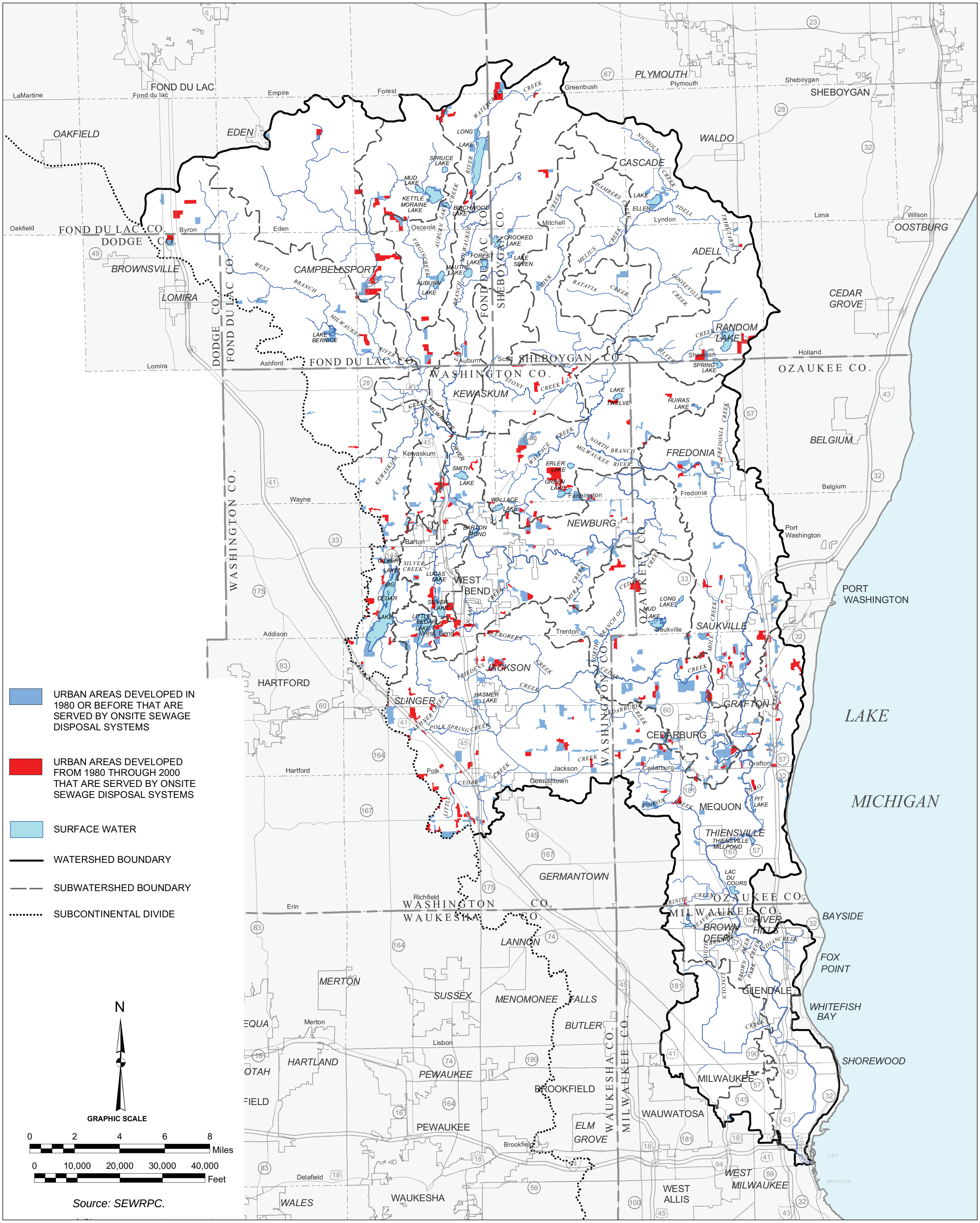
Map 69

AREAS SERVED BY CENTRALIZED SANITARY SEWERAGE SYSTEMS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Map 70

URBAN AREAS WITHIN THE MILWAUKEE RIVER WATERSHED THAT ARE SERVED BY ONSITE SEWAGE DISPOSAL SYSTEMS: 1980 AND PRIOR AND 1981 THROUGH 2000



Source: SEWRPC.

specific income, revenue, occupancy, and operation requirements. Onsite systems that are installed, replaced, or rehabilitated after the date on which the county or community elects to participate are required to have a maintenance program. Thus, given the 1978 date of establishment of the grant program, the determination of areas developed with onsite systems before 1980 and those developed in 1980 or later,[68] provides an indication of which systems are subject to the requirement of having formal maintenance programs and which are not. The counties, or communities in the case of Milwaukee County, are responsible for administering the maintenance program with the goal of assuring the onsite systems function properly. In the Milwaukee River watershed, Dodge, Fond du Lac, Ozaukee, Sheboygan, and Washington Counties currently participate in the program.

Solid Waste Disposal Sites

Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day’s operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Milwaukee River watershed, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there were two active solid waste landfills within the watershed, both located in the West Branch Milwaukee River subwatershed. As set forth in Table 118 and shown on Map 71, there are 47 inactive landfills in the watershed: 10 in the Upper Lower Milwaukee River subwatershed; six in the North Branch Milwaukee River subwatershed; four each in the Cedar Creek, Lower Milwaukee River, Middle Milwaukee River, Stony Creek, and West Branch Milwaukee River subwatersheds; three in the Lincoln Creek subwatershed; two each in the Silver Creek (West Bend) and Upper Milwaukee River subwatersheds; and one each in the Lake Fifteen Creek and Watercress Creek subwatersheds.

Rural Stormwater Runoff

Rural land uses within the Milwaukee River watershed include agricultural—mostly crop production—and woodlands, wetlands, water, and other open lands as set forth in the beginning of this chapter. As noted above, Chapter NR 151 of the *Wisconsin Administrative Code* establishes performance standards for the control of

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[68]*Since 1970, the SEWRPC land use inventory has been conducted at five-year intervals. Thus the 1980 inventory was the best available information for establishing which systems have maintenance requirements.*

Table 118

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES IN THE MILWAUKEE RIVER WATERSHED: 2005

Number on Map 71	Facility Name	Address	Municipality	Classification	Subwatershed	Facility Identification	Status
1	City of Glendale	5909 N. Milwaukee Parkway	Glendale	Landfill, unclassified	Lincoln Creek	241206900	Inactive
2	City of Mequon Compost/Closed Landfill Site	Bonniwell Road	Mequon	Landfill, 50,000-500,000 cubic yards	Lower Milwaukee River	246046460	Inactive
3	City of Milwaukee	- -	Milwaukee	- -	Lincoln Creek	- -	Inactive
4	City of Milwaukee, Bluehole Landfill	- -	Milwaukee	- -	Lower Milwaukee River	- -	Inactive
5	Village of Whitefish Bay	5201 W. Good Hope Road	Milwaukee	Landfill 50,000-500,000 cubic yards	Lincoln Creek	241218670	Inactive
6	Grafton, Lime Kiln Park	Green Bay Road	Grafton	Landfill, unclassified	Upper Lower Milwaukee River	246036780	Inactive
7	Freeman Chemical	- -	Saukville	- -	Upper Lower Milwaukee River	- -	Inactive
8	Village of Saukville	CTH O (South Main)	Saukville	Landfill, unclassified	Upper Lower Milwaukee River	246048770	Inactive
9	Village of Thiensville	STH 57	Thiensville	Landfill, unclassified	Lower Milwaukee River	246050200	Inactive
10	Town of Sherman Landfill	Pelishek Road	Sherman	Landfill 0-50,000 cubic yards	North Branch Milwaukee River	460020000	Inactive
11	Town of Sherman	- -	Sherman	Landfill, unclassified	North Branch Milwaukee River	460019890	Inactive
12	Town of Ashford Landfill	CTH W	Ashford	Landfill 50,000-500,000 cubic yards	West Branch Milwaukee River	420015860	Inactive
13	City of West Bend	- -	Barton	- -	Silver Creek West Bend	- -	Inactive
14	- -	- -	Barton	- -	North Branch Milwaukee River	- -	Inactive
15	Majerus Landfill	W5633 Campbell Road	Byron	Landfill >500,000 cubic yards	West Branch Milwaukee River	420014430	Inactive
16	Sadoff & Ruddy Industries	USH 41	Byron	Landfill >500,000 cubic yards	West Branch Milwaukee River	420018280	Active
17	Sadoff & Ruddy Industries	USH 41	Byron	Landfill >500,000 cubic yards	West Branch Milwaukee River	420018280	Active
18	City/Town of Cedarburg Compost Site/Old Landfill	Pleasant Valley Road	Cedarburg	Landfill 50,000-500,000 cubic yards	Upper Lower Milwaukee River	246049650	Inactive
19	Marvin Procknow	- -	Cedarburg	- -	Upper Lower Milwaukee River	- -	Inactive
20	Wisconsin Electric Power Company	Cedar Sauk Road	Cedarburg	Landfill, unclassified	Upper Lower Milwaukee River	246049210	Inactive
21	Village of Eden Landfill	- -	Eden	Landfill, unclassified	Upper Milwaukee River	420018720	Inactive
22	Town of Eden Landfill	- -	Eden	Landfill, unclassified	Upper Milwaukee River	420016190	Inactive
23	Lazy Days Camp Ground	- -	Farmington	Landfill, unclassified	North Branch Milwaukee River	267060310	Inactive
24	Town of Farmington	Paradise Road	Farmington	Landfill 0-50,000 cubic yards	Stony Creek	267061300	Inactive
25	Town of Fredonia	Hickory Grove Road	Fredonia	Landfill 0-50,000 cubic yards	Upper Lower Milwaukee River	246047890	Inactive
26	Ozaukee County Highway Department	CTH Y and CTH A	Fredonia	Landfill 50,000-500,000 cubic yards	Middle Milwaukee River	246049540	Inactive
27	Town of Grafton	Cedar Sauk Road	Grafton	Landfill 50,000-500,000 cubic yards	Upper Lower Milwaukee River	246048000	Inactive
28	Wisconsin Electric Power Company	- -	Grafton	- -	Lower Milwaukee River	- -	Inactive
29	Town of Jackson	CTH G	Jackson	Landfill, unclassified	Cedar Creek	267061410	Inactive
30	Village of Kewaskum	County Line Road	Kewaskum	Landfill 50,000-500,000 cubic yards	West Branch Milwaukee River	420017840	Inactive
31	Town of Kewaskum	Hickory Road	Kewaskum	Landfill 0-50,000 cubic yards	Stony Creek	267061520	Inactive

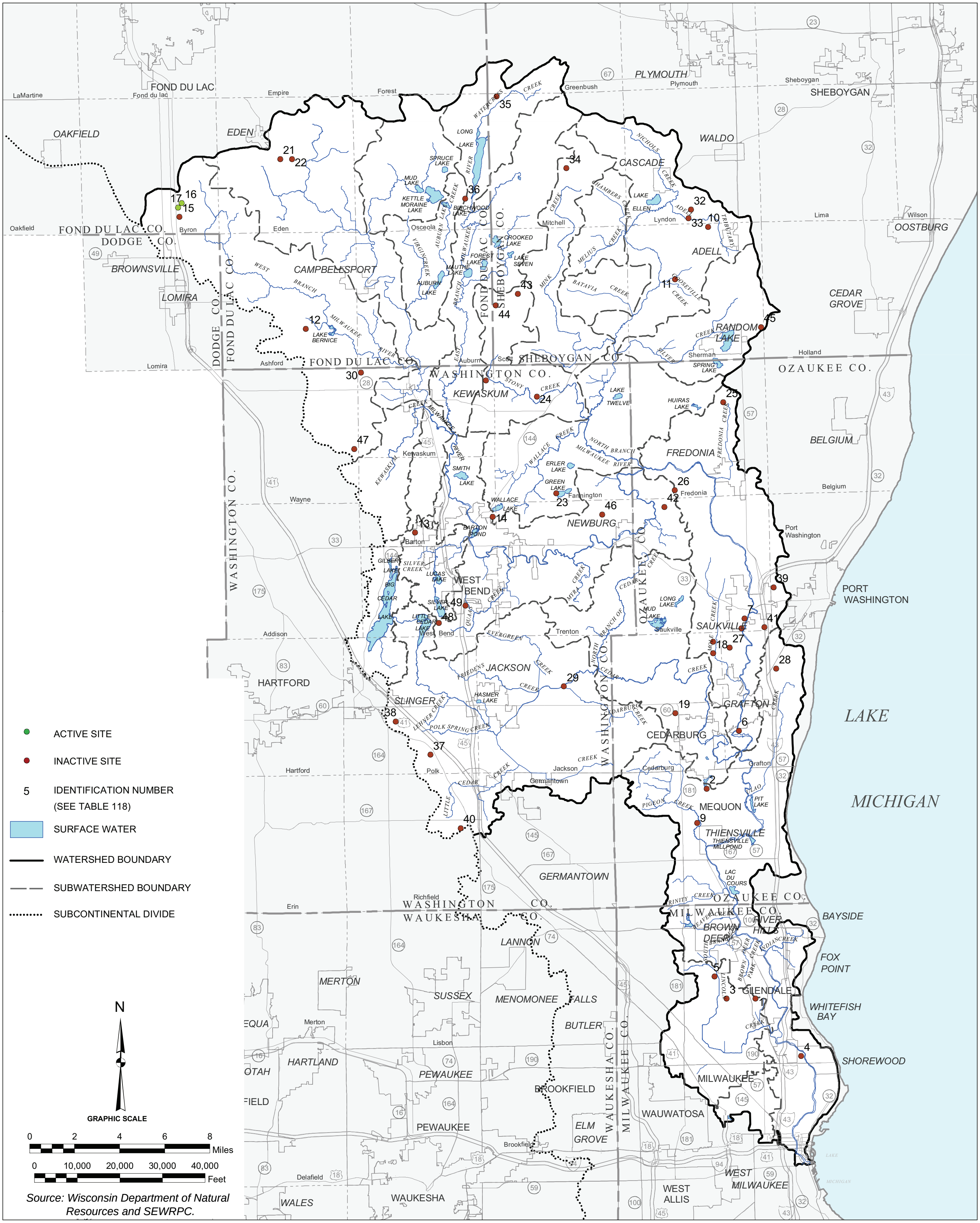
Table 118 (continued)

Number on Map 71	Facility Name	Address	Municipality	Classification	Subwatershed	Facility Identification	Status
32	Town of Lyndon and Village of Cascade Landfill	Bates Road	Lyndon	Landfill 50,000-500,000 cubic yards	North Branch Milwaukee River	460020440	Inactive
33	Sheboygan County Highway Department	- -	Lyndon	Landfill 0-50,000 cubic yards	North Branch Milwaukee River	460015600	Inactive
34	Town of Mitchell Landfill	Parnell Road	Mitchell	Landfill 50,000-500,000 cubic yards	Mink Creek	460019010	Inactive
35	WI DOC Kettle Moraine Watercress	Kettle Moraine	Mitchell	Landfill 0-50,000 cubic yards	Watercress Creek	460021760	Inactive
36	Town of Osceola Landfill	CTH F	Osceola	Landfill 50,000-500,000 cubic yards	Lake Fifteen Creek	420017070	Inactive
37	LeRoy Schmidt Dump	- -	Polk	Landfill, unclassified	Cedar Creek	267060420	Inactive
38	- -	- -	Polk	- -	Cedar Creek	- -	Inactive
39	Town of Port Washington	Northwood and Millcrest	Port Washington	Landfill, unclassified	Upper Lower Milwaukee River	246048110	Inactive
40	Town of Richfield	Mayfield Road	Richfield	Landfill 50,000-500,000 cubic yards	Cedar Creek	267063060	Inactive
41	Town of Saukville	Foster Road	Saukville	Landfill 50,000-500,000 cubic yards	Upper Lower Milwaukee River	246048220	Inactive
42	Laubenstein Sales and Service, Inc.	CTH Y	Saukville	Landfill 0-50,000 cubic yards	Middle Milwaukee River	246050090	Inactive
43	Town of Scott Landfill	CTH S	Scott	Landfill 50,000-500,000 cubic yards	Stony Creek	460019560	Inactive
44	WDNR Kettle Moraine Forest	Division Road	Scott	Landfill 0-50,000 cubic yards	Stony Creek	460021650	Inactive
45	Dimmer Disposal Operation	CTH CC	Sherman	Landfill, unclassified	Silver Creek	460021650	Inactive
46	Town of Trenton	- -	Trenton	Landfill, unclassified	Middle Milwaukee River	267061630	Inactive
47	Town of Wayne	- -	Wayne	- -	West Branch Milwaukee River	- -	Inactive
48	Town of West Bend	- -	West Bend	- -	Silver Creek West Bend	- -	Inactive
49	- -	- -	West Bend	- -	Middle Milwaukee River	- -	Inactive

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 71

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES WITHIN THE MILWAUKEE RIVER WATERSHED: 2005



nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. Agricultural performance standards are established for soil erosion, manure storage facilities, clean water diversions, nutrient management, and manure management. Those standards must only be met to the degree that grant funds are available to implement projects designed to meet the standards.

Livestock Operations

The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. Animal manure composed of feces, urine, and sometimes bedding material, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can potentially contaminate water by surface runoff, infiltration to groundwater, and volatilization to the atmosphere. During the warmer seasons of the year the manure is often scattered on cropland and pastureland where the waste material is likely to be taken up by vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Based on data from 2002, animal operations in the Milwaukee River watershed include 1,791 operations rearing a total of about 211,418 cattle and calves, 152 operations rearing a total of about 19,864 pigs, 119 operations rearing a total of about 3,998 sheep, and 231 operations rearing a total of about 34,899 chickens, mostly broilers. Most of these operations are in the portions of the watershed in Fond du Lac and Sheboygan Counties.

Five concentrated animal feeding operations (CAFO) are situated in the watershed. Abel Dairy in the Town of Eden rears about 1,700 cattle and calves. Clover Hill Dairy in the Town of Ashford rears about 850 cattle and calves. Opitz Dairy Farm in the Town of Saukville rears about 1,800 cattle and calves. R&J Partnership in the Town of Kewaskum rears up to 400,000 chickens. Vorpahl Farms in the Town of Sherman rears about 2,050 cattle and calves. Concentrated animal feeding operations are defined as livestock and poultry operations with more than 1,000 animal units. Animal units are calculated for each different type and size class of livestock and poultry. For example, facilities with 1,000 beef cattle, 700 milking cows, or 200,000 chickens each would be considered to have the equivalent of 1,000 animal units. Concentrated animal feeding operations are regulated by the State of Wisconsin under the WPDES permit program.

Crop Production

In the absence of mitigating measures, runoff from cropland can have an adverse effect on water quality within the Milwaukee River watershed by contributing excess sediments, nutrients, and organic matter, including pesticides to streams. Negative effects associated with soil erosion and transport to waterbodies includes reduced water clarity, sedimentation on streambeds, and contamination of the water from various agricultural chemicals and nutrients that are attached to the individual soil particles. Some of these nutrients, in particular phosphorus, and to some extent nitrogen, are directly associated with eutrophication of water resources. The extent of the water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. Conventional tillage practices, or moldboard plowing, involve turning over the soil completely, leaving the soil surface bare of most cover or residue from the previous year’s crop, and making it highly susceptible to erosion due to wind and rain. The use of conservation tillage practices has become common in the watershed in recent years within areas most susceptible to erosion and surface water impacts.

Crops grown in the Milwaukee River watershed include row crops, such as corn and soybeans; small grains, such as winter wheat; and hay such as alfalfa. Vegetables, such as snap beans and sweet corn, constitute less than 1 percent of the agricultural land cover. Row crops and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Crop rotations typically follow a two- or three-year sequence of corn and soybeans and occasionally winter wheat in the third year. However, hay is periodically included as part of a long-term rotation of corn, oats, and alfalfa.

Since the early 1930s, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic materials entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil conditions with little benefit to surface water quality. Despite the implementation of certain practices aimed at controlling soil erosion from agricultural land, and development of soil erosion plans and/or land water resource management plans for Milwaukee,[69] Ozaukee,[70] and Washington[71] counties, such erosion and the resultant deposition of sediment in the streams of the Milwaukee River watershed remains a significant water resource problem. Soil erosion from agricultural lands is one of the major sources of sediment and nutrients in the Milwaukee River and its tributaries.

Nutrients such as phosphorus and agri-chemicals, including herbicides and pesticides, are electrostatically attracted to silt sized particles and are transported to surface waters through soil erosion. As previously mentioned, phosphorus is one of the primary nutrients associated with eutrophication of water resources, and agri-chemicals can negatively impact the life cycles of aquatic organisms. In the eutrophication process, phosphorus enhances growth of aquatic vegetation and algae, which has the effect of accelerating the aging process of a water resource. Phosphorus is usually not susceptible to downward movement through the soil profile; instead, the majority of phosphorus reaches water resources by overland flow, or erosion. Nitrogen also is a nutrient that contributes to eutrophication; however, it is most often associated with subsurface water quality contamination. Nitrogen in the form of nitrate can be associated with respiration problems in newborn infants. Nitrogen is susceptible to downward movement through the soil profile; however, due to the nature of soils in the watershed, nitrogen is not as significant a threat due to various chemical reactions that occur within the soil.[72]

Woodlands

A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Milwaukee River watershed.

Pollution Loadings

Annual Loadings

Annual average pollutant loads to the Milwaukee River watershed are set forth in Tables 119 through 125. Average annual per acre loads are set forth in Table 126. These estimates represent point and nonpoint source loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream

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[69]*Milwaukee County Land Conservation Committee,* Milwaukee County Land and Water Resource Management Plan, *April 2001.*

[70]*SEWRPC Community Assistance Planning Report No. 171,* Ozaukee County Agricultural Soil Erosion Control Plan, *February 1989.*

[71]*SEWRPC Community Assistance Planning Report No. 170,* Washington County Agricultural Soil Erosion Control Plan, *March 1989.*

[72]*Soils that have a high clay content and stay wet for long periods of time, or even well-drained soils after a rainfall event, are susceptible to nitrogen losses to the atmosphere through a chemical reaction known as denitrification. This reaction converts nitrate,* NO_3^-*,to gaseous nitrogen,* N_2*, which is lost to the atmosphere.*

Table 119

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Batavia Creek	600	226,000	161.10	19,510	28,470	18
Cedar Creek	18,700	8,286,000	3,542.40	299,660	737,700	377
Cedar Lake	2,640	1,256,000	1,575.05	26,600	81,330	99
Chambers Creek	650	252,000	187.96	19,620	28,580	22
East Branch Milwaukee River	2,600	1,010,000	791.81	43,350	97,240	88
Kettle Moraine Lake	3,450	2,042,000	698.83	60,000	129,130	63
Kewaskum Creek	2,240	1,040,000	378.87	43,880	93,300	41
Lake Fifteen Creek	1,420	780,000	455.30	21,190	48,850	44
Lincoln Creek	7,940	2,826,000	4,178.52	42,920	217,940	381
Lower Cedar Creek	8,410	4,350,000	2,488.74	112,010	270,700	229
Lower Milwaukee River	21,520	8,268,000	8,496.57	188,580	623,130	785
Middle Milwaukee River	9,630	4,598,000	3,305.63	139,980	328,410	311
Mink Creek	1,440	566,000	446.95	51,040	66,800	49
North Branch Milwaukee River	7,720	3,198,000	2,438.55	177,620	317,620	237
Silver Creek (Sheboygan County)	2,180	824,000	895.02	48,230	89,990	79
Silver Creek (West Bend)	2,010	996,000	932.76	17,270	59,770	81
Stony Creek	1,400	534,000	460.50	41,210	61,730	48
Upper Lower Milwaukee River	8,600	4,322,000	2,954.41	141,400	303,230	277
Upper Milwaukee River	10,230	5,294,000	1,629.27	200,930	417,620	179
Watercress Creek	2,660	1,522,000	925.66	41,630	96,970	73
West Branch Milwaukee River	10,310	5,278,000	1,521.16	224,550	415,580	176
Total	126,350	57,468,000	38,465.06	1,961,180	4,514,090	3,657

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total pollutant loads set forth in Table 119 are representative of potential pollutants moved from the Milwaukee River watershed into stream channels, but are not intended to reflect the total amount of pollutants moving from those sources through the entire hydrologic-hydraulic system.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Milwaukee River watershed are set forth in Tables 120 through 125. Contributions of most of these pollutants by point sources represent a minor portion of the combined total average loads from point and nonpoint sources, generally about 15 percent or less, except for the phosphorus load, which is split about evenly between point and nonpoint sources.

Average annual point source loads of total phosphorus in the Milwaukee River watershed are shown in Table 120. The total average annual point source load of total phosphorus is about 148,150 pounds. Most of this is contributed by the Lower Milwaukee River subwatershed. Industrial dischargers and sewage treatment plants account for almost all of the contributions of total phosphorus from point sources, with relatively small contributions from combined sewer overflows and separate sanitary sewer overflows.

Table 120

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Batavia Creek	0	0	0	0	0	120	480	600	600
Cedar Creek	<10	0	0	7,400	7,400	3,310	15,390	18,700	26,100
Cedar Lake	0	0	0	0	0	390	2,250	2,640	2,640
Chambers Creek	0	0	0	0	0	150	500	650	650
East Branch Milwaukee River	0	0	0	0	0	460	2,140	2,600	2,600
Kettle Moraine Lake	0	0	0	0	0	270	3,180	3,450	3,450
Kewaskum Creek	0	0	0	0	0	370	1,870	2,240	2,240
Lake Fifteen Creek	0	0	0	0	0	220	1,200	1,420	1,420
Lincoln Creek	4,260	200	80	0	4,540	7,870	70	7,940	12,480
Lower Cedar Creek	10	10	0	5,730	5,750	3,200	5,210	8,410	14,160
Lower Milwaukee River	73,470	540	1,710	0	75,720	14,780	6,740	21,520	97,240
Middle Milwaukee River	10	0	0	14,740	14,750	3,480	6,150	9,630	24,380
Mink Creek	0	0	0	0	0	320	1,120	1,440	1,440
North Branch Milwaukee River	15,870	<10	0	6,580	22,450	1,480	6,240	7,720	30,170
Silver Creek (Sheboygan County)	0	0	0	900	900	830	1,350	2,180	3,080
Silver Creek (West Bend)	0	0	0	0	0	1,280	730	2,010	2,010
Stony Creek	0	0	0	0	0	310	1,090	1,400	1,400
Upper Lower Milwaukee River	140	30	0	12,850	13,020	3,480	5,120	8,600	21,620
Upper Milwaukee River	80	0	0	3,540	3,620	1,400	8,830	10,230	13,850
Watercress Creek	0	0	0	0	0	300	2,360	2,660	2,660
West Branch Milwaukee River	0	0	0	0	0	1,270	9,040	10,310	10,310
Total	93,840	780	1,790	51,740	148,150	45,290	81,060	126,350	274,500
Percent of Total Load	34.2	0.3	0.7	18.8	54.0	16.5	29.5	46.0	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Average annual point source loads of total suspended solids in the Milwaukee River watershed are shown in Table 121. The total average annual point source load of total suspended solids is about 915,650 pounds. Most of this is contributed by the Lower Milwaukee River and Upper Lower Milwaukee River subwatersheds. Industrial dischargers, sewage treatment plants, and combined sewer overflows represent the major sources of TSS, contributing about 50 percent, 32 percent, and 16 percent, respectively, of the total load from point sources. Separate sanitary sewer overflows contribute a relatively small amount.

Average annual point source loads of fecal coliform bacteria in the Milwaukee River watershed are shown in Table 122. The total average annual point source load of fecal coliform bacteria is about 2,361.60 trillion cells per year. Most of this is contributed by the Lower Milwaukee River subwatershed. Combined sewer overflows and separate sanitary sewer overflows account for 80 percent and 18 percent, respectively, of the total load from point sources, with a relatively small contribution from sewage treatment plants.

Average annual point source loads of total nitrogen in the Milwaukee River watershed are shown in Table 123. The total average annual point source load of total nitrogen is about 219,930 pounds. Most of this is contributed by the Lower Milwaukee River and Upper Lower Milwaukee River subwatersheds. Sewage treatment plants and industrial dischargers account for 56 percent and 34 percent, respectively, of the total load from point sources, with smaller contributions from combined sewer overflows and separate sanitary sewer overflows.

Table 121

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Batavia Creek	0	0	0	0	0	40,000	186,000	226,000	226,000
Cedar Creek	0	0	0	24,000	24,000	1,504,000	6,782,000	8,286,000	8,310,000
Cedar Lake	0	0	0	0	0	186,000	1,070,000	1,256,000	1,256,000
Chambers Creek	0	0	0	0	0	52,000	200,000	252,000	252,000
East Branch Milwaukee River	0	0	0	0	0	150,000	860,000	1,010,000	1,010,000
Kettle Moraine Lake	0	0	0	0	0	126,000	1,916,000	2,042,000	2,042,000
Kewaskum Creek	0	0	0	0	0	162,000	878,000	1,040,000	1,040,000
Lake Fifteen Creek	0	0	0	0	0	94,000	686,000	780,000	780,000
Lincoln Creek	28,000	6,000	4,000	0	38,000	2,778,000	48,000	2,826,000	2,864,000
Lower Cedar Creek	0	0	0	46,000	46,000	1,256,000	3,094,000	4,350,000	4,396,000
Lower Milwaukee River	370,000	16,000	139,650	0	525,650	5,236,000	3,032,000	8,268,000	8,793,650
Middle Milwaukee River	0	0	0	44,000	44,000	1,510,000	3,088,000	4,598,000	4,642,000
Mink Creek	0	0	0	0	0	106,000	460,000	566,000	566,000
North Branch Milwaukee River	54,000	0	0	8,000	62,000	532,000	2,666,000	3,198,000	3,260,000
Silver Creek (Sheboygan County)	0	0	0	16,000	16,000	292,000	532,000	824,000	840,000
Silver Creek (West Bend)	0	0	0	0	0	526,000	470,000	996,000	996,000
Stony Creek	0	0	0	0	0	100,000	434,000	534,000	534,000
Upper Lower Milwaukee River	0	2,000	0	130,000	132,000	1,748,000	2,574,000	4,322,000	4,454,000
Upper Milwaukee River	2,000	0	0	26,000	28,000	580,000	4,714,000	5,294,000	5,322,000
Watercress Creek	0	0	0	0	0	134,000	1,388,000	1,522,000	1,522,000
West Branch Milwaukee River	0	0	0	0	0	596,000	4,682,000	5,278,000	5,278,000
Total	454,000	24,000	143,650	294,000	915,650	17,708,000	39,760,000	57,468,000	58,383,650
Percent of Total Load	0.8	<0.1	0.3	0.5	1.6	30.3	68.1	98.4	100.0

[a] *Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Average annual point source loads of BOD in the Milwaukee River watershed are shown in Table 124. The total average annual point source load of BOD is about 719,070 pounds. Most of this is contributed by the Lower Milwaukee River and Middle Milwaukee River subwatersheds. Sewage treatment plants and industrial dischargers contribute 56 percent and 40 percent, respectively, of the total load from point sources.

Average annual point source loads of copper in the Milwaukee River watershed are shown in Table 125. The total average annual point source load of copper is about 689 pounds per year. Most of this is contributed by the Middle Milwaukee River subwatershed. Sewage treatment plants represent 92 percent of the total load from point sources.

Nonpoint Source Loads

Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source pollutant loads delivered to the streams in the watershed. The results of that analysis are set forth in Tables 119 through 125 and depicted graphically on Maps H-25 through H-36 in Appendix H. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 119 shows the average annual total nonpoint source pollutant loads for subwatersheds of the Milwaukee River watershed. Average annual per acre nonpoint source pollution loads for subwatersheds of the Milwaukee River watershed are shown in Table 126.

Table 122

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE MILWAUKEE RIVER WATERSHED[a]

	Point Sources					Nonpoint Sources			
Subwatershed	Industrial Point Sources (trillions of cells)	SSOs (trillions of cells)	CSOs (trillions of cells)	Sewage Treatment Plants (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	Total (trillions of cells)
Batavia Creek	0.00	0.00	0.00	0.00	0.00	73.50	87.60	161.10	161.10
Cedar Creek	0.01	0.00	0.00	0.20	0.21	1,664.36	1,878.04	3,542.40	3,542.61
Cedar Lake	0.00	0.00	0.00	0.00	0.00	212.84	1,362.21	1,575.05	1,575.05
Chambers Creek	0.00	0.00	0.00	0.00	0.00	82.08	105.88	187.96	187.96
East Branch Milwaukee River	0.00	0.00	0.00	0.00	0.00	270.07	521.74	791.81	791.81
Kettle Moraine Lake	0.00	0.00	0.00	0.00	0.00	157.94	540.89	698.83	698.83
Kewaskum Creek	0.00	0.00	0.00	0.00	0.00	198.48	180.39	378.87	378.87
Lake Fifteen Creek	0.00	0.00	0.00	0.00	0.00	114.69	340.61	455.30	455.30
Lincoln Creek	0.79	111.29	57.96	0.00	170.04	4,178.24	0.28	4,178.52	4,348.56
Lower Cedar Creek	0.00	2.78	0.00	1.67	4.45	1,637.71	851.03	2,488.74	2,493.19
Lower Milwaukee River	9.84	296.62	1,820.95	0.00	2,127.41	7,522.97	973.60	8,496.57	10,623.98
Middle Milwaukee River	0.02	0.00	0.00	27.70	27.72	1,909.21	1,396.42	3,305.63	3,333.35
Mink Creek	0.00	0.00	0.00	0.00	0.00	183.01	263.94	446.95	446.95
North Branch Milwaukee River	0.67	1.77	0.00	8.19	10.63	814.80	1,623.75	2,438.55	2,449.18
Silver Creek (Sheboygan County)	0.05	0.00	0.00	0.82	0.87	599.28	295.74	895.02	895.89
Silver Creek (West Bend)	0.00	0.00	0.00	0.00	0.00	722.20	210.56	932.76	932.76
Stony Creek	0.00	0.00	0.00	0.00	0.00	188.85	271.65	460.50	460.50
Upper Lower Milwaukee River	0.62	16.58	0.00	1.75	18.95	1,849.48	1,104.93	2,954.41	2,973.36
Upper Milwaukee River	0.11	0.00	0.00	1.21	1.32	820.18	809.09	1,629.27	1,630.59
Watercress Creek	0.00	0.00	0.00	0.00	0.00	201.89	723.77	925.66	925.66
West Branch Milwaukee River	0.00	0.00	0.00	0.00	0.00	697.12	824.04	1,521.16	1,521.16
Total	12.11	429.04	1,878.91	41.54	2,361.60	24,098.90	14,366.16	38,465.06	40,826.66
Percent of Total Load	<0.1	1.1	4.6	0.1	5.8	59.0	35.2	94.2	100.0

[a] *Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

The average annual nonpoint load of total phosphorus is estimated to be 126,350 pounds per year. About 16 percent of the total point and nonpoint source load is from urban nonpoint sources and about 30 percent is from rural nonpoint sources (see Table 120). The distribution of total load among the subwatersheds is shown on Map H-25 in Appendix H. Map H-26 shows the annual per acre loads of total phosphorus from the subwatersheds. Contributions of total phosphorus vary among the subwatersheds (see Table 120) from about 600 pounds per year from the Batavia Creek subwatershed to about 21,520 pounds per year from the Lower Milwaukee River subwatershed. The highest loads of total phosphorus are contributed by the Lower Milwaukee River and Cedar Creek subwatersheds. This reflects both the relatively high unit area load (pounds per acre) contributed by the Lower Milwaukee River subwatershed (see Table 121) and the large area of these subwatersheds. The highest unit area loads occur in the Lincoln Creek and Lower Milwaukee River subwatersheds.

The average annual nonpoint load of total suspended solids is estimated to be 57,468,000 pounds per year. About 30 percent of the total point and nonpoint source load is from urban nonpoint sources and about 68 percent is from rural nonpoint sources (see Table 121). The distribution of this load among the subwatersheds is shown in Map H-27 in Appendix H. Map H-28 shows the annual per acre loads of total suspended solids for the subwatersheds. Contributions of total suspended solids vary among the subwatersheds (see Table 121) from about 226,000 pounds per year from the Batavia Creek subwatershed to about 8,286,000 pounds per year from the Cedar Creek subwatershed. The highest loads of total suspended solids are contributed by the Lower Milwaukee River and the Cedar Creek subwatersheds. For both of these subwatersheds, this reflects the relatively large subwatershed areas and the relatively high unit area loads. The highest unit area loads occur in the Lincoln Creek, Cedar Lake, and Lower Milwaukee River subwatersheds.

Table 123

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Batavia Creek	0	0	0	0	0	560	18,950	19,510	19,510
Cedar Creek	40	0	0	4,580	4,620	13,420	286,240	299,660	304,280
Cedar Lake	0	0	0	0	0	1,610	24,990	26,600	26,600
Chambers Creek	0	0	0	0	0	650	18,970	19,620	19,620
East Branch Milwaukee River	0	0	0	0	0	2,080	41,270	43,350	43,350
Kettle Moraine Lake	0	0	0	0	0	1,220	58,780	60,000	60,000
Kewaskum Creek	0	0	0	0	0	1,780	42,100	43,880	43,880
Lake Fifteen Creek	0	0	0	0	0	920	20,270	21,190	21,190
Lincoln Creek	3,530	850	960	0	5,340	42,420	500	42,920	48,260
Lower Cedar Creek	<10	20	0	950	970	16,910	95,100	112,010	112,980
Lower Milwaukee River	64,010	2,270	16,950	0	83,230	79,020	109,560	188,580	271,810
Middle Milwaukee River	10	0	0	27,930	27,940	16,190	123,790	139,980	167,920
Mink Creek	0	0	0	0	0	1,420	49,620	51,040	51,040
North Branch Milwaukee River	7,560	10	0	9,530	17,100	6,410	171,210	177,620	194,720
Silver Creek (Sheboygan County)	0	0	0	350	350	3,680	44,550	48,230	48,580
Silver Creek (West Bend)	0	0	0	0	0	6,410	10,860	17,270	17,270
Stony Creek	0	0	0	0	0	1,440	39,770	41,210	41,210
Upper Lower Milwaukee River	350	130	0	77,920	78,400	17,730	123,670	141,400	219,800
Upper Milwaukee River	30	0	0	1,950	1,980	6,740	194,190	200,930	202,910
Watercress Creek	0	0	0	0	0	1,480	40,150	41,630	41,630
West Branch Milwaukee River	0	0	0	0	0	5,390	219,160	224,550	224,550
Total	75,530	3,280	17,910	123,210	219,930	227,480	1,733,700	1,961,180	2,181,110
Percent of Total Load	3.5	0.2	0.8	5.6	10.1	10.4	79.5	89.9	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

The average annual nonpoint source load of fecal coliform bacteria is estimated to be 38,465.06 trillion cells per year. About 59 percent of the total point and nonpoint source load is from urban nonpoint sources and about 35 percent is from rural nonpoint sources (see Table 122). The distribution of this load among the subwatersheds is shown in Map H-29 in Appendix H. Map H-30 shows the annual per acre loads of fecal coliform bacteria for the subwatersheds. Contributions of fecal coliform bacteria vary among the subwatersheds (see Table 122) from about 161.10 trillion cells per year from the Batavia Creek subwatershed to about 8,496.57 trillion cells per year from the Lower Milwaukee River subwatershed. The highest loads of fecal coliform bacteria are contributed by the Lower Milwaukee River and Lincoln Creek subwatersheds. This reflects the high unit area loads contributed by these subwatersheds and the relatively large area of the Lower Milwaukee River subwatershed.

The average annual nonpoint load of total nitrogen is estimated to be 1,961,180 pounds per year. About 10 percent of the total point and nonpoint source load is from urban nonpoint sources and about 80 percent is from rural nonpoint sources (see Table 123) The distribution of this load among the subwatersheds is shown in Map H-31 in Appendix H. Map H-32 shows the annual per acre loads of total nitrogen for the subwatersheds. Contributions of total nitrogen vary among the subwatersheds (see Table 123) from about 17,270 pounds per year from the Silver Creek (West Bend) subwatershed to about 299,660 pounds per year from the Cedar Creek subwatershed. The highest loads of total nitrogen are contributed by the Cedar Creek and the West Branch Milwaukee River subwatersheds. This is due to both the relatively large area of these subwatersheds and to those subwatersheds having the highest unit area loads. The highest unit area loads occur in the Cedar Creek and West Branch Milwaukee River subwatersheds.

Table 124

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE MILWAUKEE RIVER WATERSHED[a]

	Point Sources					Nonpoint Sources			
Subwatershed	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Batavia Creek	0	0	0	0	0	4,000	24,470	28,470	28,470
Cedar Creek	60	0	0	10,370	10,430	105,650	632,050	737,700	748,130
Cedar Lake	0	0	0	0	0	12,700	68,630	81,330	81,330
Chambers Creek	0	0	0	0	0	5,140	23,440	28,580	28,580
East Branch Milwaukee River	0	0	0	0	0	15,060	82,180	97,240	97,240
Kettle Moraine Lake	0	0	0	0	0	8,880	120,250	129,130	129,130
Kewaskum Creek	0	0	0	0	0	11,340	81,960	93,300	93,300
Lake Fifteen Creek	0	0	0	0	0	7,770	41,080	48,850	48,850
Lincoln Creek	15,210	1,440	720	0	17,370	216,100	1,840	217,940	235,310
Lower Cedar Creek	20	40	0	20,080	20,140	85,590	185,110	270,700	290,840
Lower Milwaukee River	259,990	3,830	22,550	0	286,370	388,570	234,560	623,130	909,500
Middle Milwaukee River	20	0	0	296,770	296,790	108,290	220,120	328,410	625,200
Mink Creek	0	0	0	0	0	10,490	56,310	66,800	66,800
North Branch Milwaukee River	7,020	20	0	6,080	13,120	50,380	267,240	317,620	330,740
Silver Creek (Sheboygan County)	4,330	0	0	2,990	7,320	26,810	63,180	89,990	97,310
Silver Creek (West Bend)	0	0	0	0	0	36,060	23,710	59,770	59,770
Stony Creek	0	0	0	0	0	10,240	51,490	61,730	61,730
Upper Lower Milwaukee River	2,770	210	0	52,690	55,670	103,450	199,780	303,230	358,900
Upper Milwaukee River	1,030	0	0	10,830	11,860	44,460	373,160	417,620	429,480
Watercress Creek	0	0	0	0	0	10,130	86,840	96,970	96,970
West Branch Milwaukee River	0	0	0	0	0	42,450	373,130	415,580	415,580
Total	290,450	5,540	23,270	399,810	719,070	1,303,560	3,210,530	4,514,090	5,233,160
Percent of Total Load	5.6	0.1	0.4	7.6	13.7	24.9	61.4	86.3	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

The average annual nonpoint load of BOD is estimated to be 4,514,090 pounds per year. About 25 percent of the total point and nonpoint source load is from urban nonpoint sources and about 61 percent is from rural nonpoint sources (see Table 124). The distribution of this load among the subwatersheds is shown in Map H-33 in Appendix H. Map H-34 shows the annual per acre loads of BOD for the subwatersheds. Contributions of BOD vary among the subwatersheds (see Table 124) from a low of about 28,470 pounds per year from the Batavia Creek subwatershed to about 737,700 pounds per year from the Cedar Creek subwatershed. The highest loads of BOD are contributed by the Cedar Creek and the Lower Milwaukee River subwatersheds. This is due to both the relatively large area of these subwatersheds and to those subwatersheds having high unit area loads. The highest unit area loads occur in the Lincoln Creek and Cedar Creek subwatersheds.

The average annual nonpoint load of copper is estimated to be 3,657 pounds per year. About 53 percent of the total point and nonpoint source load is from urban nonpoint sources and about 31 percent is from rural nonpoint sources (see Table 125). The distribution of this load among the subwatersheds is shown in Map H-35 in Appendix H. Map H-36 shows the annual per acre loads of copper for the subwatersheds. Contributions of copper vary among the subwatersheds (see Table 125) from 18 pounds per year from the Batavia Creek subwatershed to 785 pounds per year from the Lower Milwaukee River subwatershed. The highest loads of copper are contributed by the Lower Milwaukee River, Lincoln Creek, and Cedar Creek subwatersheds. In the cases of the Lincoln Creek and Lower Milwaukee River subwatersheds, this reflects relatively large unit area loads, and in the cases of the Lower Milwaukee River and Cedar Creek subwatersheds this reflects relatively large subwatershed areas. The highest unit area loads occur in the Lincoln Creek, Lower Milwaukee River, and Cedar Lake subwatersheds. The overall average urban unit area load of copper is 0.016 pound per acre per year and the average rural unit area load is 0.006 pound per acre per year.

Table 125

AVERAGE ANNUAL LOADS OF COPPER IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Batavia Creek	0	0	0	0	0	7	11	18	18
Cedar Creek	0	0	0	46	46	190	187	377	423
Cedar Lake	0	0	0	0	0	23	76	99	99
Chambers Creek	0	0	0	0	0	9	13	22	22
East Branch Milwaukee River	0	0	0	0	0	27	61	88	88
Kettle Moraine Lake	0	0	0	0	0	16	47	63	63
Kewaskum Creek	0	0	0	0	0	20	21	41	41
Lake Fifteen Creek	0	0	0	0	0	14	30	44	44
Lincoln Creek	0	1	2	0	3	380	1	381	384
Lower Cedar Creek	0	0	0	97	97	146	83	229	326
Lower Milwaukee River	0	2	50	0	52	684	101	785	837
Middle Milwaukee River	0	0	0	307	307	192	119	311	618
Mink Creek	0	0	0	0	0	19	30	49	49
North Branch Milwaukee River	0	0	0	18	18	93	144	237	255
Silver Creek (Sheboygan County)	0	0	0	15	15	49	30	79	94
Silver Creek (West Bend)	0	0	0	0	0	62	19	81	81
Stony Creek	0	0	0	0	0	18	30	48	48
Upper Lower Milwaukee River	0	0	0	113	113	181	96	277	390
Upper Milwaukee River	0	0	0	38	38	80	99	179	217
Watercress Creek	0	0	0	0	0	18	55	73	73
West Branch Milwaukee River	0	0	0	0	0	77	99	176	176
Total	0	3	52	634	689	2,305	1,352	3,657	4,346
Percent of Total Load	0	0.1	1.2	14.6	15.9	53.0	31.1	84.1	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Wet-Weather and Dry-Weather Loads

It is important to distinguish between instream water quality during dry weather conditions and during wet weather conditions. Differences between wet-weather and dry-weather instream water quality reflect differences between the dominant sources and loadings of pollutants associated with each condition. Dry-weather instream water quality reflects the quality of ground water discharge to the stream plus the continuous or intermittent discharge of various point sources, for example industrial cooling or process waters, and leakage or other unplanned dry-weather discharges from sanitary sewers or private process water systems. While instream water quality during wet weather conditions includes the above discharges, and in extreme instances discharges from separate and/or combined sanitary sewer overflows, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble or insoluble substances carried into streams by direct land surface runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales, street and highway ditches, and gutters, or by underground storm sewer systems.

Daily average loads of six pollutants—total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper, were estimated for both wet-weather and dry-weather conditions for two sites along the Milwaukee River—the Port Washington Road station (River Mile 6.91) and the Pioneer Road station near Cedarburg (River Mile 26.25)—based upon flow and water quality data. To facilitate comparison of the estimates for these two stations, flow duration curves were developed for the same period: 1981-2004. In addition, daily average loads of total phosphorus were estimated for wet weather and dry weather conditions for one tributary, the East Branch of the Milwaukee River at New Fane (River Mile 5.71). A water quality sample was assumed to represent wet-weather conditions when daily mean flow was in the upper 20th percentile of the flow duration curve for the relevant flow gauge. This includes flows that are high due to rainfall events, runoff from snowmelt, or a combination of rainfall and snowmelt. The flow duration curves for

Table 126

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds per acre)	Total Suspended Solids (pounds per acre)	Fecal Coliform Bacteria (trillions of cells per acre)	Total Nitrogen (pounds per acre)	Biochemical Oxygen Demand (pounds per acre)	Copper (pounds per acre)
Batavia Creek	0.12	45	0.03	3.92	5.72	0.004
Cedar Creek	0.39	174	0.07	6.29	15.48	0.008
Cedar Lake	0.41	197	0.25	4.17	12.74	0.016
Chambers Creek	0.11	45	0.03	3.47	5.05	0.004
East Branch Milwaukee River	0.12	45	0.04	1.95	4.38	0.004
Kettle Moraine Lake	0.30	178	0.06	5.22	11.24	0.005
Kewaskum Creek	0.30	139	0.05	5.85	12.43	0.005
Lake Fifteen Creek	0.18	99	0.06	2.69	6.21	0.006
Lincoln Creek	0.62	220	0.33	3.34	16.95	0.030
Lower Cedar Creek	0.31	162	0.09	4.16	10.06	0.009
Lower Milwaukee River	0.49	189	0.19	4.32	14.28	0.018
Middle Milwaukee River	0.29	140	0.10	4.25	9.97	0.009
Mink Creek	0.11	43	0.03	3.92	5.13	0.004
North Branch Milwaukee River	0.16	68	0.05	3.79	6.78	0.005
Silver Creek (Sheboygan County)	0.17	65	0.07	3.82	7.13	0.006
Silver Creek (West Bend)	0.33	165	0.15	2.86	9.89	0.013
Stony Creek	0.11	43	0.04	3.29	4.92	0.004
Upper Lower Milwaukee River	0.27	134	0.09	4.38	9.39	0.009
Upper Milwaukee River	0.28	147	0.05	5.60	11.63	0.005
Watercress Creek	0.25	141	0.09	3.85	8.98	0.007
West Branch Milwaukee River	0.28	143	0.04	6.10	11.28	0.005

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

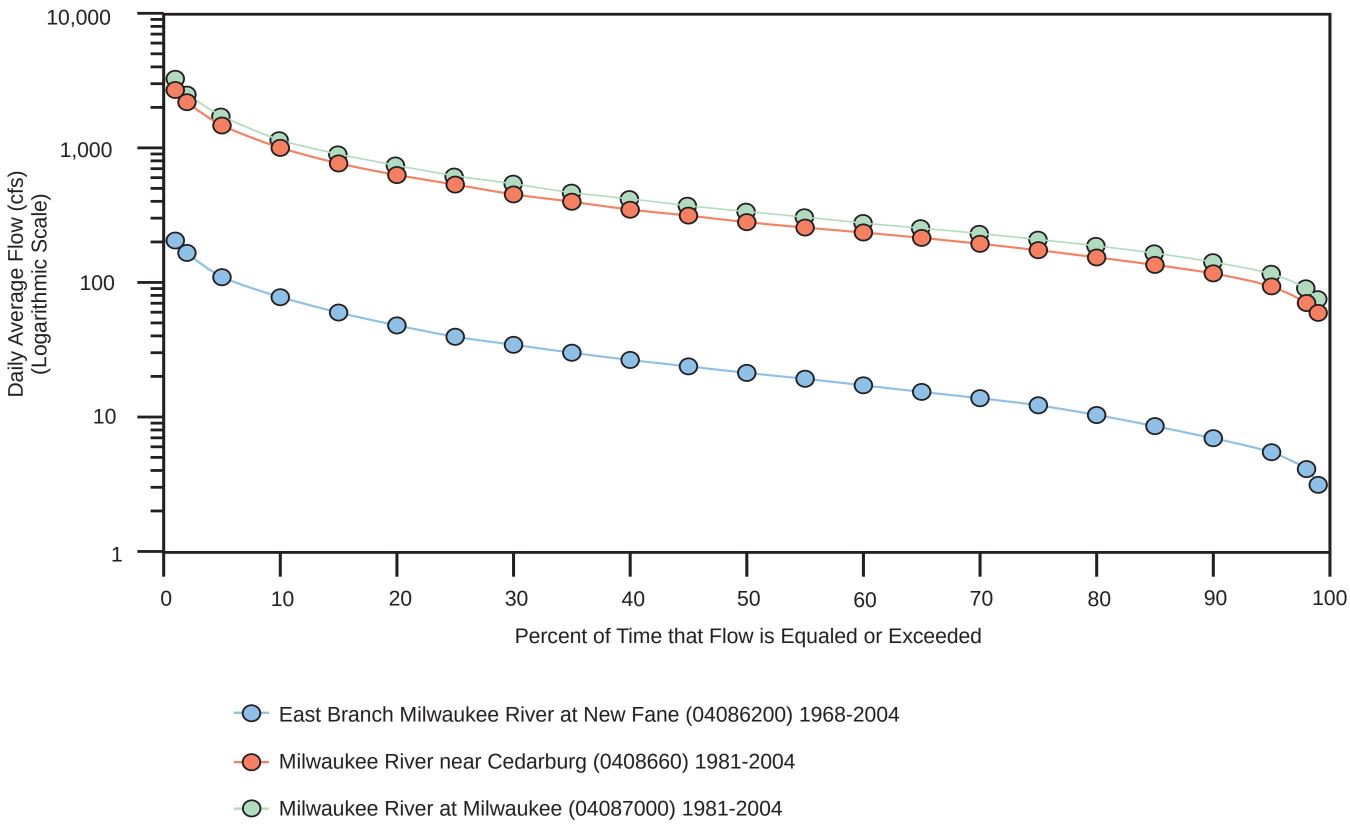
Source: Tetra Tech, Inc.

the Milwaukee River at Estabrook Park (River Mile 6.65), the gauge nearest Port Washington Road, the Milwaukee River near Cedarburg, and the East Branch of the Milwaukee River at New Fane are shown in Figure 184. For the Port Washington Road station along the Milwaukee River, water quality samples were considered to reflect wet-weather conditions when daily mean flow at Estabrook Park for the corresponding date equaled or exceeded 730 cubic feet per second (cfs). For the Pioneer Road station along the Milwaukee River, water quality samples were considered to reflect wet-weather conditions when daily mean flow at the gauge near Cedarburg equaled or exceeded 628 cfs. For the New Fane station along the East Branch of the Milwaukee River, water quality samples were considered to reflect wet-weather conditions when daily mean flow at the gauge at New Fane equaled or exceeded 48 cfs. On dates when daily mean flow was less than these thresholds, the corresponding water quality samples were considered to reflect dry-weather conditions. Daily average pollutant loads were estimated by appropriately combining daily average flow and pollutant ambient concentration.

Figure 185 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Milwaukee River at the Port Washington Road sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 1,863 pounds, which is slightly over eight times the mean estimated daily average dry-weather load of about 230 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 761,300 pounds, about 22 times the mean estimated daily average dry-weather load of about 35,130 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 135 trillion cells, about 1.5 times the mean estimated daily average dry-weather load of 83 trillion cells. For the baseline period, the mean

Figure 184

FLOW DURATION CURVES FOR USGS STREAM GAUGES IN THE MILWAUKEE RIVER WATERSHED



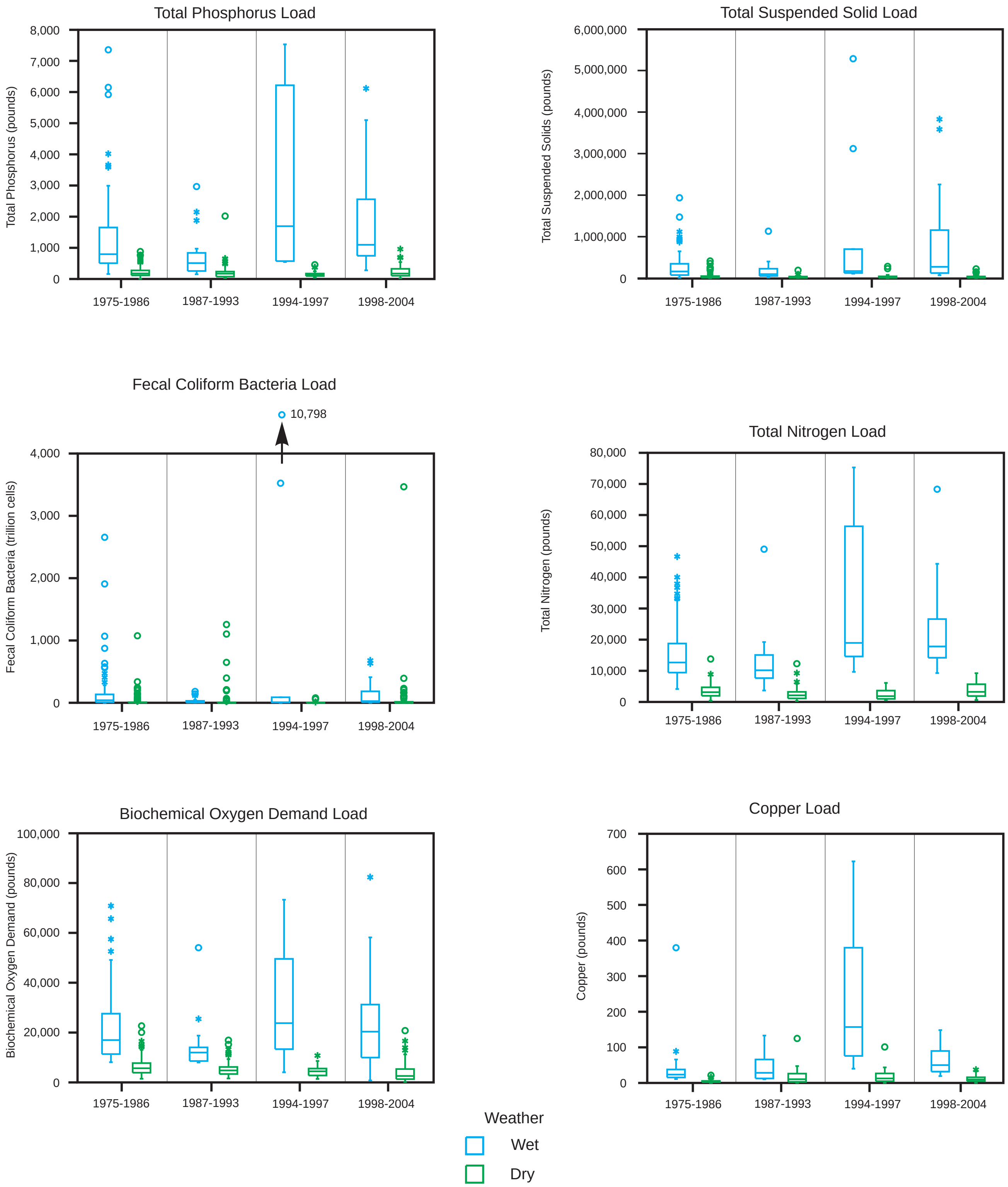
Source: U.S. Geological Survey and SEWRPC.

estimated daily average wet-weather load of total nitrogen was 23,400 pounds, nearly six times the mean estimated daily average dry-weather load of 3,983 pounds. For the baseline period, the mean estimated daily average wet-weather load of BOD was about 23,600 pounds, over five times the mean estimated daily average dry-weather load of about 4,170 pounds. For the baseline period, the mean estimated daily wet-weather load of copper was about 64.2 pounds, almost five times the mean estimated daily dry-weather load of about 13.2 pounds.

Figure 186 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Milwaukee River at the Pioneer Road sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 1,640 pounds, which is almost eight times the mean estimated daily average dry-weather load of about 208 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 415,400 pounds, about 21 times the mean estimated daily average dry-weather load of about 20,240 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 128 trillion cells, about 14 times the mean estimated daily average dry-weather load of 9.1 trillion cells. For the baseline period, the mean estimated daily average wet-weather load of total nitrogen was 22,300 pounds, over five times the mean estimated daily average dry-weather load of 4,090 pounds. For the baseline period, the mean estimated daily average wet-weather load of BOD was about 20,000 pounds, over eight times the mean estimated daily average dry-weather load of 2,420 pounds. For the baseline period, the mean estimated daily wet-weather load of copper was about 74.5 pounds, almost seven times the mean estimated daily dry-weather load of about 11.1 pounds.

Figure 185

DAILY AVERAGE POLLUTION LOADS IN THE MILWAUKEE RIVER AT PORT WASHINGTON ROAD (RIVER MILE 6.91): 1975-2004

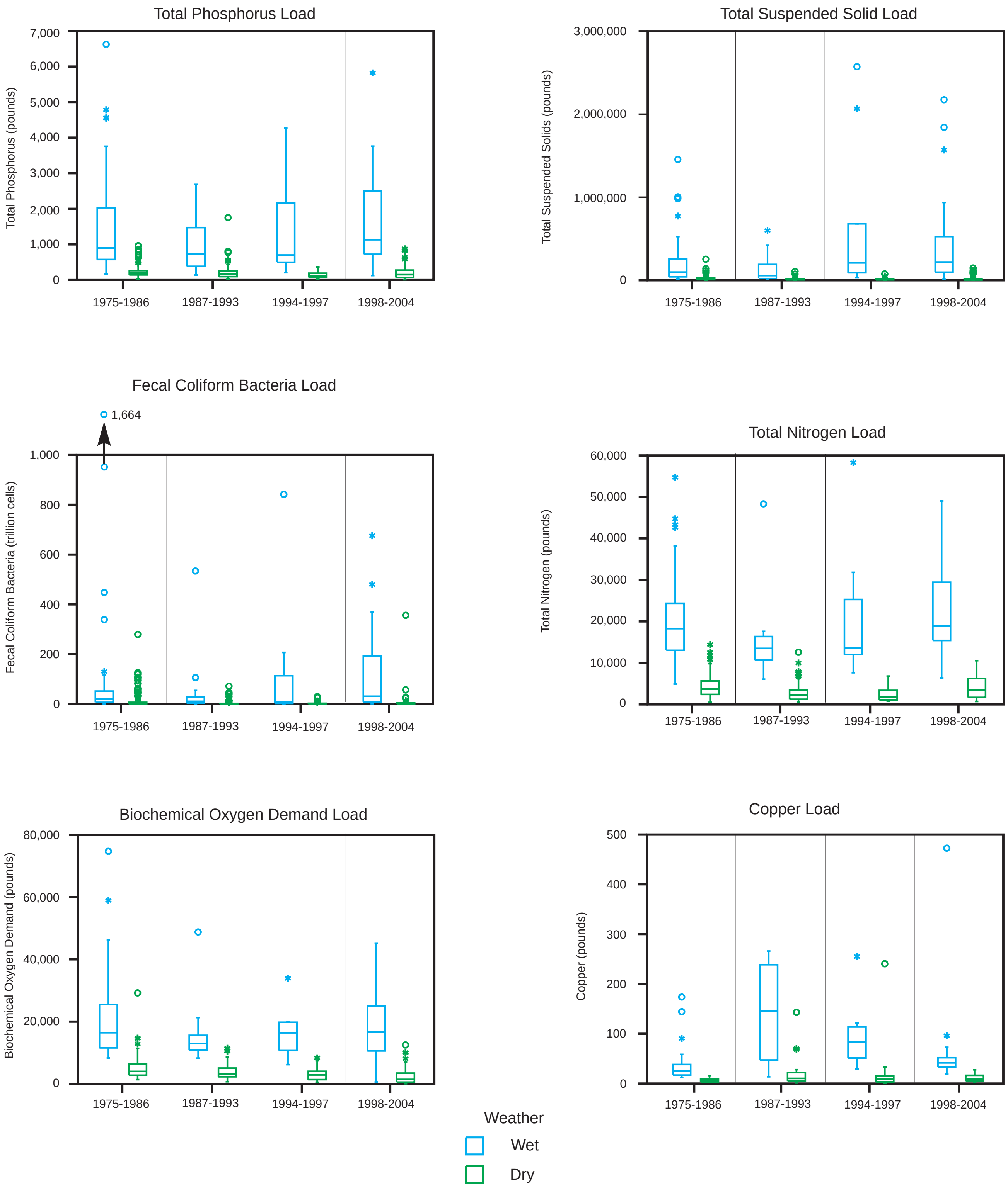


NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 186

DAILY AVERAGE POLLUTION LOADS IN THE MILWAUKEE RIVER AT PIONEER ROAD (RIVER MILE 26.25): 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

For most of the pollutants examined, the estimated mean dry-weather loads at the Pioneer Road station represented about 85 to 96 percent of the estimated mean dry-weather loads at the Port Washington Road station. There were three exceptions to this. The estimated mean dry-weather loads of TSS and BOD at Pioneer Road represented about 58 percent of the estimated mean dry-weather loads of TSS and BOD at Port Washington Road. There was an even greater difference between the estimated mean dry-weather loads of fecal coliform bacteria from these two stations. The estimated mean dry-weather load of fecal coliform bacteria at Pioneer Road represented about 11 percent of the estimated mean dry-weather load of fecal coliform bacteria at Port Washington Road. The estimated mean wet-weather loads at the Pioneer Road station also represented about 85 to 96 percent of the estimated mean wet-weather loads at the Port Washington Road station. There were two exceptions to this. The estimated mean wet-weather load of TSS at Pioneer Road represented about 55 percent of the estimated mean wet-weather load of TSS at Port Washington Road, and the estimated mean wet-weather load of copper at Pioneer Road was about 16 percent higher than the estimated mean wet-weather load at Port Washington Road. This was due to the presence of a single exceptionally high outlier in the wet-weather data from the Pioneer Road station (see Figure 186). When this outlier was removed from the data set, the estimated mean wet-weather load of copper at Pioneer Road represented about 68 percent of the estimated mean wet-weather load at Port Washington Road.

Figures 185 and 186 also show the occurrence of individual wet-weather events during which the estimated daily average pollutant load was many times higher than typical wet-weather loads. The presence of these outliers indicates that individual wet-weather events can contribute a substantial fraction of the annual pollutant load to the River. For example, Figure 185 shows that the maximum estimated daily average wet-weather load of total suspended solids detected at the Port Washington Road station during the baseline period of 1998-2004 was about 3.8 million pounds. Comparing this to Table 121 shows that this single day’s load represents about 7 percent of the estimated average annual load of total suspended solids in the entire watershed. Similarly, Figure 186 shows that the maximum daily estimated wet-weather load of copper detected at the Pioneer Road station along the mainstem during the baseline period of 1998-2004 was about 473 pounds. Comparing this to Table 125 shows that this single day’s load represents about 11 percent of the estimated average annual load of copper in the entire watershed. While these two examples may represent extreme cases, they do indicate that a large fraction of the annual pollutant load to the watershed can be contributed by a small number of wet-weather events.

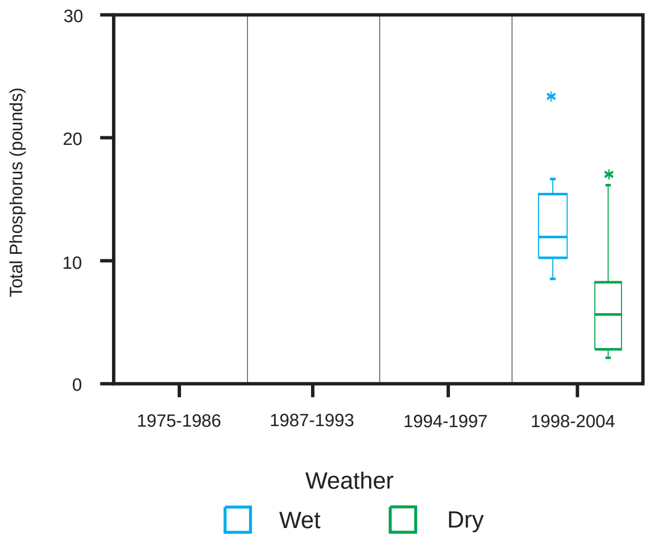
For most tributaries, there were not sufficient data to estimate average daily dry-weather and wet-weather loads of pollutants. Sufficient data were available to estimate loads of total phosphorus for the East Branch Milwaukee River at New Fane. Figure 187 shows the daily average pollutant loads for total phosphorus from the East Branch Milwaukee River at the New Fane sampling station. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 13.1 pounds, which is about twice the mean estimated daily average dry-weather load of about 6.4 pounds.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE MILWAUKEE RIVER AND ITS TRIBUTARIES

The water use objectives and the supporting water quality standards and criteria for the Milwaukee River watershed are documented in Chapter IV of this report. Most of the stream reaches in the Milwaukee River watershed are recommended for fish and aquatic life and full recreational uses. A few are recommended for coldwater uses. Auburn Lake Creek upstream from Auburn Lake, Chambers Creek, Gooseville Creek, Melius Creek, Nichols Creek, and Watercress Creek are all considered coldwater streams and subject to standards under which dissolved oxygen concentrations are not to be less than 7.0 mg/l during spawning and 6.0 mg/l during the rest of the year. The other exceptions to the fish and aquatic life and full recreational use designations are subject to variances under Chapter NR 104 of the *Wisconsin Administrative Code*. Silver Creek (Sheboygan County) downstream from the Random Lake sewage treatment plant to the first crossing of Creek Road is recommended for limited forage fish and is subject to a variance under which dissolved oxygen concentrations are not to be less than 3.0 mg/l. Indian Creek, Lincoln Creek, and the mainstem of the Milwaukee River downstream from the site of the former North Avenue dam are subject to special variances under which dissolved oxygen concentrations are

Figure 187

DAILY AVERAGE TOTAL PHOSPHORUS LOADS IN THE EAST BRANCH OF THE MILWAUKEE RIVER AT NEW FANE ROAD (RIVER MILE 5.71): 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.*

not to be less than 2.0 mg/l and concentrations of fecal coliform bacteria are not to exceed 1,000 cells per 100 ml as a geometric mean based on not less than five samples per month.

Based upon the available data for sampling stations in the watershed, the mainstem of the Milwaukee River and its major tributaries did not fully meet the water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial regional water quality management plan. Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of the streams in the watershed.[73]

During the 1998-2004 extended baseline period, the recommended water use objectives were only being partially achieved in much of the Milwaukee River watershed. Table 127 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2004 shows the following:

- Ammonia concentrations in all but one sample taken along the mainstem and all samples from 15 tributaries were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.

- Dissolved oxygen concentrations from stations along the mainstem of the Milwaukee River at Port Washington Road and at the site of the former North Avenue dam were occasionally below the relevant standard. Dissolved oxygen concentrations at stations along the mainstem of the River above the dam at Kewaskum were sometimes below the relevant standard indicating more-frequent violations of the standard. Dissolved oxygen concentrations from all of the samples from 11 tributaries were above the relevant standard, indicating compliance with the standard. In three additional tributaries, Lincoln Creek, Quaas Creek, and Southbranch Creek, dissolved oxygen concentrations were occasionally below the relevant standard. Dissolved oxygen concentrations in two tributaries, the North Branch Milwaukee River and the West Branch Milwaukee River, were commonly below the relevant standard, indicating more-frequent violations of the standard.

- Water temperatures in all samples taken from the mainstem of the Milwaukee River and from 16 tributaries were at or below the relevant standard, indicating compliance with the standard. The water temperature in one of 127 samples taken from Cedar Creek was above the relevant standard, indicating an isolated incidence of violation of the standard.

[73]*SEWRPC Memorandum Report No. 93*, op. cit.

Table 127

CHARACTERISTICS OF STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1998-2004

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Mainstem									
Milwaukee River above Dam at Kewaskum	22.9	84.0 (144)	100.0 (191)	- -	63.8 (58)	60.0 (10)	Very poor to excellent (3)	Poor to good (12)	- -
Milwaukee River between Dam at Kewaskum and CTH M near Newburg	20.5	100.0 (117)	100.0 (121)	- -	74.5 (51)	72.7 (11)	Fair to excellent (4)	Fair to good (4)	- -
Milwaukee River between CTH M near Newburg and Waubeka	12.3	100.0 (95)	100.0 (110)	- -	78.6 (42)	100.0 (9)	Fair to excellent (5)	Poor to good (10)	- -
Milwaukee River between Waubeka and Pioneer Road near Cedarburg	19.2	100.0 (95)	100.0 (95)	98.9 (90)	38.4 (112)	41.1 (90)	Good to excellent (5)	Fair to good (3)	Bacteria, fish consumption advisory[f]
Milwaukee River between Pioneer Road near Cedarburg and Brown Deer Road	11.3	100.0 (87)	100.0 (88)	100.0 (70)	44.8 (87)	30.7 (88)	- -	- -	Bacteria, fish consumption advisory
Milwaukee River between Brown Deer Road and Silver Spring Drive	6.5	100.0 (81)	100.0 (81)	100.0 (64)	42.5 (80)	38.3 (81)	Excellent (4)	Fair to good (3)	Bacteria, fish consumption advisory
Milwaukee River between Silver Spring Drive and Port Washington Road	1.6	94.1 (85)	100.0 (85)	100.0 (69)	42.9 (84)	30.6 (85)	- -	- -	Bacteria, fish consumption advisory
Milwaukee River between Port Washington Road and Estabrook Park	0.3	100.0 (75)	100.0 (76)	100.0 (76)	42.4 (92)	54.5 (11)	- -	Poor to good (3)	Bacteria, fish consumption advisory
Milwaukee River between Estabrook Park and former North Avenue Dam	3.6	98.6 (71)	100.0 (71)	100.0 (62)	37.1 (70)	19.7 (71)	Good to excellent (5)	Fair to good (9)	Bacteria, fish consumption advisory
Milwaukee River between former North Avenue Dam and Walnut Street	0.9	100.0 (87)	100.0 (87)	100.0 (74)	39.5 (86)	65.1 (83)	Very poor (1)	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Walnut Street and Wells Street	0.8	100.0 (84)	100.0 (84)	100.0 (75)	38.6 (83)	69.9 (83)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Wells Street and Water Street	0.6	100.0 (88)	100.0 (88)	100.0 (86)	37.5 (88)	68.2 (88)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Water Street and Union Pacific Railroad	0.3	100.0 (76)	100.0 (76)	100.0 (73)	64.5 (76)	77.3 (75)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Union Pacific Railroad and confluence with Lake Michigan	0.4	100.0 (2)	100.0 (2)	100.0 (2)	75.0 (4)	100.0 (3)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen consumption advisory

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries									
Upper Milwaukee River Subwatershed									
Unnamed Creek (T14N R18E NW SE 22)	1.3	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW SW 14)	1.9	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SW NE 28)	1.0	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW NE 27)	5.7	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE NW 36)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE SE 36)	0.7	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 6)	2.0	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW NE 06)	10.9	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE SW 34)	1.2	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E NW NE 9)	1.2	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E SE NE 4)	1.7	- -	- -	- -	- -	- -	- -	- -	- -
Lake Fifteen Creek Subwatershed									
Auburn Lake Creek[g]	7.4	- -	- -	- -	- -	- -	Fair to good (2)	Good (1)	- -
Unnamed Creek (T13N R19E SW NE 10) (Virgin Creek)	4.5	- -	- -	- -	- -	- -	- -	- -	- -
West Branch Milwaukee River Subwatershed									
West Branch Milwaukee River	20.1	60.0 (5)	100.0 (6)	100.0 (5)	61.5 (39)	- -	Poor to excellent (4)	Poor to good (10)	- -
Unnamed Creek (T14N R17E SE NE 36)	1.6	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE NE 16)	1.0	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R18E NW NE 26)	1.7	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 33)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Kewaskum Creek Subwatershed									
Kewaskum Creek	6.4	- -	- -	- -	70.6 (34)	- -	Fair (1)	Fair to good (5)	- -
Watercress Creek Subwatershed									
Watercress Creek	6.5	- -	- -	- -	- -	- -	Fair (1)	- -	- -
East Branch Milwaukee River Subwatershed									
East Branch Milwaukee River from Long Lake to STH 28	15.9	100.0 (125)	100.0 (139)	100.0 (6)	98.4 (62)	100.0 (10)	Fair to excellent (11)	Poor to excellent (17)	- -

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
East Branch Milwaukee River Subwatershed (continued)									
East Branch Milwaukee River from STH 28 to Confluence with West Branch Milwaukee River	2.3	- -	- -	- -	- -	- -	Good (1)	Fair (1)	- -
Unnamed Creek (T14N R19E SE NW 36) (Parnell Creek)	7.8	100.0 (6)	100.0 (6)	100.0 (7)	66.7 (6)	- -	- -	Good (5)	- -
Crooked Lake Creek	5.1	100.0 (6)	100.0 (6)	100.0 (6)	100.0 (6)	- -	Poor to very poor (2)	Fair to good (7)	- -
Lake Seven Outlet	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SW NE 14)	8.3	- -	- -	- -	- -	- -	- -	- -	- -
Middle Milwaukee River Subwatershed									
Unnamed Creek (T11N R20E SW SE 17)	2.2	- -	- -	- -	- -	- -	- -	- -	- -
Quaas Creek	5.9	99.1 (856)	100.0 (856)	- -	79.4 (34)	- -	Fair to very poor (5)	Fair to good (4)	- -
Myra Creek	2.6	- -	- -	- -	- -	- -	- -	- -	- -
Riveredge Creek	2.2	- -	100.0 (131)	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E NE SW 36)	1.5	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek West Bend Subwatershed									
Unnamed Creek (T11N R19E NE NW 14) (Engmon Creek)	1.5	- -	- -	- -	- -	- -	Very poor (1)	Good to poor (5)	- -
Silver Creek	4.0	- -	- -	- -	- -	- -	Very poor (3)	Good (1)	- -
North Branch Milwaukee River Subwatershed									
North Branch Milwaukee River	30.0	83.6 (140)	100.0 (197)	100.0 (12)	56.3 (64)	44.4 (9)	Fair (1)	Poor to good (3)	- -
Nichols Creek	3.3	- -	- -	- -	- -	- -	Poor to fair (4)	- -	- -
Unnamed Creek (T13N R21E NE NW 11)	0.5	- -	- -	- -	- -	- -	- -	- -	- -
Adell Tributary	5.1	- -	- -	- -	- -	- -	- -	Poor to fair (4)	Degraded habitat
Unnamed Creek (T14N R21E SW NE 31)	0.5	- -	- -	- -	- -	- -	- -		- -
Gooseville Creek	1.8	- -	- -	- -	- -	- -	Poor to fair (2)	- -	- -
Unnamed Creek (T12N R20E SE SE 2)	0.8	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW SW 3)	2.6	- -	- -	- -	- -	- -	- -	- -	- -
Wallace Creek	8.6	100.0 (5)	100.0 (6)	100.0 (5)	33.3 (6)	- -	Poor to fair (2)	Good (7)	- -

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
Chambers Creek Subwatershed									
Chambers Creek	2.9	- -	- -	- -	- -	- -	Poor (2)	Good (1)	- -
Unnamed Creek (T13N R20E NW NE 11)	0.9	- -	- -	- -	- -	- -	- -	- -	- -
Melius Creek	3.3	- -	- -	- -	- -	- -	Poor (2)	- -	- -
Batavia Creek Subwatershed									
Batavia Creek	5.0	- -	- -	- -	65.8 (32)	- -	- -	- -	- -
Mink Creek Subwatershed									
Mink Creek	17.3	- -	- -	- -	- -	- -	Poor to good (5)	Good (2)	- -
Unnamed Creek (T13N R20E SE NE 34)	3.6	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek Subwatershed									
Unnamed Creek (T13N R21E SE NE 23)	1.4	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek	10.5	- -	- -	- -	- -	- -	Poor (2)	Poor to good (6)	- -
Unnamed Creek (T13N R21E NE NW 32)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Stony Creek Subwatershed									
Stony Creek	10.0	100.0 (6)	100.0 (6)	100.0 (6)	100.0 (6)	- -	Poor to fair (3)	Good (6)	- -
Unnamed Creek (T12N R20E SW NW 8)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Upper Lower Milwaukee River Subwatershed									
Fredonia Creek	4.1	- -	- -	- -	- -	- -	- -	Poor to good (4)	- -
Mole Creek	4.0	100.0 (5)	100.0 (6)	100.0 (5)	100.0 (6)	- -	Very poor to fair (9)	Poor to good (11)	- -
Cedar Lake Subwatershed									
Unnamed Creek (T10N R19E NW NE 5)	1.7	- -	- -	- -	- -	- -	- -	- -	- -
Cedar Creek Subwatershed									
Cedar Creek	31.5	100.0 (124)	99.2 (127)	100.0 (6)	94.9 (59)	92.9 (14)	Good (3)	Fair to good (4)	Fish consumption advisory
Kressin Creek	4.7	- -	- -	- -	- -	- -	- -	- -	- -
Little Cedar Creek	6.0	- -	- -	- -	- -	- -	Fair (1)	Fair to good (5)	- -
Little Cedar Lake Outlet	1.7	- -	- -	- -	- -	- -	Very poor to fair (9)	Poor to good (12)	- -
Lehner Creek	0.3	- -	- -	- -	- -	- -	Very poor (2)	Good (1)	Degraded habitat, temperature

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a] Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria	Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
Tributaries (continued)									
Cedar Creek Subwatershed (continued)									
Unnamed Creek (T10N R20E SW SE 19) (Jackson Creek)	1.3	- -	- -	- -	- -	- -	- -	- -	Degraded habitat
Polk Springs Creek	1.9	100.0 (161)	100.0 (167)	100.0 (89)	48.7 (39)	- -	Very poor to poor (3)	Poor to good (6)	- -
Friedens Creek	3.8	100.0 (5)	100.0 (6)	100.0 (5)	83.3 (6)	- -	Very poor (2)	Fair to good (6)	- -
Evergreen Creek	4.9	- -	- -	- -	- -	- -	- -	- -	Degraded habitat
Cedarburg Creek	3.0	- -	- -	- -	- -	- -	- -	- -	- -
Lower Cedar Creek Subwatershed									
Unnamed Creek (T10N R20E NE NE 1)	1.0	- -	- -	- -	- -	- -	- -	- -	- -
North Branch Cedar Creek	7.3	- -	- -	- -	- -	- -	Very poor to poor (2)	Poor to good (4)	- -
Lower Milwaukee River Subwatershed									
Ulao Creek	8.6	- -	- -	- -	- -	- -	Excellent (1)	Poor to fair (3)	- -
Pigeon Creek	2.4	100.0 (5)	100.0 (6)	100.0 (5)	100.0 (6)	- -	Poor (1)	Good (3)	- -
Trinity Creek	3.1	- -	- -	- -	- -	- -	- -	- -	- -
Beaver Creek	2.6	- -	- -	- -	- -	- -	- -	- -	Aquatic toxicity
Southbranch Creek above Bradley Road	0.1	100.0 (30)	100.0 (30)	100.0 (32)	3.3 (30)	38.7 (31)	- -	- -	- -
Southbranch Creek between Bradley Road and 55th Street	0.2	100.0 (39)	100.0 (34)	100.0 (32)	12.1 (33)	32.4 (34)	- -	- -	- -
Southbranch Creek between 55th Street and 47th Street	0.5	100.0 (36)	100.0 (36)	100.0 (30)	11.4 (35)	22.2 (36)	- -	- -	- -
Southbranch Creek between 47th Street and Teutonia Avenue	0.5	91.4 (35)	100.0 (35)	100.0 (28)	29.4 (34)	8.6 (35)	- -	- -	- -
Brown Deer Park Creek	2.2	- -	- -	- -	- -	- -	- -	- -	- -
Indian Creek	1.9	100.0 (32)	100.0 (32)	100.0 (28)	75.0 (28)	71.9 (32)	Very poor (1)	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature[h]
Lincoln Creek Subwatershed									
Wahl Creek	0.5	- -	- -	- -	- -	- -	- -	- -	- -
Lincoln Creek above 60th Street	0.9	100.0 (81)	100.0 (81)	100.0 (74)	57.5 (80)	76.3 (80)	- -	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
Lincoln Creek Subwatershed (continued)									
Lincoln Creek between 60th Street and 51st Street	1.5	100.0 (79)	100.0 (80)	100.0 (65)	77.2 (79)	47.5 (80)	- -	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature
Lincoln Creek between 51st Street and 55th Street	1.1	100.0 (61)	100.0 (61)	100.0 (56)	81.7 (60)	73.3 (60)	- -	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature
Lincoln Creek between 55th Street and 47th Street	2.5	100.0 (100)	100.0 (100)	100.0 (83)	37.6 (93)	34.5 (84)	Very poor (1)	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature
Lincoln Creek between 47th Street and Green Bay Avenue	2.9	97.6 (83)	100.0 (422)	100.0 (78)	14.6 (82)	37.3 (83)	Very poor (2)	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature

[a]*Number in parentheses shows number of samples.*

[b]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[c]*Based upon the acute toxicity criterion for ammonia.*

[d]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[e]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

[f]*The section of the Milwaukee River between Pioneer Road near Cedarburg and the Village of Grafton are listed as impaired due to fish consumption advisories and bacteria. The section of the River upstream from the Village of Grafton is not listed as impaired.*

[g]*Referred to as Lake Fifteen Creek in some reports.*

[h]*The natural channel downstream of Interstate Highway 43 is considered impaired. Reaches upstream from Interstate Highway 43 are not considered impaired.*

Source: SEWRPC.

- Fecal coliform bacteria standards were commonly exceeded at stations along the mainstem of the Milwaukee River, Indian Creek, Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek, indicating frequent violations of the standard. Fecal coliform bacteria standards were exceeded in one of 14 samples taken at one station along Cedar Creek, indicating an isolated incidence of violation of the standard. Fecal coliform bacteria concentrations along the East Branch Milwaukee River were at or below the relevant standard, indicating compliance with the standard.

- Concentrations of total phosphorus in the mainstem of the Milwaukee River and 12 tributaries commonly exceeded the planning levels recommended in the original regional water quality management plan. Concentrations of total phosphorus in two additional tributaries occasionally exceeded the recommended levels in the regional water quality management plan. Concentrations of total phosphorus in four tributaries were at or below the recommended levels in the regional water quality management plan.

Thus, during the baseline period, the stream reaches for which data are available substantially met the standards for ammonia, dissolved oxygen, and water temperature, but less frequently met the regulatory standard for fecal coliform bacteria and the planning standard for phosphorus. The streams only partially achieved the recommended water use objectives.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 128 summarizes the data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Milwaukee River watershed. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from sampling conducted by the USGS specifically for the regional water quality management plan update.

Pesticides were detected in water from three stations along the mainstem of the River and from stations along two tributary streams: Lincoln Creek and the North Branch of the Milwaukee River. The concentrations detected did not exceed water quality standards. Pesticides were detected in tissue from aquatic organisms at one station during the baseline period.

The concentrations of PCBs in tissue from all aquatic organisms examined during the baseline period from the mainstem of the Milwaukee River downstream from Pioneer Road were above the threshold used by the WDNR for issuing fish consumption advisories. Upstream from Pioneer Road, this threshold was exceeded in over 20 percent of fish tissue samples. In addition, concentrations of PCBs in tissue from the majority of aquatic organisms collected from Cedar Creek were above this threshold. High concentrations of PCBs were detected in sediment in the Milwaukee River in the Estabrook Impoundment, several impoundments along Cedar Creek in the City of Cedarburg, and in Zeunert Pond in Cedarburg. Release of PCBs from these deposits appears to account for a substantial portion of PCB mass transport in the lower Milwaukee River.

Water samples from 11 stations along the mainstem of the Milwaukee River showed detectable concentrations of several PAH compounds. These compounds were also detected in water samples collected at several stations along Lincoln Creek and Southbranch Creek. PAHs were also detected in sediment collected from Cedar Creek, the East Branch of the Milwaukee River, and the North Branch of the Milwaukee River.

Limited sampling for other organic compounds showed detectable concentrations of several compounds in water from the mainstem of the Milwaukee River and from Lincoln Creek. Compounds detected included pharmaceutical and personal care products such as the stimulant caffeine, industrial solvents such as isophorone, dye components such as carbazole, aroma and flavoring agents such as acetophenone and camphor, flame retardants, insect repellants such as DEET, and metabolites of nonionic detergents. Where water quality criteria have been promulgated, the concentrations of these substances were below the relevant criteria.

Table 128

TOXICITY CHARACTERISTICS OF STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1998-2004[a]

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Mainstem															
Milwaukee River above Dam at Kewaskum	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-50 (2)	- -	- -
Milwaukee River between Dam at Kewaskum and CTH M near Newburg	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (1)	- -	- -
Milwaukee River between CTH M near Newburg and Waubeka	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (1)	- -	- -
Milwaukee River between Waubeka and Pioneer Road near Cedarburg	D (3)	- -	- -	E-15 (13)	- -	E-22 (9)	D (13)	- -	- -	D (3)	- -	- -	E-77 (53)	- -	- -
Milwaukee River between Pioneer Road near Cedarburg and Brown Deer Road	- -	- -	- -	E-8 (13)	- -	E-100 (33)	D (13)	- -	- -	- -	- -	- -	E-70 (53)	- -	E-100 (9)
Milwaukee River between Brown Deer Road and Silver Spring Drive	- -	- -	- -	E-9 (11)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-72 (53)	- -	- -
Milwaukee River between Silver Spring Drive and Port Washington Road	- -	- -	- -	E-25 (12)	- -	- -	D (13)	- -	- -	D (6)	- -	- -	E-77 (53)	- -	- -
Milwaukee River between Port Washington Road and Estabrook Park	D (49)	D (2)	- -	- -	D (91)	- -	D (3)	- -	- -	- -	- -	- -	D (2)	D (4)	- -
Milwaukee River between Estabrook Park and former North Avenue Dam	- -	- -	- -	E-42 (12)	- -	- -	D (12)	- -	- -	- -	- -	- -	E-2 (46)	- -	- -
Milwaukee River between former North Avenue Dam and Walnut Street	- -	- -	D (3)	E-31 (13)	- -	E-100 (24)	D (12)	- -	- -	- -	- -	- -	E-23 (52)	- -	E-100 (9)
Milwaukee River between Walnut Street and Wells Street	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-24 (49)	- -	- -
Milwaukee River between Wells Street and Water Street	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-9 (53)	- -	- -
Milwaukee River between Water Street and Union Pacific Railroad	- -	- -	- -	E-23 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-3 (63)	- -	- -
Milwaukee River between Union Pacific Railroad and Confluence with Lake Michigan	D (3)	- -	- -	- -	- -	- -	D (3)	- -	- -	D (3)	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Upper Milwaukee River Subwatershed															
Unnamed Creek (T14N R18E NW SE 22)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW SW 14)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SW NE 28)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW NE 27)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE NW 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE SE 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 6)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW NE 06)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE SW 34)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E NW NE 9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E SE NE 4)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lake Fifteen Creek Subwatershed															
Auburn Lake Creek[c]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SW NE 10) Virgin Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
West Branch Milwaukee River Subwatershed															
West Branch Milwaukee River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R17E SE NE 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE NE 16)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R18E NW NE 26)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 33)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Kewaskum Creek Subwatershed															
Kewaskum Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Watercress Creek Subwatershed															
Watercress Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
East Branch Milwaukee River Subwatershed															
East Branch Milwaukee River from Long Lake to STH 28	- -	N (4)	- -	- -	N (4)	- -	- -	D (4)	- -	- -	- -	- -	- -	D (4)	- -
East Branch Milwaukee River from STH 28 to Confluence with West Branch Milwaukee River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R19E SE NW 36) Parnell Creek	N (3)	- -	- -	- -	- -	- -	N (3)	- -	- -	- -	- -	- -	- -	- -	- -
Crooked Lake Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lake Seven Outlet	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SW NE 14)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Middle Milwaukee River Subwatershed															
Unnamed Creek (T11N R20E SW SE 17)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Quaas Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Myra Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Riveredge Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E NE SW 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek (West Bend) Subwatershed															
Unnamed Creek (T11N R19E NE NW 14) Engmon Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
North Branch Milwaukee River Subwatershed															
North Branch Milwaukee River	D (6)	N (4)	- -	- -	D (4)	- -	- -	D (4)	- -	- -	- -	- -	- -	D (4)	- -
Nichols Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R21E NE NW 11)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Adell Tributary	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R21E SW NE 31)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Gooseville Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SE SE 2)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW SW 3)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Wallace Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Chambers Creek Subwatershed		- -													
Chambers Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R20E NW NE 11)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Melius Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Batavia Creek Subwatershed															
Batavia Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mink Creek Subwatershed															
Mink Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R20E SE NE 34)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek (Sheboygan) Subwatershed															
Unnamed Creek (T13N R21E SE NE 23)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW NW 8)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Stony Creek Subwatershed															
Stony Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW NW 8)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Upper Lower Milwaukee River Subwatershed															
Fredonia Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mole Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cedar Lake Subwatershed															
Unnamed Creek (T10N R19E NW NE 5)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cedar Creek Subwatershed															
Cedar Creek	- -	- -	- -	E-91 (22)	D (50)	E-80 (66)	- -	D (22)	- -	- -	- -	- -	N (1)	D (10)	D (4)
Kressin Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Little Cedar Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Little Cedar Lake Outlet	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lehner Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T10N R20E SW SE 19) Jackson Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Polk Springs Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Friedens Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Evergreen Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cedarburg Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Lower Cedar Creek Subwatershed															
Unnamed Creek (T10N R20E NE NE 1)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
North Branch Cedar Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lower Milwaukee River Subwatershed															
Ulao Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pigeon Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Trinity Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Beaver Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Southbranch Creek above Bradley Road	- -	- -	- -	N (3)	- -	- -	D (3)	- -	- -	- -	- -	- -	E-7 (28)	- -	- -
Southbranch Creek between Bradley Road and 55th Street	- -	- -	- -	N (4)	- -	- -	D (5)	- -	- -	- -	- -	- -	E-25 (28)	- -	- -
Southbranch Creek between 55th Street and 47th Street	- -	- -	- -	N (5)	- -	- -	D (5)	- -	- -	- -	- -	- -	E-7 (29)	- -	- -
Southbranch Creek between 47th Street and Teutonia Avenue	- -	- -	- -	N (6)	- -	- -	D (5)	- -	- -	- -	- -	- -	E-40 (30)	- -	- -
Brown Deer Park Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Indian Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-13 (8)	- -	- -
Lincoln Creek Subwatershed															
Wahl Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lincoln Creek above 60th Street	- -	- -	- -	E-8 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-12 (66)	- -	- -
Lincoln Creek between 60th Street and 51st Street	- -	- -	- -	N (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-8 (49)	- -	- -
Lincoln Creek between 51st Street and 55th Street	- -	- -	- -	E-11 (13)	- -	- -	D (9)	- -	- -	- -	- -	- -	D (54)	- -	- -
Lincoln Creek between 55th Street and 47th Street	D (13)	N (1)	- -	N (12)	- -	- -	D (14)	- -	- -	D (11)	- -	- -	E-9 (67)	- -	- -
Lincoln Creek between 47th Street and Green Bay Avenue	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-57 (54)	- -	- -
Lincoln Creek between Green Bay Avenue and the Confluence with the Milwaukee River	- -	- -	- -	- -	D (17)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples, D denotes detection of a substance in this class in at least one sample, N denotes that no substances in this class were detected in any sample.

[a] *Number in parentheses indicates sample size.*

[b] *Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sample sizes are shown for most metals. Mercury was sampled less frequently. For mercury, exceedances were determined based on the wildlife criterion of 1.3 nanograms per liter.*

[c] *Referred to as Lake Fifteen Creek in some reports.*

Source: SEWRPC.

Water samples from the long-term stations along the mainstem of the Milwaukee River and a few tributaries were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. While the sample sizes given in Table 128 are representative of sampling for most of these metals, it is important to note that mercury was sampled less intensively. The number of samples analyzed for mercury was about two-thirds the number analyzed for other metals. Detectable concentrations of each of these metals were present in samples from most of the stations tested. Several of these metals were present at times in concentrations that exceeded water quality standards. Concentrations of mercury in water commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations, which is the wildlife criterion, is given in Table 128. In addition, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration (CMC) for copper and concentrations of cadmium, chromium, lead, nickel, and zinc occasionally exceeded the chronic toxicity criteria for aquatic life, and more rarely, the acute criteria for aquatic life. Concentrations of mercury in the tissue from aquatic organisms collected from two stations along the mainstem of the River during the baseline period were above the threshold used by the WDNR for issuing fish consumption advisories.

The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially PCBs and mercury. The fish consumption advisories in effect for the Milwaukee River shown in Table 100 reflect this.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the USEPA for approval. Wisconsin most recently submitted this list in 2004.[74] This list was subsequently approved by the USEPA. Table 127 and Map 72 indicate stream reaches in the Milwaukee River watershed that are classified as being impaired waters. Three sections of the mainstem of the Milwaukee River are listed as impaired. The section of the River upstream of the Lime Kiln dam in the Village of Grafton is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. A 25-mile section of the Milwaukee River between the City of Grafton and site of the former North Avenue dam is considered impaired due to bacterial contamination and fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. The 3.1-mile reach of variance water between the confluence with Lake Michigan and the site of the former North Avenue dam is considered impaired due to aquatic toxicity, bacterial contamination, fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach, and lack of compliance with standards for dissolved oxygen concentration. Bacteria, metals, phosphorus, and PCBs from contaminated sediment and a combination of point and nonpoint sources are cited as factors contributing to the impairment of this section of the River. Several tributary streams are also listed as impaired. Adell Tributary, Evergreen Creek, Jackson Creek, and Lehner Creek are considered impaired due to habitat degradation from sedimentation related to nonpoint source pollution. Lehner Creek is also considered impaired due to high water temperatures. Beaver Creek is considered impaired due to aquatic toxicity related to nonpoint source pollution. A five-mile section of Cedar Creek between Bridge Road in the City of Cedarburg and the confluence with the Milwaukee River is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. PCBs from contaminated sediments are cited as factors contributing to the impairment of this section of Cedar Creek. Indian Creek downstream from IH 43, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures. Metals, phosphorus, and sedimentation related to nonpoint source pollution are cited as contributing to the impairment of this section of stream. Lincoln Creek, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures. Metals, PAHs, phosphorus, and sedimentation from undetermined sources are cited as factors contributing to the impairment of this stream.

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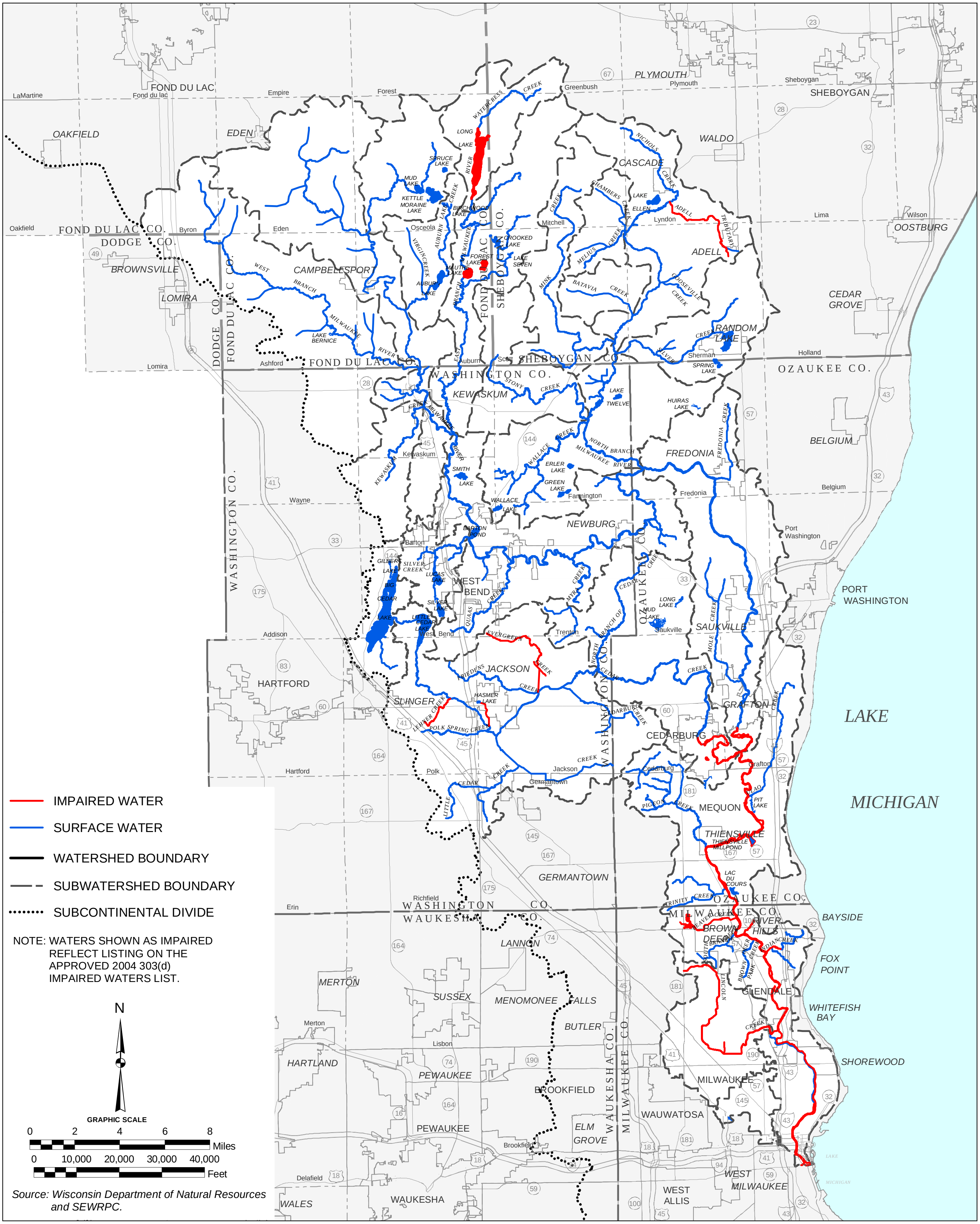
[74]*Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

Map 72

IMPAIRED WATERS WITHIN THE MILWAUKEE RIVER WATERSHED: 2004



Two lakes and one pond in the Milwaukee River watershed are also listed as being impaired. Forest Lake and Mauthe Lake are considered impaired due to fish consumption advisories necessitated by high concentrations of mercury in the tissue of fish collected from these lakes. Atmospheric deposition of mercury is cited as contributing to these impairments. Zeunert Pond in the City of Cedarburg is also considered impaired due to fish consumption advisories necessitated by high concentrations of mercury in the tissue of fish collected from this pond. Mercury in contaminated sediment is cited as contributing to this impairment.

SUMMARY

The water quality and pollution sources inventory for the Milwaukee River system has been summarized by answering five basic questions. This chapter provided detailed information needed to answer the questions. The information is presented below.

How Have Water Quality Conditions Changed Since 1975?

Water quality conditions in the Milwaukee River watershed have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality

Concentrations of several pollutants associated with combined sewer overflows such as BOD, fecal coliform bacteria, total phosphorus, and ammonia have decreased along much of the length of the Milwaukee River. These reductions in nutrients and oxygen-demanding wastes have produced some improvements in concentrations of chlorophyll-*a* and dissolved oxygen at some sampling stations, especially in the estuary during the summer. Decreases in the concentrations of some pollutants have also been detected in some tributaries to the Milwaukee River. These include decreases in concentrations of ammonia, BOD, and total phosphorus which have resulted in some improvements in chlorophyll-*a* concentrations in Cedar Creek and dissolved oxygen concentrations at some stations along Cedar Creek and Lincoln Creek. Improvements have also occurred in the concentrations of several toxic metals detected in the Milwaukee River and Lincoln Creek. These improvements likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the sanitary sewerage systems, and the implementation of treatment requirements for all industrial discharges.

No Change or Reductions in Water Quality

Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper, total suspended solids, and zinc have increased along much of the mainstem of the River. Increases in chloride concentration have also been observed in tributaries and lakes in the watershed for which sufficient data exist to assess trends. Concentrations of some nutrients, such as nitrate, total nitrogen, and dissolved phosphorus during the summer have also increased at several stations along the mainstem of the River. In addition, specific conductance has increased at most stations along the mainstem of the River, suggesting that the total concentration of dissolved material in the water has increased.

How Have Toxicity Conditions Changed Since 1975?

In some respects, toxicity conditions in the Milwaukee River watershed have improved since 1975; in other respects, they have declined or not changed.

Improvements in Toxicity Conditions

The concentrations of PCBs in water in Cedar Creek have declined. In addition, examinations of PCB congener composition indicate that the percentage of PCB congeners of greatest environmental concern in PCB samples in water has decreased over time at some sites along Cedar Creek. As part of remediation efforts, sediments contaminated with PCBs have been removed from Ruck Pond along Cedar Creek and from the banks of the former Hamilton Pond along Cedar Creek. This should reduce the toxic effects related to contaminated sediments in the Cedar Creek and the mainstem of the Milwaukee River.

No Change in Toxicity Conditions
Transport of PCBs from upstream is contributing about 15 kg per year of PCBs to the estuary sections of the Milwaukee River. In addition, fish consumption advisories remain in effect for portions of the watershed due to PCB contamination.

Inconclusive Toxicity Data
In some cases the available data are not adequate to assess changes. For example, pesticides continue to be detected in water samples in the mainstem of the Milwaukee River and several tributaries; however, methodological differences in the collection and analysis of historical and recent samples prevent assessment of trends in concentration. Similarly, PAHs continue to be detected in downstream sections of the mainstem of the Milwaukee River and in Lincoln Creek, but methodological differences in the collection and analysis of historical and recent samples prevent assessment of trends in concentration.

Sediment Conditions
The removal of sediments contaminated with PCBs from Ruck Pond and the banks of the former Hamilton Pond along Cedar Creek should reduce the toxicity of sediments in Cedar Creek and the mainstem of the Milwaukee River below the confluence with Cedar Creek; however, deposits of PCBs remain in sediment in impoundments along Cedar Creek, in the mainstem of the Milwaukee River at Thiensville Millpond and Estabrook Impoundment, in Lincoln Creek, and in Zeunert Pond in Cedarburg.

In the available data on sediment toxicity, the expected incidence of toxicity to benthic organisms ranges from less than 1 percent up to 100 percent at sites along the mainstem of the Milwaukee River. Most reaches along the mainstem with high toxicity are downstream from the confluence with Cedar Creek. In reaches along the mainstem upstream from Cedar Creek, the expected incidence of toxicity to benthic organisms is less than about 5 percent.

Data on sediment toxicity is available for only a few tributary streams. In Lincoln Creek and Cedar Creek, the expected incidence of toxicity to benthic organisms ranges from 20 to 100 percent and 9 to 100 percent, respectively. By contrast, the expected incidences of toxicity to benthic organisms in samples from the East Branch of the Milwaukee River are below 20 percent and the expected incidences of toxicity to benthic organisms from samples in the North Branch of the Milwaukee River and from Gooseville Creek are below 10 percent. The overall quality of sediment, as measured by mean PEC-Q, remains poor. Sediment at locations in the Milwaukee River watershed contains concentrations of PAHs arsenic, cadmium, chromium, copper, manganese, mercury, nickel, and zinc high enough to likely produce some toxic effects in benthic organisms and concentrations of PCBs high enough to pose substantial risks of toxicity to benthic organisms

Sediment Conditions
What Are the Sources of Water Pollution?
The Milwaukee River watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources
Twelve public sewage treatment plants and two private plants currently discharge into streams of the Milwaukee River watershed. MMSD has 65 combined sewer overflow outfalls that discharge to the streams of the Milwaukee River watershed. These outfalls convey a combination of stormwater runoff and sanitary sewage from the combined sewer system to the surface water system as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. Prior to 1994, overflows from these sites typically occurred around 50 times per year. Since MMSD's inline storage system came online in 1994, the number of combined sewer overflows per year has declined to about three. Since 1995, separate sanitary sewer overflows have been reported at 54 locations: 15 within MMSD's SSO area and 39 within local communities. The number of SSO events occurring per year has also declined compared to the time period prior to completion of the MMSD Water Pollution Abatement Program facilities in 1993. As of February 2003, 130 industrial dischargers

and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Milwaukee River watershed. About one third of the permitted facilities discharged noncontact cooling water. The remaining discharges are of a nature which typically meets or exceeds the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources

The Milwaukee River watershed is comprised of combinations of urban land uses and rural land uses. As of 2000, about 79 percent of the watershed was in rural and other open land uses. About 21 percent of the watershed is contained within planned sewer service areas: 8 percent within MMSD's planned service area, 3 percent within the sanitary sewer service areas of local communities that are connected to MMSD's conveyance and treatment systems, 4 percent within the City of West Bend's planned sewer service area, about 1 percent within each of the City of Cedarburg and Villages of Grafton and Jackson's planned sewer service areas, and less than 1 percent each within the City of Port Washington, the Villages of Adell, Campbellsport, Cascade, Fredonia, Kewaskum, Lomira, Newburg, Random Lake, and Slinger and Waubeka's planned sewer service areas. The status of adoption of stormwater management ordinances and/or plans and of construction erosion control ordinances in each community and county in the watershed is set forth in Table 117. That table also indicates which communities have established either stormwater utilities, general funds, or stormwater fee programs. As of 2005, there were two active solid waste landfills within the watershed, both located in the West Branch Milwaukee River subwatershed. As set forth in Table 118 and shown on Map 71, there are 47 inactive landfills in the watershed: 10 in the Upper Lower Milwaukee River subwatershed; six in the North Branch Milwaukee River subwatershed; four each in the Cedar Creek, Lower Milwaukee River, Middle Milwaukee River, Stony Creek, and West Branch Milwaukee River subwatersheds; three in the Lincoln Creek subwatershed; two each in the Silver Creek (West Bend) and Upper Milwaukee River subwatersheds; and one each in the Lake Fifteen Creek and Watercress Creek subwatersheds.

Quantification of Pollutant Loads

The annual average load of BOD to streams of the Milwaukee River watershed is estimated to be 5,233,160 pounds per year. Sewage treatment plants, combined sewer overflows, and separate sanitary sewer overflows contribute about 7.6 percent, 0.4 percent, and 0.1 percent, respectively, of this load. Industrial discharges contribute about 5.6 percent of this load. The rest of BOD load to streams in the Milwaukee River watershed, about 86.3 percent, is contributed by nonpoint sources, with 61.4 percent coming from rural sources and 24.9 percent from urban sources.

The annual average load of TSS to streams of the Milwaukee River watershed is estimated to be 58,383,650 pounds per year. Sewage treatment plants, combined sewer overflows, separate sanitary sewer overflows, and industrial discharges contribute 0.5 percent, 0.3 percent, less than 0.1 percent, and 0.8 percent, respectively, of this load. The rest of the TSS load to streams in the Milwaukee River watershed, about 98.4 percent, is contributed by nonpoint sources, with 68.1 percent coming from rural sources and 30.3 percent from urban sources.

The annual average load of fecal coliform bacteria to streams of the Milwaukee River watershed is estimated to be 40,826.66 trillion cells per year. Combined sewer overflows, sewage treatment plants, and separate sanitary sewer overflows contribute 4.6 percent, 0.1 percent and about 1.1 percent, respectively, of this load. Industrial discharges contribute less than 0.1 percent of this load. The rest of the fecal coliform bacteria load to streams in the Milwaukee River watershed, about 94.2 percent, is contributed by nonpoint sources, with 35.2 percent coming from rural sources and 59.0 percent from urban sources.

The annual average load of total phosphorus to streams of the Milwaukee River watershed is estimated to be 274,500 pounds per year. Industrial discharges and sewage treatment plants contribute about 34.2 percent and 18.8 percent, respectively, of this load. Combined sewer overflows and separate sanitary sewer overflows contribute about 0.7 percent and 0.3 percent, respectively, of this load. The rest of total phosphorus loadings to streams in the Milwaukee River watershed, about 46.0 percent, are contributed by nonpoint sources, with 29.5 percent coming from rural sources and 16.5 percent from urban sources.

What is the Current Condition of the Fishery?

Except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good and in some cases excellent fishery quality, the watershed of the Milwaukee River in general contains a poor to fair fishery. The fish community contains a high abundance of both warmwater and coldwater species of fishes, seems trophically balanced in the highest quality areas, contains a good percentage of top carnivores (except for those species stocked), and is not dominated by tolerant fishes. Macroinvertebrate communities are classified as fair to good-very good at present. The macroinvertebrate community is also generally trophically balanced and not dominated by tolerant taxa. Overall, the fish and macroinvertebrate communities in the Milwaukee River watershed are of a better quality than those communities in the other watersheds in the study area.

The habitat quality was shown to largely be limited by siltation, as well as reduced amounts and quality of instream cover throughout the watershed. In addition, although there have been some water quality improvements in the downstream areas in the watershed, those areas also continue to be impaired due to sediment toxicity problems. Therefore, in differing degrees throughout the watershed, water, sediment, and habitat quality are important factors limiting both the fishery and macroinvertebrate community. There are several other factors that are likely to be limiting the aquatic community, including, but not limited to, 1) periodic stormwater loads and sediment toxicity; 2) decreased base flows; 3) continued fragmentation due to dams, drop structures, culverts, concrete lined channels, and enclosed conduits; 4) past channelization; 5) cropland erosion, and/or 5) increased water temperatures due to urbanization.

To What Extent Are Water Use Objectives and Water Quality Standards Being Met?

During the 1998 to 2004 extended study baseline period, the Milwaukee River partially met the water quality criteria supporting its recommended water use classification. In all of the samples taken from the mainstem of the River, temperatures were in compliance with the relevant water quality standards. In almost all of the samples taken from the mainstem of the River, concentrations of ammonia were in compliance with the relevant water quality standards. In all samples at stations below the site of the former North Avenue dam, dissolved oxygen concentrations equaled or exceeded the 2.0 mg/l special variance standard applying to the estuary. At most stations above the estuary, concentrations of dissolved oxygen in all samples equaled or exceeded the 5.0 mg/l standard for fish and aquatic life. There were three exceptions to this: concentrations of dissolved oxygen occasionally fell below 5.0 mg/l in the sections of the River above the dam at Kewaskum in Washington and Fond du Lac Counties, between Silver Spring Drive and Port Washington Road in Milwaukee County, and between Estabrook Park and the site of the North Avenue dam, also in Milwaukee County. In the estuary, concentrations of fecal coliform bacteria in the Milwaukee River were usually less than or equal to the variance standard of 1,000 cells per 100 ml. While the rate of compliance varied among stations, it was generally between 65 percent and 77 percent. In the section of the River upstream from the estuary, concentrations of fecal coliform bacteria usually exceeded the recreational use standard of 200 cells per 100 ml. Between Pioneer Road in Cedarburg and the site of the former North Avenue dam, concentrations of fecal coliform bacteria exceeded 200 cells per ml in the majority of samples. Depending upon the station, the percentage of samples in this section of the River that complied with the standard ranged between about 20 and 55 percent. Upstream from Pioneer Road, fecal coliform bacteria concentrations met, or exceeded, the standard in the majority of samples at the stations at Waubeka, Newburg, and above the dam at Kewaskum, although, at Newburg and Kewaskum, concentrations occasionally exceeded the standard. Compliance with the planning standard for total phosphorus recommended in the original regional water quality management plan was also low with the number of samples showing total phosphorus below the 0.1 mg/l planning standard ranging from 37 to 79 percent at stations along the mainstem. At most stations along the mainstem of the River, concentrations of total phosphorus were below the standard in about 37 percent to 45 percent of the samples. The exception to this generalization occurred at the downstream stations nearest to the confluence with Lake Michigan and the three stations farthest upstream. At the two stations downstream from Water Street, dissolved phosphorus concentrations were below 0.1 mg/l in 65 to 75 percent of the samples. This may reflect the influence of Lake Michigan on the water chemistry of the River. At the three stations farthest upstream dissolved phosphorus concentrations were below the recommended standard in about 64 to 78 percent of samples.

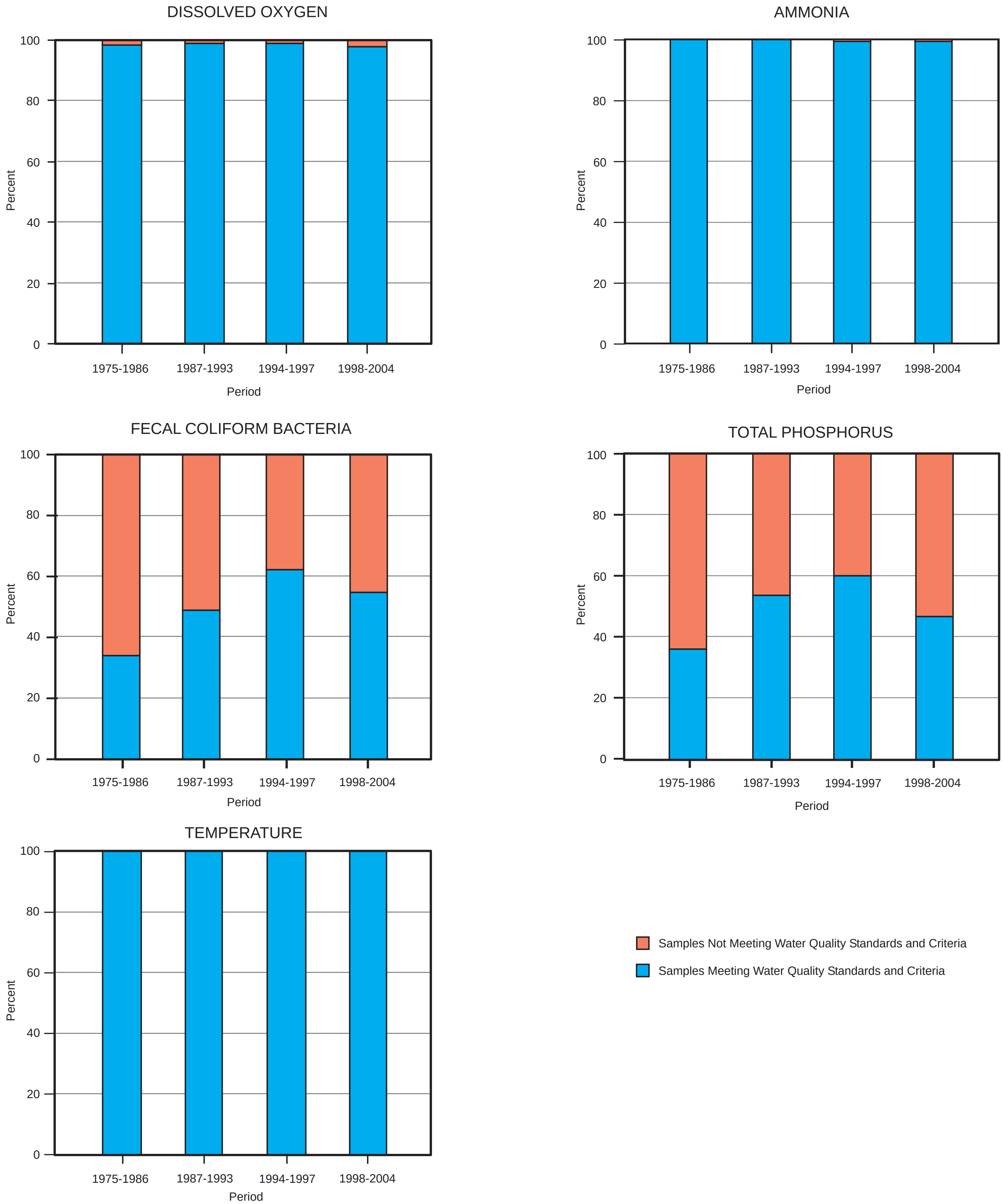
Figure 188 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for the Milwaukee River. Over the entire study period of 1975-2004, water temperatures were in compliance with the applicable water quality standards in all of the samples. Over that same period, concentrations of ammonia were in compliance with the applicable water quality standards in almost all of the samples. A very small percentage of samples in each period had concentrations of dissolved oxygen that were not in compliance with the applicable water quality standard. By contrast, a significant percentage of samples collected in each period had concentrations of fecal coliform bacteria or total phosphorus that were not in compliance with the applicable water quality standard. During each period, dissolved oxygen concentrations in about 99 percent of the samples collected from the mainstem of the River were in compliance with the applicable standard. The rate of compliance with the planning standard recommended for total phosphorus in the original regional water quality management plan increased over much of the study period, but showed a decrease in the 1998-2004 baseline period. During the period 1975-1986, total phosphorus concentrations were less than or equal to 0.1 mg/l in about 36 percent of the samples collected. By the period 1994-1997, this rate of compliance had increased to 60 percent. During the baseline period of 1998-2004, the rate of compliance with the recommended total phosphorus standard decreased to 47 percent. The rate of compliance with the applicable standards for fecal coliform bacteria followed a different pattern. The percentage of samples in which the concentrations of fecal coliform bacteria were equal to or below the applicable standard increased from about 34 percent during the period 1975-1986 to about 64 percent during the period 1994-1997. During the 1998-2004 baseline period this rate of compliance decreased to about 55 percent.

Relatively few data are available for assessing whether streams tributary to the Milwaukee River are meeting water use objectives and water quality standards. Data were available to evaluate whether one or more standard was met for 19 of 76 tributary streams. In 16 tributary streams, temperatures in all samples were at or below the 31.7ºC fish and aquatic life standard. In one other tributary, Cedar Creek, temperatures were at or below the standard in the vast majority of samples. In the 15 tributary streams for which data were available, ammonia concentrations were at or below the applicable standard in all samples. Dissolved oxygen concentrations in 11 tributaries equaled or exceeded the applicable standard in all samples, indicating compliance with the standard. In four tributaries, Lincoln Creek, the North Branch Milwaukee River, Quaas Creek, and Southbranch Creek, dissolved oxygen concentrations occasionally dropped below the standard. In only one tributary, the West Branch Milwaukee River, were dissolved oxygen concentrations frequently below the standard. Fecal coliform concentrations frequently exceeded the applicable standard in four tributaries: Indian Creek, Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek. In the North Branch Milwaukee River and Southbranch Creek, concentrations of fecal coliform bacteria were out of compliance with the standard in the majority of samples. By contrast, concentrations of fecal coliform bacteria only occasionally exceeded the applicable standard in Cedar Creek. Concentrations of fecal coliform bacteria in the East Branch Milwaukee River were at or below the applicable standard in all samples collected. Total phosphorus concentrations exceeded the 0.1 mg/l planning standard recommended in the original regional water quality management plan in most tributaries for which data were available. In three tributaries, Polk Springs Creek, Southbranch Creek, and Wallace Creek, total phosphorus concentrations exceeded the recommended planning standard in the majority of samples. In eight more tributaries, Batavia Creek, Indian Creek, Kewaskum Creek, Lincoln Creek, the North Branch Milwaukee River, Parnell Creek, Quaas Creek, and the West Branch Milwaukee River, total phosphorus concentrations frequently exceeded the recommended standard. In three more tributaries, Cedar Creek, the East Branch Milwaukee River, and Friedens Creek, total phosphorus concentrations occasionally exceeded the recommended standard. In only four tributaries, Crooked Lake Creek, Mole Creek, Pigeon Creek, and Stony Creek, were total phosphorus concentrations at or below the recommended standard in all samples.

Two sections of stream in the Milwaukee River are listed as impaired pursuant to Section 303(d) of the Clean Water Act. The mainstem of the Milwaukee River below the site of the former North Avenue dam is considered impaired due to aquatic toxicity, bacterial contaminations, concentrations of dissolved oxygen which do not meet the applicable water quality standard, and fish consumption advisories necessitated by the concentrations of PCBs in the tissue of fish collected in this reach. The mainstem of the Milwaukee River in Milwaukee and Ozaukee Counties is considered impaired due to bacterial contamination and fish consumption advisories necessitated by

Figure 188

PROPORTION OF SAMPLES MEETING WATER QUALITY STANDARDS AND CRITERIA FOR SEVERAL CONSTITUENTS IN THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

the concentrations of PCBs in the tissue of fish collected in this reach. Reaches in several tributary streams are also considered impaired. Adell Tributary, Evergreen Creek, Jackson Creek, and Lehner Creek are considered impaired due to habitat degradation. Lehner Creek is also considered impaired due to high water temperatures. Beaver Creek is considered impaired due to aquatic toxicity. A five-mile section of Cedar Creek between Bridge Road in the City of Cedarburg and the confluence with the Milwaukee River is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. PCBs from contaminated sediments are cited as factors contributing to the impairment of this section of Cedar Creek. Indian Creek downstream from IH 43, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures. Lincoln Creek, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures.

Some toxic substances have been detected in the Milwaukee River watershed at concentrations that may impair beneficial uses. Concentrations of mercury in water samples taken from the Milwaukee River often exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. In addition, concentrations of copper in water samples occasionally exceeded the USEPA’s criterion maximum concentration. Concentrations of mercury and copper in water occasionally exceeded both of these standards in Lincoln Creek and in Southbranch Creek. Concentrations of PCBs in water samples collected from the mainstem of the Milwaukee River below the confluence with Cedar Creek and from Lincoln Creek exceeded the wildlife criterion for surface water quality occasionally to often, depending upon the sampling station. Concentrations of PCBs in almost all water samples collected from Cedar Creek exceeded the wildlife criterion for surface water quality. Concentrations of PCBs in tissue of several species of fish collected from the mainstem of the Milwaukee River below Grafton and Cedar Creek below Bridge Road in Cedarburg are high enough that special consumption advisories have been issued. The statewide consumption advisory for mercury also applies to the watershed.