Prepared in cooperation with the Lake St. Clair Regional Monitoring Project; Michigan Department of Environmental Quality; and Macomb, Oakland, St. Clair, and Wayne Counties, Michigan

Water Quality of the St. Clair River, Lake St. Clair, and Their U.S. Tributaries, 1946–2005

Scientific Investigations Report 2007–5172

U.S. Department of the Interior
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Cover.

The St. Clair River near Robert's Landing water-quality monitoring station operated by the Lake St. Clair Regional Monitoring Project partners. (Photograph by Don James, U.S. Geological Survey.)

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By Denis F. Healy, Douglas B. Chambers, Cynthia M. Rachol, and Richard S. Jodoin

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Suggested citation:
Healy, D.F., Chambers, D.B., Rachol, C.M., and Jodoin, R.S., 2008, Water quality of the St. Clair River, Lake St. Clair, and their U.S. tributaries, 1946–2005: U.S. Geological Survey Scientific Investigations Report 2007–5172, 92 p.

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Conversion Factors and Definitions

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
centimeter (cm)	0.3937	inch (in.)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
liter (L)	0.2642	gallon (gal)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)
megagram per year (Mg/yr)	1.102	ton per year (ton/yr)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L). Concentrations of bacteria in water are given in colony-forming units per 100 milliliters (CFU/100 mL).

Map projection base from U.S. Geological Survey digital data 1:100,000 1983.

Universal Transverse Mercator projection, Zone 16,

Standard parallel 0° (equator), Central meridian 87° W.

North American Datum 1983

Definitions

Censored data: Data that contains “less than” or “greater than” values.

Uncensored data: Data that does not contain “less than” or “greater than” values.

Flow-adjusted concentrations (FAC): Since most of the variability in load calculations year-to-year is due to variation in hydrology (flow), FAC is used to flow normalize load estimates and look for trend.

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Water Quality of the St. Clair River, Lake St. Clair, and Their U.S. Tributaries, 1946–2005

By Denis F. Healy, Douglas B. Chambers, Cynthia M. Rachol, and Richard S. Jodoin

Abstract

The St. Clair River/Lake St. Clair waterway forms an international boundary between the United States and Canada. The waters of the area are an important part of the cultural heritage of the area and serves as an important water-supply and power-generating resource; the waterway also supports an economy based largely on recreation, agriculture, and manufacturing. This report was undertaken as part of the Lake St. Clair Regional Monitoring Project for the purpose of providing a comprehensive assessment of the hydrological, chemical, and physical state of the surface water of Lake St. Clair and its tributaries. The data varied in focus and density over the period of compilation which in many cases this variation prevented the completion of statistical analyses because data did not meet minimum comparability or quality requirements for those tests.

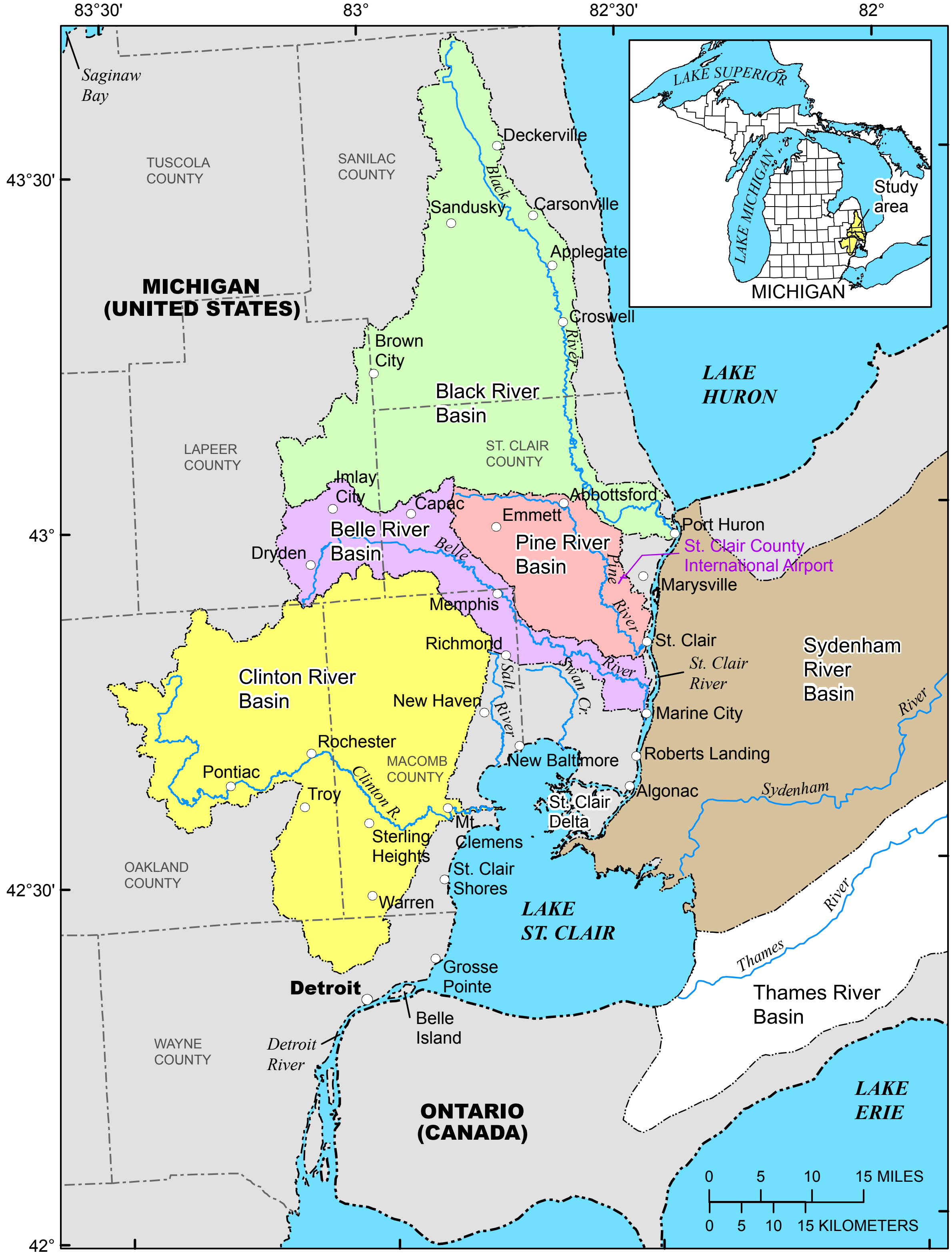
Comparison of water quality of the Belle, Black, Clinton, and Pine River Basins, as well as basins of minor rivers in the study area, showed that water quality in many of the tributaries, particularly the Clinton River and some of the minor rivers, was degraded compared to the water quality of the St. Clair River/Lake St. Clair waterway. Data analyses included comparison of nutrients, chloride, specific conductance, turbidity, biochemical oxygen demand (BOD), and pesticides among the basins and the St. Clair River. Median concentrations of total nitrate were well below the recommended USEPA total nitrogen ambient water-quality criterion of 0.54 mg/L as N for nutrient ecoregion VII for all study-area streams except the Clinton River. More than 93 percent of the phosphorus concentrations for the Belle, Black, Pine and minor river basins and 84 percent of the phosphorus concentrations for the Clinton River Basin are greater than the USEPA recommended ambient total phosphorus criterion of 0.033 mg/L for rivers and streams. Nine chloride concentrations exceeded the USEPA criterion maximum concentration (CMC) for chloride set at 860 mg/L for all study-area streams, with the six largest being in the Belle River Basin. Higher chloride concentrations were increasingly common from 2002 to 2005. The urban minor river basins had the highest median specific conductance, whereas the agricultural Pine River Basin had the lowest median specific conductance. The median values of BOD for the five basins in the study area ranged from 2.4 mg/L for the Pine River Basin to 3.2 mg/L for the Black and Clinton River Basins, whereas the median for the St. Clair River was 0.5 mg/L. In 1985, the highest concentrations of pesticides were found in samples from the mouth of the Clinton River; however, in 1996–98, the majority of high pesticide concentrations were found in samples from the Black River. Changing land-use patterns, specifically conversion of agricultural lands to urban/residential lands in the Clinton River Basin, may explain this difference.

Trend analysis was done for four stream sites where adequate data were available. These analyses identified no significant water-quality changes at a stream site on the Black River, where land-use patterns have changed little in the past few decades. This stands in marked contrast to trend analysis for three stream sites in the Clinton River Basin, which has undergone significant land-use change. The changes at the Clinton River stream sites, ranging from 5 to 13 significant trends, were generally decreases in nutrients and increases in total dissolved solids (TDS) and chloride.

The greater flow volume of the St. Clair River/Lake St. Clair waterway is able to assimilate incoming dissolved and suspended constituents from tributaries with little effect upon its overall water quality, although incomplete mixing may result in localized water-quality impairment downstream from tributary confluences. Mixing effects on Lake St. Clair water quality was also demonstrated in analysis of *Escherichia coli (E. coli)* data collected at paired nearshore/offshore sites, which reflected similarity in water quality among many paired sites.

Introduction

The St. Clair River, Lake St. Clair, and the Detroit River form a waterway that connects Lake Huron with Lake Erie and is part of the international boundary between the United States and Canada (fig. 1). In addition to flow from Lake Huron, the waterway is fed by discharges from the Belle, Black, Clinton, and Pine Rivers in the United States and the Thames and Sydenham Rivers in Ontario, Canada, as well as numerous smaller streams, canals, and drains. The waterway serves as a water supply for about 4 million people, is a critical habitat for maintaining biodiversity in the aquatic environment



Base from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 1. Lake St. Clair, the St. Clair River, and major tributary drainage basins.

and supporting fisheries, and provides major recreational opportunities for southeastern Michigan and southern Ontario.

The Great Lakes Water Quality Board of the International Joint Commission (IJC) designated the St. Clair River and Clinton River as Areas of Concern (AOC) (International Joint Commission, 1989). The AOC designation commits state and provincial governments to develop and implement Remedial Action Plans (RAPs) as part of their watershed planning efforts. In 1997, the Macomb County Blue Ribbon Commission on Lake St. Clair developed a Plan of Action to address the degraded water quality of Lake St. Clair and the Clinton River (Macomb County Blue Ribbon Commission on Lake St. Clair, 1997). Further monitoring plans were presented in the RAPs for the St. Clair River AOC and Clinton River AOC (Michigan Department of Natural Resources, 1988; St. Clair River RAP Team, 1991).

In 2003, as part of the ongoing monitoring, assessment, and remediation efforts in this region, the Macomb County Health Department (MCHD), Environmental Consulting & Technology, Inc., Oakland County Drain Commission, St. Clair County Health Department, and Wayne County Department of the Environment, in cooperation with the U.S. Geological Survey (USGS) and the Michigan Department of Environmental Quality (MDEQ), developed plans for a 3-year water-quality assessment and monitoring of basins within the United States that drain to the St. Clair River and Lake St. Clair. The Lake St. Clair Regional Monitoring Project (LSCRMP) is a comprehensive assessment of the hydrological, chemical, and physical state of the surface waters that flow to the St. Clair River and Lake St. Clair from the U.S. part of the basin. The project design included streamflow and water-quality monitoring; collection of discrete (grab) samples at 23 sites and automatic water-quality samples at 13 sites (fig. 2); and analyses of historic water-quality, bed-sediment data, and LSCRMP-collected data. Descriptions of the LSCRMP and data collected during the project are available at *http://www.lakestclairdata.net*

Purpose and Scope

This report (1) documents the spatial and temporal extent of water-quality data collected in the U.S. tributaries to the St. Clair River and Lake St. Clair from 1946 to 2005; (2) compares concentrations of selected water-quality constituents to water-quality standards and criteria for the Belle River Basin, Black River Basin, Clinton River Basin, Pine River Basin, minor river basins, and the St. Clair River; (3) presents the results of trend analyses on water-quality data from one site in the Black River Basin and three sites in the Clinton River Basin; (4) presents monthly load estimates of selected water-quality constituents for one site in the Belle River Basin, two sites in the Black River Basin, and three sites in the Clinton River Basin for June 2004 through October 2005; (5) summarizes MCHD *Escherichia coli (E. coli)* data from 65 sites in the Clinton River and minor river basins collected from January 2000 through December 2005 and compares these data to ambient water standards; and (6) presents the results of cluster analyses on 34 MCHD Lake St. Clair Assessment data collection sites from 1998 through 2003.

The study area consists of the U.S. drainages along the reach from the origin of the St. Clair River (the southern edge of Lake Huron) to the outlet of Lake St. Clair (the Detroit River). Water-quality data for samples collected from tributary rivers, streams, and drains; the St. Clair River; and Lake St. Clair were compiled for the study area from electronically available databases accessible via the Internet and from non-Web-accessible databases via electronic downloads by LSCRMP partners. The compiled data are described by waterbodies and by time period and sampling frequency.

Because of the large number of physical properties and chemical constituents included in the downloaded data, only selected properties or constituents that represented major groups of data such as major ions, nutrients, or onsite physical measurements were examined spatially across basins. All compiled data were compared to appropriate 2006 ambient water-quality standards and criteria. Thirteen sites with long-term water-quality data were examined for feasibility of trend analyses and (or) load estimation.

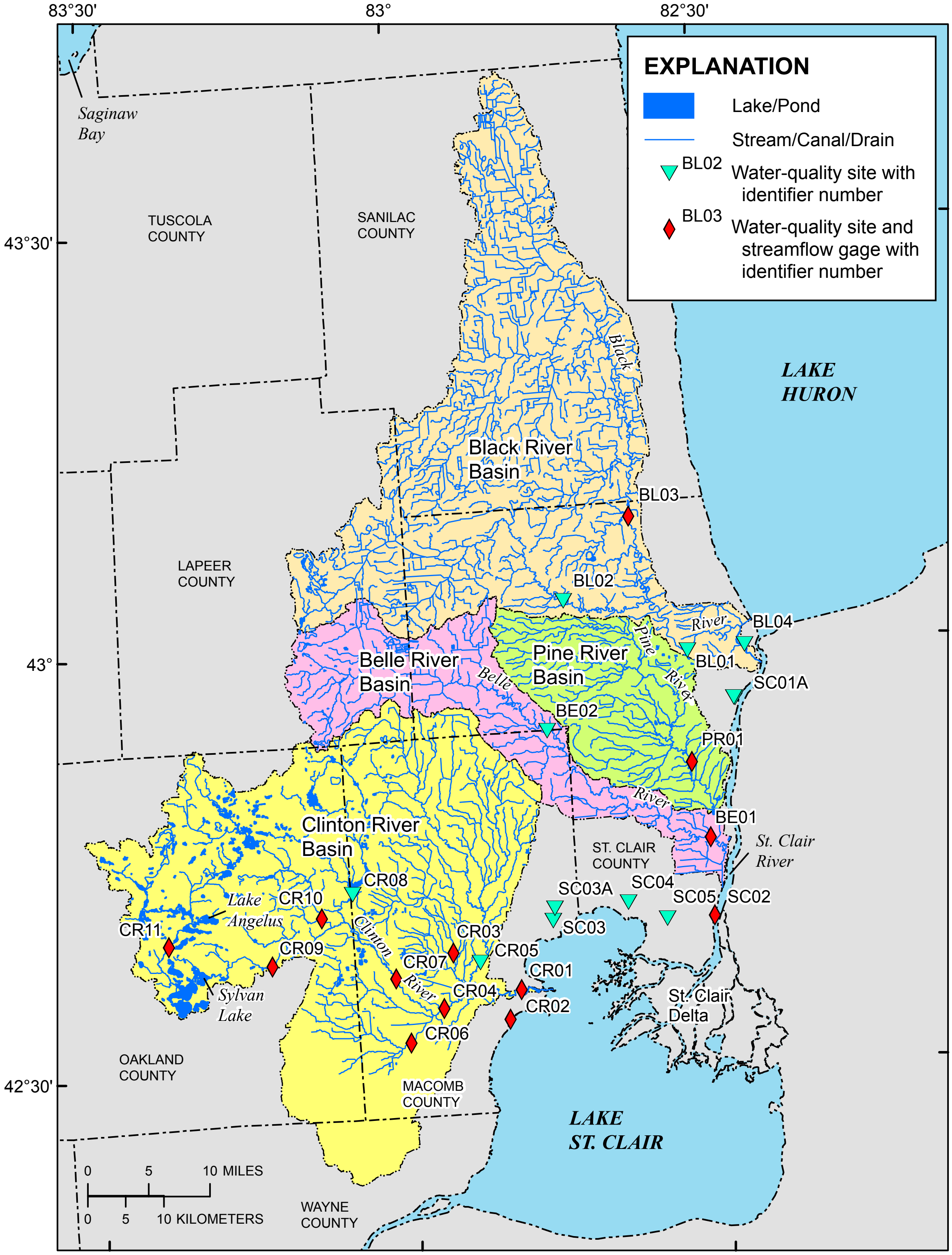
Analysis of microbiological data was limited to *E. coli* concentration data collected from 23 nearshore sites and 11 offshore sites in Lake St. Clair from 2000 through 2005 by MCHD. These data were compared to ambient water-quality standards and used to assess influence of major discharges on nearshore water quality.

Description of Study Area

The St. Clair River originates at the outlet of Lake Huron and empties into Lake St. Clair through the largest delta in the Great Lakes, the St. Clair Delta (figs. 1 and 8). Lake St. Clair drains the upper Great Lakes (Lakes Superior, Michigan, and Huron) and has an estimated drainage area of 228,800 mi^2 at its outlet into the Detroit River. The drainage area for the reach from the origin of the St. Clair River to the outlet of Lake St. Clair is approximately 6,520 mi^2. The main U.S. tributaries within this reach are the Black, Belle, Pine, and Clinton Rivers.

St. Clair River

The St. Clair River flows approximately 40 mi from Lake Huron to Lake St. Clair. The average annual flow is approximately 182,000 ft^3/s with monthly mean flows ranging from 106,000 to 232,000 ft^3/s (U.S. Army Corps of Engineers, 2004). At the average annual flow rate, it takes approximately 21 hours for water to flow the length of the river. Drifting-buoy deployments indicate that there may be cross-channel mixing upstream from the confluence with the Black River (Holtschlag and Aichele, 2001). Downstream from the



Base from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 2. Streamflow and water-quality data-collection sites of the Lake St. Clair Regional Monitoring Project, Michigan.

Black River, however, the mixing is more subdued because channel curvature and velocities are less. The majority of flow is contained within the center of the river (U.S. Army Corps of Engineers, 2004). Discharge plumes from tributaries and other sources have been observed to hug the riverbanks (U.S. Army Corps of Engineers, 2004). The extent to which these plumes mix with the slower flows along the river banks and eventually the main flow is currently (2007) being studied. In the delta region, the river divides into three main channels and several lesser channels. The amount of flow through each channel is affected by the quantity of flow in the St. Clair River, ice buildup and plant growth in the channels, and wind and other meteorological factors (U.S. Army Corps of Engineers, 2004).

Land use adjacent to the St. Clair River is mainly urban and industrial. In addition to the nonpoint runoff from these lands, the river receives discharges from municipal and industrial treatment facilities, outflows from storm sewers and drains, and overflows from combined and sanitary sewers. The largest tributaries to the St. Clair River are the Black, Belle, and Pine Rivers on the U.S. side and the Sydenham River, which flows into the Channel Ecart in the delta region, on the Canadian side (figs. 1 and 8). These tributaries drain an area that is more agricultural and forested than the land immediately adjacent to the St. Clair River.

Lake St. Clair

Lake St. Clair is a shallow lake with a surface area of approximately 430 mi^2. The depth of the lake averages 12 ft and has a retention time of approximately 9 days. A shipping channel, 59 ft wide and 27 ft deep, cuts the lake from the St. Clair Delta South Channel to the lake's outlet at the Detroit River. The main tributaries to the lake downstream from the St. Clair River are the Clinton River on the U.S. side and the Thames River on the Canadian side. However, approximately 98 percent of the flow entering the lake comes from the upper Great Lakes through the St. Clair River (U.S. Army Corps of Engineers, 2004). The U.S. Army Corps of Engineers (USACE) (2004) identifies three main circulatory regions within Lake St. Clair. The eastern region receives inflow from the St. Clair Delta channels near Walpole Island and from the Thames River, the central region receives inflow from the St. Clair Delta South and Cutoff Channels, and the western region receives inflow from the St. Clair Delta North and Middle Channels and from the Clinton River as well as many smaller rivers, creeks, and drains (figs. 1 and 8). Wind direction and strength have a strong influence on these circulatory patterns in Lake St. Clair (David Holtschlag, U.S. Geological Survey, oral commun. 2006). Under other, more unusual wind conditions, the central region appears to have a strong flow from the St. Clair River to the Detroit River. Under some wind conditions the eastern and western regions may form circular flow patterns called gyra. Whether there is mixing between the eastern and western regions and, if so, to what extent, is under investigation.

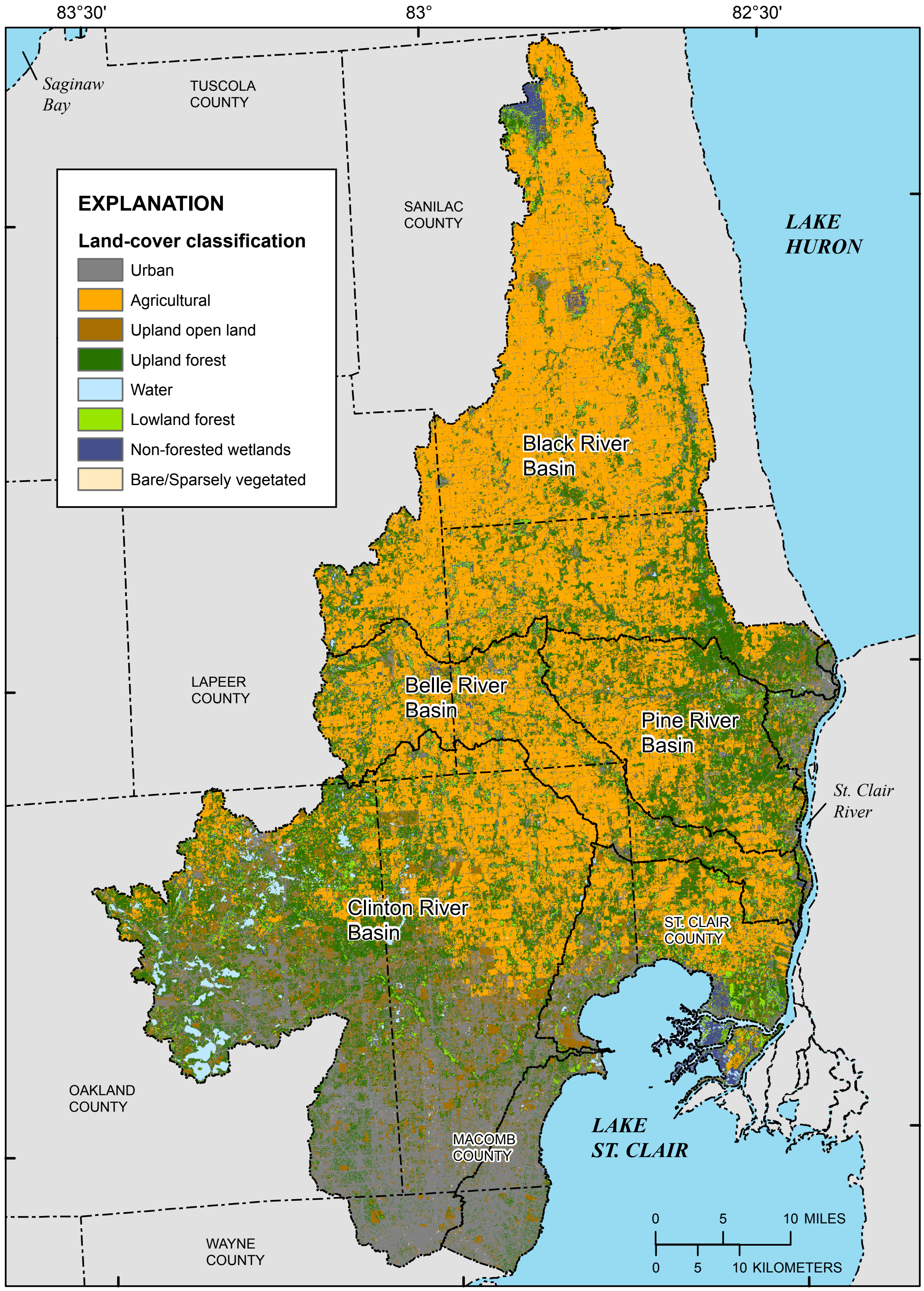
Land use around Lake St. Clair is highly urban, with a large population on the U.S. side and lower overall population density (mainly agricultural areas with urban pockets) on the Canadian side. The lake receives discharges from municipal and industrial wastewater-treatment facilities, outflows from storm sewers and drains, and overflows from combined and sanitary sewers.

U.S. Tributary Basins

The study area covers parts of Lapeer, Oakland, Sanilac, and Wayne Counties; most of St. Clair County; and all of Macomb County in southeastern Michigan (fig. 1). These counties, which contain 23 percent of the population of Michigan (U.S. Census Bureau, 2002), are some of the fastest growing counties in the State. Between 1990 and 2000, St. Clair County had a population increase of 12.8 percent, and Macomb County had a population increase of 9.9 percent (Obiero, 2001).

Land use within the study area is a mix of urban areas, agricultural land, forests, and wetlands. Land-cover data collected between 1997 and 2000 (fig. 3) show that the northern part of the study area is dominated by agricultural land and forest, whereas the southern part is mostly urban and forest, the latter generally in the form of parkland (Pacific Meridian Resources, 2001). Areas of urban land use increased 17 percent in southeastern Michigan between 1990 and 2000 (U.S. Army Corps of Engineers, 2004), but this growth was not uniform. Syed and Jodoin (2006) found that the land use in the Belle, Black, and Pine River Basins did not significantly change during this period.

Black River.—The coalescing of agricultural drains in the northern part of Sanilac County gives rise to the Black River. The river flows approximately 80 mi south through a basin composed of approximately 79 percent agricultural land, 12 percent forest, and 7 percent wetlands and water (table 1) until it reaches its terminus at the St. Clair River in Port Huron (figs. 1, 3, and 4). This 710-mi^2 basin is characterized by morainal hills along its eastern, northern, and western boundaries and a flat glacial lakebed feature over much of its central part (Knutilla, 1970). The river is entrenched as much as 100 ft below this plain in its downstream reaches. The Black River is fed by many agricultural drains as it flows by or through Deckerville, Carsonville, Applegate, and Croswell (fig. 1). The water from streams in the Black River Basin is of the calcium magnesium bicarbonate type and is considered very hard (Knutilla, 1970). The main tributaries are the Berry Drain, which flows east from the Sandusky area; the Elk River, which flows north-east from the Brown City area; and Mill Creek, which flows east from Lapeer County. Just upstream from Port Huron, the Black River Canal connects the river to Lake Huron. During periods of low flow in the Black River, the canal is used to provide extra water from Lake Huron to increase streamflow in the lower reach of the Black River to prevent sediments from settling in this reach.



Land-cover data from Michigan Department of Natural Resources, Forest, Mineral and Fire Management Division, 2003
Base from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 3. Land cover in the U.S. drainages to the St. Clair River and Lake St. Clair.

Table 1. Land use in the Belle, Black, Clinton, and Pine River Basins, Michigan.

[mi^2, square miles]

Land-use type	Belle River		Black River		Clinton River		Pine River	
	Percent of basin	Area (mi^2)	Percent of basin	Area (mi^2)	Percent of basin	Area (mi^2)	Percent of basin	Area (mi^2)
Residential	1.4	3.1	1.4	10.2	16.3	130.0	1.0	2.0
Commercial /industrial/ transportation	.7	1.5	.4	2.5	9.2	73.0	.7	1.4
Agricultural/parks /golf courses	71.2	161.6	78.9	560.1	22.6	180.1	59.9	116.5
Herbacous open land/grasslands	.0	.0	.0	.0	14.5	115.2	.0	.0
Forest	19.7	44.7	12.4	88.1	31.3	249.6	28.7	55.8
Water/wetlands	7.0	15.8	6.8	48.5	5.9	47.1	9.5	18.5
Bare land/sparsely vegetated	.2	.3	.1	.5	.3	2.0	.2	.4
Total	100	227	100	710	100	797	100	195

Belle River.—The Belle River begins in the wetlands south of Dryden in southeastern Lapeer County and flows in a generally southeasterly direction through the town of Memphis to discharge into the St. Clair River at Marine City (figs. 1 and 5). Along its route, the river is fed by many small creeks and agricultural drains, the larger of which are the North Branch Belle River, which flows through Imlay City, the Lemon Drain, Ashery Creek, and Jerome Creek. Along its lower reaches, the river is entrenched 30 ft below the surrounding countryside (Knutilla, 1969a).

The Belle River Basin extends 227 mi^2 over three counties (figs. 1 and 3) and is approximately 71 percent agricultural land, 20 percent forest, and 7 percent wetlands and water (table 1). Other population centers in the basin are Capac and Richmond. The surficial geology of the basin is mainly glacial lakebed in the east and central parts and predominantly morainal features in the west (Knutilla, 1969a). The water in the Belle River Basin is generally a calcium bicarbonate type (Knutilla, 1969a).

Pine River.—The Pine River begins at the confluence of the Foley and Sullivan Drains northeast of Emmett in central St. Clair County (figs. 1 and 6). The river flows generally eastward until it reaches the vicinity of Abbottsford where it turns south to flow towards its meeting with the St. Clair River, 43 mi downstream at the city of St. Clair. The 195-mi^2 basin is a relatively flat or gently undulating northwest-to-southeast glacial lake plain (Knutilla, 1969a). Land use in the basin is approximately 60 percent agricultural land, and 29 percent forest (fig. 3 and table 1); however, the basin contains the St. Clair County International airport and developed urban areas west and southwest of Marysville. The river is fed by many agricultural drains; the largest tributaries are the Cowhy Drain, Smiths Creek, and Rattle Run. All three rise in the western part of the basin and flow east to join with the Pine River. The waters of the Pine River Basin are a very hard calcium magnesium bicarbonate type with low sulfates and chlorides (Knutilla, 1969b).

Clinton River.—The Clinton River originates in the lake region in north-central Oakland County and meanders approximately 80 mi in a generally eastward direction through the most populated basin in Michigan (figs. 1 and 7). Major tributaries of the Clinton River include Paint Creek, Stony Creek, Red Run, and the North Branch Clinton River. The basin is overlain by morainal features in the west and central parts and glacial lakebed features in the east. Stream water in the Clinton River Basin is of the calcium magnesium bicarbonate type and is very hard (Nowlin, 1973). The 2001 land-use data (Michigan Department of Natural Resources, 2003) shows the 797-mi^2 basin to be approximately 31 percent forest, 26 percent urban, 23 percent agricultural land, and 14 percent grasslands/open areas (fig. 3 and table 1). Generally, the agricultural lands are more towards the northern sections of the tributaries, whereas the urban lands are more towards the main stem and southern tributaries. The basin contains most of Macomb County and parts of Oakland, Lapeer, and St. Clair Counties and includes suburbs of Detroit. Warren and Sterling Heights, the cities with the third and fifth largest populations in Michigan in 2000 (U.S. Census Bureau, 2002), are entirely within the basin. Other population centers include Pontiac, Rochester, Mount Clemens, and part of Troy. About 9 mi upstream from the mouth of the river, the Clinton River Spillway (also called the Clinton River Bypass) connects the river to Lake St. Clair. This bypass was built to alleviate flooding problems in Mount Clemens. Although not technically part of the Clinton River Basin, lands adjacent to the spillway and the out-of-basin drains that flow into the spillway are considered part of the Clinton River Basin for the purposes of this report.

Minor River Basins.—The minor river basins include the parts of the study area that are not in the Black, Belle, Pine, and Clinton River Basins (figs. 1 and 8). These parts include the basins of the Milk River, Salt River, Crapaud Creek, Swan Creek, Bunce Creek, and Beaubien Creek; the U.S. shoreline areas of the St. Clair River and Lake St. Clair and the U.S. sections of the St. Clair Delta. The Milk River Basin and the shoreline areas are mainly urban. The Salt River and Crapaud Creek Basins are among the fastest developing areas in Michigan. The Swan Creek and Beaubien Creek Basins are also developing but are still are about 50 percent agricultural land (fig. 3). The delta areas are mainly wetlands, open land, and forest. Twenter and others (1975) found the waters in the minor river basins to have less than 500 mg/L of dissolved solids and to be a very hard calcium bicarbonate type. As the dissolved solids concentration increased, the relative concentrations of sodium, chloride, and sulfate increased.

Water-Quality Data for the St. Clair River, Lake St. Clair, and Their U.S. Tributaries, 1946–2005

During the compilation of water-quality data for this report, Federal, State, and local agencies and private stakeholders were contacted to determine what environmental data existed, whether the data were available for use by this project, and in what format the data were stored. Electronically stored water-quality data made available to this project, as well as data collected during LSCRMP, were compiled for this report.

Data Sources

Discrete environmental-data values and ancillary data that were used to identify the sample as to its time and location of collection were compiled from five electronic databases and file sets: (1) USGS National Water Information System (NWIS), (2) U.S. Environmental Protection Agency (USEPA) Storage and Retrieval (STORET) Legacy Data Center, (3) USEPA Modernized STORET, (4) LSCRMP Lake St. Clair Watershed Data Base, and (5) electronic files from the MCHD.

Data Description

Water-quality and ancillary data were collected for 763 parameters from 17,645 discrete water-quality samples and 19,331 MCHD *E. coli* samples. In this report, the term "parameter" is used to refer to one of the various chemical, microbiological, or physical characteristics of the water column and the ancillary data collected to assist in the interpretation of the sample. And, for purposes of this report, "sample" is defined as a representative unit from a waterway collected for chemical or biological analyses and/or a measurement of streamflow or water-quality monitor parameters designated by a unique combination of location and time. The samples were collected at 586 sites in the U.S. tributary rivers, the St. Clair River, and Lake St. Clair and covered a time period from September 26, 1946, through November 5, 2005 (Appendix 1). Because different agencies collected at the same location at different times, the 586 sites with data represent 396 unique locations. Site identifiers, listed in Appendix 1–1 to 1-4 are referred to as the "site number" in the text, tables, and figures for this report. Locations of sampling sites for each basin are shown in the following figures: figure 4, the Black River Basin; figure 5, the Belle River Basin; figure 6, the Pine River Basin; figure 7, the Clinton River Basin; and figure 8, the minor river basins.

In addition to discrete water-quality samples, daily mean value data from 46 USGS streamflow gages, 15 continuous water-quality monitoring sites (daily median values are used for pH), and 1 daily suspended-sediment site were compiled to be use as ancillary data in trend analyses and load estimation. Figure 9 and table 2 show the location of the streamflow gages and water-quality monitors in the study area. The daily value data covered a period from May 1934 through October 2005.

The 763 parameters were divided into 16 groups to facilitate the design of the database and analyses of the data. The groups are based on the parameter grouping system in Legacy STORET (U.S. Environmental Protection Agency, 2006a). The system was modified by moving polychlorinated biphenyls (PCB) parameters from the general organics group to a separate group. Table 3 lists the STORET groups in this compilation.

During the 59 years of discrete water-quality sample collection in the study area, samples were collected for various reasons including regulatory enforcement, spatial and temporal trend assessments, and calculation of loads to the Great Lakes. Through an examination of the data, site descriptions, reports, and personal contacts with employees from the collecting agencies, the discrete samples were grouped into 19 project groups based on the agency or stakeholder involved and the purpose or objective of the sampling. The groups may represent a single project, such as the USGS National Water-Quality Assessment Program (NAWQA), or a collection of projects by the same agency with the same objectives, such as the Michigan Department of Environmental Quality (MDEQ) regulatory projects. Table 4 presents the project groups, the number of sites sampled by each group in each basin, and the time period that samples were collected. Some sites were assigned to more than one group.

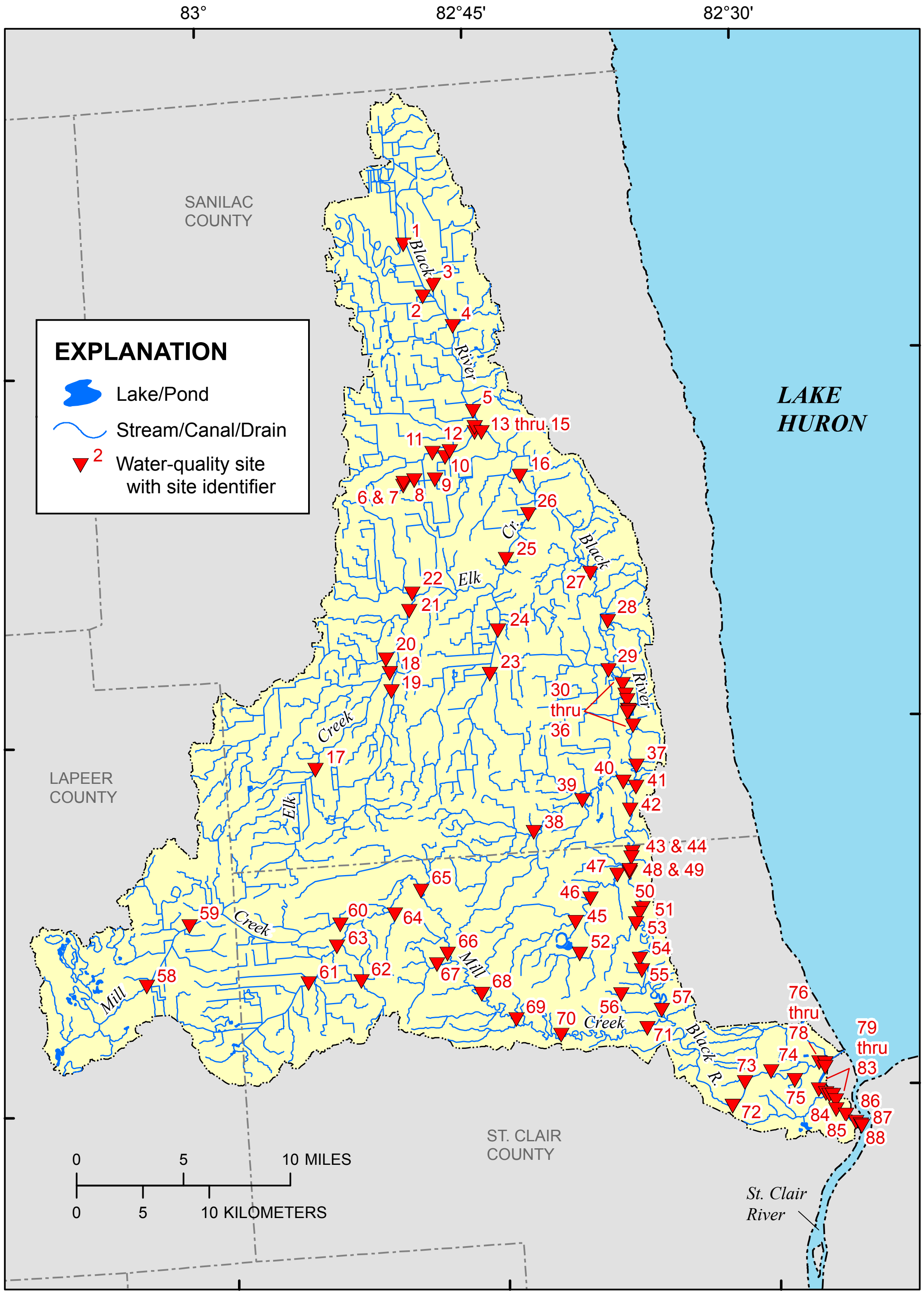


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Figure 4. Water-quality sites in the Black River Basin, Michigan.

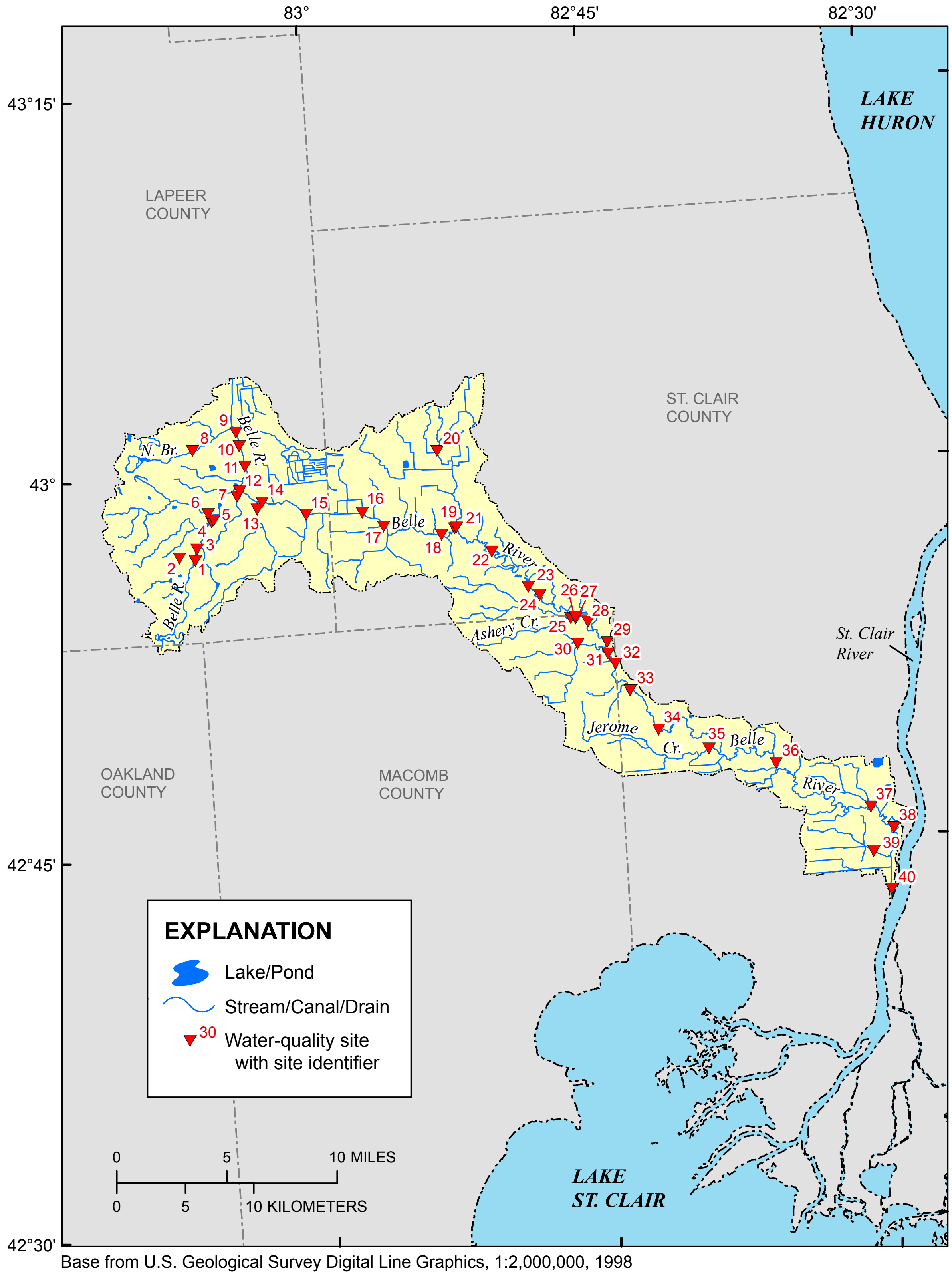
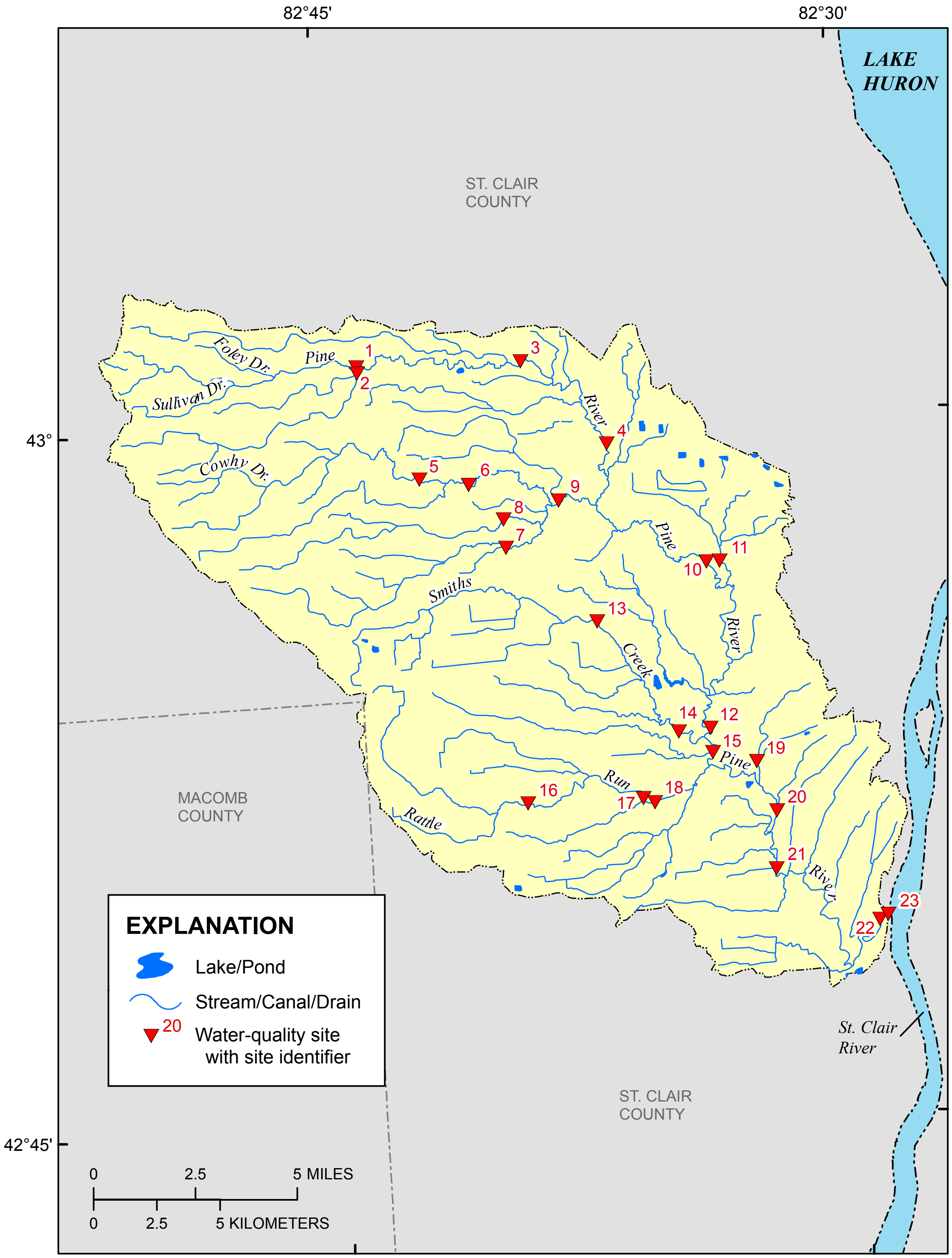
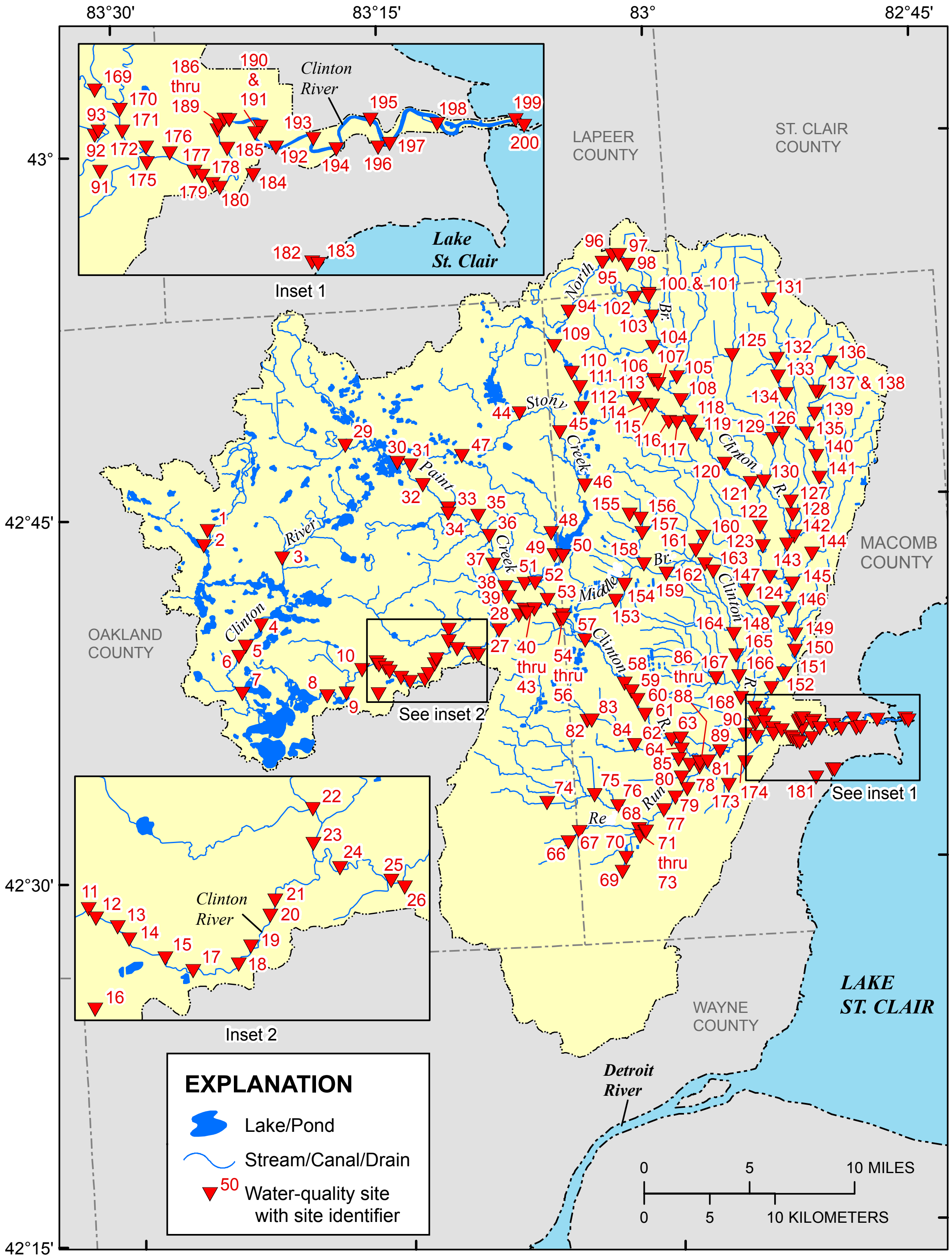


Figure 5. Water-quality sites in the Belle River Basin, Michigan.



Base from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 6. Water-quality sites in the Pine River Basin, Michigan.



Base from U.S. Geological Survey digital Line Graphics, 1:2,000,000, 1998

Figure 7. Water-quality sites in the Clinton River Basin, Michigan.

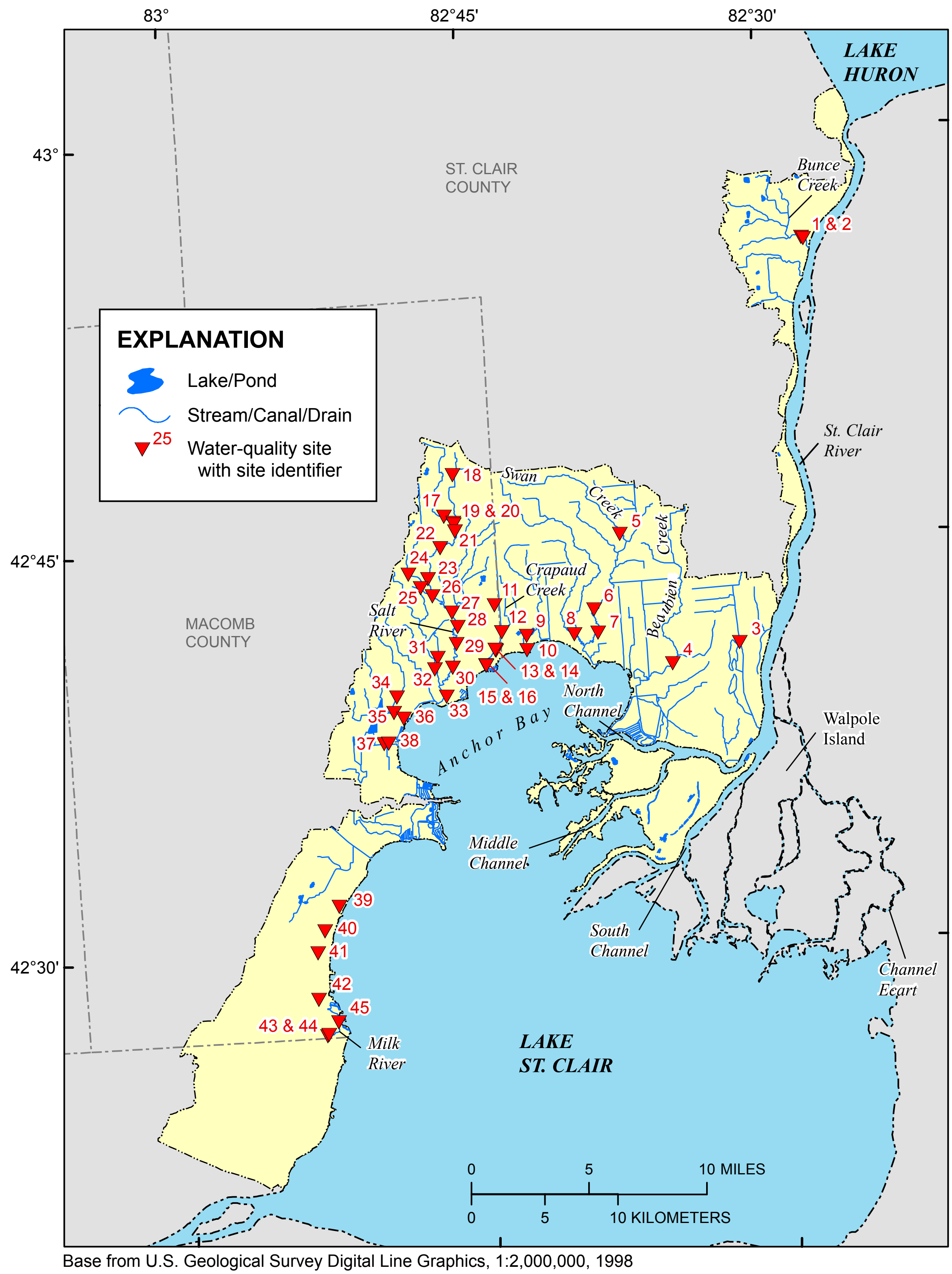
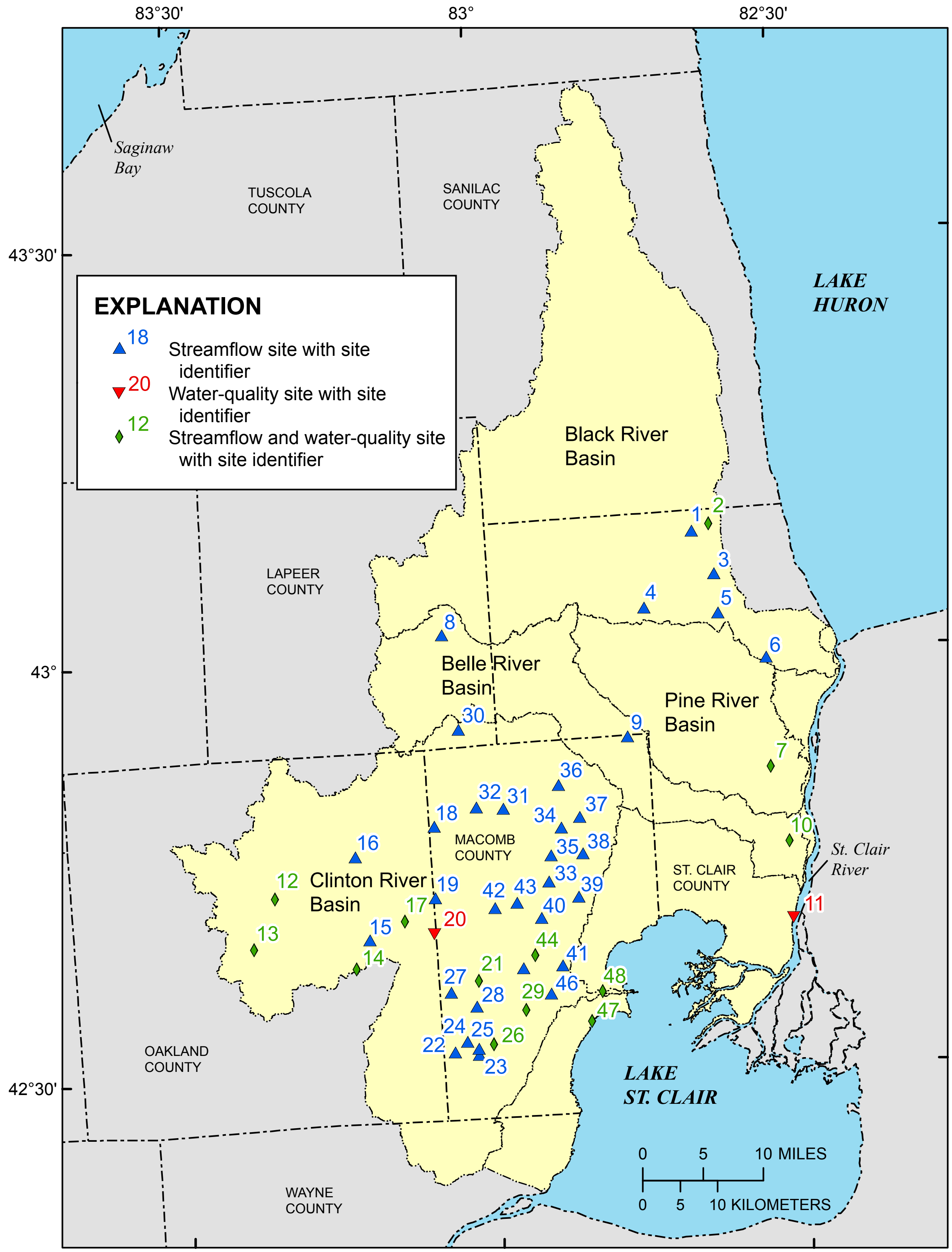


Figure 8. Water-quality sites in the minor river basins, Michigan.



Base from U.S. Geological Survey Digital Line Graphics, 1:2,000,000, 1998

Figure 9. Streamflow gages and water-quality monitors in the study area and on the St. Clair River, Michigan. (Numbers on figure can be used to cross-reference station numbers and names on table 2.)

Table 2. Streamflow gages and water-quality monitors in the study area and on the St. Clair River.

[Site names are presented as they appear in the origin database; °, degrees; ’, minutes; ”, seconds; MI, Michigan; map numbers shown on fig. 9]

Map number (on fig. 9)	Site number	Site name	Latitude			Longitude		
			°	′	″	°	′	″
1	04159488	Silver Creek near Jeddo, MI	43	08	40	82	39	07
2	04159492	Black River near Jeddo, MI	43	09	09	82	37	27
3	04159500	Black River near Fargo, MI	43	05	32	82	37	05
4	14159900	Mill Creek near Avoca, MI	43	03	16	82	44	05
5	04160000	Mill Creek near Abbottsford, MI	43	02	42	82	36	50
6	04160050	Black River near Port Huron, MI	42	59	24	82	32	16
7	04160398	Pine River near Marysville, MI	42	51	31	82	32	17
8	04160570	North Branch Belle River at Imlay City, MI	43	01	49	83	04	02
9	04160600	Belle River at Memphis, MI	42	54	03	82	46	09
10	04160625	Belle River near Marine City, MI	42	46	06	82	30	44
11	04160635	St. Clair River near Robert’s Landing, MI	42	40	32	82	30	39
12	04160800	Sashabaw Creek near Drayton Plains, MI	42	43	12	83	21	13
13	04160900	Clinton River near Drayton Plains, MI	42	39	37	83	23	25
14	04161000	Clinton River at Auburn Hills, MI	42	38	00	83	13	28
15	04161100	Galloway Creek near Auburn Heights, MI	42	40	02	83	12	02
16	04161500	Paint Creek near Lake Orion, MI	42	46	03	83	13	12
17	04161540	Paint Creek at Rochester, MI	42	41	18	83	08	35
18	04161580	Stony Creek near Romeo, MI	42	48	03	83	05	25
19	04161800	Stony Creek near Washington, MI	42	42	55	83	05	31
20	04161810	Clinton River at Avon Road At Yates, MI	42	40	18	83	05	47
21	04161820	Clinton River at Sterling Heights, MI	42	36	52	83	01	36
22	04162010	Red Run near Warren, MI	42	31	46	83	04	07
23	04162400	Red Run at Van Dyke Road near Warren, MI	42	31	32	83	01	46
24	04162900	Big Beaver Creek near Warren, MI	42	32	31	83	02	52
25	04163000	Big Beaver Creek at Van Dyke Road at Warren, MI	42	31	58	83	01	46
26	04163030	Red Run at Warren, MI	42	32	16	83	00	21
27	04163400	Plum Brook at Utica, MI	42	36	05	83	04	17
28	04163500	Plum Brook near Utica, MI	42	35	01	83	01	50
29	04164000	Clinton River near Fraser, MI	42	34	38	82	57	05
30	04164010	North Branch Clinton River at Almont, MI	42	54	59	83	02	42
31	04164050	North Branch Clinton River at 33 Mile Road near Romeo, MI	42	49	11	82	58	35
32	04164100	East Pond Creek at Romeo, MI	42	49	21	83	01	13
33	04164150	North Branch Clinton River at 27 Mile Road near Meade, MI	42	43	50	82	54	23
34	04164200	Coon Creek at North Avenue near Armada, MI	42	47	41	82	52	58
35	04164250	Tupper Brook at Ray Center, MI	42	45	42	82	54	04
36	04164300	East Branch Coon Creek at Armada, MI	42	50	45	82	53	06
37	04164350	Highbank Creek at 32 Mile Road near Armada, MI	42	48	24	82	51	08
38	04164360	East Branch Coon Creek at 29 Mile Road near New Haven, MI	42	45	46	82	50	57
39	04164400	Deer Creek at 25-1/2 Mile Road near Meade, MI	42	42	39	82	51	32
40	04164450	Mcbride Drain at 24 Mile Road near Macomb, MI	42	41	14	82	55	14
41	04164500	North Branch Clinton River near Mt. Clemens, MI	42	37	45	82	53	20
42	04164600	Middle Branch Clinton River at Schoenherr Road near Macomb, MI	42	42	03	82	59	44

Table 2. Streamflow gages and water-quality monitors in the study area and on the St. Clair River.—Continued

[Site names are presented as they appear in the origin database; o, degrees; ‘, minutes; “, seconds; Map numbers shown on fig. 9]

Map number (on fig. 9)	Site number	Site name	Latitude			Longitude		
			°	‘	“	°	‘	“
43	04164800	Middle Branch Clinton River at Macomb, MI	42	42	23	82	57	33
44	04164980	Middle Branch Clinton River near Waldenburg, MI	42	38	34	82	56	00
45	04165200	Gloede Ditch near Waldenburg, MI	42	37	39	82	57	10
46	04165500	Clinton River at Moravian Drive at Mt. Clemens, MI	42	35	45	82	54	32
47	04165557	Clinton River Bypass at Mouth at Mt. Clemens, MI	42	33	41	82	50	43
48	04165559	Clinton River near Mt. Clemens, MI	42	35	47	82	49	34

Table 3. U.S. Environmental Protection Agency STORET Legacy data center parameter groups.

[Groups 01, 17, and 18 were not used in the report]

Group	Group name
01	Administrative
02	Bacteriological
03	Biological
04	Dissolved oxygen
05	Flow
06	General inorganic
07	General organic
08	Metal and semi-metal
09	Nitrogen
10	Oxygen demand
11	Pesticides
12	Phosphorus
13	Physical
14	Radiological
15	Solid
16	Temperature
17	Miscellaneous
18	Other
19	PCBs

Data Quality

The objectives of each sampling project determined the protocols used to collect and analyze the samples. These protocols, in turn, determined the quality of the data collected for each of the projects. Therefore, data quality, including accuracy and precision, varied among the projects. Often, data quality restricted the usefulness of the water-quality data beyond that of the project for which it was collected.

Water-quality data used in the analyses for this report were collected for many purposes by many different stakeholders and agencies that used different field and analytical methods. For the most part, these stakeholders and agencies did not coordinate with site selection and protocols and try to work in a consistent and coherent manner. Field methods varied from hand dipping a bottle or instrument from the bank to collecting width-depth integrated samples with specially designed Teflon samplers. Samples may have been processed (filtered and/or preservatives added) at the collection site, later at another location, or in a laboratory. The sample may have been analyzed in the field with analytical kits or portable instruments or shipped to a laboratory to be analyzed by methods that range from wet chemistry to gas chromatography/mass spectrometry. For most of the samples, references to the type of field and analytical methods used to collect and analyze the samples were not given in the databases.

Water-Quality Characteristics of the St. Clair River, Lake St. Clair, and Their U.S. Tributaries, 1946–2005

The database derived from the data compilation described above provided an opportunity for analysis of data over a nearly 60-year period of change in the U.S. drainages to the St. Clair River/Lake St. Clair waterway. However, difficulty often arises when trying to combined data from many projects with varying objectives, methods, and data standards into a consistent and coherent dataset for analysis. Although a wealth of data is available in the study area, trend and load analyses were precluded at many sites because of the piecemeal fashion in which data were collected. In cases where data were of sufficient consistency and length of record, analyses appropriate to the data were performed. These analyses included comparison of nutrients, chloride, specific conductance, turbidity, and biochemical oxygen demand (BOD) among the basins and the St. Clair River. Microbiological data are not discussed in this section of the report. However, analyses of *Escherichia coli* data are discussed in the section *“Escherichia coli* in Lake St. Clair, the St. Clair River, and the U.S. Tributaries.”

Table 4. Water-quality-sampling program, numbers of sampling sites by basin, and sampling time period.

[MCHD, Macomb County Health Department; MDEQ, Michigan Department of Environmental Quality; USEPA, U.S. Environmental Protection Agency; IJC, International Joint Commission; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers]

Program	Number of sites					Time period			
	Belle River Basin	Black River Basin	Clinton River Basin	Pine River Basin	Minor basins, St. Clair River, Lake St. Clair	1945–1965	1966–1980	1981–1995	1996–2005
Heidelberg College—Pesticide Loading to Lake Erie	1	1	1	1				X	
Lake St Clair Regional Monitoring Project	2	4	11	1	5				X
MCHD Lake St. Clair Assessment			2		53				X
MCHD Surface Water Quality Network			51		13				
Michigan Regulatory Programs	20	14	58	4	18	X	X	X	X
MDEQ long-term water quality	1	1	3	1			X	X	X
Michigan Water Chemistry Monitoring Program		1	2		3				X
USEPA IJC Great Lakes Assessment		2	26			X	X		
USEPA MDEQ nutrient study		26	34				X		
USEPA Toxic Assessment		6					X		
USGS Extreme Conditions	2	2	24				X		
USGS miscellaneous		1	2				X		
USGS National Stream Quality Accounting Network			1		1		X	X	
USGS National Water-Quality Assessment Program		1	1						X
USGS North Branch Clinton River Assessment			38				X		
USGS Statewide low flow study	6	10	11	4			X		
USGS-Oakland County Cooperative Assessment Study			18						X
USGS-USACE Cooperative Study	18	33	38	18	9		X		

The data compiled for this report are neither spatially nor temporally uniform. Of the 17,645 discrete water-quality samples available, approximately 40 percent were collected in the Clinton River Basin; approximately 34 percent were collected in Lake St. Clair for the MCHD Lake Assessment or for beach monitoring; and approximately 26 percent were collected in the Belle River Basin, Black River Basin, Pine River Basin, minor river basins, and St. Clair River.

Water-quality sampling peaked in the study area during 1966–80 and was very active again from 1995 to the present (fig. 10). Although sampling to fulfill regulatory requirements was ongoing over the period of record, other objectives such as assessments, loads, or trends dominated certain periods. The period 1966–80 included several assessment studies by the USGS and MDEQ that sampled relatively large numbers of sites only once or twice and for only a few parameters. The emphasis shifted during 1981–95 to studies estimating parameter loads and/or trends. These studies which included the USGS National Stream Quality Accounting Network (NASQAN), the MDEQ long-term water-quality sites program, and Heidelberg College Lake Erie tributary loads program, collected many samples at few sites (fig. 11).

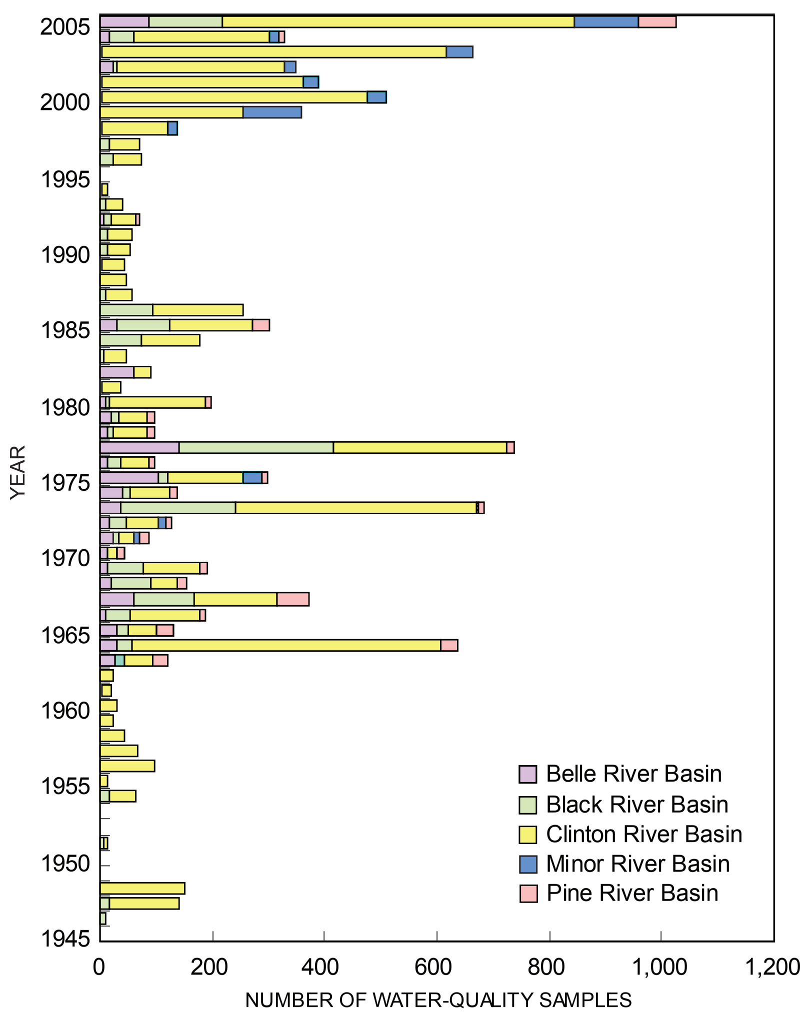


Figure 10. Number of water-quality samples collected in the St. Clair River/Lake St. Clair study-area river basins, by year.

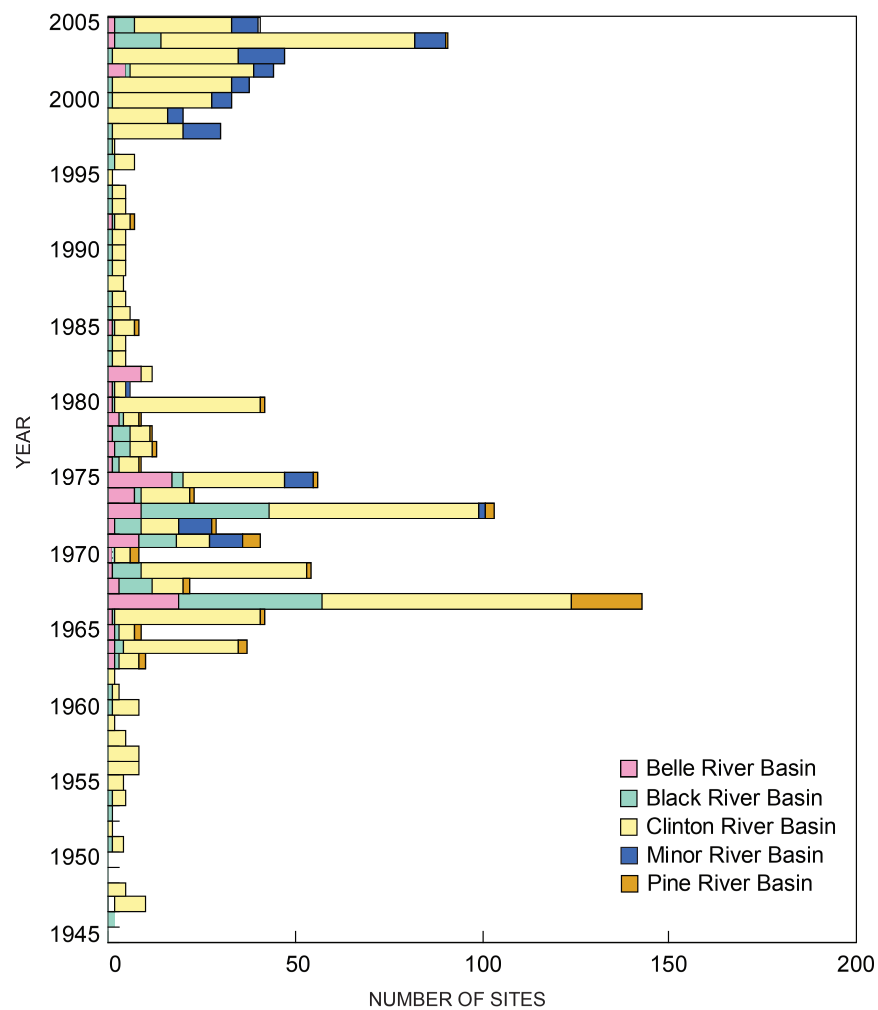


Figure 11. Number of water-quality sampling sites in the St. Clair River/Lake St. Clair study-area river basins, by year.

The period 1995–2005 saw studies that combined both assessment with loading estimates or trends. During this period, the USGS National Water-Quality Assessment (NAWQA), a nationwide study, and the Michigan Water Chemistry Monitoring Project (MWCMP), a statewide study, sampled intensely at a few sites to estimate loads, set baselines for trends, and determine the presence/absence of specific priority or emerging chemicals of concern. The USGS Oakland study assessed the water resources of Oakland County, which includes the upper Clinton River Basin. The LSCRMP sampled intensely over a 2-year period to assess water quality in the study area and estimate storm loading to Lake St. Clair. MCHD ran a countywide surface-water-quality network to sample for fecal bacteria indicators and a Lake Assessment program that collected samples from Lake St. Clair for regulatory programs and trend assessments.

Statistical and Graphical Methods

Statistical and graphical methods were both used to analyze and interpret the Lake St. Clair Region dataset. Helsel and Hirsch (2002) list characteristics of water-quality datasets that may influence the statistical methods used. These characteristics included seasonal patterns in data, nonnormal distribution, and presence of outliers, among others. These data characteristics were evaluated and the appropriate method selected for analysis.

"Detection limit" is used throughout this report for the concentration at which a laboratory reports a censored or nonquantitative symbol. The method of reporting censored data varied among the different reporting agencies and has changed over time. Censored data (data that contains "less than" or "greater than" values) have been reported as zero values (0), nondetects (ND), and less than the detection limit (< value). However, zero values may also be the result of rounding to significant figures for some constituents, and ND and < values have been used together—ND representing samples in which the constituent was not detected and the < value representing samples where the constituent was detected at a concentration below the detection limit. For this project, censored data were included as reported in the source database. Data reported at concentrations below the detection limit were typically flagged as estimated values.

Boxplots, also known as box-and-whisker plots, are a graphical representation of a dataset. The two ends of the box are the 25th and 75th percentiles, and the centerline is the median. The relative sizes of the two halves of the box show whether the data are evenly spread or skewed. Lines extending from both the 25th and 75th percentile line represent data values that fall within one and a half times the interquartile range from the 25th or 75th percentile: these values are called adjacent values. Data falling beyond the adjacent values are called outliers, and their presence may indicate that the data are not normally distributed.

Relations among parameters were examined by use of Kendall's tau correlation coefficients, a rank-based procedure that measures the strength of a monotonic relation between two parameters (Helsel and Hirsch, 2002). This procedure is resistant to outliers, measures linear and nonlinear monotonic correlations, and can be used with censored data. For this report, coefficients greater than or equal to 0.7 or less than or equal to -0.7 show a strong relation; coefficients between 0.3 and 0.7 or between -0.3 and -0.7 show a moderate correlation; and coefficients between -0.3 and 0.3 inclusive show no correlation.

The Wilcoxon rank-sum test and the Kruskal-Wallis test were used in this report to examine the relation between datasets of a single variable (Ott, 1993). The Wilcoxon rank-sum test is a nonparametric test that compares the ranks of data from two datasets. This test is similar to a t-test and can be used when the data sets do not fit the requirements of the t-test, such as normal distribution and equal variances. The test results are compared to critical values determined whether the number of data values and a predetermined probability (α) to determine if the two data sets come from independent populations. The test hypothesis is that there is no difference between the populations. The rank-sum test for this report was two-tailed, and α was set at 0.05.

The Kruskal-Wallis test extends the concept of a rank-sum test to more than two populations (Ott, 1993). It is a nonparametric test that uses the ranks of the data to determine whether three or more populations are independent; however, the test does not identify which of the populations differs from the others. The test hypothesis is that there are no differences between the populations. For this report, test results with probabilities less than 0.05 were considered to show significant differences between the populations. A more detailed description of the Wilcoxon rank-sum test and the Kruskal-Wallis test can be found in Helsel and Hirsch (2002) and Ott (1993).

A contingency table and a chi-square test of independence (Ott, 1993) were used in this report to examine the temporal relations of chloride samples and the number of chloride samples with concentrations that exceeded the chloride ambient water-quality criteria. The contingency table was a two-way table that categorized the data above and below each water-quality criterion and before and after 1998. The chi-square test used the observed cell counts and the expected cell counts to calculate a test statistic that was compared to the critical value in the chi-square table for a $\alpha = 0.05$ and 1 degree of freedom. Descriptions of contingency tables and the chi-sqare test of independence can be found in Ott (1993).

Trend Analysis

Trends in water-quality characteristics were examined by use of the ESTREND statistical program developed by the USGS (Schertz and others, 1991) and incorporated in the statistical package S-Plus (Insightful Corp., 2001). This package employs the Seasonal Kendall trend test and an adjusted maximum likelihood estimation method developed by Cohn (1988), called Tobit, to analyze for trends. The Seasonal Kendall trend test was used for datasets with less than 5 percent censored data or data that had been censored at a single detection limit. For use with uncensored data, the Seasonal Kendall trend analysis test requires 5 years or more of data; a minimum number of water-quality values that are at least 3 times the number of designated annual seasons, with a minimum of 10; and a user-defined minimum percentage of total seasonal water-quality values in the beginning and ending fifths of the record. For use with censored data, a minimum of one water-quality data value per year is also required in the beginning and ending fifths of the record. For datasets with multiple detection limits and/or highly censored data, Tobit was used (Schertz and others, 1991). The criteria for use of the Tobit are a minimum of 5 years of record, a minimum of 10 uncensored water-quality values, a user-specified minimum percentage of the data must be uncensored water-quality values, and a minimum of one water-quality value per year must be in the beginning and ending fifths of the record.

Two time periods were chosen to examine for trends from 13 locations in the Belle, Black, Clinton, and Pine River Basins. The first, from approximately the mid-1970s to the mid-1990s, was used to examine for long-term trends. The second, from 1998 to 2005, was used to examine more recent short-term trends.

The steps followed in the ESTREND program are (1) examine the data, (2) define and pick seasons, (3) flow-adjust the concentrations, if applicable, and (4) run the trend analyses. Seasons are divisions of the year and may range from 1 to 12 in number. Flow-adjusted concentrations (FAC) were developed by normalizing the concentrations to streamflow with the smoothing-curve method LOESS (Cleveland and Devlin, 1988). The step-by-step procedures followed in the ESTREND program can be found in Stark and others (2003).

Load Estimation

Loads are mass per time period and can be expressed for any time period, such as seconds (commonly referred to as instantaneous), hours, days, months, and years. Methods for estimating loads include integration methods, ratio estimators, and regression methods. Loads for this report were estimated by regressing parameter concentrations or the natural logarithms of the concentrations with daily mean streamflow for the sampling date or the natural logarithm of the daily mean streamflow. The sampling dates and streamflow data used to develop the regression equations and the specific time frame during which the data was collected differed from basin to basin; however, the relations they represent are considered to be consistent enough to be used to estimate loads for specific parameters given flow conditions observed during the LSCRMP period.

Loads were estimated at a single location within the Belle River Basin, at two locations within the Black River Basin, and at three locations within the Clinton River Basin. Regression models were developed for each parameter analyzed within each basin, resulting in model coefficients specific to the basin and parameter. Independent variables, examined as part of this analysis, were continuously monitored water-quality parameters (such as specific conductance, dissolved oxygen, temperature, or pH), streamflow, and seasonality. The concentration of selected water-quality parameters were the dependant variables. The smoothing method LOESS was used for parameter concentration data with less than 5 percent censored values, and Tobit was used for datasets with greater than 5 percent censored values.

The resulting model was then used with the daily mean streamflow, collected as part of the LSCRMP, to calculate a daily load estimate for the parameter. The daily load estimates were summed by month and are presented as total monthly load estimates for the period of June 2004 to October 2005. It is important to note that this analysis assumes that the relation between the water-quality parameter and the independent variables is consistent within the basin up to the sampling location and over the time period the samples were collected and that these conditions have not changed appreciably since the data was collected.

Water-Quality Standards and Criteria

The 2006 legal and recommended standards and criteria referenced in this report are applied as reference levels to all data no matter when they were collected and whether the collection procedure followed the described protocols, such as number of samples within a specified time period. The exceptions were the *E. coli* standards, for which the collection protocols are taken in consideration. Rule 57 and Rule 62 are from Part 4 of the Environmental Quality Section of the Michigan Administrative Code and set legal standards and criteria for toxic substances and microorganisms, respectively (State of Michigan, 2006). Under Rule 57, criteria values are set for ambient waters by their use, which include human contact, human contact including drinking, non-aquatic wildlife protection, and aquatic wildlife protection (table 5). The most stringent applicable criterion is the criterion applied to the waterway. Under Rule 62, standards for *E. coli* bacteria are set by the time of the year. The full body contact standard of 300 colony forming units (CFU) per 100 milliliters (mL) is in effect May 1 through October 31. The partial body contact standard of 1,000 CFU is in effect November 1 through April 30.

The USEPA uses a system of ecoregions (Omernik, 1987) based on a perceived pattern of causal and integrative factors including land use, land-surface form, potential natural vegetation, and soils to set regional criteria for nutrients. The USEPA recommended ambient water-quality criteria for total nitrogen, total phosphorus, and turbidity referred to in this report are specific to rivers and streams in ecoregion VII, a mostly glaciated area that extends from Minnesota through Wisconsin, Michigan, Ohio, Pennsylvania, and New York (U.S. Environmental Protection Agency, 2000a).

Table 5. Water-quality standards and criteria.

Name	Definition
State of Michigan	
Aquatic maximum value—AMV	The highest concentration of a material in the ambient water column to which an aquatic community can be exposed briefly without resulting in unacceptable effects.
Final acute value—FAV	The level of a chemical or mixture of chemicals that does not allow the mortality or other specified response of aquatic organisms to exceed 50 percent when exposed for 96 hours, except where a shorter time period is appropriate for certain species.
Final chronic value—FCV	The level of a substance or mixture of substances that does not allow injurious or debilitating effects in an aquatic organism resulting from repeated long-term exposure to a substance relative to the organism's lifespan.
Human cancer value—HCV	The maximum ambient water concentration of a substance at which a lifetime of exposure from either drinking the water, consuming fish from the water, and conducting water-related recreation activities (drink) or consuming fish from the water and conducting water-related recreation activities (non-drink) will represent a plausible upper bound risk of contracting cancer of 1 in 100,000.
Human noncancer value—HNV	The maximum ambient water concentration of a substance at which adverse noncancer effects are not likely to occur in the human population from lifetime exposure through either drinking the water, consuming fish from the water, and conducting water-related recreation activities (drink) or consuming fish from the water and conducting water-related recreation activities (non-drink).
Wildlife value—WL	The maximum ambient water concentration of a substance at which adverse effects are not likely to result in population-level impacts to mammalian and avian wildlife populations from lifetime exposure through drinking water and aquatic food supply.
Escherichia coli (*E. coli*) full body contact recreation, 30-day geometric mean	All surface waters of the state protected for full body contact recreation shall not contain more than 130 *Escherichia coli (E. coli)* per 100 milliliters, as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during 5 or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of 3 or more samples taken at representative locations within a defined sampling area.
Escherichia coli (*E. coli*) full body contact recreation, acute	At no time shall the surface waters of the state protected for full body contact recreation contain more than a maximum of 300 *E. coli* per 100 milliliters. Compliance shall be based on the geometric mean of 3 or more samples taken during the same sampling event at representative locations within a defined sampling area.
Escherichia coli (*E. coli*) partial body contact recreation	All surface waters of the State protected for partial body contact recreation shall not contain more than a maximum of 1,000 *E. coli* per 100 milliliters. Compliance shall be based on the geometric mean of 3 or more samples, taken during the same sampling event, at representative locations within a defined sampling area
U.S. Environmental Protection Agency	
Criterion continuous concentration—CCC	The CCC is a multiday average concentration of a pollutant in ambient water that should not be exceeded more than once every three years on the average. This criterion is used to protect aquatic life from chronic effects.
Criteria maximum concentration—CMC	The CMC is the one-hour average concentration in ambient water that should not be exceeded more than once every three years. This criterion is used to protect aquatic life from acute effects.
Maximum Contaminant Level—MCL	The highest level of a contaminant that is allowed in drinking water.

Basin-to-Basin Comparison

Because the environmental setting of each of the U.S. tributaries differs from the others, the water-quality characteristics of the tributaries are expected to vary. Concentrations of nitrogen and phosphorus species and chloride and values of specific conductance, turbidity, and BOD were compared among the Belle River Basin, Black River Basin, Clinton River Basin, Pine River Basin, and the minor river basins, which were treated as a single entity. Pesticides, which have been sampled for sporadically throughout the study area, are compared among the basins where data are available. Values for the St. Clair River were also included in the comparisons. For all boxplots in this report, data censored at concentrations larger than the detection limit used in the graph were not used as part of the analyses.

Nitrogen

Nitrogen species are important nutrients and can contribute to cultural eutrophication. Surface waters have been analyzed for concentrations of various forms of nitrogen—total nitrogen, nitrate, nitrite, and ammonia, to name but a few—since the 1940s. Nitrogen data first appear in the LSCRMP database in 1956 and continue to be collected.

Total nitrate data (fig. 12) are available for 1956 through 2005. The data contain values censored at four detection limits. The limit of 0.02 mg/L as nitrogen (N) used in the graph allowed for maximum presentation of information with the least loss of data. Two values censored at 0.05 mg/L as N and five values censored at 0.099 mg/L as N were not used in the construction of the graph.

Kruskal-Wallis and Wilcoxon rank-sum tests (Ott, 1993) showed that, at a 95-percent confidence interval, there are significant differences between the nitrate concentrations in the different basins. Concentrations in the Belle and Black River Basins are not significantly different from each other ($p = 0.326$), whereas concentrations in the Pine River Basin significantly differed from both ($p = 0.027$ for the Belle and $p = 0.015$ for the Black).

Median concentrations of total nitrate were well below the recommended USEPA total nitrogen ambient water-quality criterion of 0.54 mg/L as N for nutrient ecoregion VII for all study-area streams except the Clinton River. Approximately 75 percent of samples from the Clinton River Basin had concentrations of total nitrate that exceeded the limit for total nitrogen without the inclusion of other nitrogen species (ammonia, organic nitrogen, and nitrite). Although the majority of the nitrate concentrations often exceeded the USEPA recommended total nitrogen criterion, nitrate concentrations rarely exceeded the drinking-water standard's Maximum Contaminant Level (MCL) of 10 mg/L. Total nitrate concentrations in the St. Clair River exceeded the USEPA criterion for total nitrogen twice out of 187 samples, and the highest total nitrate concentration measured in the St. Clair River was approximately an order of magnitude less than the drinking-water standard.

In addition to total nitrate samples, a larger number of dissolved nitrite plus nitrate samples were collected from 1972 to 2005 (fig. 13). In well-oxygenated surface waters, nitrite concentrations are usually substantially less than nitrate concentrations and, in addition, dissolved species should have concentrations less than total species concentrations of the same parameter. However, the median concentrations of dissolved nitrite plus nitrate for the five basins in the study area are significantly larger than the total nitrate concentrations from figure 12. The differences between the two datasets are partially due to the inclusion of nitrite in one dataset. In addition, all censored values in the nitrate dataset were collected prior to 1972 or are from the LSCRMP study. The dissolved nitrite plus nitrate data do show a high percentage of values above the recommended ambient criterion (63.3 percent), and there are four values from the Black and Clinton Basins greater than the total nitrogen ambient criterion.

Phosphorus

In many parts of the United States, phosphorus is considered the limiting nutrient because it is the first of the nutrients to be depleted in water bodies, thereby limiting algal and plant growth. The USEPA recommends an ambient total phosphorus criterion of 0.033 mg/L for rivers and streams in this study area (U.S. Environmental Protection Agency, 2000a). Phosphorus samples have been collected from 1967 to the present. The median value for total phosphorus concentrations in the five basins in the study area ranged from 0.083 mg/L as P for the Pine River Basin to 0.14 mg/L as P for the Clinton River and minor river basins (fig. 14). The median value for the St. Clair River was at the detection limit of 0.0099 mg/L as P. More than 93 percent of the phosphorus concentrations for the Belle, Black, Pine and minor river basins and 84 percent of the phosphorus concentrations for the Clinton River Basin are greater than this criterion. Only 9.1 percent of the phosphorus concentrations from the St. Clair River are greater than the criterion.

Chloride

Major anthropogenic sources of chloride in the study area are agricultural and urban runoff and municipal and industrial wastewater discharges. Samples were collected in the study area since 1947, and data were available from all five databases. Because chloride ions do not significantly enter into oxidation/reduction reactions, form solute complexes, adsorb on mineral surfaces, or form salts of low solubility (Hem, 1985), the dissolved and total chloride data were treated as a single dataset unlike nitrate and phosphorus above. Chloride concentrations in the study area appear to have a log-normal distribution, with medians that range from 42 mg/L for the Black River Basin to 140 mg/L for the minor river basins (fig. 15). The median for the St. Clair River was 6.0 mg/L.

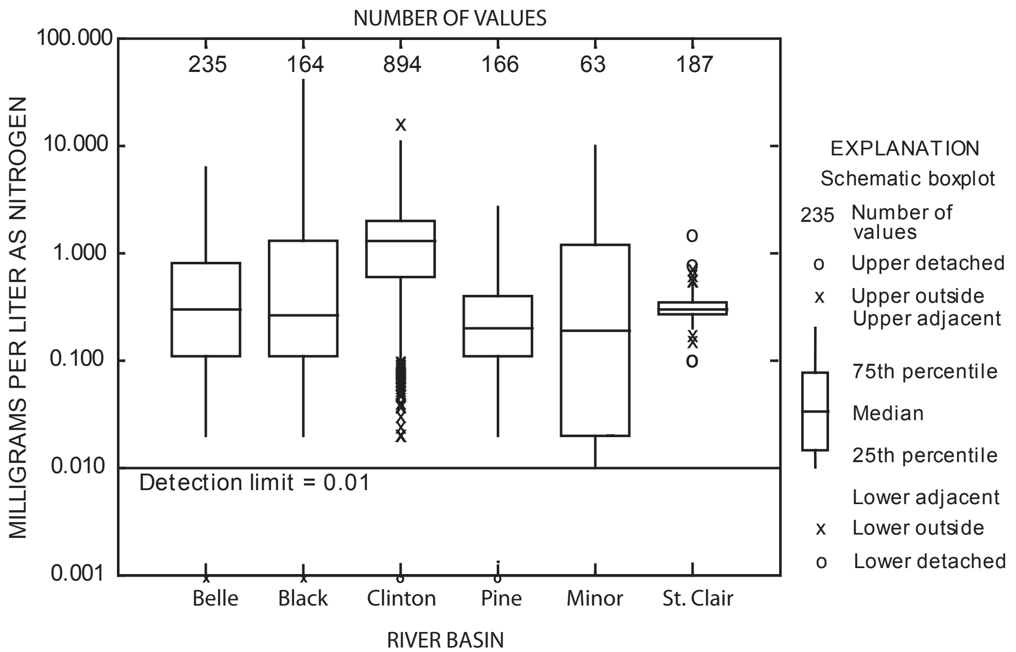


Figure 12. Nitrate concentrations in the Belle, Black, Clinton, Pine, and minor river basins and the St. Clair River. (Criterion is the USEPA recommended total nitrogen criterion for ecoregion VII, 0.54 milligrams per liter.)

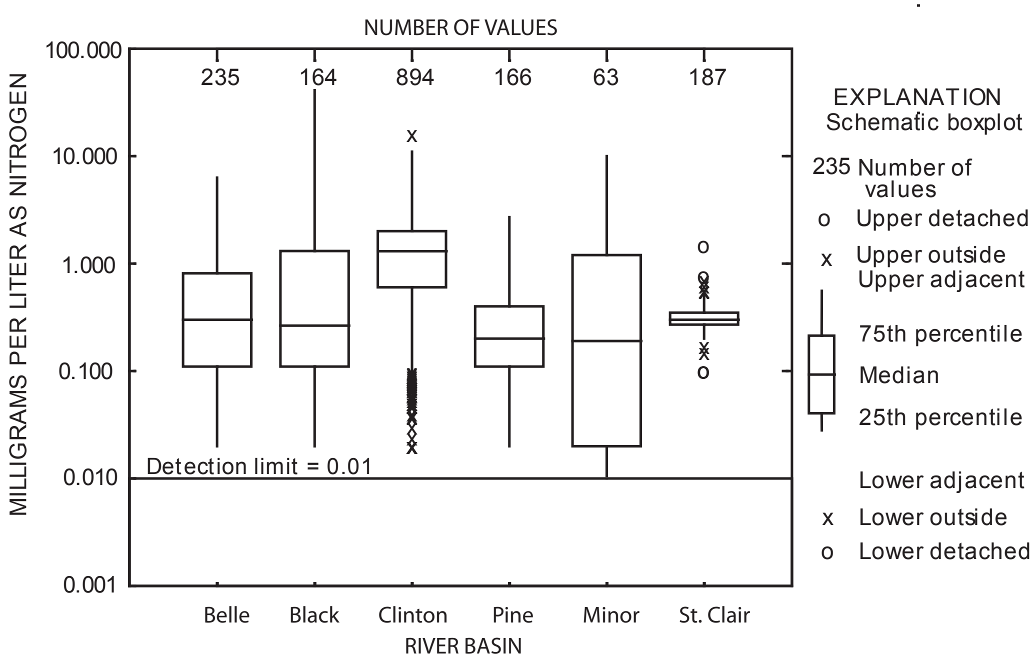


Figure 13. Dissolved nitrate plus nitrite concentrations in the Belle, Black, Clinton, Pine, and minor river basins and the St. Clair River. (Criterion is the USEPA recommended total nitrogen criterion for ecoregion VII, 0.54 milligrams per liter).

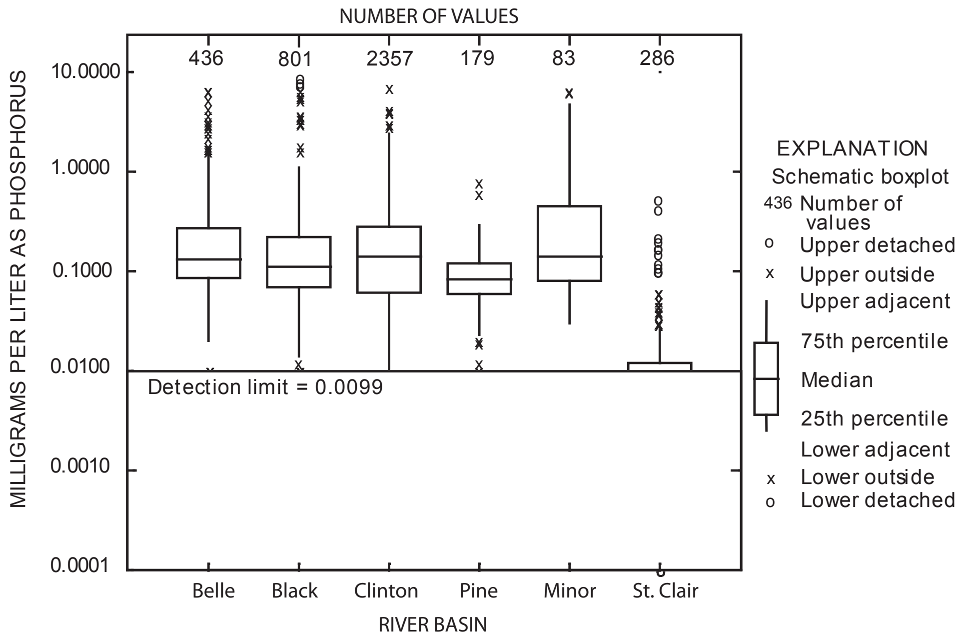


Figure 14. Total phosphorus concentrations in the Belle, Black, Clinton, Pine, and minor river basins and the St. Clair River. (Criterion is the USEPA recommended total phosphorus criterion for ecoregion VII, 0.033 milligrams per liter).

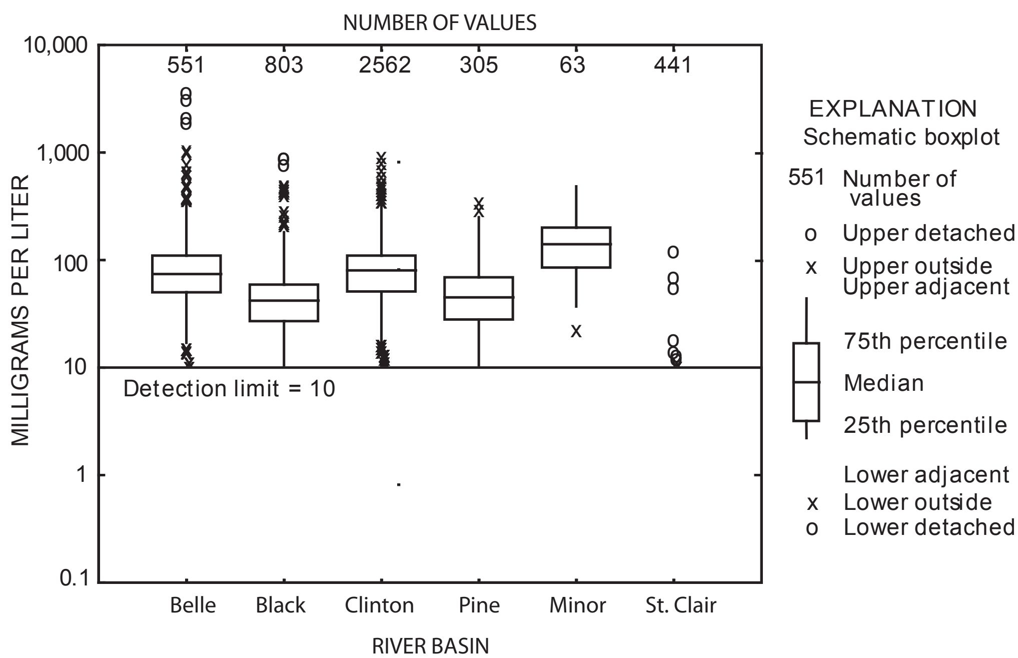


Figure 15. Chloride concentrations in the Belle, Black, Clinton, Pine, and minor river basins and the St. Clair River. (CCC, Criterion Continuous Concentration is 230 milligrams per liter; CMC, Criterion Maximum Concentration is 860 milligrams per liter).

Chloride data were censored at two detection limits; the larger of the two, 10 mg/L, was used in figure 15. A total of 518 samples with uncensored values were censored at this limit; 407 of these values were from the St. Clair River.

The USEPA criterion maximum concentration (CMC) for chloride is 860 mg/L, and the criterion continuous concentration (CCC) is 230 mg/L (U.S. Environmental Protection Agency, 1988). For chloride, the CMC is the concentration that should not be exceeded for 1 hour once every 3 years; the CCC is the concentration that should not be exceeded for 4 days once every 3 years. Nine chloride concentrations exceeded the CMC, with the six largest being in the Belle River Basin. An additional 159 chloride concentrations exceeded the CCC. Approximately 46 percent (73) of the concentrations that exceeded the CCC were from 2002 through 2005, a period during which only 14 percent of the chloride samples were collected. A contingency-table analysis of these data indicated that the probability of nearly half of all exceedances randomly occurring within 14 percent of all samples is less than 0.001. Therefore, it appears that high chloride concentrations were increasingly common from 2002 to 2005; however, more detailed analyses, such as point-source locations and runoff conditions at time of sampling, would be need to confirm this finding.

Specific Conductance

Conductance is the ability of a substance to conduct electricity, and specific conductance is the conductance over a unit length and cross section at a specific temperature (Hem, 1985). For water, the unit length and cross section are 1 centimeter, and the temperature is 25 degrees Celsius. Specific conductance is an easily measured indication of ion concentration and is often correlated with dominant ionic species. The data presented in figure 16 are for discrete samples measured from 1951 through 2005.

The urban minor river basins had the highest median specific conductance, whereas the agricultural Pine River Basin had the lowest median specific conductance (fig. 16). The agricultural Belle River Basin median specific conductance measurement was higher than the median measurement from the mixed agricultural/urban Clinton River Basin. This relation may reflect basin conditions or be the result of where samples are collected for the different studies in the basins to identify point sources. The specific conductance measurements from the St. Clair River were significantly less than the measurements in any of the basins. The median measurement value for the St. Clair River, 210 μS/cm is approximately 40 percent that of the Pine River Basin, 462 μS/cm. Over the entire study area, specific conductance has a strong correlation to chloride, a Kendall's tau correlation coefficient of 0.68; to total solids, a Kendall's tau correlation of 0.82; and to total dissolved solids, a Kendall's tau correlation coefficient of 0.84.

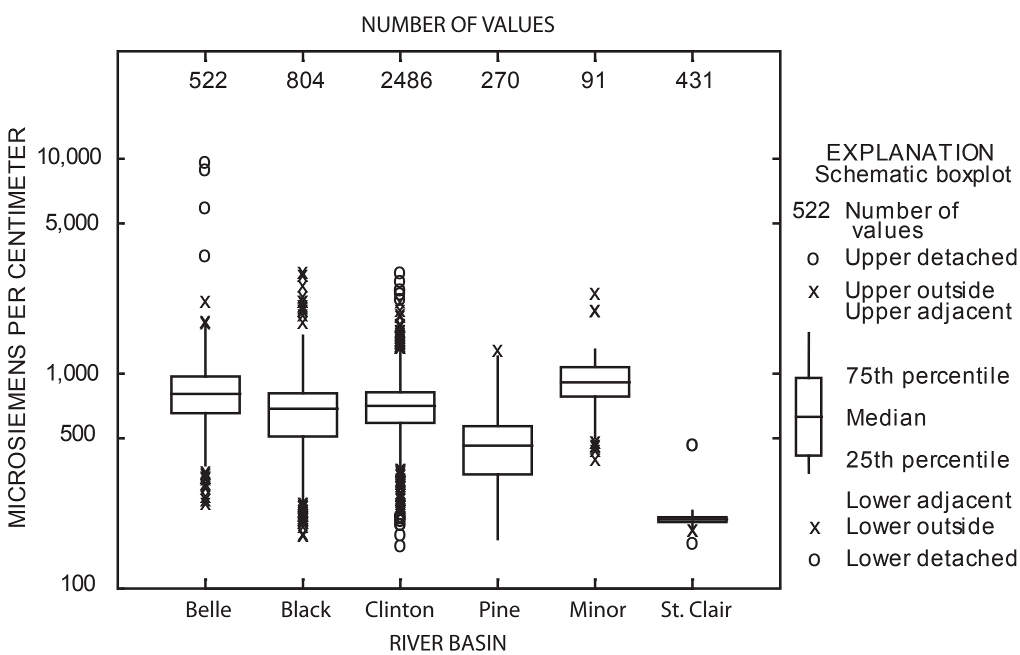


Figure 16. Specific conductance measurements in the Belle, Black, Clinton, Pine, and minor river basins and the St. Clair River.

Biochemical Oxygen Demand

The decomposition of organic matter whether from natural or anthropogenic sources puts a demand on the dissolved oxygen concentrations in water bodies. Measures of this demand include biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC). The oxygen demand parameter with the most data values in the study area is BOD, 5-day, 20 degrees, which is the amount of dissolved oxygen required by aerobic microorganism to decompose the organic matter in 1 liter of water over 5 days at 20 degrees Celsius. This measurement has been found to be approximately two-thirds of the total oxygen requirement required to decompose all organic matter in the sample.

The median values of BOD for the five basins in the study area ranged from 2.4 mg/L for the Pine River Basin to 3.2 mg/L for the Black and Clinton River Basins, whereas the median for the St. Clair River was 0.5 mg/L (fig. 17). The data were collected from 1947 through 2005. The detection limit of 2 mg/L was the highest of three limits at which data were censored and required that 1 value censored at 6 mg/L be discarded and 878 uncensored data values be shown as censored data on figure 17. The use of a lower detection limit would require that 170 values censored at 2 mg/L be discarded from the graph. Neither the MDEQ nor the USEPA have set an ambient water criterion for BOD; criteria are set directly for dissolved oxygen concentrations. However, it is generally considered that if BOD concentrations are between 6 to 10 mg/L, conditions are poor and the water body is somewhat polluted.

Pesticides

Pesticides, herbicides, insecticides, and fungicides, have been sampled for in the study area sporadically since 1972, typically as part of a focused study of their occurrence and distribution. In particular, studies by Heidelberg College (Richards, 1994) and the USGS NAWQA program (Myers and others, 2000) gathered much information on pesticides in the study area. The Heidelberg College study analyzed 125 samples from 4 sites (near the mouth of the Belle, Black, Clinton, and Pine Rivers) for 10 pesticides during the 1985 growing season. USGS NAWQA samples, collected as part of the Lake Erie/Lake Saint Clair study, amounted to 66 samples from two sites (Black and Clinton Rivers) from 1996 to 1998. These samples were analyzed for 44 pesticides and 3 pesticide degradates.

The Heidelberg College study (1985) detected all 10 pesticides at least once at each of the sites. Atrazine was the most commonly detected pesticide, found in 103 of 125 samples. The highest concentrations of pesticides were found in samples from the mouth of the Clinton River.

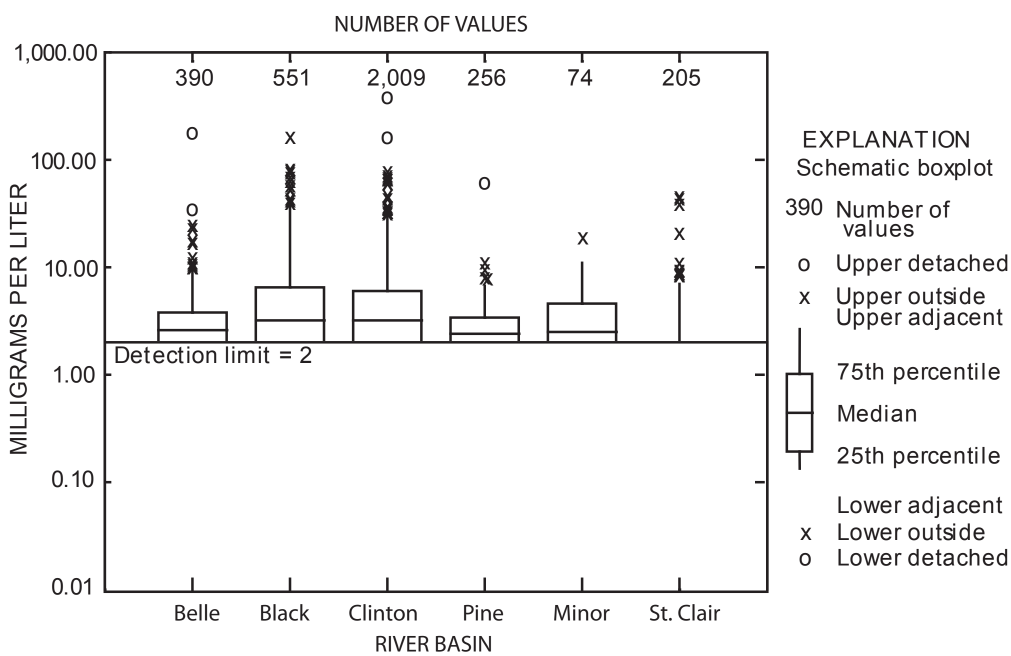


Figure 17. Biochemical oxygen demand concentrations in the Belle, Black, Clinton, Pine, and minor river basins and the St. Clair River.

The USGS NAWQA study (1996–98) detected atrazine and metalochlor in every sample (Black and Clinton Rivers), with metalochlor being present in the highest concentration of any pesticide. The highest concentration of metalochlor (37.3 μg/L) and atrazine (7.32 μg/L) were found in the Black River on June 26, 1997. In contrast to the earlier Heidelberg College study, the NAWQA study found the majority of high pesticide concentrations, 47 of the 50 highest, in samples from the Black River. Changing land-use patterns, specifically conversion of agricultural lands to urban/residential lands in the Clinton River Basin, may explain this difference.

Water-Quality Trends in the Black and Clinton River Basins

For this report, 13 sites in the Belle River, Black River, Clinton River, and Pine River Basins were examined for long-term and (or) short-term trends as described in the methods section. Two time periods were chosen to examine for trends from 13 locations in the Belle, Black, Clinton, and Pine River Basins. The first, from approximately the mid-1970s to the mid-1990s, was used to examine for long-term trends. The second, from 1998 to 2005, was used to examine more recent short-term trends. Data from nine of the sites did not fit the requirements for trend analysis. Of the remaining four sites, three were in the Clinton River Basin and one in the Black River Basin; data from the Clinton River at Moravian Drive at Mount Clemens site (04165500) had recently been analyzed for trends by Syed and Fogarty (2005) with the same trend-analysis procedures and programs used for this report. Data from the Black River at Wadhams Road Bridge, Kimball Township (740153); the Clinton River at Hamlin Road Bridge, Avon Township (630252); and the Clinton River at Gratiot Avenue in Mount Clemens (500233) were examined for long-term trends.

Trend analyses of the Black River data were conducted on 4 physical parameters and on flow-adjusted concentrations (FAC) for 16 water-quality parameters (table 6). Uncensored Seasonal Kendall test were used to analyze all 20 parameters. No significant trends were found for the period 1978 through 1994 at the $p = 0.05$ level.

Five physical parameters and 13 FAC water-quality parameters for the Clinton River at Hamlin Road Bridge were examined for trends from 1972 through 1993 (table 7). Uncensored Seasonal Kendall tests were used to analyze 16 parameters, and Tobit regression was used to analyze total suspended solids. For the period 1978 through 1994, significant positive trends were found for dissolved oxygen and pH at the $p = 0.05$ level. Significant negative trends were found for BOD, total ammonia, and un-ionized ammonia.

Twenty-five parameters from the Clinton River at Moravian Drive at Mount Clemens for the period 1973 through 1995 were examined for trends by Syed and Fogarty (2005) (table 8). They found significant positive trends for pH, dissolved calcium, dissolved magnesium, dissolved chloride, and hardness; and significant negative trends for dissolved sulfate, total ammonia, total ammonia plus organic nitrogen, total nitrite plus nitrate, total nitrogen, and total phosphorus at $p = 0.05$. Uncensored Seasonal Kendall tests were used to analyze all parameters.

Four physical parameters and 15 FAC water-quality parameters from the Clinton River at Gratiot Avenue in Mount Clemens were examined for trends for the period 1974 through 1993 (table 9). Uncensored Seasonal Kendall tests were used to analyze all parameters. Significant increasing (positive) trends were found for specific conductance, dissolved oxygen, pH, total solids, and chloride; and significant negative trends were found for turbidity, BOD, total ammonia, un-ionized ammonia, total ammonia plus organic nitrogen, total phosphorus, TOC, and total orthophosphate.

The number of significant trends, either positive or negative, found at each site ranged from none at the Black River at Wadhams Road Bridge to 13 at the Clinton River at Gratiot Avenue in Mount Clemens. The Clinton River sites, in Avon Township (Rochester Hills) and Moravian Road and Gratiot Avenue, both in Mount Clemens, show an increasing number of trends in the downstream direction; however, it should be noted that the sites were not sampled for the same parameters or species. The Moravian Road site samples were analyzed mainly for dissolved species, whereas the other two sites were sampled for total species. Less than half that number of trends was found at the Avon Township (Rochester Hills) site, upstream from the urbanized areas of the basin, than at the two downstream sites. The two Mount Clemens Clinton River sites are within 1-½ mi of one another, the Gratiot Avenue site being further downstream. At both sites, dissolved solids are increasing and nutrients are decreasing. A positive trend for pH and a negative trend for ammonia were found at all three sites. Negative trends for BOD and un-ionized ammonia were found at the Avon Township (Rochester Hills) and Gratiot Avenue in Mount Clemens sites; BOD was not sampled for and un-ionized ammonia not calculated for the Moravian Avenue in Mount Clemens site.

Trend analysis can identify significant monotonic trends and estimate the magnitude of the trend; however, it does not discern the underlying reasons for it. Land-use changes are likely strong influences on water-quality trends. The three Clinton River sites, in areas of rapid land-use change, had from 5 to 13 significant trends, whereas the Black River site, in a basin that has undergone little land-use change, had no significant water-quality trends. Other influences on water quality include improvements in wastewater treatment, such as increases in treatment efficiency; increases in treatment capacity and separation of sewerage; and stormwater runoff.

Table 6. Water-quality trends at Black River site 740153, 1978–94.

[Uncensored Seasonal Kendall test applied to all parameters; Cross reference between site identifier and map number are in Appendix 1-1]

Parameter	Begin year	Number of years	Number of seasons	Flow-adjusted concentration model	Number of seasonal observations	Trend	Percentage of median value	Probability value	Significance and direction
Water temperature	1978	16	6	None	68	0	0.000	0.3046	None
Turbidity	1978	16	6	Loess	68	-.2531	-1.633	.3005	None
Specific conductance	1978	16	6	Loess	68	1.50687	.207	.3175	None
Dissolved oxygen	1978	16	1	None	12	.20315	2.539	.1905	None
Biochemical oxygen demand	1978	16	1	Loess	12	-.13025	-5.210	.0641	Down
pH	1978	16	4	None	46	0	.000	.8492	None
Acid-neutralizing capacity	1978	16	6	Loess	57	1.79642	.921	.2803	None
Total solids	1978	16	6	Loess	68	.61978	.124	.4081	None
Total suspended solids	1978	16	6	Loess	68	-.3748	-1.562	.3774	None
Total organic nitrogen	1978	16	6	Loess	57	-.0101	-1.008	.1623	None
Total ammonia	1978	16	6	Loess	68	-.0003	-.522	.8879	None
Nitrite	1983	11	6	Loess	53	-.0005	-2.725	.3542	None
Un-ionized ammonia	1978	16	6	None	68	1.36E-05	.978	.6893	None
Ammonia plus organic nitrogen	1978	16	2	Loess	17	-.009	-.749	.8144	None
Total nitrate plus nitrite	1978	16	6	Loess	68	.0025	.209	.8119	None
Total phosphorus	1978	16	6	Loess	68	-.0017	-2.189	.1109	None
Total organic carbon	1978	16	1	Loess	10	-.365	-3.318	.0736	Down
Chloride	1978	16	6	Loess	68	.287268	.569	.3639	None
Chlorophyll *a*	1978	16	6	Loess	55	.2565	6.412	.1757	None
Total dissolved solids	1978	16	1	Loess	11	-.0007	-1.788	.5334	None

Table 7. Water-quality trends at Clinton River site 630252, 1972–93.

[USK, uncensored Seasonal Kendall test; Cross reference between site identifier and map number are in Appendix 1-4]

Parameter	Begin year	Number of years	Number of seasons	Type of test	Flow-adjusted concentration model	Number of seasonal observations	Trend	Percentage of median value	Probability value	Significance and direction
Water temperature	1972	22	6	USK	None	130	0	0.000	0.4019	None
Turbidity	1974	20	6	USK	Loess	79	-.11767	-2.942	.1381	None
Specific conductance	1972	22	6	USK	Loess	91	4.242222	.535	.1764	None
Dissolved oxygen	1972	20	6	USK	None	118	.066667	.641	.0143	Up
Biochemical oxygen demand	1972	20	6	USK	Loess	92	-.70607	-5.244	.0006	Down
pH	1972	22	6	USK	None	127	.010526	.132	.0083	Up
Acid-neutralizing capacity	1972	22	6	USK	Loess	80	-.38657	-.227	.2400	None
Total solids	1972	22	6	USK	Loess	92	2.796062	.520	.1104	None
Total suspended solids	1972	22	6	Tobit	None	134	NA	-2.406	.1060	None
Total organic nitrogen	1972	22	6	USK	Loess	92	.007002	.834	.3180	None
Total ammonia	1972	22	6	USK	Loess	92	-.15315	-13.563	.0025	Down
Un-ionized ammonia	1972	22	6	USK	None	130	-.00021	-6.884	.0016	Down
Ammonia plus organic nitrogen	1979	14	6	USK	Loess	52	-.01023	-.384	.9744	None
Total nitrate plus nitrite	1972	22	6	USK	Loess	88	.048423	2.306	.0960	None
Total phosphorus	1972	22	6	USK	Loess	92	-.01363	-1.217	.0546	None
Chloride	1972	22	6	USK	Loess	92	.611827	.594	.3151	None
Total Dissolved solids	1972	20	6	USK	Loess	92	-.09468	-8.989	.1418	None

Table 8. Water-quality trends at Clinton River site 04165500, 1973–95.

[From Syed and Fogarty (2005); uncensored Seasonal Kendall test applied to all parameters; --, data not provided; Cross reference between site identifier and map number are in Appendix 1-4]

Parameter	Begin year	Number of years	Trend	Percentage of median value	Probability value	Significance and direction
Water temperature	1973	22	--	--	0.544	None
Turbidity	1978	17	--	--	.076	None
Dissolved oxygen	1974	21	--	--	.474	None
pH	1973	22	0.018079	0.226	.001	Up
Specific conductance	1973	22	--	--	.059	None
Calcium	1974	21	.485428	.693	.001	Up
Magnesium	1974	21	.121549	.579	.007	Up
Sodium	1974	21	--	--	.066	None
Potassium	1974	21	--	--	.257	None
Chloride	1973	22	1.934193	2.102	.006	Up
Sulfate	1973	22	-.63448	-1.094	.003	Down
Fluoride	1974	21	--	--	.444	None
Silica	1974	21	--	--	.622	None
Dissolved ammonia	1979	16	--	--	.456	None
Total ammonia	1977	15	-.00752	-5.369	.008	Down
Total ammonia plus organic nitrogen	1974	21	-.02448	-2.448	.007	Down
Total nitrogen	1974	21	-.06293	-1.748	.004	Down
Total organic nitrogen	1978	17	--	--	.482	None
Dissolved nitrate plus nitrite	1979	16	-.05465	-2.277	.004	Down
Dissolved phosphorus	1977	18			.67	None
Total phosphorus	1974	21	-.00572	-3.268	.001	Down
Hardness	1974	95	1.593312	.613	.001	Up
Suspended-sediment concentration	1974	21	--	--	.162	None
Fecal coliform	1976	19	--	--	.196	None
Fecal streptococcus	1976	19	--	--	.602	None

Table 9. Water-quality trends at Clinton River site 500233, 1974–93.

[Uncensored Seasonal Kendall test applied to all parameters; Cross reference between site identifier and map number are in Appendix 1-4]

Parameter	Begin year	Number of years	Number of seasons	Flow-adjusted concentration model	Number of seasonal observations	Trend	Percentage of median value	Probability value	Significance and direction
Water temperature	1974	20	6	None	104	0	0.000	0.7741	None
Turbidity	1974	20	6	Loess	102	-.3043	-2.766	.0133	Down
Specific conductance	1974	20	6	Loess	104	9.9582	1.276	.0001	Up
Dissolved oxygen	1974	20	6	None	92	.0625	.679	.0326	Up
Biochemical oxygen demand	1974	20	6	Loess	93	-.61458	-4.130	.0020	Down
pH	1974	20	6	None	101	.01	.125	.0342	Up
Acid-neutralizing capacity	1974	20	6	Loess	93	.5116	.269	.1961	None
Total solids	1974	20	6	Loess	104	6.624	1.245	.0001	Up
Total suspended solids	1974	20	6	Loess	104	-.01686	-.078	.9298	None
Total organic nitrogen	1974	20	6	Loess	93	.0028	.328	.4180	None
Total ammonia	1974	20	6	Loess	104	-.0077	-5.036	.0009	Down
Un-ionized ammonia	1974	20	6	None	104	-.000094	-2.648	.0352	Down
Ammonia plus organic nitrogen	1979	15	4	Loess	45	-.01688	-1.563	.0261	Down
Total nitrate plus nitrite	1974	20	6	Loess	104	-.01577	-.717	.4266	None
Total phosphorus	1974	20	6	Loess	104	-.00696	-3.670	.0017	Down
Orthophosphate	1974	18	6	Loess	92	-.00585	-5.471	.0012	Down
Total organic carbon	1975	18	6	Loess	75	-.08629	-1.269	.0122	Down
Chloride	1974	20	6	Loess	104	1.78164	1.888	.0003	Up
Chlorophyll *a*	1974	17	6	Loess	81	.066885	1.338	.3422	None

Estimated Loads in the Belle, Black, and Clinton River Basins

The monthly loads presented in this report (tables 10–15) are estimates for the period June 2004 through October 2005. It should be noted, however, that most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994. This may affect the accuracy of the regression equations because water quality may have changed since 1994 as a result of population growth or land-use changes.

Trend analysis (1978–94) of one Black River site showed no significant changing trends in water quality and Syed and Jodoin (2006) found little change in land use in the Belle, Black, and Pine River Basins during the period 1991 through 2001. These points of information support an assumption that water quality changed little since 1994 in the Belle, Black and Pine Rivers and that regression analysis done with earlier data may still yield valid load estimates for these basins. However, land-use change has been rapid in the Clinton River Basin, and the previous section described significant changing water-quality trends. Therefore, current load estimates (2004–05) for the Clinton River, based on regression analyses containing mostly pre-1994 data, must be viewed with some caution.

Monthly loads were estimated for the Belle River near Marine City, the most downstream site and nearest to the confluence with the St. Clair River. Streamflow data collected as part of the LSCRMP from June 2004 through October 2005 and streamflow and water-quality data from Belle River site 04160625 (table 10), as well as additional data from Belle River site 740167 and site BE01, were used in the regression analyses.

Table 10. Estimated monthly parameter loads at Belle River site 04160625, June 2004–October 2005.

[Monthly loads are given in tons per year; ft^3/s, cubic feet per second; Cross reference between site identifier and map number are in Appendix 1-2; most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994]

Month	Mean streamflow (ft^3/s)	Biochemical oxygen demand	Total solids	Total ammonia	Total ammonia plus organic nitrogen	Total nitrate plus nitrite	Total phosphorus	Chloride	Total orthophosphate
Jun-04	135	25.6	5,570	0.42	5.1	11.4	1.4	726	0.40
Jul-04	158	31.7	6,638	.53	6.3	16.7	1.7	805	.49
Aug-04	72.9	13.4	3,328	.21	3.6	4.6	.67	464	.20
Sep-04	21.5	3.02	1,068	.05	1.4	.28	.14	198	.05
Oct-04	24.1	3.62	1,218	.06	1.7	.48	.16	214	.06
Nov-04	69.5	12.1	3,149	.18	3.2	3.1	.58	460	.18
Dec-04	269	59.1	9,930	1.3	11.3	43.0	3.8	1,043	1.08
Jan-05	510	122	16,272	3.6	31.7	85.2	8.6	1,452	2.8
Feb-05	390	83.2	11,402	2.6	23.0	51.8	5.8	1,085	2.0
Mar-05	403	91.3	13,954	2.0	16.2	75.1	6.2	1,344	1.7
Apr-05	246	52.3	8,807	1.2	10.4	36.5	3.4	944	.98
May-05	107	20.2	4,854	.31	4.1	5.5	1.0	684	.30
Jun-05	56.2	9.3	2,696	.14	2.4	1.7	.42	416	.14
Jul-05	81.3	16.2	3,375	.33	3.9	8.7	.96	443	.29
Aug-05	17.7	2.5	928	.04	1.3	.14	.12	180	.04
Sep-05	20.8	3.0	1,021	.05	1.4	.39	.14	179	.05
Oct-05	15.5	2.1	801	.04	1.2	.11	.10	158	.04
Total for time period		550	95,011	13.1	128	345	35.0	10,794	10.8

Monthly load estimates (June 2004 through October 2005) for Black River site 04159492 (table 11) were calculated from streamflow and water-quality data from site 04159492 and site BL03 data collected as part of the LSCRMP. Only three of the nine parameters examined had the required amount of data to do the regression analyses at this site.

Monthly load estimates (June 2004 through October 2005) for nine parameters at Black River site 04160050 (table 12) were calculated from streamflow and water-quality data from site 740167 and site BL01 to develop the regression relations. Because the gaging station at site 04160050 was not in operation during the LSCRMP, the daily mean streamflow data were estimated at site 04160050 by the area-ratio method from the daily mean streamflow at sites 04159492 and 04159900.

Table 11. Estimated monthly parameter loads at Black River site 04159492, June 2004–October 2005.

[Monthly loads are given in tons per year; ft^3/s, cubic feet per second; Cross reference between site identifier and map number are in Appendix 1-1; most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994]

Month	Mean streamflow (ft^3/s)	Total ammonia plus organic nitrogen	Total phosphorus	Chloride
Jun-04	268	22.5	2.4	929
Jul-04	193	16.3	1.7	719
Aug-04	68.5	4.7	.40	312
Sep-04	32.5	1.9	.16	182
Oct-04	32.7	1.8	.16	184
Nov-04	116	8.7	.76	452
Dec-04	482	45.6	6.4	1,636
Jan-05	1,071	119	21.9	3,262
Feb-05	529	48.8	8.2	1,650
Mar-05	775	77	11.0	2,631
Apr-05	471	44.8	6.8	1,578
May-05	205	16.9	1.5	768
Jun-05	155	11.7	1.0	574
Jul-05	72.6	4.9	.40	326
Aug-05	27.9	1.5	.14	169
Sep-05	20.9	.83	.09	132
Oct-05	21.4	2.0	.22	292
Total for time period		429	63.4	15,796

Table 12. Estimated monthly parameter loads at Black River site 04160050, June 2004–October 2005.

[Monthly loads are given in tons per year; ft^3/s, cubic feet per second; Cross reference between site identifier and map number are in Appendix 1-1; most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994]

Month	Mean streamflow (ft^3/s)	Biochemical oxygen demand	Total solids	Total ammonia	Total ammonia plus organic nitrogen	Total nitrate plus nitrite	Total phosphorus	Chloride	Total ortho-phosphate
Jun-04	415	92.0	15,879	2.7	44.4	60.9	3.6	1,322	1.1
Jul-04	306	69.4	12,304	2.0	32.5	41.1	2.5	1,051	.77
Aug-04	117	25.7	4,993	.64	10.0	8.1	.67	478	.24
Sep-04	49.4	10.4	2,065	.25	3.3	.52	.25	237	.09
Oct-04	53.7	11.7	2,313	.28	3.8	.96	.29	259	.10
Nov-04	175	37.7	7,071	.98	15.8	18.1	1.1	641	.37
Dec-04	737	178	26,870	6.2	95.3	129	9.8	2,098	2.7
Jan-05	1,540	427	48,372	20.6	226	247	32.6	3,163	9.7
Feb-05	839	194	26,285	8.0	102	123	13.0	1,887	3.6
Mar-05	1,153	285	41,316	10.5	156	213	17.0	3,053	4.6
Apr-05	689	166	23,829	6.3	87.0	109	10.1	1,785	2.8
May-05	312	69.6	12,891	1.8	30.6	41.0	2.1	1,106	.71
Jun-05	218	46.8	8,770	1.2	19.7	23.5	1.3	777	.46
Jul-05	90.6	19.8	3,894	.48	7.4	3.8	.50	389	.18
Aug-05	38.6	8.4	1,664	.20	2.5	.20	.20	202	.07
Sep-05	31.0	6.5	1,291	.15	1.9	.12	.16	162	.06
Oct-05	32.5	7.0	1,399	.17	2.0	.12	.17	176	.06
Total for time period		1,656	241,206	62.5	840	1,020	95.5	18,785	27.5

Monthly loads (June 2004 through October 2005) for eight parameters at Clinton River site 04160900 (table 13) were estimated from streamflow and water-quality data collected as part of the LSCRMP from sites 04160900, 630529, and CR11. Monthly loads for six parameters discharging from the Clinton River Basin upstream from Mount Clemens for site 04165500 (table 14) were estimated from streamflow and water-quality data collected as part of the LSCRMP for sites 04165500 and 500010. The monthly loads for eight parameters at Clinton River site 500233 (table 15) discharging to the Lake St. Clair through the lower reaches of the Clinton River and the Spillway were estimated from streamflow data collected as part of the LSCRMP for sites 04165500 and 500233.

MDEQ estimated annual loading rates from 2001 through 2004 for seven parameters from samples collected by MWCMP at Clinton River site 500233 (table 16) (Aiello, 2003, 2004, 2005, and 2006). These parameters were chloride, phosphorus, total suspended solids, mercury, chromium, copper, and lead. MDEQ refers to the latter three trace elements as trace metal water-quality indicators. The loads were calculated with the stratified Beale Ratio Estimator (Richards, 1994).

For the period used to estimate monthly loads (June 2004 to October 2005), the Clinton River carried the greatest total load of all the tributary streams. This was mainly due to the larger streamflow in the Clinton River. As would be expected, large monthly estimated loads correlated with the larger monthly mean streamflow during the winter months for this period. The estimated loads for sites 500233 and 04165500, which are within 1 ½ mi of each other on the main stem of the Clinton River, agreed well considering the possible interferences mentioned previously. The total phosphorus and chloride estimates at 500233 also agreed well with the annual estimates from the MWCMP (tables 15 and 16).

Table 13. Estimated monthly parameter loads at Clinton River Site 04160900, June 2004–October 2005.

[Monthly loads are given in tons per year; ft^3/s, cubic feet per second; Cross reference between site identifier and map number are in Appendix 1-4; most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994]

Month	Mean streamflow (ft^3/s)	Biochemical oxygen demand	Total solids	Total ammonia	Total ammonia plus organic nitrogen	Total nitrate plus nitrite	Total phosphorus	Chloride	Total ortho-phos-phate
Jun-04	96.5	14.3	2,920	0.47	4.7	1.6	0.14	419	0.007
Jul-04	32.9	4.7	1,076	.21	1.8	.48	.05	170	.006
Aug-04	27.6	3.9	912	.18	1.4	.36	.04	147	.005
Sep-04	8.75	1.2	307	.07	.40	.11	.01	57.7	.002
Oct-04	15.3	2.1	522	.11	.82	.21	.02	89.1	.003
Nov-04	49.5	6.9	1,566	.29	2.5	.61	.07	244	.007
Dec-04	81.9	12.2	2,619	.44	4.2	1.1	.12	405	.009
Jan-05	105	16.0	3,280	.53	5.4	1.6	.15	484	.008
Feb-05	92.1	12.6	2,638	.43	4.3	1.2	.12	402	.008
Mar-05	86.5	12.9	2,755	.46	4.4	1.2	.13	428	.009
Apr-05	59.8	8.6	1,845	.32	3.1	.82	.09	282	.007
May-05	50.2	7.3	1,617	.30	2.6	.63	.08	249	.008
Jun-05	18.5	2.5	600	.13	.90	.23	.03	99.0	.004
Jul-05	29.7	4.3	974	.19	1.5	.40	.04	157	.005
Aug-05	11.8	1.6	416	.09	.63	.17	.02	75.8	.003
Sep-05	20.8	3.0	674	.12	1.0	.27	.03	114	.003
Oct-05	9.8	1.4	355	.07	.48	.12	.01	67.1	.002
Total for time period		116	25,075	4.4	40	11	1.2	3,891	.09

Table 14. Estimated monthly parameter loads at Clinton River site 04165500, June 2004–October 2005.

[Monthly loads are given in tons per year; ft³/s, cubic feet per second; Cross reference between site identifier and map number are in Appendix 1-4; most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994]

Month	Mean streamflow (ft³/s)	Total ammonia	Total ammonia plus organic nitrogen	Total nitrate plus nitrite	Total phosphorus	Chloride	Total orthophosphate
Jun-04	919	12.6	80.0	147	12.7	6,210	6.5
Jul-04	502	7.4	41.2	102	7.0	3,870	4.8
Aug-04	504	7.2	44.1	104	7.8	3,712	5.4
Sep-04	236	3.1	19.5	66.1	4.3	1,834	3.9
Oct-04	282	3.9	23.5	74.7	4.9	2,249	4.3
Nov-04	504	7.1	39.7	98.4	6.7	3,771	4.5
Dec-04	853	12.2	77.1	146	12.8	6,024	6.6
Jan-05	1,213	16.3	115	189	20.0	7,864	8.8
Feb-05	1,099	13.2	91.6	157	15.5	6,411	7.2
Mar-05	978	13.6	85.7	158	12.9	6,710	6.6
Apr-05	610	8.5	51.5	114	8.6	4,237	5.5
May-05	406	6.1	33.0	91.1	6.1	3,251	4.5
Jun-05	198	2.6	16.8	62.5	4.0	1,565	3.9
Jul-05	521	7.3	46.6	102	8.1	3,751	5.0
Aug-05	195	2.5	16.9	60.7	3.8	1,608	3.6
Sep-05	330	4.2	27.8	70.8	4.9	2,479	3.4
Oct-05	207	2.7	17.6	65.1	4.2	1,687	4.1
Total for time period		131	828	1,807	144	67,235	88

Table 15. Estimated monthly parameter loads at Clinton River site 500233, June 2004–October 2005.

[Monthly loads are given in tons per year; ft³/s, cubic feet per second; Cross reference between site identifier and map number are in Appendix 1-4; most of the discrete water-quality data used to generate the regression analyses for these estimates were collected before 1994]

Month	Mean streamflow (ft³/s)	Biochemical oxygen demand	Total solids	Total ammonia	Total ammonia plus organic nitrogen	Total nitrate plus nitrite	Total phosphorus	Chloride	Total ortho-phos-phate
Jun-04	919	259	39,184	11.5	88.8	131	12.3	6,973	5.0
Jul-04	502	124	23,626	6.8	47.5	85.6	6.8	4,518	3.9
Aug-04	504	139	22,874	6.7	49.3	85.9	7.5	4,247	3.8
Sep-04	236	59.4	10,761	2.8	21.3	52.0	3.9	2,179	2.5
Oct-04	282	70.7	13,405	3.7	26.2	59.4	4.6	2,674	2.9
Nov-04	504	119	23,033	6.6	46.0	83.4	6.4	4,440	3.7
Dec-04	853	242	37,393	11.1	85.6	127	12.0	6,669	5.2
Jan-05	1,213	361	49,813	15.4	126	168	18.0	8,612	7.2
Feb-05	1,099	289	41,083	12.8	103	138	14.2	7,194	6.0
Mar-05	978	282	43,597	12.6	97.3	141	12.5	7,775	5.1
Apr-05	610	164	26,670	7.8	57.7	95.5	8.2	4,889	4.0
May-05	406	95.9	19,434	5.7	37.8	75.0	5.8	3,799	3.7
Jun-05	198	50.4	9,069	2.4	17.8	48.1	3.7	1,875	2.4
Jul-05	521	146	23,351	6.5	51.2	87.7	7.5	4,287	3.6
Aug-05	195	51.7	9,295	2.3	18.1	48.8	3.5	1,928	2.2
Sep-05	330	87.4	14,807	3.7	30.6	62.3	4.7	2,870	2.4
Oct-05	207	54.0	9,725	2.5	19.2	49.9	3.8	2,007	2.5
Total for time period		2,596	417,121	121	923	1,538	135	76,937	65.9

Table 16. Estimated annual loads of selected parameters at Clinton River site 500233, 2001–04.

[From Aiello (2003, 2004, 2005, and 2006); ft^3/s, cubic feet per second; one megagram is equal to 1.102 tons; cross reference between site identifier and map number are in Appendix 1-4]

Year	Mean streamflow (ft^3/s)	Annual loads (megagrams per year)						
		Chloride	Phosphorus	Total suspended solids	Chromium	Copper	Lead	Mercury
2001	758	71,844	164	57,457	2,810	4,234	4,017	6
2002	485	57,285	83	24,422	1,186	2,116	1,649	13
2003	508	76,691	118	44,306	2,263	3,795	3,248	6
2004	709	80,268	152	59,478	3,047	4,185	3,788	8

Escherichia coli in Lake St. Clair, the St. Clair River, and the U.S. Tributaries

Since 1986, the USEPA has used *Escherichia coli (E. coli)* as an indicator of recreational water quality (U.S. Environmental Protection Agency, 2000b). *E. coli* is naturally present in the feces of warmblooded animals, including humans. Studies by the USEPA have shown that *E. coli* is correlated with swimming-associated gastroenteritis in freshwater systems. Current (2006) water-quality standards for *E. coli* established by the MDEQ are based on time of year and assume that recreational use of rivers, lakes, and streams occur only during certain months. According to the Michigan Water Quality Standard Rule 62, the full body contact standard is in effect from May 1 through October 31 of each year and is set at 300 CFU/100 mL of water for a daily geometric mean calculated from three or more samples collected during the single sampling event. Also in effect during these summer to fall months is a standard for a 30-day geometric mean (calculated from five or more sampling events collected within a 30-day time period), which is set at 130 CFU/100 mL of water. The partial body contact standard is in effect from November 1 through April 30 of each year and is set at 1,000 CFU/100 mL of water for a daily geometric mean calculated from three or more samples collected during the sampling event. For the protection of the public, the MCHD recommends limited contact in waters containing *E. coli* concentrations greater than 300 CFU per 100 mL regardless of the time of year. They also recommends that full or partial body contact recreation only be under taken at public beaches that are properly managed to avoid other swimming associated hazards (Gary White, Macomb County Health Department, oral commun., 2006).

As part of this LSCRMP water-quality study, an analysis of MCHD *E. coli* data was done. These data consisted of samples collected at 65 locations by MCHD staff members throughout January 2000 to December 2005 (fig. 18, table 17). The sampling was done regularly, samples being collected weekly at most sites (Cole Shoemaker, Macomb County Health Department, oral commun., 2006). The percentage of *E. coli* samples exceeding contact standards and summary statistics were calculated, and graphs of seasonal patterns in *E. coli* concentration were created for each sampling location (Appendix 2).

Table 18 lists the percentage of samples that exceeded each contact standard that was in effect at the time the sample was collected. The percentage of samples that exceeded the partial body contact standard from November to April ranged from 3 percent in the Milk River (site W 58) and in East Pond Creek (site W 93) to 90 percent in Bear Creek (site W 82). The percentage of samples that exceeded the full body contact standard from May to October ranged from 15 percent in the Milk River (site W 58) to 99 percent in Lorraine Drain (site W 85). The percentage of samples that exceeded the MCHD recommendation of 300 CFU/100 mL (regardless of when the sample was collected) ranged from 10 percent in the Milk River (site W 58) to 94 percent in Lorraine Drain (site W 85).

In each subbasin in the study area, there were places where samples containing high concentrations of *E. coli* were consistently collected. Appendix 2 shows boxplots of the *E. coli* data based on the full and partial body contact standards. The standard used for comparison in Appendix 2 reflects the standard that was in effect during the time of year when the sample was collected. (For example, the first set of boxplots in Appendix 2 shows data collected between May and October (2000–05); therefore, the standard used for comparison is full body contact standard of 300 CFU/100 mL of water.)

The median *E. coli* concentration at 48 sample locations exceed the full body contact standard from May to October (2000–05) and were found in every subbasin (table 19). The median *E. coli* concentration at only three sample locations exceed the partial body contact standard from November to April (table 20). These locations were in the Red Run and two of Red Run's minor subbasins.

Graphs of the *E. coli* data show that, for most locations, the data exhibit a seasonal cycle in concentrations—increasing during the late spring (April and May), peaking during the late summer and early fall (July to September), and decreasing to a low during the winter (fig. 19).

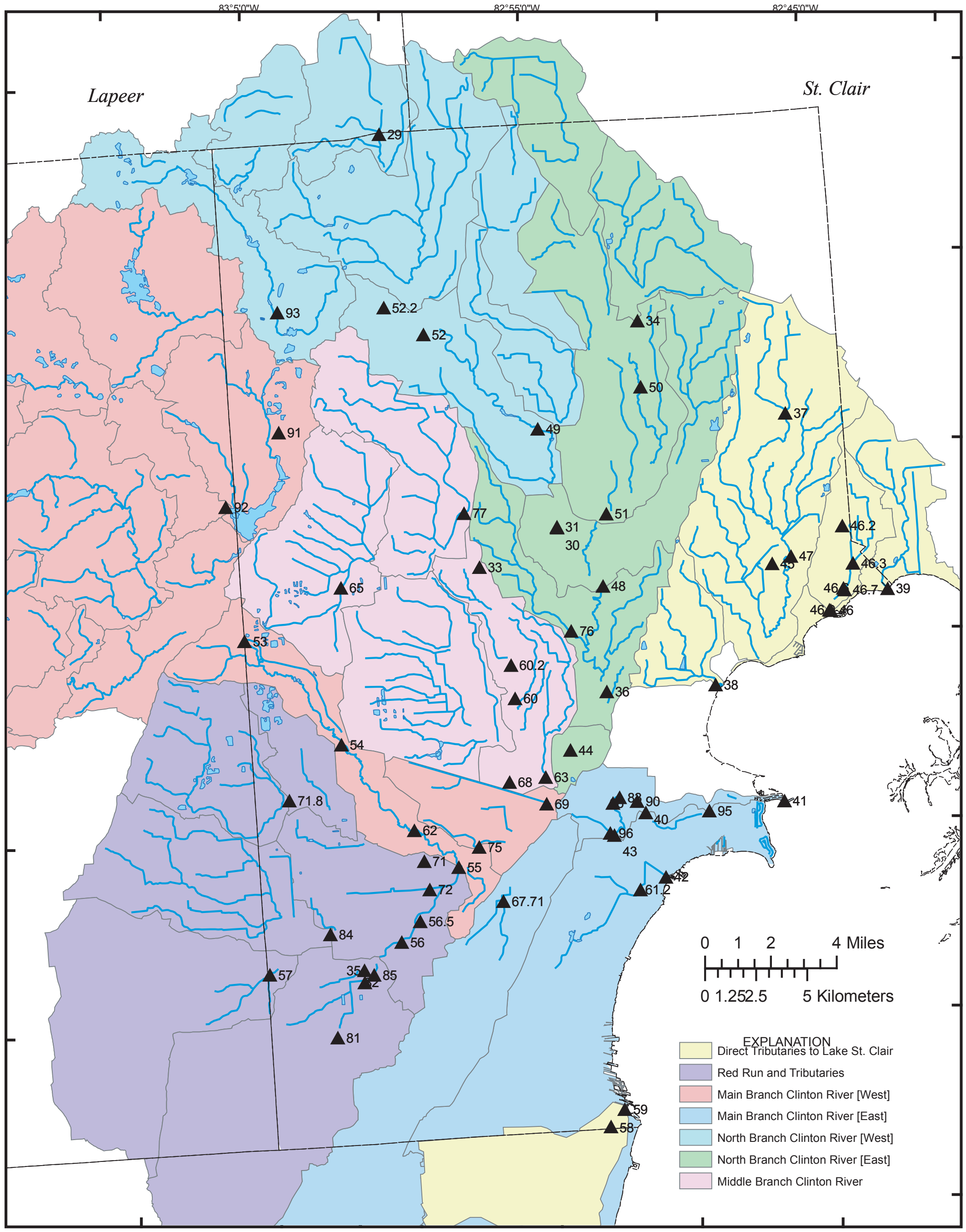


Figure projection is Hotine Oblique Mercator, Type 2, Scale factor at the projection's center 0.9996; longitude of the projection's center 86 00 00 W; latitude of the projection's center 45 18 33 N; Azimuth at the projection's center 337.255555555556.
County names and locations from U.S. Geological Survey 1:100,000 digital raster graphics.
Drainage divides from Michigan Department of Environmental Quality Land and Water Management, 1:24,000.
Hydrologic features from U.S. Environmental Protection Agency 1:100,000 Reach File 3.

Figure 18. Macomb County Health Department sites for *E. coli*, 2000–05. (Sites are described in table 17.).

Table 17. *Escherichia coli* samples collected by the Macomb County Health Department, 2000–05.

[Site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Date of first sample	Date of latest sample	Number of samples collected between May and October	Number of samples collected between November and April	Total number of samples collected
Direct Tributaries to Lake St. Clair	W 37-Salt River at 29 Mile Road	1/4/2000	12/27/2005	154	121	275
	W 38-River Voss at Jefferson Road	12/2/2003	12/27/2005	50	32	82
	W 39-Marsac Drain at Ruidsale Park	7/31/2001	11/29/2005	144	64	208
	W 45-Salt River at Jefferson Road	1/11/2000	12/27/2005	155	94	249
	W 46-Crapaud Creek at Main Street	1/4/2000	12/27/2005	194	141	335
	W 46.2-Drainage Ditch West of County Line Road at Hobarth	11/8/2000	12/27/2005	114	91	205
	W 46.3-Crapaud Creek at County Line Road	1/4/2000	12/27/2005	154	107	261
	W 46.6-Vanderbenne Drain at Fox Pointe Road	1/16/2001	12/27/2005	129	90	219
	W 46.7-Crapaud Creek at Ashley Street	1/4/2000	12/13/2005	154	126	280
	W 46.9-Crapaud Creek at Green Street	6/13/2000	12/27/2005	150	131	281
	W 47-Salt River at Washington Street	1/4/2000	12/27/2005	155	113	268
	58-Milk River at Alger Road	1/4/2000	12/13/2005	156	108	264
	W 59-Milk River at Clairwood Road	1/11/2000	11/29/2005	215	116	331
Red Run and Tributaries [Clinton River]	W 35-Red Run Drain at Van Dyke Road	1/4/2000	12/27/2005	216	157	373
	W 55-Red Run Drain	1/4/2000	12/28/2004	190	147	337
	W 56-Red Run Drain at 14 Mile Road	1/4/2000	12/27/2005	158	144	302
	W 56.5 Schoenherr Relief Drain at Red Run	5/11/2005	12/27/2005	27	11	38
	W 57-Red Run Drain at Dequindre Road	1/4/2000	12/27/2005	216	174	390
	W 71-Plumbrook Drain at Schoenherr Road	1/4/2000	12/27/2005	157	127	284
	W 71.8-Plumbrook Drain at Ryan Road	2/28/2001	12/27/2005	130	116	246
	W 72-Sterling Relief Drain at Freedom Hill	1/4/2000	12/6/2005	156	137	293
	W 81-Bear Creek at Mound Road	1/4/2000	12/27/2005	159	137	296
	W 82-Bear Creek at Old 13 Mile Road	1/4/2000	12/27/2005	213	174	387

Table 17. *Escherichia coli* samples collected by the Macomb County Health Department, 2000–05.—Continued

[Site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Date of first sample	Date of latest sample	Number of samples collected between May and October	Number of samples collected between November and April	Total number of samples collected
Red Run and Tributaries	W 84-Beaver Creek at Mound Road	1/4/2000	12/27/2005	158	112	270
	W 85-Lorraine Drain at Bear Creek	1/11/2000	12/27/2005	216	171	387
Main Branch Clinton River [East]	W 40-Clinton River at I-94	1/4/2000	12/27/2005	215	139	354
	W 41-Clinton River at Lake St. Clair DNR site	1/11/2000	12/6/2005	441	152	593
	W 42-Clinton River Spill-way at Jefferson	1/4/2000	12/27/2005	440	155	595
	W 43-Clinton River & Spillway	1/4/2000	12/27/2005	156	111	267
	W 61.2-Clinton Relief Drain at Shook Road	2/29/2000	12/27/2005	218	136	354
	W 66-Clinton River at Amvet Drive	1/4/2000	12/27/2005	158	130	288
	W 67-Harrington Drain at Harrington Road	1/4/2000	12/27/2005	160	127	287
	W 67.71-Sweeney Drain at 15 Mile Road	4/18/2000	12/27/2005	217	128	345
	W 68-Clinton River at Moravian	1/4/2000	12/27/2005	213	167	380
	W 83-Clinton River at Mt. Clemens YMCA	1/4/2000	12/27/2005	217	145	362
	W 90-Clinton River at Riverview	1/4/2000	12/27/2005	216	143	359
	W 95-Clinton River at Albatross Landing	1/4/2000	12/27/2005	217	148	365
	W 96-Clinton River at Shadyside Park	1/4/2000	12/27/2005	219	147	366
Main Branch Clinton River [West]	W 53-Clinton River at Dequindre Road	1/4/2000	12/27/2005	159	140	299
	W 54-Clinton River at Hall Road	1/4/2000	12/27/2005	158	135	293
	W 62-Clinton River at Kleino Road	1/4/2000	12/6/2005	217	146	363
	W 69-Canal Drain at Clinton River Road	1/4/2000	12/27/2005	157	124	281
	W 75-Clinton River at Garfield Road	1/4/2000	12/27/2005	215	175	390
	W 91-Stony Creek at Inwood Road	1/4/2000	12/27/2005	157	129	286
	W 92-West Branch Stony Creek at Park Road	1/4/2000	12/27/2005	160	110	270

Table 17. *Escherichia coli* samples collected by the Macomb County Health Department, 2000–05.—Continued

[Site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Date of first sample	Date of latest sample	Number of samples collected between May and October	Number of samples collected between November and April	Total number of samples collected
North Branch Clinton River [West]	W 29-North Branch Clinton River at Boardman Road	10/3/2000	12/27/2005	137	108	245
	W 30-North Branch Clinton River at 26 Mile Road	1/11/2000	12/27/2005	158	109	267
	W 49-North Branch Clinton River at 29 Mile Road	1/4/2000	12/27/2005	158	115	273
	W 52-East Pond Creek at Powell Road	1/4/2000	12/27/2005	161	148	309
	W 52.2-East Pond Creek at M-53	3/21/2000	12/27/2005	152	133	285
	W 93-East Pond Creek east of Fisher Road	1/4/2000	12/27/2005	159	128	287
North Branch Clinton River [East]	W 31-East Branch Coon Creek at 26-Mile Road	1/11/2000	12/6/2005	157	100	257
	W 34-Highbank Drain at 32 Mile Road	2/29/2000	12/27/2005	156	98	254
	W 36-North Branch Clinton River at 21 Mile Road	1/11/2000	12/27/2005	156	108	264
	W 44-North Branch Clinton River	1/4/2000	12/27/2005	217	132	349
	W 48-Deer Creek at North Avenue	1/11/2000	12/27/2005	157	107	264
	W 50-East Branch Coon Creek at 30 Mile Road	1/4/2000	12/27/2005	157	116	273
	W 51-East Branch Coon Creek	1/4/2000	12/27/2005	156	128	284
	W 76-McBride Drain at Card Road	1/11/2000	12/27/2005	154	102	256
Middle Branch Clinton River	W 33-Middle Branch Clinton River at 25 Mile Road	1/16/2001	12/27/2005	131	102	233
	W 60.2-Middle Branch Clinton River at 22 Mile Road	1/16/2001	12/27/2005	130	99	229
	W 60-Middle Branch Clinton River at 21 Mile Road	1/16/2001	12/27/2005	154	115	269
	W 63-Middle Branch Clinton River	5/23/2000	12/27/2005	174	123	297
	W 65-Middle Branch Clinton River at Van Dyke Road	1/16/2001	12/27/2005	131	113	244
	W 77-Healy Brook Drain at Romeo Plank Road south of 27 Mile Road	1/16/2001	12/27/2005	131	103	234

Table 18. Percentage of Macomb County Health Department *Escherichia coli* samples exceeding State of Michigan Rule 62 standards.

[CFU/100 mL, colony-forming units per 100 milliliters; site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Percent exceeding full contact standards (300 CFU / 100 mL)	Percent exceeding partial contact standard (1,000 CFU / 100 mL)	Percent exceeding 300 CFU/100 mL year round	Percent exceeding 30-day geomean standard (130 CFU / 100 mL)
Direct Tributaries to Lake St. Clair	W 37-Salt River at 29 Mile Road	73	12	57	94
	W 38-River Voss at Jefferson Road	56	31	46	88
	W 39-Marsac Drain at Ruidsale Park	16	27	19	26
	W 45-Salt River at Jefferson	25	19	22	32
	W 46.2-Drainage Ditch-West of County Line Road at Hobarth	54	34	45	93
	W 46.3-Crapaud Creek at County Line Road	62	21	45	87
	W 46.6-Vanderbenne Drain at Fox Pointe Road	84	36	64	93
	W 46.7-Crapaud Creek at Ashley Street	90	36	66	98
	W 46.9-Crapaud Creek at Green Street	36	30	33	71
	W 46-Crapaud Creek at Main Street	47	38	43	84
	W 47-Salt River at Washington Street	74	26	53	98
	W 58-Milk River at Alger Road	15	3	10	27
	W 59-Milk River at Clairwood Road	19	14	17	23
Red Run and Tributaries [Clinton River]	W 35-Red Run Drain at Van Dyke Road	88	66	78	99
	W 55-Red Run Drain	96	78	88	100
	W 56-Red Run Drain at 14 Mile Road	94	85	90	100
	W 56.5 Schoenherr Relief Drain at Red Run	85	82	84	100
	W 57-Red Run Drain at Dequindre Road	92	60	77	100
	W 71-Plumbrook Drain at Schoenherr Road	83	24	57	100
	W 71.8-Plumbrook Drain at Ryan Road	75	23	51	94
	W 72-Sterling Relief Drain at Freedom Hill	94	86	90	100
Red Run and Tributaries	W 81-Bear Creek at Mound Road	92	85	89	100
	W 82-Bear Creek at Old 13 Mile Road	96	90	93	99
	W 84-Beaver Creek at Mound Road	84	46	69	97
	W 85-Lorraine Drain at Bear Creek	99	87	94	100

Table 18. Percentage of Macomb County Health Department *Escherichia coli* samples exceeding State of Michigan Rule 62 standards. —Continued

[CFU/100 mL, colony-forming units per 100 milliliters; site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Percent exceeding full contact standards (300 CFU / 100 mL)	Percent exceeding partial contact standard (1,000 CFU / 100 mL)	Percent exceeding 300 CFU/100 mL year round	Percent exceeding 30-day geomean standard (130 CFU / 100 mL)
Main Branch Clinton River [East]	W 40-Clinton River at I-94	72	42	60	96
	W 41-Clinton River at Lake St. Clair DNR site	18	18	18	27
	W 42-Clinton River Spillway at Jefferson Road	26	21	25	45
	W 43-Clinton River & Spillway	24	25	24	28
	W 61.2-Clinton Relief Drain at Shook Road	77	59	70	97
	W 66-Clinton River at Amvet Drive	58	32	47	100
	W 67-Harrington Drain at Harrington Road	86	69	79	100
	W 67.71-Sweeney Drain at 15 Mile Road	80	70	76	98
	W 68-Clinton River at Moravian Road	74	40	59	100
	W 83-Clinton River at Mt. Clemens YMCA	65	44	57	97
	W 90-Clinton River at Riverview Road	63	37	53	94
	W 95-Clinton River at Albatross Landing	42	30	37	65
	96-Clinton River at Shadyside Park	74	39	60	100
Main Branch Clinton River [West]	W 53-Clinton River at Dequindre Road	49	15	33	91
	W 54-Clinton River at Hall Road	41	13	28	86
	W 62-Clinton River at Kleino Road	61	16	43	95
	W 69-Canal Drain at Clinton River Road	84	41	65	98
	W 75-Clinton River at Garfield Road	84	57	72	100
	W 91-Stony Creek at Inwood Road	60	5	35	93
	W 92-West Branch Stony Creek at Park Road	47	4	29	82

Table 18. Percentage of Macomb County Health Department *Escherichia coli* samples exceeding State of Michigan Rule 62 standards. —Continued

[CFU/100 mL, colony-forming units per 100 milliliters; site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Percent exceeding full contact standards (300 CFU / 100 mL)	Percent exceeding partial contact standard (1,000 CFU / 100 mL)	Percent exceeding 300 CFU/100 mL year round	Percent exceeding 30-day geomean standard (130 CFU / 100 mL)
North Branch Clinton River [West]	W 29-North Branch Clinton River at Boardman Road	76	11	47	95
	W 30-North Branch Clinton River at 26 Mile Road	50	18	37	88
	W 49-North Branch Clinton River at 29 Mile Road	32	21	27	91
	W 52-East Pond Creek at Powell Road	68	32	51	95
	W 52.2-East Pond Creek at M-53	64	9	39	92
	W 93-East Pond Creek East of Fisher Road	33	3	20	78
North Branch Clinton River [East]	W 31-East Branch Coon Creek at 26-Mile Road	35	22	30	72
	W 34-Highbank Drain at 32 Mile Road	42	36	39	75
	W 36-North Branch Clinton River at 21 Mile Road	63	22	46	95
	W 44-North Branch Clinton River	61	30	49	97
	W 48-Deer Creek at North Avenue	54	36	47	84
	W 50-East Branch Coon Creek at 30 Mile Road	57	29	45	89
	W 51-East Branch Coon Creek	82	38	62	96
	W 76-McBride Drain at Card Road	81	27	59	100
Middle Branch Clinton River	W 33-Middle Branch Clinton River at 25 Mile Road	81	21	55	99
	W 60.2-Middle Branch Clinton River at 22 Mile Road	85	34	63	99
	W 60-Middle Branch Clinton River at 21 Mile Road	86	39	66	99
	W 63-Middle Branch Clinton River	89	49	72	100
	W 65-Middle Branch Clinton River at Van Dyke Road	82	26	56	98
	W 77-Healy Brook Drain at Romeo Plank Road south of 27 Mile Road	89	60	76	100

Table 19. Macomb County Health Department sites with median *Escherichia coli* concentrations greater than Rule 62 full contact standard, May–October (2000–05).

[Full body contact standard is in effect from May 1 through October 31 of each year and is set at 300 CFU/100 mL of water for a daily geometric mean calculated from three or more samples collected during the single sampling event; site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Sample median
Direct Tributaries to Lake St. Clair	W 37-Salt River at 29 Mile Road	581
	W 38-River Voss at Jefferson	312
	W 46.2-Drainage Ditch West of County Line Road at Hobarth	374
	W 46.3-Crapaud Creek at County Line Road	491
	W 46.6-Vanderbenne Drain at Fox Point Road	1,223
	W 46.7-Crapaud Creek at Ashley Street	1,223
	W 47-Salt River at Washington Street	487
Red Run and Tributaries [Clinton River]	W 35-Red Run Drain at Van Dyke	1,911
	W 55-Red Run Drain	1,601
	W 56-Red Run Drain at 14 Mile Road	1,109
	W 56.5-Schoenherr Relief Drain at Red Run	1,785
	W 57-Red Run Drain at Dequindre Road	1,616
	W 71-Plumbrook Drain at Schoenherr Road	620
	W 71.8-Plumbrook Drain at Ryan Road	576
	W 72-Sterling Relief Drain at Freedom Hill	1,597
	W 81-Bear Creek at Mound Road	2,187
	W 82-Bear Creek at Old 13 Mile Road	3,448
	W 84-Beaver Creek at Mound Road	961
	W 85-Lorraine Drain at Bear Creek	12,903
Main Branch Clinton River [East]	W 40-Clinton River at I-94	591
	W 61.2-Clinton Relief Drain at Shook Road	946
	W 66-Clinton River at Amvet Drive	339
	W 67-Harrington Drain at Harrington Road	789
	W 67.71-Sweeney Drain at 15 Mile Road	1,162
	W 68-Clinton River at Moravian Road	771
	W 83-Clinton River at Mt. Clemens YMCA	512
	W 90-Clinton River at Riverview Road	455
	W 96-Clinton River at Shadyside Park	650
Main Branch Clinton River [West]	W 62-Clinton River at Kleino Road	404
	W 69-Canal Drain at Clinton River	1,014
	W 75-Clinton River at Garfield Road	860
	W 91-Stony Creek at Inwood Road	359
North Branch Clinton River [West]	W 30-North Branch Clinton River at 26 Mile Road	304
	W 29-N. Branch Clinton River at Boardman Road	576
	W 52-East Pond Creek at Powell Road	422
	W 52.2-East Pond Creek at M-53	364
North Branch Clinton River [East]	W 36-North Branch Clinton River at 21 Mile Road	416
	W 44-North Branch Clinton River	413
	W 48-Deer Creek at North Avenue	336
	W 50-East Branch Coon Creek at 30 Mile Road	345
	W 51-East Branch Coon Creek	718
	W 76-McBride Drain at Card Road	907
Middle Branch Clinton River	W 33-Middle Branch Clinton River at 25 Mile Road.	624
	W 60-Middle Branch Clinton River at 21 Mile Road.	921
	W 60.2-Middle Branch Clinton River at 22 Mile Road.	844
	W 63-Middle Branch Clinton River	909
	W 65-Middle Branch Clinton River at Van Dyke Road.	862
	W 77-Healy Brook Drain at Romeo Plank Road south of 27 Mile Road	865

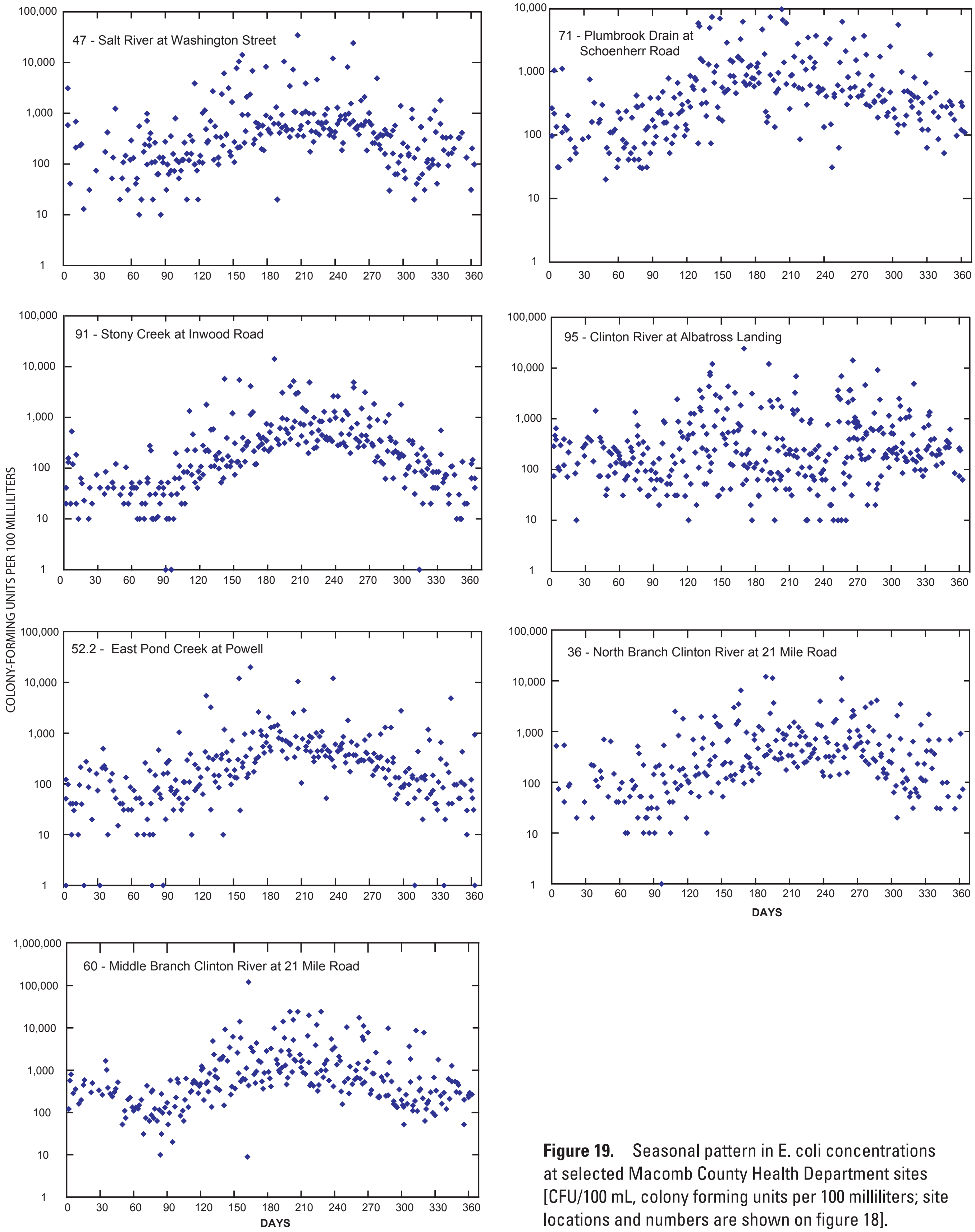


Figure 19. Seasonal pattern in E. coli concentrations at selected Macomb County Health Department sites [CFU/100 mL, colony forming units per 100 milliliters; site locations and numbers are shown on figure 18].

Table 20. Macomb County Health Department sites with median *Escherichia coli* concentrations greater than Rule 62 partial body contact standard, November–April (2000–05).

[Partial body contact standard is in effect from November 1 through April 30 of each year and is set at 1,000 CFU/100 mL of water for a daily geometric mean calculated from three or more samples collected during the sampling event; site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Sample median
Red Run and Tributaries	W 56.5-Schoenherr Relief Drain at Red Run	2,359
	W 72-Sterling Relief Drain at Freedom Hill	1,012
	W 85-Lorraine Drain at Bear Creek	1,414

Influence of Red Run on the Clinton River

Samples collected in the Clinton River upstream from its confluence with Red Run had medians that ranged from 172.5 to 243 CFU/100 mL. Samples collected within Red Run upstream of its confluence with the Clinton River had medians that ranged from 311 to 5,172 CFU/100 mL (table 21). Two locations were sampled in the Clinton River within close proximity downstream of the confluence. The median concentrations at this third location were 599.5 and 613 CFU/100 mL. This increase in *E. coli* concentration is most likely due exclusively to the waters of Red Run mixing into the relatively lower concentrated waters of the upper main stem of the Clinton River.

Interactions between Lake St. Clair and the Clinton River

Sampling locations within the Clinton River Basin immediately upstream from its mouth did not reflect the high concentrations of *E. coli* that were found upstream in the Clinton River and its tributaries. Table 22 lists the medians of the overall dataset for sampling locations near the Clinton River mouth. Data collected at sample locations within the Clinton River Spillway (sites W 43 and W 42) and at the natural channel mouth (site W 41) had medians that were an order of magnitude lower than data collected at upstream locations. These sampling locations may reflect the concentration of *E. coli* within the body of Lake St. Clair rather than of the Clinton River—or a mix of the two, with Lake St. Clair water being the main influence.

Modeling efforts by the USACE have documented the influence of seiches, wind-driven water-level oscillations observed in lakes, on Lake St. Clair (W.F. Baird and Associates, Ltd., 2005). In a model of sediment transport within the Clinton River, the USACE noted reverse-flow phenomena between the Clinton River and Lake St. Clair. Under certain wind conditions, water from Lake St. Clair is pushed into the Clinton River channel and can travel upstream as far as the I–94 overpass (site W 40).

An alternative explanation of the apparent reduction of *E. coli* concentrations near the mouth of the Clinton River is stratification, rather than dilution by upstream flow of lake water. Clinton River water, with its higher concentration of dissolved solids, may flow along the bottom of the channel, below a lens of dilute lake water, similar to the formation of a “salt wedge” in tidal rivers. If *E. coli* analyses were done on near-surface samples, instead of depth-integrated samples, then Clinton River water—and therefore Clinton River bacteria would be underrepresented in these samples.

Because of the large differences in volume between water entering Lake St. Clair from the Clinton River and the main body of Lake St. Clair, the Clinton River may not have a large effect on Lake St. Clair as a whole with respect to *E. coli.* Given that the waters of the Clinton River contain elevated concentrations of *E. coli* at most of the sampling locations upstream from its mouth into Lake St. Clair, these waters do not immediately mix with the river seiche water (as shown at sites W 41, W 42, and W 43) and are likely to become diluted only after they enter the lower-concentration body of the Lake.

Lake St. Clair Nearshore and Offshore Sites

From 1998 through 2005, the MCHD monitored water quality along the Macomb County Lake St. Clair shoreline as part of a larger study to characterize water and sediment quality in Lake St. Clair and the Clinton River Basin. This monitoring effort was referred to as the “Lake Assessment” program. Water-quality and/or sediment samples were collected at 30 nearshore sites and 13 offshore sites in Lake St. Clair and, in 1998, at 10 inshore sites (fig. 20, table 23). The nearshore sites were near point discharges to Lake St. Clair, including the mouth of rivers and storm drains. The offshore sites were approximately ¼ mi from the shoreline. Seven of these sites were close to major nearshore sites. The inshore sites were also close to major discharges to Lake St. Clair. The inshore site data were included in the Clinton River and minor river basin analyses previously in this report.

Table 21. Median *Escherichia coli* concentrations at Macomb County Health Department sites on Clinton River near confluence of Red Run and in Red Run subbasin.

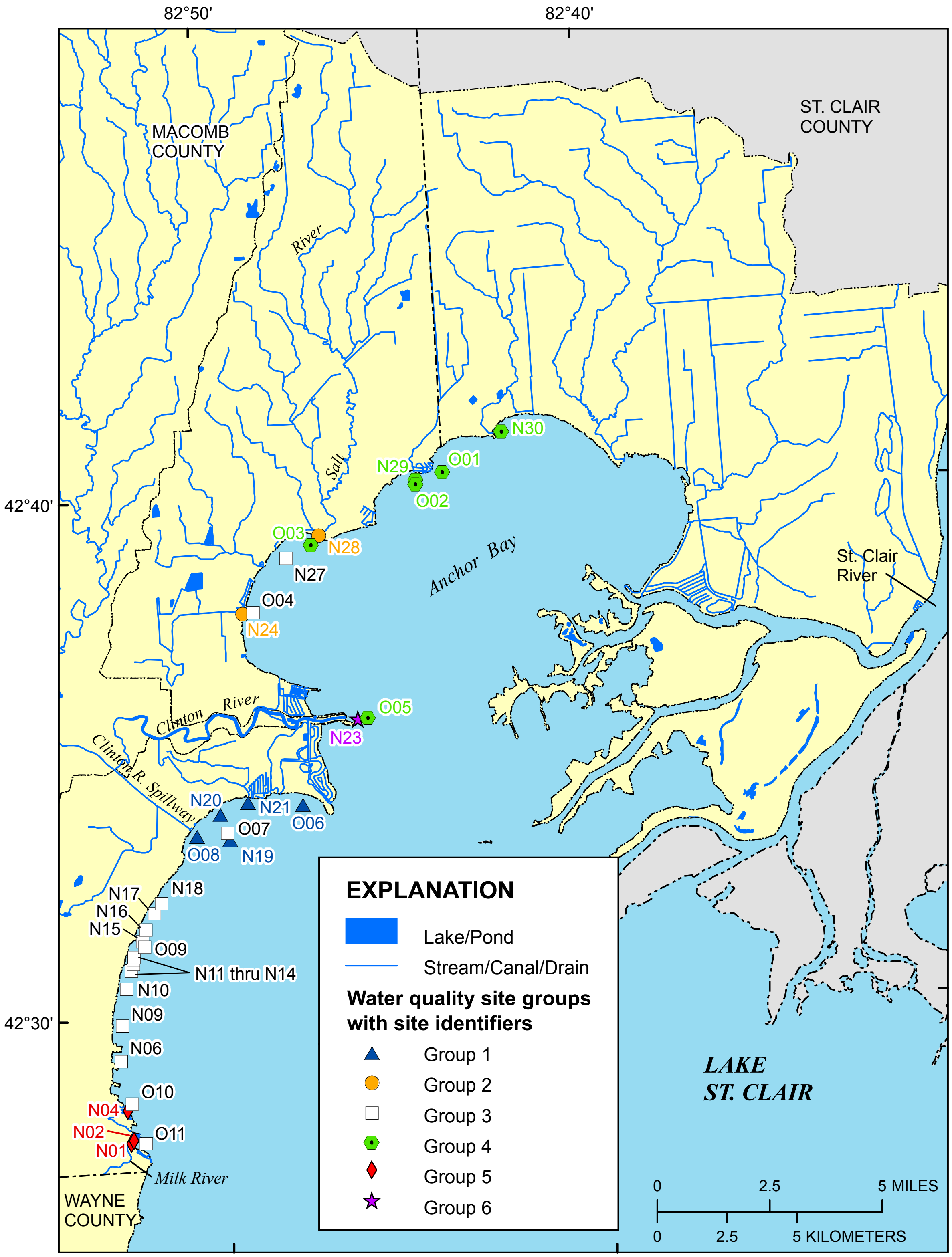
[The medians presented here represent the overall dataset collected at each location, regardless of when the sample was collected; CFU/100 mL; colony-forming units per 100 milliliters; site locations and numbers are shown on fig. 18]

Subbasin		Site number and name	Median *E. coli* concentration (CFU/100 mL)
Main Branch Clinton River [West]	Upstream from Red Run	W 53-Clinton River at Dequindre Road	187
		W 54-Clinton River at Hall Road	173
		W 62-Clinton River at Kleino Road	243
		W 91-Stony Creek at Inwood Road	172.5
		W 92-West Branch Stony Creek at Park Road	145
	Downstream from Red Run	W 69-Canal Drain at Clinton River Road	613
		W 75-Clinton River at Garfield Road	599.5
Red Run and Tributaries		W 35-Red Run Drain at Van Dyke Road	913
		W 55-Red Run Drain	1,050
		W 56-Red Run Drain at 14 Mile Road	1,030
		W 56.5 Schoenherr Relief Drain at Red Run	2,072
		W 57-Red Run Drain at Dequindre Road	809
		W 71-Plumbrook Drain at Schoenherr Road	386
		W 71.8-Plumbrook Drain at Ryan Road	311
		W 72-Sterling Relief Drain at Freedom Hill	1,198
		W 81-Bear Creek at Mound Road	1,414
		W 82-Bear Creek at Old 13 Mile Road	1,789
		W 84-Beaver Creek at Mound Road	593
		W 85-Lorraine Drain at Bear Creek	5,172

Table 22. Median of *Escherichia coli* concentrations at Macomb County Health Department sites along the lower reaches of the Clinton River and its tributaries.

[The medians presented here represent the overall dataset collected at each location, regardless of when the sample was collected; CFU/100 mL; colony-forming units per 100 milliliters; site locations and numbers are shown on fig. 18]

Subbasin	Site number and name	Median *E. coli* concentration (CFU/100 mL)
Main Branch Clinton River [East]	W 40-Clinton River at I-94	388.5
	W 41-Clinton River at Lake St. Clair DNR site	59
	W 42-Clinton River Spillway at Jefferson	86
	W 43-Clinton River & Spillway	73
	W 61.2-Clinton Relief Drain at Shook Rd.	545.5
	W 66-Clinton River at Amvet Drive	265.5
	W 67-Harrington Drain at Harrington Rd	663
	W 67.71-Sweeney Drain at 15 Mile Rd	820
	W 68-Clinton River at Moravian	368.5
	W 83-Clinton River at Mt. Clemens YMCA	352
	W 90-Clinton River at Riverview	327
	W 95-Clinton River at Albatross Landing	203
	W 96-Clinton River at Shadyside Park	438



Base from U.S. Geological Survey digital Line Graphics, 1:2,000,000, 1998

Figure 20. Locations of Lake St. Clair nearshore/offshore sampling sites with cluster-analysis group membership shown. (Sites are described in table 23.)

Table 23. Nearshore and offshore Lake Assessment water-quality sites.

[Site names are presented as they appear in the original data base (Shoemaker and Misuraca, 2000; Shoemaker and Wuennecke, 2001; Shoemaker and others, 2002; Shoemaker and Buzonik, 2003, 2004; and Buzonik and Shoemaker, 2005) site locations and numbers are shown on fig. 20]

Site number	Site name	Latitude	Longitude
N01	Milk River near Shore	42.4603	-82.8759
N02	8-1/2 Mile Drain near Shore	42.4613	-82.8747
N03	Chapotan Drain near Shore	42.4625	-82.8727
N04	Stephens Drain near Shore	42.4710	-82.8770
N05	10 Mile Drain near Shore	42.4752	-82.8813
N06	Martin Drain (SMSD) near Shore	42.4868	-82.8792
N07	Alexander Relief Drain near Shore	42.4925	-82.8825
N08	I-696 Drain near Shore	42.4969	-82.8786
N09	11-1/2 Mile Drain near Shore	42.4982	-82.8781
N10	12 Mile Relief Drain near Shore	42.5101	-82.8757
N11	Lake Blvd. Drain near Shore	42.5159	-82.8733
N12	Forton Relief Drain near Shore	42.5179	-82.8722
N13	13 Mile Drain near Shore	42.5194	-82.8721
N14	Socia Couches Relief Drain near Shore	42.5202	-82.8719
N15	Hetchler Relief Drain	42.5251	-82.8680
N16	Mulso-Lipke Relief Drain	42.5289	-82.8663
N17	Tebo Drain near Shore	42.5340	-82.8623
N18	Cottrell Drain near Shore	42.5372	-82.8591
N19	Clinton River Spillway near Shore	42.5568	-82.8280
N20	Murdock Ballard Drain near Shore	42.5650	-82.8319
N21	Venter De Bueff Drain near Shore	42.5686	-82.8198
N22	Black Creek near Shore	42.5675	-82.7842
N23	Clinton River near Shore	42.5943	-82.7705
N24	Irwin Branch Relief Drain near Shore	42.6294	-82.8189
N25	Schmidt Drain near Shore	42.6313	-82.8171
N26	River Voss near Shore	42.6442	-82.8090
N27	Dykemann Drain near Shore	42.6469	-82.7992
N28	Salt River near Shore	42.6539	-82.7846
N29	Crapaud Creek near Shore	42.6704	-82.7414
N30	Marsac Drain near Shore	42.6849	-82.7032
O01	New Baltimore off Shore	42.6726	-82.7296
O02	Crapaud Creek off Shore	42.6690	-82.7415
O03	Salt River off Shore	42.6507	-82.7881
O04	Irwin Branch Relief Drain off Shore	42.6297	-82.8145
O05	Clinton River off Shore	42.5944	-82.7662
O06	Metropolitan Beach off Shore	42.5673	-82.7959
O07	Mt. Clemens off Shore	42.5590	-82.8292
O08	Clinton River Spillway off Shore	42.5583	-82.8424
O09	Memorial Park off Shore	42.5233	-82.8671
O10	Coast Guard Station (SCS) off Shore	42.4731	-82.8750
O11	Milk River off Shore	42.4600	-82.8697
O12	North Channel	42.6267	-82.7163
O13	South Channel	42.5127	-82.6988

Data were collected under three different designs at the Lake Assessment sites (Shoemaker and Misuraca, 2000; Shoemaker and Wuennecke, 2001; Shoemaker and others, 2002; Shoemaker and Buzonik, 2003, 2004; and Buzonik and Shoemaker, 2005). Nutrients and a suite of parameters consisting of aluminum, chloride, BOD, and TOC were collected at the nearshore and offshore sites three times per year, during the spring, summer, and fall. *E. coli,* water temperature, specific conductance, pH, dissolved oxygen concentrations, and turbidity were sampled or measured on a roughly weekly basis at the nearshore sites. Trace elements were collected at the inshore sites in 1998. Not all sites were sampled every year, and nitrite, COD, TSS, and chlorophyll were sampled at the nearshore and offshore sites only in 1998.

An informative presentation of the water-quality data and summary statistics for the Lake Assessment sites can be found in Shoemaker and Misuraca (2000), Shoemaker and Wuennecke (2001), Shoemaker and others (2002), Shoemaker and Buzonik (2003, 2004), and Buzonik and Shoemaker (2005). In this report, temporal trends were examined.

The partitioning cluster analysis method k-means was used in this report to cluster MCHD Lake Assessment sites into groups; k-means classifies observations into groups by calculating the centroid for each group and assigning each observation to the group with the closest centroid (Insightful Corp., 2001).

The measurement or concentration of the parameters specific conductance, pH, total chloride, total ammonia, total ammonia plus organic nitrogen, total nitrate, total phosphorus, total orthophosphate, total organic carbon, and turbidity were used to cluster the Lake Assessment sites into six groups (table 24). Six groups were used because as the number of groups increased, more groups of one site were appearing.

Table 24. Groups of Lake Assessment sites as separated by cluster analyses.

Group	Lake Assessment site numbers
1	N19, N20, N21, O06, O08
2	N24, N28
3	N06, N09, N10, N11, N12, N13, N14, N15, N16, N17, N18, N27, O04, O07, O09, O10, O11
4	N29, N30, O01, O02, O03, O05
5	N01, N02, N04
6	N23

The means of the measurements or concentrations for each parameter at each site were normalized to the population mean by subtracting the population mean from the individual site means and dividing by the standard deviation of the population. Because the total orthophosphate concentrations could not be calculated for three sites, the normalized means for all parameters were ranked and the three sites assigned the lowest rank for total orthophosphate. The ranks were transformed to the scale 0 to 1 by the equation

$$\text{transformed rank} = (\text{rank-1})/(\text{total number of sites} - 1)$$

The cluster analyses k-means method was run using the transformed ranks.

The statistical package S-Plus was used for the statistical analyses (Insightful Corp., 2002), and the geographical information system (GIS) Arcview was used for spatial analyses (Environmental Systems Research Institute, 1992–2002).

Cluster analysis was done on water-quality data collected at 23 nearshore sites and 11 offshore sites in Lake St. Clair (table 24). Samples collected at these sites were analyzed for concentrations of *E. coli*, nutrients, total organic carbon, and chloride. Additionally, field measurements of water temperature, specific conductance, pH, and turbidity were recorded at these sites.

The nearshore and offshore sites assignments are as follows (fig. 20): Group 1 consists of the Clinton River Spillway nearshore and offshore sites, the Murdock Ballard Drain nearshore, Venter de Bueff nearshore, and Metropolitan Beach offshore sites. Group 2 consists of the Irwin Branch relief drain nearshore and the Salt River nearshore sites. Group 3 consists of 11 nearshore and 5 offshore sites. Group 4 consists of Crapaud Creek and Marsac Drain nearshore sites plus the New Baltimore, Crapaud Creek, Salt River and Clinton River offshore sites. Group 5 consists of the Milk River, 8-½ mile Drain, and Stephens Drain nearshore sites. The Clinton River nearshore site is the sole member of Group 6.

In most of the Lake St. Clair nearshore and offshore sample sites, paired nearshore and offshore sites (group 3; fig. 20) tend to cluster together, indicating that the concentrations of nutrients and *E. coli* change little in the area approximately ¼ mi out from the shoreline. This similarity in water-quality among many paired nearshore and offshore sites suggest that water flowing into Lake St. Clair does not rapidly mix and may affect nearshore water quality downstream from tributary confluences. However, the Clinton River nearshore site (group 6) comprised a group of one very early in the cluster partitioning, indicating large differences in nearshore and offshore water quality at that location. Concentrations of nutrients and chloride at the Clinton River nearshore site (group 6) differed significantly from those of most other groups (fig. 21). The Clinton River nearshore site (group 6) was most similar to nearshore sites in group 2 (consisting of the Irwin Branch relief drain nearshore site and the Salt River nearshore site), with no significant differences in concentrations of ammonia, total phosphorus, and total organic carbon.

Although several of the paired nearshore and offshore sites clustered together (groups 1, 3, and 4), the Clinton River nearshore/offshore sites (N23 and O05) do not, suggesting rapid change in water quality. The exposed location of the Clinton River offshore site (O05) potentially makes it more susceptible to mixing due to wind and wave action, whereas other nearshore/offshore site pairs are in more sheltered locations.

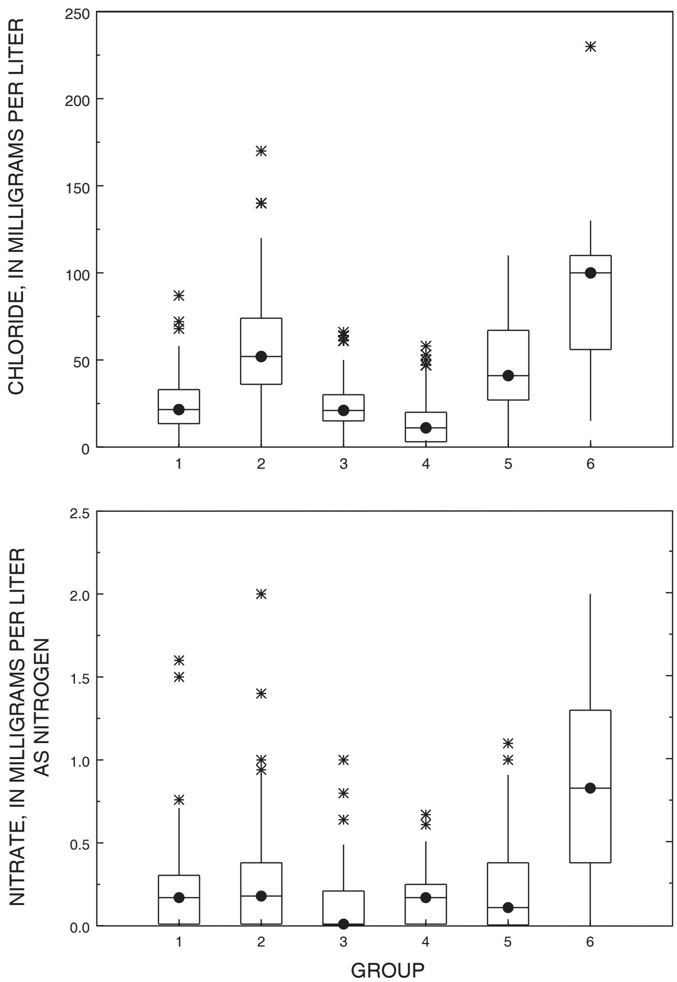


Figure 21. Comparison of chloride and nitrate concentrations among groups of Lake St. Clair offshore/nearshore sampling sites.

Summary and Conclusions

The compilation of water-quality data for the St. Clair River, Lake St. Clair, and their U.S. tributaries provided a historic perspective of the water resources in the region. Data collected by Federal, State, and local-government agencies, as well as academic institutions, from 1946 to 2005 were combined to create an extensive dataset for use by resource managers and others charged with improving present and future regional water quality. Analysis of this dataset offers the potential to discern patterns in water quality, both spatially and over time. These data were analyzed by making basin-to-basin comparisons of water-quality characteristics, identification of temporal changes in water quality, and estimation of loads.

The difficulty in combining data from many studies collected by several agencies or entities and with widely varying objectives is clearly demonstrated in this effort. It is extremely difficult to meet the assumptions or data requirements of statistical tests when data have been collected in a piecemeal fashion. The Lake St. Clair study area is data rich. However, these data are not sufficiently comparable to allow detailed analyses at all sites.

Much of the data collection and analysis was done, in part, to determine the influence of the water quality of tributaries on the St. Clair River/Lake St. Clair. In light of these objectives, it should be kept in mind that the flow of the St. Clair River—annual mean flow of 182,000 ft^3/s and monthly means ranging from 106,000 to 232,000 ft^3/s—dwarfs the flows of the tributaries in the LSCRMP study area. This comparison suggests that tributary loads are diluted by this greater volume of water, and water-quality data indicate this is largely true. However, flow patterns in both nearshore areas of the St. Clair River and in Lake St. Clair may create areas where mixing and dilution may be reduced. These areas include nearshore areas in the river and in wind-formed gyres in the lake.

The basin-to-basin comparison of water-quality characteristics indicated significant differences among the tributary basins and in their relation to the St. Clair River and Lake St. Clair. Comparisons were made for nitrogen species, phosphorus, chloride, specific conductance, BOD and pesticides. Although the St. Clair River and Lake St. Clair had consistently better water quality than the tributaries, significant variability was found among the tributary basins.

Median concentrations of total nitrate in study area streams were well below the recommended USEPA total nitrogen ambient water-quality criterion of 0.54 mg/L as N for nutrient ecoregion VII except for the Clinton River. Approximately 75 percent of samples from the Clinton River Basin had concentrations of total nitrate that were greater than this limit, even without the inclusion of other nitrogen species (ammonia, organic nitrogen, and nitrite). The Clinton River Basin is the most urban/suburban basin and is undergoing the greatest change in land use/land cover in the LSCRMP study area. It is interesting to note that nitrite, which usually accounts for a small fraction of mineralized nitrogen, was a significant fraction of total nitrogen in the study area. Median concentrations of dissolved nitrate plus nitrite were greater than the recommended total nitrogen criteria for all river basins except those of the Pine and St. Clair Rivers. If samples had been analyzed for total nitrogen, it is clear that concentrations in all streams, except perhaps the St. Clair River, would have been well above this criterion.

Phosphorus concentrations varied little among the LSCRMP study area tributary streams; all phosphorus concentrations were greater than the USEPA total phosphorus ambient water-quality criterion of 0.033 mg/L for nutrient ecoregion VII. More than 93 percent of phosphorus concentrations in the Belle, Black, Pine, and minor river basins and 84 percent of concentrations in the Clinton River Basin were greater than this value. Concentrations in the St. Clair River were markedly lower.

Chloride concentrations varied among the LSCRMP study-area tributaries, ranging from a median of 42 mg/L in the Black River Basin to 140 mg/L in the minor river basins. In sharp contrast to the median values for the tributaries is the 6.0 mg/L median value for the St. Clair River. Chloride concentrations in nine samples were greater than the USEPA criterion maximum concentration of 860 mg/L, with six of those samples coming from the Belle River Basin. Chloride concentrations in 159 samples were greater than the criterion continuous concentration of 230 mg/L, with many of these samples coming from the Clinton River Basin. These concentrations above the criteria were more common in recent samples—those from 2000 to 2005—suggesting that chloride concentration may be increasing in most basins.

One objective of this study was to identify trends in water quality from 1946 to 2005. Trend analyses were limited to four sites (one site in the Black River Basin and three sites in the Clinton River Basin) because of lack of comparability in the data.

An analysis of data from the Black River near Port Huron detected no significant trend in 20 water-quality parameters during 1978–93. The absence of significant trends in water quality likely reflects the fact that land-use practices in the basin changed little during this time.

Trend analysis was done on water-quality data from three sites in the Clinton River Basin: Clinton River at Hamlin Road Bridge, Avon Township (Rochester Hills), in a less densely urban upstream part of the basin; and Clinton River at Moravian Drive and at northbound Gratiot Avenue in Mount Clemens, two closely located sites in the densely urbanized downstream parts of the Clinton River Basin.

The Clinton River at Hamlin Road Bridge, Avon Township (Rochester Hills) site showed water-quality trends for 18 parameters during periods from 1972 to 1994. Significant trends were identified for five parameters during 1978–94. Significant, but weak, positive (upward) trends were detected for dissolved oxygen concentration and pH. Significant negative (downward) trends were identified for total and un-ionized ammonia and biochemical oxygen demand, although the trends for BOD and un-ionized ammonia were weak.

Trends analyses for water-quality data from the two closely located downstream Clinton River sites generally support each other. Although sampling schedules and periods differed between the sites, both indicate significant, although weak, downward trends in nutrient species and significant upward trends in chloride, hardness, total solids, and specific conductance.

In general, the trend in the Clinton River Basin appears to be a slight reduction in nutrients, possibly attributable to improvements in wastewater treatment, and increases in parameters that reflect increased development.

Estimates of loads delivered to the St. Clair River and Lake St. Clair were calculated for the Belle, Black, and Clinton Rivers. Not surprisingly, the Clinton River, with the highest streamflow and highest concentrations of many constituents, contributed the highest loads of chloride, nutrients, and biochemical oxygen demand.

Concentrations of *E. coli* were analyzed in comparison to Michigan water-quality standards set for fully and partial body contact. *E. coli* concentrations exceeded partial body contact standards in tributary basins from 3 percent of the time in the Milk River to 90 percent of the time in Bear Creek. Strong seasonal patterns were seen, with concentrations typically increasing through spring, peaking during summer, and decreasing into the winter. Red Run is a significant contributor of *E. coli* load to the upper Clinton River: median *E. coli* concentrations below the confluence of Red Run and the Clinton River are 2 to 3 times higher than median concentrations above the confluence.

From 1998 through 2005, the MCHD monitored water quality along the Macomb County Lake St. Clair shoreline as part of a larger study to characterize water and sediment quality in Lake St. Clair and the Clinton River Basin. The nearshore sites were near point discharges to Lake St. Clair, including the mouth of rivers and storm drains. The offshore sites were approximately ¼ mi from the shoreline. Further investigation of the 1998 to 2005 *E. coli* data, through cluster analysis of *E. coli* concentrations and other water-quality characteristics, grouped many nearshore sites with their corresponding offshore sites, indicating that nearshore concentrations were not rapidly diluted in most cases.

The compilation and analysis of available water-quality data from the St. Clair River, Lake St. Clair, and their U.S. tributaries illustrated several points regarding water quality and water-quality data in the area:

- One of the main lessons to be learned from this analysis is the necessity of a consistent, long-term monitoring program if identification of temporal trends is an objective. As mentioned previously, the study area is data rich; however, lack of uniformity and comparability in the data prevented some analyses.

- The data were sufficient to show spatial patterns and temporal trends in the data, and some conclusions can be drawn from these analyses. For example, the data showed that water quality in many of the tributaries, particularly the Clinton River and some of the minor rivers, was degraded compared to the water quality of the St. Clair River. This contrast may indicate that the St. Clair River, with flows far exceeding those of any of the tributaries in the study area, is able to assimilate loads from the tributaries with little effect upon its water quality.

- Although the St. Clair River's overall water quality is better than that of many of the tributaries, flow studies indicate that water flowing into Lake St. Clair does not rapidly mix in the nearshore area and may affect nearshore water quality downstream from tributary confluences. This indication of delayed mixing is supported by the results of the analysis of nearshore/offshore *E. coli* data, which reflected similarity in water quality among many paired nearshore and offshore sites.

- Trend analysis was done at the four sites where comparable data were available for a sufficient period. These analyses identified no significant water-quality changes in the Black River, where land-use patterns have changed little. This finding stands in marked contrast to trend analysis of three sites in the Clinton River Basin, which has undergone significant land-use change. The changes at the Clinton River sites, ranging from 5 to 13 significant trends, were generally decreases in nutrients and increases in TDS and chloride.

- The validity of future statistical analysis of water-quality data rests upon the assumption that the data will come from samples that reflect ambient conditions. All natural waters will vary both spatially and temporally and therefore can rarely be adequately represented by a single sample collected from a single point. It is important to note that seasonal and annual variation in streamflow may affect interpretation of water-quality trends. Other factors affecting the determination of water-quality trends include the selection of input data, the geographic locations of data, sample-collection schedules, sample-collection methods, sample-processing methods, analytical methods, and the period of sample collection.

Overall, the results of this study reflect a complex and dynamic system, made even more complex by rapid watershed changes occurring in parts of the study area. To understand whether the observed trends have continued or how tributary water quality will influence the water quality of the St. Clair River and Lake St. Clair in the future can only be determined through continued monitoring of these important resources.

Considerations for Establishing Future Water-Quality Networks

In the future, the validity of statistical analysis of water-quality data rests upon the assumption that the data will come from samples that reflect ambient conditions. One of the greatest challenges of any water-quality-sampling program is to collect a sample that accurately represents the sampled water; therefore, sampling sites should be selected so that samples represent the environment of interest, typically the entire upstream drainage area, rather than a localized influence, such as a point discharge. Furthermore, all natural waters will vary both spatially and temporally and therefore can rarely be adequately represented by a single sample collected from a single point; hence, samples should be collected in such a fashion that both temporal and spatial variability are captured and reflected in a data set.

Many times, a thorough analysis of data compiled from studies are thwarted by either inadequacies of the dataset or inconsistencies within a dataset. Many water-quality monitoring programs are characterized by data-collection efforts that are sporadic (that is stopping, restarting, and/or changing focus) resulting in data with varying parameter sets, discontinuous records for constituents of interest, or data so old as to be no longer relevant to current conditions. The goals of many water-quality investigations often include estimation of mass of a constituent delivered to a receiving water body (loading) or determining changes in water-quality over time (trend identification). The data needed to accurately estimate constituent loading and detect significant trends in water quality require that samples be collected in a consistent, coherent fashion over a sufficient span of time, and, optimally, with ancillary data that will facilitate analysis and interpretation.

Sampling to Determine Water Quality

Water quality at a site will vary over time at differing scales; seasonally, over the course of a storm, and over daily cycles. Sampling throughout the year ensures variability in water quality due to seasonal patterns in climate that affect weather, streamflow, and ecological processes are sufficiently reflected in the data. Sampling during changes in streamflow, often referred to as "sampling across the hydrograph," is important to understanding transport of constituents—some associated with base flow, others present at greater concentrations during increases in streamflow. Daily, or diel, changes in water quality are often overlooked, although photosynthetically driven diel cycles in dissolved oxygen concentration and pH are well known. Recent studies have noted diel changes in metals, particularly changes in partitioning of metal species in solution (Nimick and others, 2005).

The chemical and physical characteristics in streams and lakes alike may vary with depth and lakes may be sharply stratified, requiring proportional collection of water from the entire water column. Stream waters may not be well mixed horizontally or vertically, with water quality varying from bank to bank in response to varying flows. The convergence of streams with differing water-quality characteristics is the most common cause of poorly mixed streams and the potential for nonrepresentative samples.

To collect a representative stream sample, the appropriate depth- and flow-integrated sampler and sampling method must be determined. For streams with relatively uniform depths and velocities and with flows greater than 1.5 ft/s, the equal-width-increment method (EWI) can be used at several points, typically 10, across the entire stream width (U.S. Geological Survey, 2006). EWI samples are collected by lowering and raising an isokinetic sampler through the water column at the center of each increment. The combination of the same constant transit rate used to sample at each vertical and the isokinetic property of the sampler results in a discharge-weighted sample that is proportional to total streamflow. Additionally, if suspended-sediment samples or unfiltered water samples are to be analyzed, isokinetic samplers—those that accurately sample suspended sediments—must be used (Edwards and Glysson, 1999).

For streams with varying depths and/or velocities and flows less than 1.5 ft/s, the equal-discharge-increment method (EDI) can be used at several points, typically three or four, across the entire stream width (U.S. Geological Survey, 2006). EDI samples are collected by dividing the flow in the cross section into increments of equal discharge. Equal-volume, depth-integrated samples are collected at the centroid of each of the equal-discharge increments along the cross section. The EDI method collects a discharge-weighted sample that represents the entire flow passing through the cross section by obtaining a series of samples, each representing equal volumes of stream discharge.

Estimating Loads

Estimation of constituent load is based on multiple regression time series of streamflow, constituent concentration, and additional variables (Runkel and others, 2004). Loads are mass per time period and can be expressed for any time period, such as seconds, hours, days, months, and years. The substance could be anything that enters a water body, but the term “loads” usually describes nutrients, sediments, and specific chemicals of concern. The methods used to estimate loads vary, but the basic calculations involve the sample concentration multiplied by volume per unit time (usually 12 monthly samples) to produce an annual mass per unit time (Beale, 1962). A dataset spanning several years is preferred in order to capture the year-to-year climatic and hydrologic variability inherent in streamflow data.

Data needed to develop accurate load models include continuous streamflow records and periodic water-quality samples collected on a consistent basis. For example, investigators examining nutrient contributions to the Chesapeake Bay have used a rolling 9-year window to revise regression formulae, resulting in annually updated models for load estimation (Yochum, 2000). Recent studies have also used data from continuous water-quality monitors to further refine relations among streamflow and chemical characteristics (Rasmussen and others, 2005).

Detecting Trends

Water-quality trends indicate whether the concentrations of a substance are changing over a period of time. Positive trends indicate an increase in load or concentration with time, which are generally associated with degraded water quality; and negative trends indicate a decrease in load or concentration with time, which are generally associated with improved water quality. Whereas the loads estimated in the previous section describe a volume of a substance, trends can help determine whether management practices are working or whether water quality is improving or getting worse over time.

The statistical tests commonly used for trend analysis, both the censored and uncensored seasonal Kendall test and the Tobit test (Schertz and others, 1991), have data requirements that must be met in order to accurately detect significant trends. Trend detection requires a sufficient period of data be collected: a minimum of 5 years of data is recommended for samples collected monthly, and a longer period of record would be needed to analyze data collected less frequently (Schertz and others, 1991). During this period of data collection, procedures used for sample collection, processing, and analysis should remain consistent, as deviation from consistent practices “may confound the detection of trends in ambient water quality or even directly cause false trends to appear in water-quality records” (Schertz and others, 1991). Particular attention should be given to laboratory reporting limits for the parameters of interest because this influences which statistical test should be used for the analysis. The preferred, uncensored seasonal Kendall test can reliably provide unbiased results when used with data consisting of less than 5 percent censored values, but other procedures must be used if censored values make up more than 5 percent of water-quality record (Schertz and others, 1991).

It is important to note that seasonal and annual variation in streamflow may affect interpretation of water-quality trends. The sources of many substances are subject to seasonal variation (for example, pesticides and nutrients tend to be applied to agricultural areas during the spring and summer months) or streamflow patterns (for example, higher flows observed during spring months due to snowmelt and spring showers versus lower flows observed during late summer, which tends to be drier). Other factors affecting the determination of water-quality trends include the selection of input data, the geographic locations of data, sample-collection schedules, sample-collection methods, sample-processing methods, analytical methods, and the period of sample collection (Schertz and others, 1991).

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Appendixes 1–1 through 2–14

Appendix 1–1. Water-quality sites in the Black River Basin and number of samples collected by time period.

[Site names are listed as they appear in the origin database; sites are shown on fig. 4]

Map number (on fig. 4)	Site identifier	Site name in Black River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
1	04159134	BLACK RIVER AT MILLS ROAD NEAR PALM, MI	43.5825	-82.8119	0	2	0	0
2	04159135	CARROLL DRAIN AT STRINGER ROAD NEAR DECKERVILLE, MI	43.5467	-82.7953	0	2	0	0
3	04159140	BISHOP DRAIN AT STONE ROAD NEAR DECKERVILLE, MI	43.5544	-82.7856	0	2	0	0
4	760108	BLACK RIVER AT DECKERVILLE ROAD; WHEATLAND TWP, SEC 36	43.5264	-82.7675	0	29	0	0
4	04159145	BLACK RIVER AT DECKERVILLE ROAD NEAR DECKERVILLE, MI	43.5258	-82.7686	0	2	0	0
5	04159150	BLACK RIVER AT SNOVER ROAD NEAR MCGREGOR, MI	43.4678	-82.7528	0	2	0	0
6	760142	DWIGHT CR 333YD ABV SANDUSKY TP; WTRTOWN TWP S4	43.4190	-82.8203	0	0	1	0
7	760174	BERRY DRAIN AT DOWNSTREAM SANDUSKY WWTP; T11N R14E S04	43.4211	-82.8199	0	0	0	1
8	760086	BERRY DRAIN AT BANNER ROAD BR; CUSTER TWP, SEC 34	43.4225	-82.8100	0	2	0	0
9	760207	BERRY DRAIN UPSTREAM OF STRINGER ROAD (U/S MICHIGAN PEAT OUT	43.4218	-82.7992	0	0	0	1
9	760087	BERRY DRN AT STRINGER ROAD BR; CUSTER TWP, SEC 35	43.4225	-82.7908	0	2	0	1
10	760088	BERRY DRAIN AT EDDY ROAD BR; CUSTER TWP, SEC 26	43.4372	-82.7806	0	2	0	0
11	760206	DWIGHT DRAIN AT STRINGER ROAD, T12N R14E S34	43.4405	-82.7921	0	0	0	1
12	760079	BERRY DRAIN AT BERKSHIRE ROAD; CUSTER TWP, SEC 25	43.4411	-82.7758	0	4	0	0
13	760089	BERRY DRAIN AT CUSTER ROAD BR; CUSTER TWP, SEC 24	43.4528	-82.7522	0	2	0	1
13	04159170	BERRY DRAIN AT RANGE LINE ROAD NEAR MCGREGOR, MI	43.4533	-82.7519	0	2	0	0
14	04159175	FYE DRAIN AT RANGE LINE ROAD NEAR CARSONVILLE, MI	43.4569	-82.7519	0	1	0	0
15	760090	BERRY DRAIN 0.1 MILES FROM MOUTH; BRHAMPTON TWP,	43.4533	-82.7458	0	2	0	1
16	04159180	BLACK RIVER AT CHURCH ROAD NEAR CARSONVILLE, MI	43.4228	-82.7117	0	2	0	0
17	04159190	ELK CREEK AT BROOKS ROAD NEAR VALLEY CENTER, MI	43.2286	-82.9117	0	2	0	0
18	04159200	ELK CREEK AT PALDI ROAD NEAR PECK, MI	43.2925	-82.8394	0	2	0	0
19	04159202	EB SPEAKER AND MAPLE VALLEY DRAIN NEAR PECK, MI	43.2800	-82.8386	0	2	0	0
20	04159206	MCDONALD DRAIN AT STILSON ROAD NEAR WATERDOWN, MI	43.3017	-82.8425	0	2	0	0
21	04159210	ELK CREEK AT MARLETTE ROAD AT WATERTOWN, MI	43.3341	-82.8192	0	2	0	0

Appendix 1–1. Water-quality sites in the Black River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites are shown on fig. 4]

Map number (on fig. 4)	Site identifier	Site name in Black River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
22	04159215	FRIZZLE DRAIN AT MORRIS ROAD AT WATERTOWN, MI	43.3458	-82.8161	0	2	0	0
23	04159222	POTTS DRAIN AT HALL ROAD NEAR PECK, MI	43.2891	-82.7467	0	2	0	0
24	04159225	POTTS DRAIN AT AITKEN ROAD NEAR WATERTOWN, MI	43.3186	-82.7375	0	2	0	0
25	04159230	ELK CREEK AT FRENCH LINE ROAD NEAR APPLEGATE, MI	43.3667	-82.7275	0	2	0	0
26	760010	ELK RIVER AT WASHINGTON ROAD. BR; WASHINGTON TWP SEC 9	43.3965	82.7050	0	2	0	0
27	04159250	BLACK RIVER AT APPLEGATE ROAD AT APPLEGATE, MI	43.3550	-82.6494	0	2	0	0
28	760009	BLACK RIVER AT AITKEN ROAD; LEXINGTON TWP, SEC 7	43.3219	-82.6353	0	43	0	0
29	04159270	ARNOT CREEK AT BLACK RIVER ROAD AT CROSWELL, MI	43.2886	-82.6364	0	2	0	0
30	760052	BLACK RIVER, AT HARRINGTON ROAD BR; CITY OF CROSWELL	43.2789	-82.6239	0	14	0	0
31	760053	BLACK RIVER AT SANBORN STREET; CITY OF CROSWELL	43.2717	-82.6215	0	8	0	0
32	760054	BLACK RIVER, AT MICH SUGAR CO DAM; CITY OF CROSWELL	43.2678	-82.6203	0	22	0	0
33	760130	BLACK RIVER 75FT DNST CROSWELL WWTP; LEXTN TWP SEC 32	43.2611	-82.6200	0	6	0	0
34	760082	CROSWELL DRAIN NEAR MOUTH; LEXINGTON TWP, SEC 32	43.2606	-82.6187	0	14	0	0
35	760129	BLACK RIVER. 1600FT DNSTR M-90; LEXINGTON TWP SEC 32	43.2594	-82.6203	0	6	0	0
36	760048	BLACK RIVER AT SHERIDAN LINE ROAD; LEXINGTON TWP SEC 32	43.2506	-82.6158	0	59	0	0
37	04159300	BLACK RIVER NEAR CROSWELL, MI	43.2233	-82.6136	0	3	0	0
37	760056	BLACK RIVER, AT BURNS LINE ROAD; WORTH TWP, SEC 17	43.2232	-82.6140	0	22	0	0
38	04159445	BLACK CREEK AT COMSTOCK ROAD NEAR ROSEBURG, MI	43.1811	-82.7117	0	2	0	0
39	04159470	BLACK CREEK AT FARGO ROAD NEAR ROSEBURG, MI	43.2011	-82.6653	0	2	0	0
40	04159480	BLACK CREEK AT BLACK RIVER ROAD NEAR CROSWELL, MI	43.2128	-82.6267	0	2	0	0
40	760083	BLACK CR AT BLACK RIVER ROAD BRIDGE; WORTH TWP, SEC 18	43.2125	-82.6264	0	6	0	0
41	760057	BLACK RIVER, AT GARDNER LINE ROAD; WORTH TWP, SEC 20	43.2089	-82.6153	0	23	0	0
42	760058	BLACK RIVER, AT GALBRAITH ROAD BR; WORTH TWP, SEC 28	43.1937	-82.6218	0	29	0	0
43	760059	BLACK RIVER, AT FISHER ROAD BRIDGE; WORTH TWP, SEC 32	43.1647	-82.6213	0	29	0	0
44	0202002	BLACK RIVER ABOVE SILVER CREEK	43.1611	-82.6222	0	5	0	0

Appendix 1–1. Water-quality sites in the Black River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites are shown on fig. 4]

Map number (on fig. 4)	Site identifier	Site name in Black River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
45	0202001	HAYES DRAIN AT GREENWOOD ENERGY CENTER	43.1189	-82.6764	0	4	0	0
46	04159487	SILVER CREEK AT YALE ROAD NEAR FARGO, MI	43.1344	-82.6617	0	1	0	0
47	04159490	SILVER CREEK AT JEDDO ROAD NEAR JEDDO, MI	43.1497	-82.6358	0	2	0	0
48	04159492	BLACK RIVER NEAR JEDDO, MI	43.1525	-82.6242	0	0	0	31
49	740154	BLACK RIVER AT JEDDO ROAD BRIDGE.; GRANT TWP, SEC. 5	43.1511	-82.6244	0	13	0	0
48	BL03	BLACK RIVER NEAR JEDDO, MI	43.1525	-82.6242	0	0	0	70
50	0202004	BLACK RIVER ABOVE PLUM CREEK	43.1264	-82.6139	0	5	0	0
51	740268	BLACK RIVER AT COMSTOCK ROAD; GRANT TWP., SEC. 17	43.1231	-82.6169	0	5	0	0
52	0202003	PLUM CREEK AT GREENWOOD ENERGY CENTER	43.0972	-82.6736	0	4	0	0
53	04159495	PLUM CREEK AT GRAHAM ROAD NEAR BLAINE, MI	43.1164	-82.6203	0	2	0	0
54	04159500	BLACK RIVER NEAR FARGO, MI	43.0922	-82.6181	1	85	0	0
54	740234	BLACK RIVER AT NORMAN ROAD BRIDGE; GRANT TWP., SEC. 32	43.0922	-82.6181	0	126	0	0
55	0202006	BLACK RIVER BETWEEN MILL & PLUM CREEKS	43.0844	-82.6167	0	2	0	0
56	04159510	O'DETTE DRAIN AT KINGSLEY ROAD NEAR FARGO, MI	43.0686	-82.6367	0	1	0	0
57	0202005	BLACK RIVER ABOVE MILL CREEK	43.0569	-82.6000	0	5	0	0
58	04159700	ELK LAKE CREEK AT HWY M53 AT GOODLAND, MI	43.0858	-83.0753	0	2	0	0
59	04159750	NB MILL C AT BROWN CITY ROAD NEAR GOODLAND, MI	43.1258	-83.0339	0	2	0	0
60	04159800	NB MILL CREEK AT MASON ROAD AT YALE, MI	43.1233	-82.8942	0	2	0	0
61	04159850	SB MILL CREEK AT NORMAN ROAD NEAR CAPAC, MI	43.0842	-82.9253	0	2	0	0
62	04159865	LOVEJOY DRAIN AT NORMAN ROAD NEAR CAPAC, MI	43.0844	-82.8767	0	1	0	0
63	04159870	SB MILL CREEK AT FULTON ROAD NEAR YALE, MI	43.1086	-82.8978	0	2	0	0
64	04159875	MIDDLETON DRAIN AT YALE ROAD NEAR YALE, MI	43.1289	-82.8433	0	1	0	0
65	04159890	MILL CREEK AT JEDDO ROAD NEAR YALE, MI	43.1442	-82.8184	0	2	0	0
65	740026	MILL CREEK AT JEDDO ROAD; BROCKWAY TOWNSHIP, SEC 10	43.1439	-82.8186	0	2	0	0
66	04159893	MILL CREEK AT WILKES ROAD NEAR YALE, MI	43.1008	-82.7958	0	1	0	0
67	04159895	SHEEHY DRAIN AT CORNELL ROAD NEAR YALE, MI	43.0939	-82.8061	0	1	0	0

Appendix 1–1. Water-quality sites in the Black River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites are shown on fig. 4]

Map number (on fig. 4)	Site identifier	Site name in Black River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
68	04159898	MILL CREEK AT METCALF ROAD AT BROCKWAY, MI	43.0728	-82.7656	0	1	0	0
69	04159900	MILL CREEK NEAR AVOCA, MI	43.0544	-82.7347	0	5	0	0
69	740235	MILL CR AT BRICKER ROAD. BR; KENOCKEE TWP., SEC 8	43.0544	-82.7347	0	128	0	0
69	BL02	MILL CREEK NEAR AVOCA, MI	43.0544	-82.7347	0	0	0	30
70	04159950	MILL CREEK AT KILGORE ROAD NEAR AVOCA, MI	43.0427	-82.6936	0	1	0	0
71	04160000	MILL CREEK NEAR ABBOTSFOROAD, MI	43.0450	-82.6139	0	3	0	0
72	740153	BLACK RIVER AT WADHAMS ROAD BRIDGE; KIMBALL TWP, SEC 2	42.9983	-82.5381	0	36	326	9
72	04160050	BLACK RIVER NEAR PORT HURON, MI	42.9900	-82.5378	0	2	0	0
72	BL01	BLACK RIVER NEAR PORT HURON, MI	42.9900	-82.5378	0	0	0	46
73	740152	BLACK RIVER AT END OF NORTH ROAD; CLYDE TWP, SEC 36	43.0056	-82.5256	0	8	0	0
74	740151	BLACK RIVER 0.3MI W STATE ROAD; F. GRATIOT TWP SEC 30	43.0125	-82.5011	0	5	0	0
75	740150	BLACK RIVER AT W END OF OXBOW; FORT GRATIOT TWP SEC 32	43.0056	-82.4797	0	4	0	0
76	740149	BLACK RIVER AT N. RIVER ROAD PK; F. GRATIOT TWP SEC 27	43.0169	-82.4564	0	8	0	0
76	740267	BLACK RIVER 450FT UPST BLK RIVER CANAL;F GRAT TWP SEC27	43.0169	-82.4556	0	3	0	0
77	740148	BLACK RIVER CANAL AT M-136; FORT GRATIOT TWP SEC 27	43.0164	-82.4508	0	8	0	0
78	740266	BLACK RIVER 975FT DNST BLK RIVER CANAL;F GRAT TWP SEC27	43.0136	-82.4508	0	3	0	0
79	740147	BLACK RIVER AT FOOT OF WOODSTOCK DR; P. HURON TWP SEC4	42.9986	-82.4578	0	5	0	0
80	740270	BLACK RIVER. 1500 FT UPSTR I-94; CITY OF PORT HURON	42.9958	-82.4511	0	3	0	0
81	740146	STOCK CREEK AT DOCK NO 15; PORT HURON TWP, SEC 4	42.9947	-82.4481	0	5	0	0
82	04160075	BLACK RIVER AT PORT HURON, MI	42.9944	-82.4450	0	0	0	23
82	740161	BLACK RIVER AT I-94 BRIDGE.; CITY OF PORT HURON	42.9944	-82.4456	0	6	0	0
82	BL04	BLACK RIVER AT PORT HURON, MI	42.9944	-82.4450	0	0	0	14
83	740145	BLACK RIVER. AT END OF THOMAS ST; CITY OF PORT HURON	42.9908	-82.4425	0	4	0	0
84	740265	BLACK RIVER AT GD TRUNK RR UPSTR 10TH AV IN PORT HURON	42.9847	-82.4424	0	3	0	0
85	255289	BLACK RIVER (TRIB TO ST CLAIR RIVER)	42.9808	-82.4336	7	0	0	0
86	255290	BLACK RIVER (TRIB TO ST CLAIR RIVER)	42.9756	-82.4244	17	0	0	0
87	255004	BLACK RIVER (TRIB TO ST CLAIR RIVER)	42.9736	-82.4203	57	0	0	0
88	255235	BLACK RIVER (TRIB TO ST CLAIR RIVER)	42.9728	-82.4192	39	0	0	0

Appendix 1–2. Water-quality sites in the Belle River Basin and number of samples collected by time period.

[Site names are listed as they appear in the origin database; site shown on fig 5]

Map number (on fig. 5)	Site identifier	Site name in Belle River Basin	Latitude	Longitude	Time period 1963–1965	1966–1980	1981–1995	1996–2005
1	04160550	BELLE RIVER AT DRYDEN ROAD AT DRYDEN, MI	42.9464	-83.1072	0	2	0	0
2	440089	DRYDEN DR AT GR. TRUNK RR BR; DRYDEN TWP SEC 12	42.9486	-83.1217	0	5	0	0
3	440086	BELLE RIVER. AT BISHOP ROAD BR; DRYDEN TWP., SEC 12	42.9539	-83.1057	0	5	0	0
4	440088	BELLE RIVER OFF HALL ROAD AT LAKE OUTLET;ALMONT TWP SEC 6	42.9717	-83.0917	0	5	0	0
5	04160559	BELLE RIVER AT HALL ROAD NEAR DRYDEN, MI	42.9728	-83.0897	0	2	0	0
6	04160560	WESTON DR AT BLACKS CORNERS ROAD NEAR DRYDEN, MI	42.9772	-83.0944	0	2	0	0
7	440080	BELLE RIVER. AT M-53 BRIDGE; IMLAY TWP., SEC 32	42.9878	-83.0681	0	6	6	0
8	440081	N. BR. BELLE RIVER. AT SUMMERS ROAD; IMLAY TWP, SEC 19	43.0189	-83.1067	0	3	4	0
9	440167	NORTH BRANCH BELLE RIVER AT M-21 UPSTREAM OF IMLAY CITY; T07	43.0300	-83.0672	0	0	0	5
9	440050	N. BR. BELLE RIVER. AT M-21; IMLAY TWP SEC 16	43.0300	-83.0672	0	4	0	0
9	04160570	NORTH BRANCH BELLE RIVER AT IMLAY CITY, MI	43.0303	-83.0672	0	11	15	0
10	440051	BELLE RIVER OFF END WWTP ROAD.; IMLAY TWP, SEC 21,	43.0211	-83.0644	0	2	0	0
11	440010	BELLE RIVER. AT NEWARK ROAD. BR; IMLAY TWP, SECS 21,28	43.0075	-83.0603	0	43	10	0
11	440169	NORTH BRANCH BELLE RIVER AT NEWARK UPSTREAM OF VLASIC FOODS	43.0083	-83.0606	0	0	0	5
12	440052	BELLE RIVER EAST OF PICKEREL POND; IMLAY TWP SEC 28,	42.9911	-83.0658	0	9	4	0
13	04160573	BELLE RIVER TR AT ROSS ROAD NEAR IMLAY CITY, MI	42.9789	-83.0506	0	2	0	0
14	440053	BELLE RIVER AT BOWMAN ROAD BRIDGE; IMLAY TWP, SEC 34	42.9833	-83.0458	0	8	6	5
15	440054	BELLE RIVER AT GLOVER ROAD BRIDGE; ALMONT TWP, SECS 1	42.9744	-83.0069	0	2	0	0
15	04160575	BELLE RIVER AT GLOVER ROAD NEAR ALMONT, MI	42.9744	-83.0067	0	2	7	0
16	740160	BELLE RIVER AT SCHULTZ ROAD BRIDGE.; BERLIN TWP, SEC 5	42.9744	-82.9564	0	2	4	0
17	04160578	BELLE RIVER AT CAPAC ROAD NEAR IMLAY CITY, MI	42.9647	-82.9378	0	2	0	0
17	740159	BELLE RIVER AT CAPAC ROAD BRIDGE; BERLIN TWP, SEC. 9	42.9647	-82.9378	0	2	4	0
18	04160580	BELLE RIVER AT BERVILLE ROAD AT LESTERVILLE, MI	42.9578	-82.8861	0	2	0	0
18	740025	BELLE RIVER AT BERVILLE ROAD; BERLIN TWP, SEC. 12	42.9575	-82.8861	0	1	0	5
19	04160581	BELLE RIVER AT LYNCH ROAD NEAR LESTERVILLE, MI	42.9619	-82.8742	0	1	0	0

Appendix 1–2. Water-quality sites in the Belle River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; site shown on fig 5]

Map number (on fig. 5)	Site identifier	Site name in Belle River Basin	Latitude	Longitude	Time period 1963–1965	1966–1980	1981–1995	1996–2005
20	04160584	COX-DOTY DRAIN AT M-21 NEAR CAPAC, MI	43.0131	-82.8875	0	2	0	0
21	04160590	LEMON DRAIN AT HUNT ROAD NEAR LESTERVILLE, MI	42.9625	-82.8728	0	2	0	0
22	04160593	BELLE RIVER AT RILEY CENTER, MI	42.9456	-82.8419	0	1	0	0
22	740388	BELLE RIVER AT RILEY CENTER ROAD, RILEY TOWNSHIP, SEC 17	42.9453	-82.8419	0	0	0	5
23	04160595	BELLE RIVER NEAR BELLE RIVER ROAD NEAR MEMPHIS, MI	42.9217	-82.8103	0	1	0	0
24	740024	BELLE RIVER AT BRAIDWOOD ROAD; RILEY TWP., SEC 27	42.9160	-82.8006	0	12	0	0
25	04160599	SAGE CREEK AT BELLE RIVER ROAD AT MEMPHIS, MI	42.9000	-82.7736	0	2	0	0
26	740214	SAGE CREEK AT MILL ST. BR; RILEY TWP., SEC. 35	42.8997	-82.7692	0	1	0	0
27	04160600	BELLE RIVER AT MEMPHIS, MI	42.9008	-82.7692	0	5	0	0
27	740215	BELLE RIVER AT MEMPHIS ROAD; RILEY TWP., SEC. 35	42.9011	-82.7736	0	141	0	0
27	BE02	BELLE RIVER AT MEMPHIS, MI	42.9008	-82.7692	0	0	0	31
28	500304	BELLE RIVER AT BORDMAN ROAD; RICHMOND TWP., SEC 1	42.8972	-82.7583	0	11	0	0
29	04160603	BELLE RIVER AT CARROLL ROAD NEAR MEMPHIS, MI	42.8833	-82.7419	0	1	0	0
30	04160610	ASHERY CREEK AT M-19 AT MEMPHIS, MI	42.8831	-82.7681	0	2	0	0
31	04160612	BELLE RIVER AT WEBER ROAD NEAR MEMPHIS, MI	42.8758	-82.7414	0	1	0	0
31	500305	BELLE RIVER AT WEBER ROAD BR; RICHMOND TWP., SEC 12	42.8758	-82.7414	0	11	0	0
32	740216	BELLE RIVER AT END MESKILL ROAD; COLUMBUS TWP SEC 18	42.8689	-82.7350	0	11	0	0
33	740217	BELLE RIVER AT KRONER ROAD; COLUMBUS TWP., SEC. 19	42.8511	-82.7231	0	11	0	0
34	04160615	BELLE RIVER AT US-25 NEAR RICHMOND, MI	42.8244	-82.6986	0	2	0	0
35	04160618	JEROME CREEK AT HESSEN ROAD NEAR ADAIR, MI	42.8108	-82.6544	0	2	0	0
36	04160620	BELLE RIVER AT ST CLAIR HWY NEAR ADAIR, MI	42.7997	-82.5953	0	2	0	0
37	04160625	BELLE RIVER NEAR MARINE CITY, MI	42.7683	-82.5122	0	2	0	0
37	BE01	BELLE RIVER NEAR MARINE CITY, MI	42.7683	-82.5122	0	0	0	72
38	740167	BELLE RIVER AT MEISNER ROAD BR; CITY OF ST. CLAIR	42.7539	-82.4925	0	79	37	0
39	04160630	BAIRD DRAIN AT KING ROAD NEAR MARINE CITY, MI	42.7389	-82.5111	0	1	0	0
40	255002	BELLE RIVER (TRIB TO ST CLAIR RIVER)	42.7136	-82.4967	29	0	0	0
40	740019	BELLE RIVER AT BRIDGE ST NEAR MOUTH; MARINE CITY	42.7133	-82.4883	59	108	0	0

Appendix 1–3. Water-quality sites in the Pine River Basin and number of samples collected by time period.

[Site names are listed as they appear in the origin database; sites shown on fig. 6]

Map number (on fig. 6)	Site identifier	Site name in Pine River Basin	Latitude	Longitude	Time period 1963–1965	1966–1980	1981–1995	1996–2005
1	04160170	PINE RIVER AT BRICKER ROAD NEAR EMMETT, MI	43.0219	-82.7328	0	2	0	0
2	04160180	EMMETT DRAIN AT BRICKER ROAD NEAR EMMETT, MI	43.0197	-82.7325	0	2	0	0
3	04160195	PINE RIVER AT FARGO ROAD AT ABBOTTSFORD, MI	43.0217	-82.6533	0	2	0	0
4	04160200	PINE RIVER AT M-21 NEAR ABBOTTSFORD, MI	42.9914	-82.6131	0	2	0	0
5	04160300	SB PINE RIVER AT WEBB ROAD NEAR GOODELLS, MI	42.9811	-82.7044	0	3	0	0
6	04160303	SB PINE RIVER AT CENTER ROAD AT GOODELLS, MI	42.9786	-82.6806	0	1	0	0
7	04160310	APPLEY DRAIN AT GOODELLS ROAD NEAR GOODELLS, MI	42.9558	-82.6639	0	2	0	0
8	04160317	EDDY DRAIN AT GOODELLS ROAD NEAR GOODELLS, MI	42.9658	-82.6644	0	2	0	0
9	04160320	SB PINE RIVER AT CASTOR ROAD AT THORNTON, MI	42.9717	-82.6375	0	3	0	0
10	04160325	PINE RIVER AT DOVE ROAD AT KIMBALL, MI	42.9481	-82.5672	0	2	0	0
11	04160332	BIG CREEK AT DOVE ROAD AT KIMBALL, MI	42.9481	-82.5608	0	2	0	0
12	740023	PINE RIVER AT FRITH ROAD; ST.CLAIR TWP, SEC. 9	42.8889	-82.5686	0	2	0	0
13	04160340	SMITHS CREEK AT MAYER ROAD NEAR SMITHS CREEK, MI	42.9283	-82.6211	0	2	0	0
14	04160346	SMITHS CREEK AT FRITH ROAD NEAR RATTLE RUN, MI	42.8881	-82.5839	0	2	0	0
15	04160350	PINE RIVER AT GRATIOT ROAD NEAR RATTLE RUN, MI	42.8803	-82.5678	0	2	0	0
16	04160387	RATTLE RUN AT HESSEN ROAD AT COLUMBUS, MI	42.8647	-82.6581	0	2	0	0
17	04160388	RATTLE RUN AT US-25 AT RATTLE RUN, MI	42.8650	-82.6022	0	1	0	0
18	04160390	RATTLE RUN AT RATTLE RUN ROAD AT RATTLE RUN, MI	42.8633	-82.5967	0	2	0	0
19	04160395	MOAK DRAIN AT KLETTNER ROAD NEAR RATTLE RUN, MI	42.8764	-82.5467	0	1	0	0
20	04160398	PINE RIVER NEAR MARYSVILLE, MI	42.8586	-82.5381	0	1	0	0
20	PR01	PINE RIVER NEAR MARYSVILLE, MI	42.8586	-82.5381	0	0	0	76
21	04160400	PINE RIVER AT VINE ROAD NEAR ST CLAIR, MI	42.8381	-82.5394	0	2	0	0
22	740166	PINE RIVER AT ST CLAIR CITY DOCK; CITY OF ST CLAIR	42.8186	-82.4906	0	80	37	0
23	255003	PINE RIVER (TRIB TO ST CLAIR RIVER)	42.8203	-82.4861	30	0	0	0
23	740020	PINE RIVER AT M-29 NEAR THE MOUTH; CITY OF ST CLAIR	42.8203	-82.4864	59	104	0	0

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period.

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period			
					1947–1965	1966–1980	1981–1995	1996–2005
1	04160750	CLINTON R AT BLUEGRASS DRIVE AT CLARKSTON, MI	42.7406	-83.4228	0	3	0	0
2	04160760	DEER LK OUTLET AT WHITE LK RD AT CLARKSTON, MI	42.7303	-83.4264	0	3	0	0
3	04160800	SASHABAW CREEK NEAR DRAYTON PLAINS, MI	42.7200	-83.3536	0	6	0	17
3	630680	SASHABAW CR AT MAYBEE RD; INDEPENDANCE TWP. SEC.26	42.7200	-83.3536	0	126	0	0
4	631002	CLINTON R. AT HATCHERY RD. WATERFORD TWP. SEC.10	42.6744	-83.3756	0	0	0	10
5	04160900	CLINTON RIVER NEAR DRAYTON PLAINS, MI	42.6603	-83.3903	0	7	0	15
5	630529	CLINTON R AT M-59 BRIDGE; WATERFORD TWP, SEC 21	42.6603	-83.3903	0	88	155	0
5	CR11	CLINTON RIVER NEAR DRAYTON PLAINS, MI	42.6603	-83.3903	0	0	0	69
6	630629	CLINTON R AT PONTIAC LK RD; WATERFORD TWP SEC 21	42.6533	-83.3969	0	3	0	0
7	630630	CLINTON R. AT COOLEY LK RD; WATERFORD TWP SEC 33	42.6278	-83.3947	0	3	0	0
8	04160950	CLINTON R AT ORCHARD LK RD AT SYLVAN LAKE, MI	42.6242	-83.3158	0	5	0	0
8	630631	CLINTON R. AT ORCHARD LK RD; PONTIAC TWP. SEC 31	42.6242	-83.3158	0	3	0	0
9	630600	CLINTON R. AT GILLESPIE STREET; CITY OF PONTIAC	42.6258	-83.2978	0	10	0	0
10	255152	CLINTON RIVER—C008	42.6417	-83.2825	3	0	0	0
11	255153	CLINTON RIVER—C010	42.6467	-83.2700	35	2	0	0
11	630599	CLINTON R ABV PONTIAC STP NO1 IN PONTIAC, SEC 27	42.6467	-83.2689	0	16	0	0
12	630728	CLINTON R 50 FT DWNSTR AUBURN WWTP, PONTIAC, MI	42.6446	-83.2667	0	1	0	0
13	630632	CLINTON R AT M-59 BRIDGE; PONTIAC TWP, SECTION 27	42.6425	-83.2603	0	4	0	0
14	630598	CLINTON R ABV PONTIAC STP NO2 IN PONTIAC, SEC 27	42.6397	-83.2569	0	13	0	0
15	255154	CLINTON RIVER—C020	42.6353	-83.2464	25	2	0	0
16	631096	MURPHEY CREEK AT EAST BLVD., T3N R10E S34	42.6244	-83.2678	0	0	0	1
17	630717	CLINTON R AT I-75 BR; PONTIAC TWP, SEC 35	42.6322	-83.2381	0	3	0	0
18	04161000	CLINTON RIVER AT AUBURN HILLS, MI	42.6333	-83.2244	0	8	0	15
18	255155	CLINTON RIVER C-30	42.6389	-83.2247	45	3	0	0
18	630597	CLINTON R AT AUBURN RD; PONTIAC TWP., SEC 26	42.6336	-83.2247	0	17	0	1
18	630633	CLINTON R. AT AUBURN RD; PONTIAC TWP. SEC 25	42.6339	-83.2242	0	6	0	0
18	CR09	CLINTON RIVER AT AUBURN HILLS, MI	42.6333	-83.2244	0	0	0	68

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
19	630596	CLINTON R AT SQUIRREL RD; PONTIAC TWP, SEC 25	42.6372	-83.2206	0	17	0	0
20	630725	CLINTON RIVER AT M-59 BR; PONTIAC TWP, SEC 25	42.6439	-83.2144	0	3	0	0
21	255156	CLINTON RIVER C040	42.6472	-83.2128	24	2	0	0
22	04161100	GALLOWAY CREEK NEAR AUBURN HEIGHTS, MI	42.6672	-83.2006	0	7	0	0
23	630715	GALLOWAY CR AT BUTLER RD BR; PONTIAC TWP, SEC 19	42.6594	-83.2008	0	4	0	0
24	255157	CLINTON RIVER C050	42.6539	-83.1925	24	2	0	0
24	630595	CLINTON R AT ADAMS RD BRIDGE; AVON TWP, SEC. 19	42.6539	-83.1931	0	21	0	0
25	630252	CLINTON R AT HAMLIN RD BR; AVON TOWNSHIP, SEC 29	42.6507	-83.1778	0	145	172	12
26	630067	CLINTON R. AT CROOKS RD; AVON TOWNSHIP, SEC 20	42.6492	-83.1739	0	17	0	0
27	255158	CLINTON RIVER--C060	42.6656	-83.1453	38	2	0	0
27	630594	CLINTON R AT AVON RD; AVON TWP, SEC 21 NE 1/4	42.6658	-83.1536	0	19	0	0
28	630602	CLINTON R AT DIVERSION RD IN CITY OF ROCHESTER	42.6756	-83.1347	0	6	0	1
29	04161300	PAINT CREEK DRAIN NR OXFORD, MI	42.7964	-83.2914	0	3	0	0
30	630613	PAINT CREEK AT M-24 BRIDGE; ORION TWP., SEC 2	42.7833	-83.2431	0	8	0	0
31	630614	PAINT CR AT ATWATER ST; CITY OF L. ORION, SEC 12	42.7814	-83.2311	0	7	0	0
32	04161500	PAINT CREEK NEAR LAKE ORION, MI	42.7675	-83.2200	1	7	0	0
32	630615	PAINT CREEK AT KERN RD; ORION TWP., SEC. 13	42.7675	-83.2183	0	6	0	0
33	630616	PAINT CR AT ADAMS RD; OAKLAND TWP., SEC. 20	42.7508	-83.1972	0	6	0	0
34	04161524	TROUT CREEK AT ADAMS RD NR GOODISON, MI	42.7472	-83.1972	0	2	0	0
34	630617	TROUT CREEK AT ADAMS RD; OAKLAND TWP., SEC. 20	42.7472	-83.1972	0	6	0	0
35	630618	PAINT CREEK AT GUNN RD; OAKLAND TWP., SEC. 28	42.7450	-83.1694	0	6	0	0
36	630619	PAINT CREEK AT ORION RD; OAKLAND TWP., SEC. 28	42.7311	-83.1597	0	7	0	0
37	630620	PAINT CREEK AT DUTTON ROAD; AVON TWP., SEC.4	42.7111	-83.1572	0	6	0	0
38	630004	PAINT CREEK AT TIENKEN RD; AVON TWP., SEC 10	42.6953	-83.1464	0	4	0	0
39	04161540	PAINT CREEK AT ROCHESTER, MI	42.6883	-83.1431	1	8	0	16
39	255159	PAINT CR. (TRIB TO CLINTON RIV.)	42.6869	-83.1411	8	2	0	0
39	630621	PAINT CREEK AT WOODWARD ST; AVON TWP., SEC. 10	42.6886	-83.1422	0	7	0	0
39	CR10	PAINT CREEK AT ROCHESTER, MI	42.6883	-83.1431	0	0	0	66
40	631003	PAINT CR. AT E. SECOND ST. AVON TWP. SEC 11	42.6794	-83.1294	0	0	0	9

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
41	630622	PAINT CR AT GTW RAILROAD BR.; AVON TWP., SEC. 14	42.6781	-83.1283	0	11	0	0
41	631023	PAINT CREEK AT SOUTH ELIZABETH STREET	42.6775	-83.1284	0	0	0	1
42	630604	CLINTON R AT ROCHESTER WWTP,; AVON TWP, SEC 14	42.6794	-83.1197	0	5	0	0
43	630636	CLINTON R 100 YDS BELOW PAINT CR;AVON TWP SEC 14	42.6767	-83.1269	0	3	0	0
44	04161570	STONY CREEK NR LAKEVILLE, MI	42.8147	-83.1275	0	3	0	0
45	04161580	STONY CREEK NEAR ROMEO, MI	42.8008	-83.0903	0	7	0	4
45	500012	STONY CREEK AT 32 MILE RD; WASHINGTON TWP, SEC 6	42.8008	-83.0917	0	2	0	0
46	W 91	STONY CREEK AT INWOOD RD.	42.7635	-83.0686	0	0	0	0
47	04161600	WB STONY C AT PREDMORE RD NR LAKEVILLE, MI	42.7867	-83.1828	0	2	0	0
48	04161760	WEST BRANCH STONEY CREEK NEAR WASHINGTON, MI	42.7314	-83.1019	0	3	0	0
48	W 92	WEST BRANCH STONY CREEK AT PARK RD.	42.7315	-83.1019	0	0	0	0
49	04161790	STONY LAKE NEAR WASHINGTON, MI	42.7161	-83.0994	0	2	0	0
50	04161800	STONY CREEK NEAR WASHINGTON, MI	42.7153	-83.0919	0	4	0	0
50	CR08	STONY CREEK NEAR WASHINGTON, MI	42.7153	-83.0919	0	0	0	31
51	631097	UNNAMED TRIBUTARY TO STONY CREEK AT LAKEVIEW ROAD (CROSS CRE	42.6971	-83.1282	0	0	0	1
52	631098	UNNAMED TRIBUTARY TO STONY CREEK AT CLEAR CREEK ROAD (POND O	42.6975	-83.1184	0	0	0	1
53	255160	STONY CREEK (TRIB TO CLINTON R.)	42.6853	-83.1075	8	2	0	0
53	630605	STONY CR AT PARKDALE RD; AVON TOWNSHIP, SEC 12	42.6856	-83.1072	0	5	0	0
54	255175	CLINTON RIVER C069	42.6747	-83.0942	13	0	0	0
55	04161810	CLINTON RIVER AT YATES, MI	42.6717	-83.0964	0	4	0	17
55	255161	CLINTON RIVER C070	42.6719	-83.0964	17	2	0	0
55	630606	CLINTON R AT AVON RD. BRIDGE; AVON TWP, SEC 13	42.6719	-83.0972	0	5	0	0
56	W 53	DEQUINDRE RD & CLINTON RIVER	42.6722	-83.0934	0	0	0	21
57	500201	CLINTON R AT RYAN RD BR; SHELBY TWP, SECS 19, 20	42.6567	-83.0736	0	9	0	0
58	255162	CLINTON RIVER—C080	42.6258	-83.0378	4	2	0	0
58	500202	CLINTON R AT AUBURN RD; CITY OF UTICA, SEC 33	42.6261	-83.0383	0	6	0	0
58	W 54	CLINTON RIVER AT HALL RD.	42.6252	-83.0378	0	0	0	0
59	255163	CLINTON RIVER C090	42.6203	-83.0322	4	3	0	0
59	500203	CLINTON R AT VAN DYKE RD; CITY OF UTICA, SEC 3,4	42.6206	-83.0319	0	8	0	0
60	04161820	CLINTON RIVER AT STERLING HEIGHTS, MI	42.6144	-83.0267	0	0	0	111
60	CR07	CLINTON RIVER AT STERLING HEIGHTS, MI	42.6144	-83.0267	0	0	0	69

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
61	500204	CLINTON R AT M-53 BR; CITY OF STERLING HEIGHTS	42.6042	-83.0200	0	6	0	0
62	500205	CLINTON R AT KLEINO RD; CITY OF STERLING HEIGHTS	42.5864	-82.9969	0	5	0	0
62	W 62	CLINTON RIVER AT KLEINO RD	42.5864	-82.9961	0	0	0	103
63	255164	CLINTON RIVER—C100	42.5869	-82.9878	4	2	0	0
64	500206	CLINTON R AT RAMMLER GOLF COURSE IN STERLING HGHTS	42.5792	-82.9872	0	5	0	0
65	255165	CLINTON RIVER C110	42.5697	-82.9714	149	2	0	0
65	500047	CLINTON R AT HAYES RD BR; CLINTON TWP, SEC 19	42.5703	-82.9711	0	42	0	0
66	04162000	RED RUN NEAR ROYAL OAK, MI	42.5183	-83.0956	0	3	0	0
67	W 57	DEQUINDRE & RED RUN	42.5250	-83.0852	0	0	0	113
68	04162400	RED RUN AT VAN DYKE RD NR WARREN, MI	42.5256	-83.0294	0	4	0	0
68	500036	RED RUN AT M-53 BRIDGE; CITY OF WARREN	42.5256	-83.0292	30	0	0	1
68	W 35	RED RUN DRAIN AT VAN DYKE	42.5256	-83.0288	0	0	0	98
69	W 81	BEAR CREEK AT MOUND	42.4964	-83.0461	0	0	0	2
70	500035	BEAR CREEK AT 12 MILE ROAD; CITY OF WARREN	42.5061	-83.0422	30	0	0	0
71	500034	BEAR CREEK AT M-53 BRIDGE; CITY OF WARREN	42.5200	-83.0292	30	0	0	0
71	W 82	VAN DYKE RD—BEAR CREEK	42.5203	-83.0288	0	0	0	121
72	04162500	BEAR CREEK AT CHICAGO RD NR WARREN, MI	42.5233	-83.0239	0	2	0	0
73	W 85	CHICAGO RD—LORRAINE DRAIN	42.5235	-83.0231	0	0	0	80
74	631095	SPENCER DRAIN AT CHICAGO ROAD, T2N R11E S35	42.5459	-83.1141	0	0	0	1
75	500493	BIG BEAVER CREEK AT RYAN ROAD, T2N R12E S31	42.5499	-83.0698	0	0	0	1
76	04162900	BIG BEAVER CREEK NEAR WARREN, MI	42.5419	-83.0478	0	7	0	0
76	W 84	BEAVER CREEK AT MOUND RD	42.5419	-83.0483	0	0	0	18
77	500011	RED RUN AT 14 MILE RD BRIDGE; CITY OF WARREN	42.5373	-83.0064	115	61	0	1
77	CR06	RED RUN AT WARREN, MI	42.5378	-83.0058	0	0	0	58
77	W 56	RED RUN DRAIN AT 14 MILE	42.5374	-83.0060	0	0	0	21
78	500227	RED RUN AT 15 MILE ROAD; STERLING TWP, SEC 25	42.5519	-82.9833	0	3	0	1
79	W 56.5	SCHOENHERR RELIEF DRAIN AT RED RUN	42.5462	-82.9946	0	0	0	0
80	W 72	STERLING RELIEF DRAIN AT FREEDOM HILL	42.5601	-82.9882	0	0	0	0
81	500207	RED RUN AT 16 MI RD BR; CITY OF STERLING HEIGHTS	42.5667	-82.9711	0	6	0	0
82	04163400	PLUM BROOK AT UTICA, MI	42.6014	-83.0742	0	7	0	0
83	W 71.8	PLUMBROOK DRAIN AT RYAN	42.6014	-83.0700	0	0	0	0
84	04163500	PLUM BROOK NEAR UTICA, MI	42.5836	-83.0306	0	0	1	0
85	500046	PLUM BROOK AT SCHOENHERR DR; STERLING TWP SEC 24	42.5725	-82.9903	0	16	0	1
85	W 71	PLUMBROOK DRAIN AT SCHOEHERR RD	42.5727	-82.9909	0	0	0	17

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
86	04163800	PLUM BROOK AT MCINERNEY DRIVE AT CADY, MI	42.5686	-82.9800	0	2	0	0
87	255166	RED RUN (TRIB TO CLINTON RIVER)	42.5686	-82.9700	103	2	0	0
87	W 55	UTICA RD & RED RUN	42.5695	-82.9705	0	0	0	115
88	255167	CLINTON RIVER—C120	42.5703	-82.9631	10	2	0	0
89	04164000	CLINTON RIVER NEAR FRASER, MI	42.5772	-82.9514	1	40	0	0
89	255168	CLINTON RIVER—C130	42.5775	-82.9528	86	4	0	0
89	500208	CLINTON R AT GARFIELD RD BR; CLINTON TWP, SEC 19	42.5783	-82.9542	0	6	0	0
89	CR04	CLINTON RIVER NEAR FRASER, MI	42.5772	-82.9514	0	0	0	67
89	W 75	CLINTON RIVER AT GARFIELD RD AND CLINTON RIVER RD	42.5781	-82.9579	0	0	0	103
90	500209	CLINTON R OFF CLINTON R RD; CLINTON TWP, SEC 16	42.5878	-82.9278	0	4	0	0
90	W 70	CLINTON RIVER AT BUDD PARK	42.5880	-82.9276	0	0	0	2
91	255176	CLINTON RIVER—C134	42.5861	-82.9167	14	2	0	0
92	500225	CLINTON R AT R. RD PUMPHOUSE; CLINTON TWP P.C. 546	42.5950	-82.9181	0	3	0	0
93	W 69	CANAL DRAIN AT CLINTON RIVER RD	42.5960	-82.9168	0	0	0	0
94	04164007	NORTH BRANCH CLINTON RIVER NEAR ALMONT, MI	42.8836	-83.0783	0	0	0	3
94	500467	NORTH BRANCH CLINTON RIVER AT FISHER ROAD; BRUCE TWP., SEC 5	42.8836	-83.0784	0	0	0	4
95	04164010	NORTH BRANCH CLINTON RIVER AT ALMONT, MI	42.9164	-83.0450	0	5	0	0
95	440059	N BR CLINTON R AT M-59 BR; ALMONT TWP., SEC 27	42.9164	-83.0450	0	17	0	0
96	440060	N BR CLINTON R AT KIDDER RD; ALMONT TWP., SEC 26	42.9211	-83.0356	0	5	0	0
97	440084	N.BR. CLINTON R. AT ALMONT RD; ALMONT TWP SEC 27	42.9214	-83.0294	0	13	0	0
97	440175	NORTH BRANCH CLINTON RIVER AT ALMONT/ KIDDER ROAD INTERSECTION	42.9214	-83.0294	0	0	0	1
98	440061	N BR CLINTON R AT HOUGH RD; ALMONT TWP., SEC 26	42.9142	-83.0214	0	13	0	1
99	440102	N BR CLINTON R ABV BORDMAN RD; ALMONT TWP, SEC 26	42.8936	-83.0033	0	8	0	0
100	440101	UNAMED TRIB, N OF BORDMAN RD; ALMONT TWP, SEC 36	42.8936	-83.0028	0	7	0	0
101	04164020	NORTH BRANCH CLINTON RIVER NR ALMONT, MI	42.8922	-83.0025	0	1	0	0
101	W 29	NORTH BRANCH CLINTON RIVER AT BROADMAN	42.8932	-83.0024	0	0	0	0
102	500361	UNNAMED TRIB OFF BORDMAN RD; BRUCE TWP, SEC 2	42.8913	-83.0163	0	4	0	0
103	500362	N BR CLINTON R AT MCKAY RD, BRUCE TWP., SEC 1	42.8782	-83.0007	0	5	0	0

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
104	04164030	APEL DRAIN NR ROMEO, MI	42.8572	-83.0006	0	1	0	0
105	04164040	NEWLAND DRAIN NR ROMEO, MI	42.8358	-82.9792	0	3	0	0
106	500492	WILSON DRAIN AT MCKAY ROAD, T5N R12E S23	42.8344	-83.0006	0	0	0	1
107	04164045	MAHAFFY DRAIN NR ROMEO, MI	42.8314	-82.9967	0	1	0	0
108	04164050	N BRANCH CLINTON RIVER AT 33 MILE RD NR ROMEO, MI	42.8197	-82.9764	0	5	0	0
108	500241	N BR CLINTON R AT 33 MILE RD; ARMADA TWP, SEC 30	42.8194	-82.9761	0	4	0	0
109	04164090	EAST POND CREEK NEAR LAKEVILLE, MI	42.8603	-83.0931	0	1	0	0
110	500289	EAST POND CR. AT UNNAMED RD; BRUCE TWP., SEC 20	42.8414	-83.0775	0	4	0	0
111	500288	EAST POND CR. AT 34 MILE RD; BRUCE TWP., SEC 29	42.8314	-83.0703	0	4	0	1
112	04164095	EAST POND CREEK AT SCHOOLEY RD NR RO	42.8169	-83.0694	0	1	0	0
112	500287	EAST POND CR. AT 33 MILE RD; BRUCE TWP., SEC 32	42.8161	-83.0697	0	4	0	0
112	W 93	EAST POND CREEK EAST OF FISCHER RD.	42.8163	-83.0670	0	0	0	0
113	04164100	EAST POND CREEK AT ROMEO, MI	42.8225	-83.0203	1	5	0	0
113	500290	EAST POND CR. AT M-53 BR; BRUCE TWP., SEC 26	42.8228	-83.0200	0	4	0	0
114	500291	EAST POND CR. AT 33 MILE RD; BRUCE TWP., SEC 35	42.8175	-83.0097	0	4	0	0
114	500434	EAST POND CREEK AT 33 MILE ROAD; T05N R12E S26	42.8171	-83.0089	0	0	0	1
115	W 52.2	EAST POND CREEK AT M-53	42.8168	-83.0033	0	0	0	0
116	500292	EAST POND CR. AT UNNAMED RD; BRUCE TWP., SEC 36	42.8050	-82.9881	0	5	0	0
117	04164110	EAST POND CREEK AT POWELL RD NR ROMEO, MI	42.8044	-82.9803	0	1	0	0
117	500110	EAST POND CR. AT POWELL ROAD; RAY TWP, SEC 6	42.8044	-82.9800	0	7	0	0
117	500439	EAST POND CREEK AT POWELL ROAD; T05N R12E S36	42.8042	-82.9805	0	0	0	1
117	W 52	EAST POND CREEK AT POWELL ST	42.8044	-82.9801	0	0	0	20
118	500242	N BR CLINTON R AT 32 MILE RD; RAY TWP., SEC 6	42.8050	-82.9681	0	4	0	0
118	500446	NORTH BRANCH CLINTON RIVER AT 32 MILE ROAD; T05N R13E S31	42.8050	-82.9681	0	0	0	1
119	500243	N BR CLINTON R AT ROMEO PLANK RD; RAY TWP SEC 16	42.7956	-82.9625	0	5	0	0
120	04164130	NORTH BRANCH CLINTON RIVER NR RAY CENTER, MI	42.7750	-82.9372	0	1	0	0
121	W 49	NORTH BRANCH CLINTON RIVER AT 29 MILE RD.	42.7611	-82.9139	0	0	0	0
122	04164150	N BRANCH CLINTON RIVER AT 27 MILE RD NR MEADE, MI	42.7306	-82.9064	0	3	0	0
123	W 30	NORTH BRANCH CLINTON RIVER AT 26 MILE RD	42.7172	-82.9045	0	0	0	0
124	500489	NORTH BRANCH CLINTON RIVER AT CARD RD., T3N R13E S10	42.6959	-82.8990	0	0	0	1

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
125	04164190	COON CREEK AT ARMADA CENTER RD AT ARMADA, MI	42.8497	-82.9267	0	1	0	0
126	04164200	COON CREEK AT NORTH AVENUE NEAR ARMADA, MI	42.7947	-82.8828	0	3	0	0
127	500491	COON CREEK AT 28 MILE ROAD, T4N R14E S19	42.7472	-82.8768	0	0	0	1
128	04164210	COON CREEK AT NORTH RD NR MEADE, MI	42.7383	-82.8756	0	3	0	0
129	04164230	TUPPER BROOK AT 31-MILE RD NR ARMADA, MI	42.7908	-82.8917	0	1	0	0
130	04164250	TUPPER BROOK AT RAY CENTER, MI	42.7617	-82.9011	0	4	0	0
131	04164290	EB COON CREEK AT PRATT RD NR ARMADA, MI	42.8869	-82.8906	0	1	0	0
132	04164300	EAST BRANCH COON CREEK AT ARMADA, MI	42.8458	-82.8850	1	5	0	0
132	500293	E.BR. COON CR. AT PROSPECT ROAD; CITY OF ARMADA	42.8458	-82.8847	0	5	0	1
133	500294	E.BR. COON CR. AT NORTH AVE.; ARMADA TWP, SEC 26	42.8336	-82.8844	0	4	0	0
134	500295	E.BR. COON CR. AT 33 MILE RD; ARMADA TWP, SEC 36	42.8214	-82.8778	0	4	0	0
134	500432	EAST BRANCH COON CREEK AT 33 MILE ROAD, T05N R13E S25	42.8210	-82.8774	0	0	0	1
135	04164310	EB COON CREEK AT OMO RD NR ARMADA, MI	42.7936	-82.8597	0	1	0	0
136	04164320	HIGHBANK C AT ARMADA RIDGE RD NR ARMADA, MI	42.8419	-82.8353	0	1	0	0
137	04164330	HIGHBANK CREEK AT 33-MILE RD NR ARMADA, MI	42.8219	-82.8472	0	1	0	0
138	04164340	CEMETERY CREEK NR ARMADA, MI	42.8222	-82.8494	0	1	0	0
139	04164350	HIGHBANK CREEK AT 32 MILE ROAD NEAR ARMADA, MI	42.8067	-82.8522	0	5	0	0
139	W 34	HIGHBANK DRAIN AT 32 MILE RD.	42.8070	-82.8518	0	0	0	0
140	W 50	EAST BRANCH COON CREEK AT 30 MILE RD.	42.7779	-82.8515	0	0	0	0
141	04164360	EAST BRANCH COON C AT 29-MILE RD NR NEW HAVEN, MI	42.7628	-82.8492	0	2	0	0
142	04164385	EB COON CREEK AT NORTH RD AT MEADE, MI	42.7231	-82.8747	0	2	0	0
142	W 51	EAST BRANCH COON CREEK AT NORTH AVENUE	42.7226	-82.8747	0	0	0	11
143	04164390	COON CREEK AT 26-MILE RD AT MEADE, MI	42.7175	-82.8819	0	1	0	0
143	500490	COON CREEK AT 26 MILE ROAD, T4N R13E S35	42.7176	-82.8817	0	0	0	1
143	W 31	EAST BRANCH COON CREEK AT 26-MILE RD	42.7176	-82.8819	0	0	0	0
144	04164400	DEER CREEK AT 25 1/2 MILE ROAD NEAR MEADE, MI	42.7108	-82.8589	0	3	0	0
145	W 48	DEER CREEK AT NORTH AVE.	42.6909	-82.8783	0	0	0	0
146	04164420	NORTH BRANCH CLINTON RIVER NR MEADE, MI	42.6736	-82.8822	0	1	0	0
146	500015	N. BR. CLINTON R. AT 23 MI RD; MACOMB TWP SEC 23	42.6733	-82.8822	0	1	0	0
147	04164450	MCBRIDE DRAIN AT 24 MILE ROAD NEAR MACOMB, MI	42.6872	-82.9206	0	2	0	0
148	W 76	MCBRIDE DRAIN AT CARD RD.	42.6716	-82.8983	0	0	0	0
149	04164470	HART DRAIN AT NORTH AVE NEAR MT. CLEMENS, MI	42.6558	-82.8772	0	1	0	0

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
150	500436	NORTH BRANCH CLINTON RIVER AT 24 MILE ROAD; T03N R13E S26	42.6442	-82.8786	0	0	0	1
150	W 36	NORTH BRANCH CLINTON RIVER AT 21 MILE RD.	42.6444	-82.8784	0	0	0	0
151	04164500	NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	42.6292	-82.8889	3	4	0	0
151	500045	N BR CLINTON R AT M59 BRIDGE; MACOMB TWP, SEC 35	42.6292	-82.8892	0	34	0	0
151	CR05	NORTH BRANCH CLINTON RIVER NEAR MT. CLEMENS, MI	42.6292	-82.8903	0	0	0	27
152	W 44	NORTH BRANCH CLINTON RIVER AT DUNHAM RD.	42.6192	-82.9014	0	0	0	108
153	04164520	MB CLINTON RIVER AT 24-MILE RD AT UTICA, MI	42.6833	-83.0439	0	1	0	0
154	W 65	CLINTON RIVER MIDDLE BRANCH AT VAN DYKE	42.6942	-83.0347	0	0	0	0
155	500286	TAFT DRAIN AT M-53 BR; WASHINGTON TWP., SEC 27	42.7422	-83.0278	0	4	0	0
156	500285	TAFT DRAIN AT JEWELL RD; WASHINGTON TWP SEC 26	42.7392	-83.0178	0	4	0	0
157	500284	YATES DRAIN AT 27 MILE RD; WASHINGTON TWP SEC 35	42.7292	-83.0167	0	4	0	0
158	04164550	YATES DRAIN AT JEWELL RD AT MACOMB, MI	42.7078	-83.0161	0	1	0	0
159	04164600	MIDDLE BR CLINTON R AT SCHOENHERR RD NR MACOMB, MI	42.7008	-82.9956	0	5	0	0
160	W 77	HEALY BROOK DRAIN AT ROMEO PLANK RD., SOUTH OF 27 MILE RD.	42.7251	-82.9597	0	0	0	0
161	04164700	HEALY DRAIN AT 26-MILE RD AT MACOMB, MI	42.7161	-82.9672	0	1	0	0
162	04164800	MIDDLE BRANCH CLINTON RIVER AT MACOMB, MI	42.7064	-82.9592	0	5	0	0
162	500014	M BR CLINTON R AT GARFLD-ROM. RD; MACOMB TWP SEC 5	42.7064	-82.9592	0	1	0	0
163	W 33	CLINTON RIVER MIDDLE BRANCH AT 25 MILE RD	42.7011	-82.9517	0	0	0	1
164	W 60.2	CLINTON RIVER MIDDLE BRANCH AT 22 MILE RD.	42.6575	-82.9349	0	0	0	0
165	500013	M BR. CLINTON R AT 21 MILE RD; MACOMB TWP SEC 33	42.6428	-82.9333	0	1	0	0
165	CR03	MIDDLE BRANCH CLINTON RIVER NEAR WALDENBURG, MI	42.6428	-82.9333	0	0	0	68
165	W 60	CLINTON RIVER MIDDLE BRANCH AT 21 MILE RD	42.6429	-82.9333	0	0	0	30
166	04165000	MIDDLE BRANCH CLINTON RIVER AT M-59 NR WALDENBURG, MI	42.6283	-82.9311	0	4	0	0
167	04165200	GLOEDE DITCH NEAR WALDENBURG, MI	42.6275	-82.9528	0	6	0	0
168	500488	MIDDLE BRANCH CLINTON RIVER EAST OF 19 MILE ROAD, T2N R13E S	42.6132	-82.9299	0	0	0	1
169	04165220	MB CLINTON R AT HEYDREICH RD AT MT. CLEMENS, MI	42.6061	-82.9175	0	1	0	0

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
169	W 63	HEYDENREICH/MIDDLE BRANCH CLINTON RIVER	42.6077	-82.9167	0	0	0	119
170	255171	NORTH BRANCH (TRIB TO CLINTON R)	42.6014	-82.9094	19	2	0	0
170	500210	N BR CLINTON AT CASS AVE BRIDGE; CLINTON TWP	42.6011	-82.9094	0	5	0	0
171	04165500	CLINTON RIVER AT MORAVIAN DRIVE AT MT. CLEMENS, MI	42.5958	-82.9089	2	85	126	18
171	255169	CLINTON RIVER—C140	42.5967	-82.9089	83	2	0	0
171	500010	CLINTON R AT MORAVIAN DRV; W. SIDE OF MT. CLEMENS	42.5961	-82.9089	107	153	0	0
171	W 68	MORAVIAN RD BRIDGE—CLINTON RIVER	42.5958	-82.9089	0	0	0	119
172	500211	CLINTON R AT GOLF COURSE BRIDGE; CLINTON TWP	42.5917	-82.9011	0	5	0	0
173	W 67.71	SWEENY DRAIN AT 15 MILE RD	42.5538	-82.9446	0	0	0	79
174	04165550	HARRINGTON DRAIN NR CADY, MI	42.5689	-82.9286	0	2	0	0
175	255172	HARRINGTON DN.(TRIB TO CLINTON)	42.5878	-82.9011	6	0	0	0
175	500212	HARRINGTON DRN AT HARRINGTON BLVD; CLINTON TWP	42.5878	-82.9011	0	5	0	0
175	W 67	HARRINGTON DRAIN AT CLINTON RIVER	42.5905	-82.5905	0	0	0	17
176	255170	CLINTON RIVER—C150	42.5900	-82.8933	24	0	0	0
177	255173	CLINTON RIVER—C160	42.5853	-82.8853	34	2	0	0
178	500233	CLINTON R AT NO. BOUND GRATIOT AVE IN MT. CLEMENS	42.5842	-82.8828	0	81	362	92
178	LLRSLS0001	CENTER OF THE GRATIOT ST. BRIDGE	42.5842	-82.8828	0	0	14	0
179	I6	WELLINGTON CRESCENT/HARPER-CLINTON RIVER & SPILLWAY	42.5786	-82.8739	0	0	0	2
179	W 96	CLINTON RIVER AT SHADYSIDE PARK	42.5821	-82.8795	0	0	0	79
180	500188	CLINTON R SPILL AT HARPER AVE; CLINTON TWP SEC 24	42.5764	-82.8708	0	16	0	0
180	W 43	WELLINGTON CRESCENT/HARPER-CLINTON RIVER & SPILLWAY	42.5811	-82.8771	0	0	0	30
181	W 61.2	CLINTON RIVER DRAIN AT SHOOK RD	42.5567	-82.8628	0	0	0	79
182	500229	CLINTON R. SPILLWAY AT JEFFERSON BR; HARRISON TWP	42.5621	-82.8476	0	6	0	0
182	W 42	CLINTON RIVER SPILLWAY AT JEFFERSON	42.5618	-82.8473	0	0	0	79
183	CR02	CLINTON RIVER BYPASS AT MOUTH AT MT. CLEMENS, MI	42.5614	-82.8453	0	0	0	61
184	500366	CLINTON R 1300 FT DNST OF SPILLWAY IN MT CLEMENS	42.5839	-82.8658	0	1	0	0
185	500365	CLINTON R 2700 FT ABV CASS AVE BR IN MT CLEMENS	42.5906	-82.8742	0	3	0	0
186	W 66	CLINTON RIVER AT AMVET DRIVE	42.5952	-82.8772	0	0	0	0
187	500213	CLINTON R AT CROCKER ST BR; CITY OF MT CLEMENS	42.5964	-82.8767	0	9	0	0
188	255177	CLINTON RIVER—C170	42.5978	-82.8747	14	2	0	0
189	W 83	CLINTON RIVER AT MT CLEMENS YMCA	42.5976	-82.8731	0	0	0	95

Appendix 1–4. Water-quality sites in the Clinton River Basin and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 7]

Map number (on fig. 7)	Site identifier	Site name in Clinton River Basin	Latitude	Longitude	Time period 1947–1965	1966–1980	1981–1995	1996–2005
190	W 90	CLINTON RIVER AT RIVERVIEW	42.5957	-82.8628	0	0	0	95
191	500375	CLINTON RIVER 2300 FT ABV I-94 BR; CLINTON TWP	42.5942	-82.8646	0	2	0	0
192	500214	CLINTON R AT I-94 BRIDGE; HARRISON TWP	42.5906	-82.8575	0	11	0	0
192	W 40	CLINTON RIVER AT I-94	42.5905	-82.8579	0	0	0	112
193	500364	CLINTON R 3600 FT DNST OF I94 BR, T2N, R14E	42.5922	-82.8453	0	2	0	0
194	500363	CLINTON R 7200 FT DNST OF I94 BR, T2N, R14E	42.5894	-82.8378	0	2	0	0
195	255001	CLINTON R (TRIB TO LAKE ST CAIR)	42.5964	-82.8258	30	0	0	0
195	255178	CLINTON RIVER C180	42.5964	-82.8258	90	2	0	0
195	500008	CLINTON R BRIDGEVIEW RD AT MOUTH; HARRISON TWP	42.5964	-82.8258	59	117	0	0
195	CR01	CLINTON RIVER NEAR MT. CLEMENS, MI	42.5964	-82.8261	0	0	0	69
196	500189	CLINTON RIVER AT S RIVER ROAD; IN MT CLEMENS	42.5894	-82.8239	0	5	0	0
197	I7	RIVERBANK RD - CLINTON RIVER	42.5906	-82.8202	0	0	0	2
197	W 95	CLINTON RIVER AT ALBATROSS LANDING	42.5903	-82.8200	0	0	0	98
198	500215	CLINTON R AT ISLAND NEAR MOUTH; HARRISON TWP	42.5947	-82.8039	0	6	0	0
199	255150	CLINTON AT MOUTH (TRIB TO LK.S.C)	42.5950	-82.7778	3	16	0	0
200	W 41	CLINTON RIVER AT LAKE ST CLAIR DNR SITE	42.5934	-82.7750	0	0	0	79

Appendix 1–5. Water-quality sites in the minor river basins and number of samples collected by time period.

[Site names are listed as they appear in the origin database; sites shown on fig. 8]

Map number (on fig. 8)	Site identifier	Site name in minor river basins	Latitude	Longitude	Time period 1971–1980	1981–1995	1996–2005
1	SC01A	BUNCE CREEK (A) NEAR SOTH PARK, MI	42.9322	-82.4658	0	0	38
2	SC01	BUNCE CREEK NEAR SOUTH PARK, MI	42.9314	-82.4639	0	0	1
3	04160640	MARINE CITY DRAIN NEAR BROADBRIDGE STATION, MI	42.6847	-82.5311	2	0	0
4	04160645	BEAUBIEN CREEK NEAR STARVILLE, MI	42.6733	-82.5875	2	0	0
4	SC05	BEAUBIEN CREEK NEAR STARVILLE, MI	42.6733	-82.5875	0	0	15
5	04160650	SWAN CREEK AT MEISNER ROAD NEAR PETERS, MI	42.7542	-82.6272	2	0	0
6	04160655	SWAN CREEK AT ARNOLD ROAD NEAR FAIRHAVEN, MI	42.7083	-82.6514	3	0	0
7	SC04	SWAN CREEK AT SHORTCUT ROAD NEAR FAIRHAVEN, MI	42.6939	-82.6486	0	0	20
8	04160660	SWAN CREEK TRIBUTARY NEAR ANCHORVILLE, MI	42.6936	-82.6683	3	0	0
9	04160670	MARSAC CREEK AT BETHUY ROAD AT NEW BALTIMORE, MI	42.6936	-82.7083	2	0	0
10	W 39	MARSAC DRAIN AT RUIDSALE PARK	42.6850	-82.7086	0	0	0
11	W 46.2	DRAINAGE DITCH WEST OF COUNTY LINE ROAD AT HOBARTH	42.7134	-82.7343	0	0	0
12	500487	CRAPAUD CREEK AT COUNTY LINE ROAD	42.6964	-82.7289	0	0	1
12	W 46.3	CRAPAUD CREEK AT COUNTY LINE ROAD	42.6968	-82.7288	0	0	29
13	W 46.7	CRAPAUD CREEK AT ASHLEY STREET	42.6853	-82.7344	0	0	29
14	W 46.6	VANDERBENNE DRAIN AT FOX POINTE ROAD	42.6860	-82.7350	0	0	0
15	I10	GREEN ROAD—CRAPAU CREEK	42.6761	-82.7434	0	0	2
15	W 46.9	CRAPAUD CREEK AT GREEN ST.	42.6766	-82.7439	0	0	0
16	W 46	CRAPAUD CREEK AT MAIN STREET	42.6764	-82.7429	0	0	47
17	500283	SALT R AT N.MOST XING LOWE PLANK; LENOX TWP, SEC 14	42.7689	-82.7736	4	1	0
18	500486	FISTLER DRAIN AT ST. CLAIR HIGHWAY (31 MILE)	42.7943	-82.7649	0	0	1
19	500282	FISTLER DR 30 FEET ABOVE MOUTH; LENOX TOWNSHIP, SEC 14	42.7650	-82.7658	4	0	0
20	W 37	SALT RIVER AT 29 MILE ROAD AND GRATIOT ROAD	42.7639	-82.7656	0	0	17
21	500281	SALT RIVER AT N. MOST CROSSING M-19; LENOX TWP, SEC 23	42.7597	-82.7647	4	0	0
22	04160680	SALT RIVER AT 28-MILE ROAD NEAR NEW HAVEN, MI	42.7497	-82.7775	2	0	0
22	500297	SALT RIVER AT 28-MILE ROAD BR; LENOX TWP, SEC 27	42.7494	-82.7778	4	0	0
23	500280	SALT RIVER AT S. MOST X-ING GRATIOT; LENOX TWP, SEC 34	42.7308	-82.7889	4	0	0
24	500481	SHOOK DRAIN AT CEMETARY OFF 27-MILE ROAD	42.7341	-82.8052	0	0	1
25	500279	SHOOK DRIVE AT ACCESS ROAD BR; LENOX TWP, SEC 33	42.7256	-82.7953	4	0	0
26	500278	SALT RIVER AT 26-MILE BR; CHESTERFIELD TWP, SEC 3	42.7203	-82.7856	4	0	0
27	04160688	SALT RIVER AT I-94 NEAR NEW HAVEN, MI	42.7097	-82.7700	1	0	0
28	500277	SALT RIVER AT WASHINGTON AVENUE; CHESTERFIELD TWP, SEC 11	42.7008	-82.7667	4	0	0
28	W 47	SALT RIVER AT WASHINGTON STREET	42.7009	-82.7656	0	0	0
29	04160690	SALT RIVER AT 24-MILE ROAD NEAR NEW BALTIMORE, MI	42.6903	-82.7672	3	0	0

Appendix 1–5. Water-quality sites in the minor river basins and number of samples collected by time period. —Continued

[Site names are listed as they appear in the origin database; sites shown on fig. 8]

Map number (on fig. 8)	Site identifier	Site name in minor river basins	Latitude	Longitude	Time period 1971–1980	1981–1995	1996–2005
29	SC03A	SALT CREEK AT 24-MILE ROAD NEAR NEW BALTIMORE, MI	42.6903	-82.7673	0	0	36
30	SC03	SALT CREEK AT 23-MILE ROAD NEAR NEW BALTIMORE, MI	42.6758	-82.7708	0	0	4
31	500483	WEST BRANCH FISH CREEK AT SASS ROAD	42.6823	-82.7833	0	0	1
32	04160700	FISH CREEK AT 23-MILE ROAD NEAR NEW BALTIMORE, MI	42.6753	-82.7858	3	0	0
33	I9	JEFFERSON ROAD—SALT RIVER	42.6581	-82.7770	0	0	2
33	W 45	SALT RIVER AT LAKE ST CLAIR	42.6581	-82.7770	0	0	12
34	500482	SUTHERLAND AND OEMIG DRAIN AT IRIS ROAD	42.6589	-82.8185	0	0	1
35	500485	PITTS DRAIN AT CHESTER TOWNSHIP HALL	42.6493	-82.8214	0	0	1
36	W 38	RIVER VOSS AT JEFFERSON	42.6456	-82.8134	0	0	0
37	I8	WILLIAM B RUSSO ROAD—IRWIN RELIEF DRAIN	42.6305	-82.8306	0	0	2
38	500484	ROSSO HIGHWAY DRAIN, NORTH BORDER OF SELFRIDGE ANGB	42.6306	-82.8268	0	0	1
39	I5	BROOKDALE ROAD/MILSI-LIPKE RELIEF DRAIN	42.5315	-82.8728	0	0	2
40	I4	LAKE BLVD. RELIEF DRAIN	42.5167	-82.8854	0	0	2
41	I3	GREATER MACK/MARTIN ROAD/11.5 MILE RELIEF DRAIN	42.5032	-82.8921	0	0	2
42	I2	KRAMER ROAD—STEPHENS RELIEF DRAIN	42.4747	-82.8929	0	0	2
43	I1	ROSEDALE ROAD—MILK RIVER	42.4521	-82.8865	0	0	2
44	W 58	ALGER ROAD—MILK RIVER	42.4529	-82.8855	0	0	15
45	W 59	MILK RIVER AT CLEARWOOD	42.4603	-82.8770	0	0	95

Appendix 2. *Escherichia coli* Concentrations

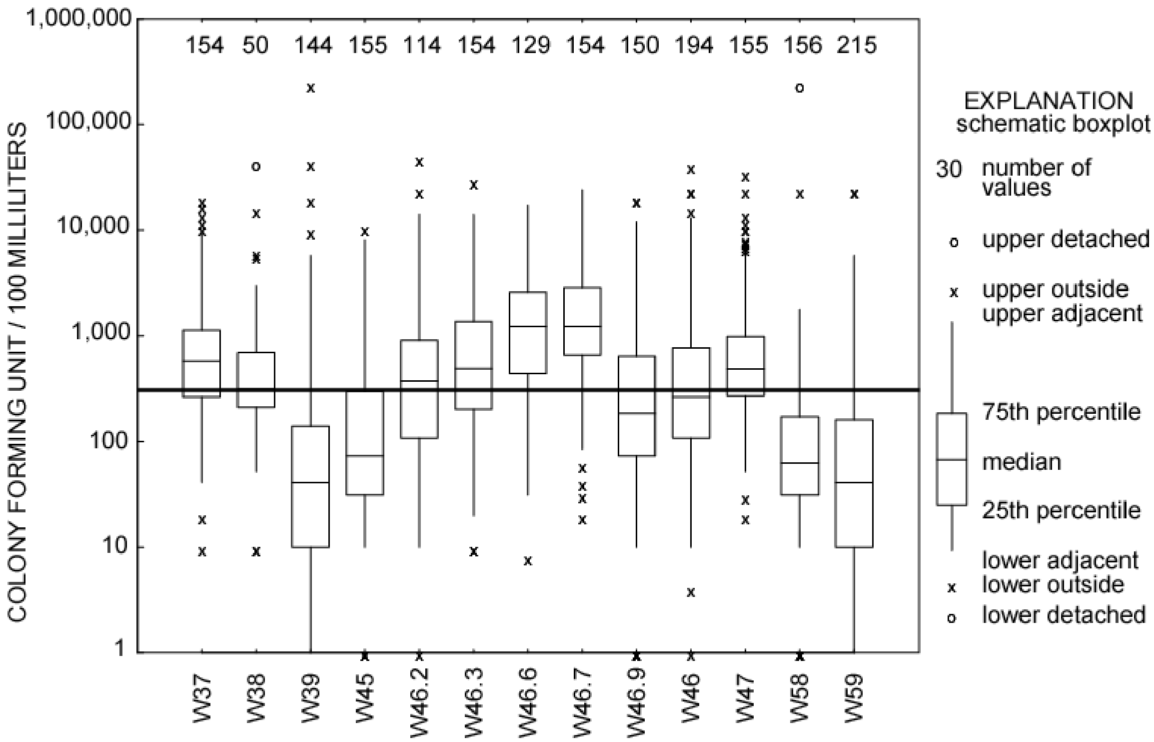

Figure 2–1. *Escherichia coli* concentrations for sites on the direct tributaries to Lake St. Clair, May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

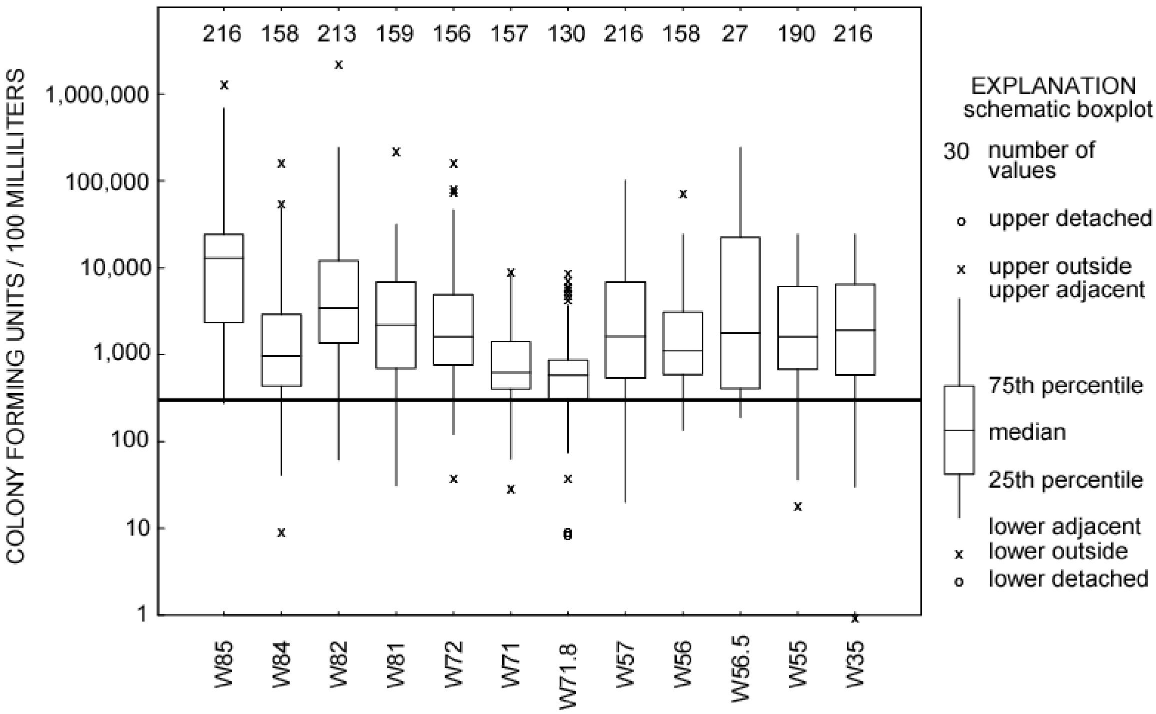

Figure 2–2. *Escherichia coli* concentrations for sites on Red Run and tributaries, May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

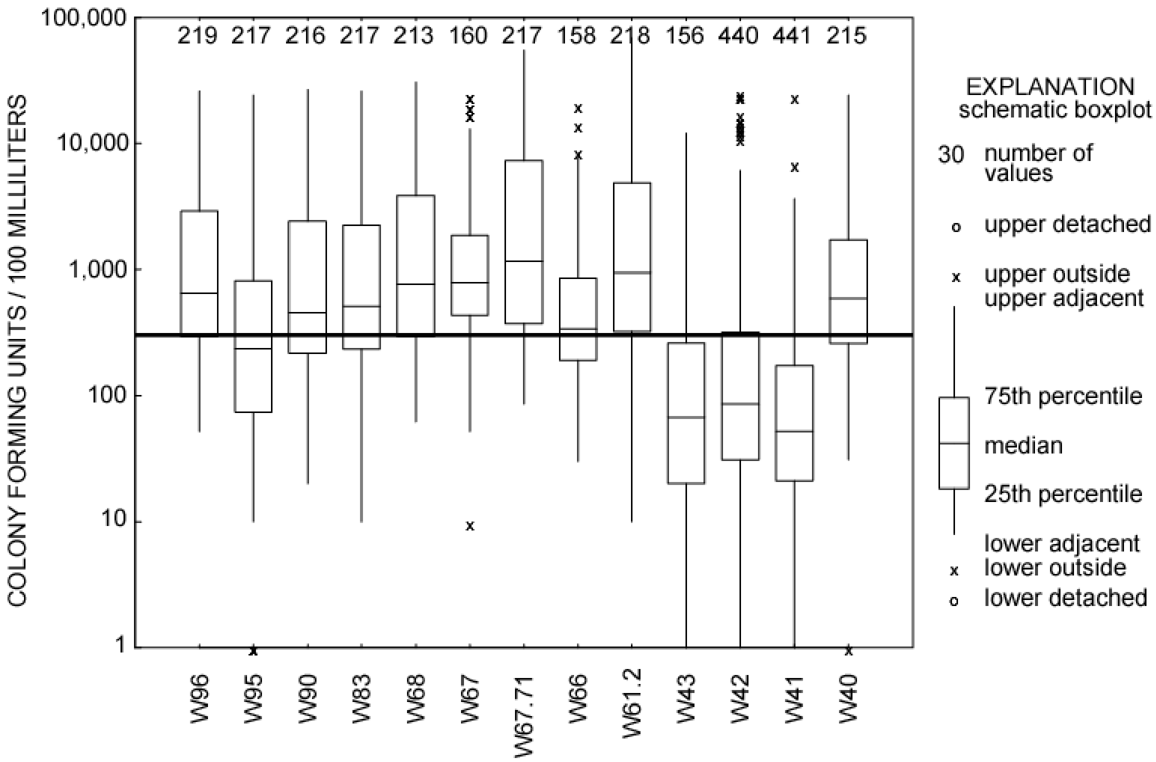

Figure 2–3. *Escherichia coli* concentrations for sites on the main stem Clinton River (East), May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

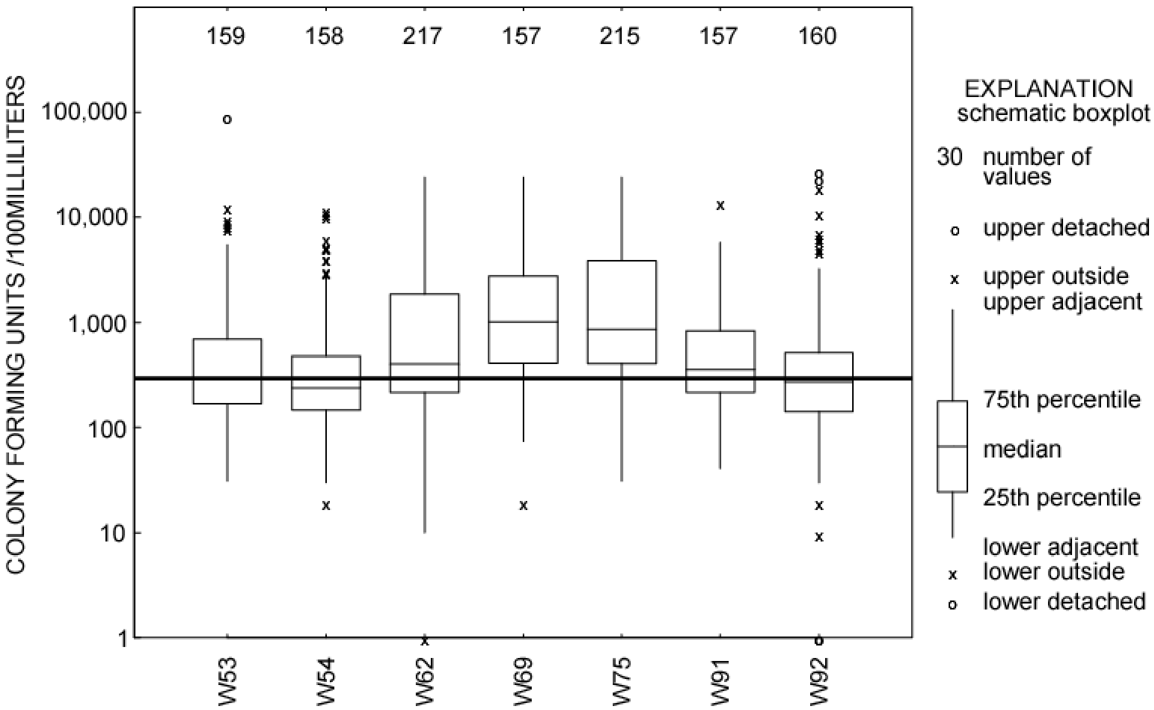

Figure 2–4. *Escherichia coli* concentrations for sites on the main stem Clinton River (West), May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

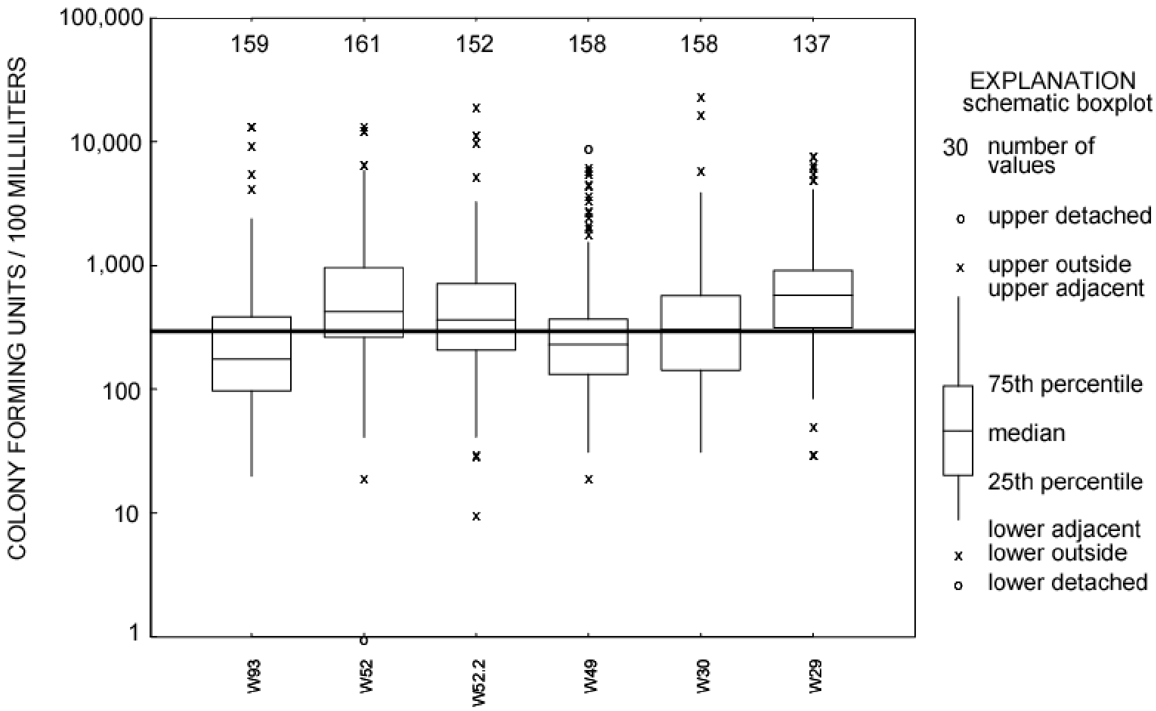

Figure 2–5. *Escherichia coli* concentrations for sites on the North Branch Clinton River (West), May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

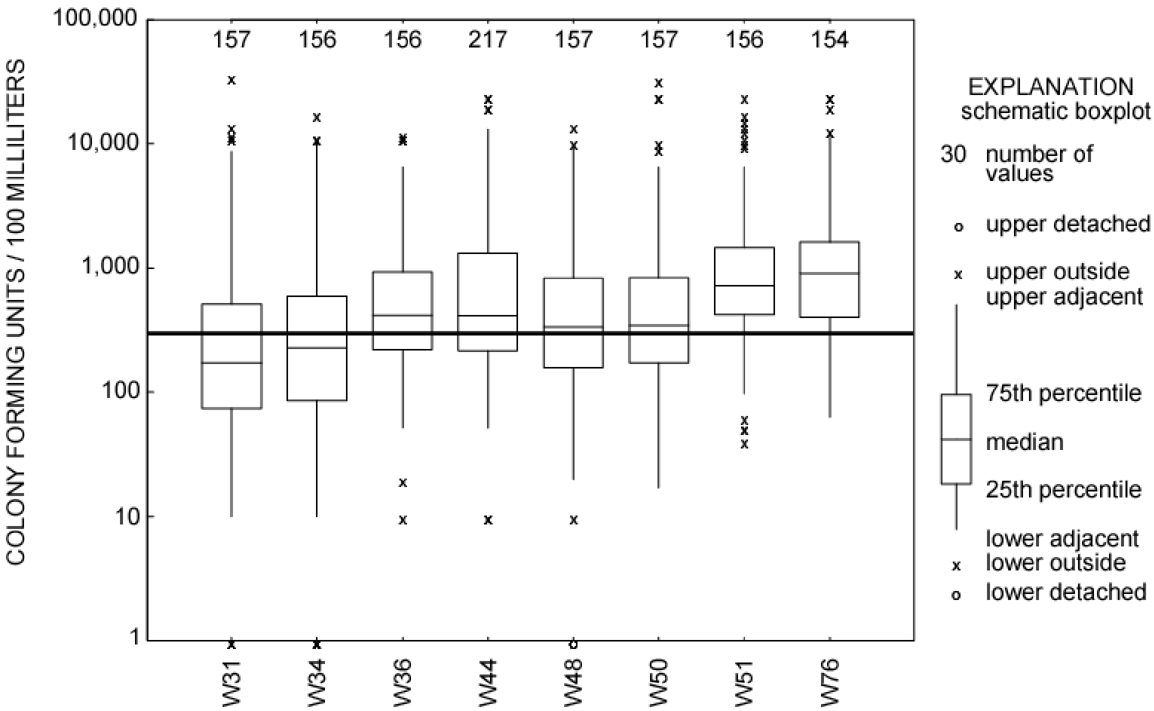

Figure 2–6. *Escherichia coli* concentrations for sites on the North Branch Clinton River (East), May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

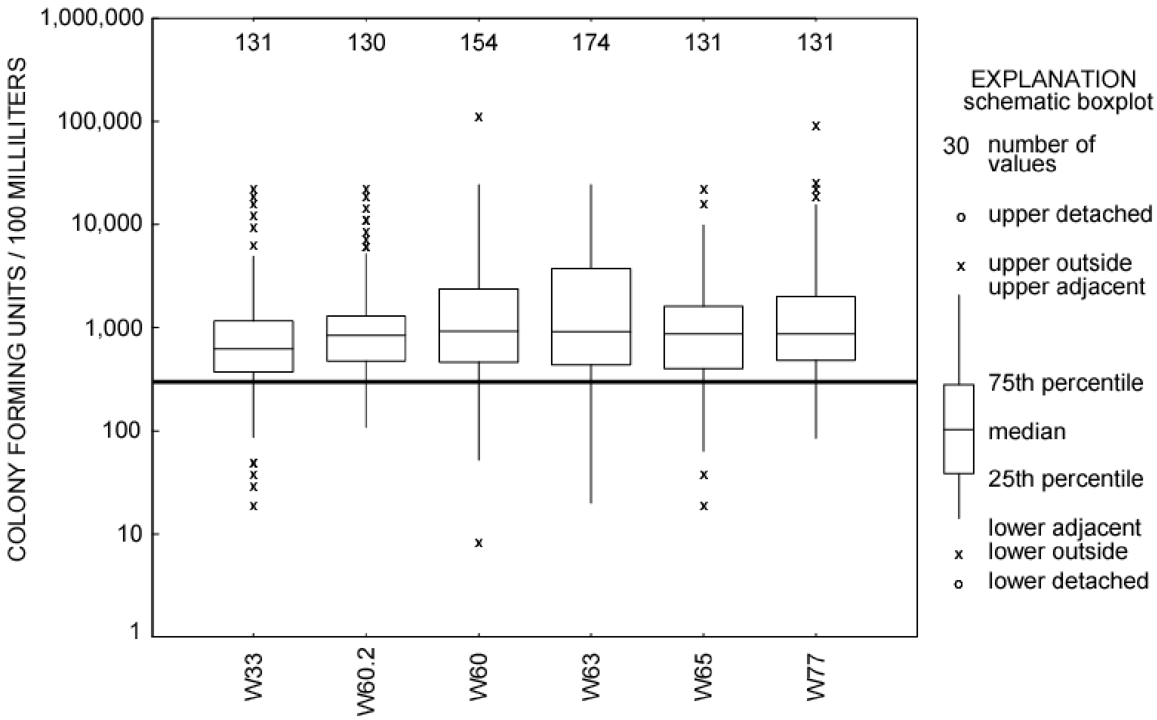

Figure 2–7. *Escherichia coli* concentrations for sites on at the Middle Branch Clinton River, May to October (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

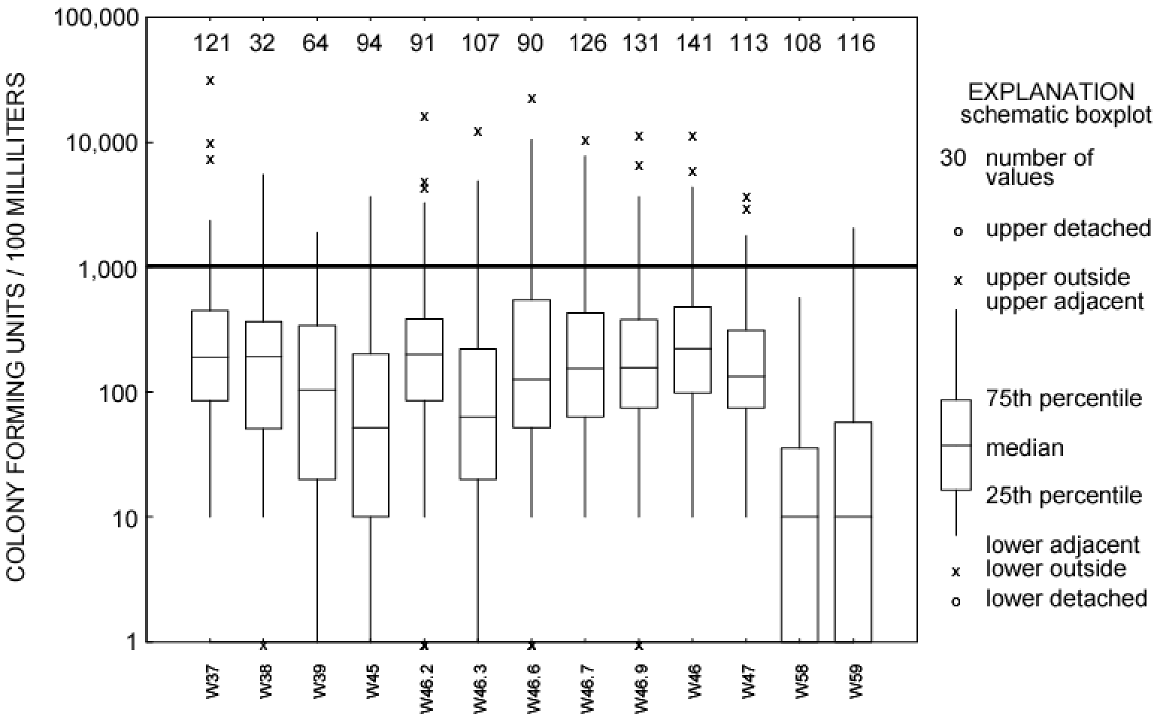

Figure 2–8. *Escherichia coli* concentrations for sites on the direct tributaries to Lake St. Clair, November to April (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

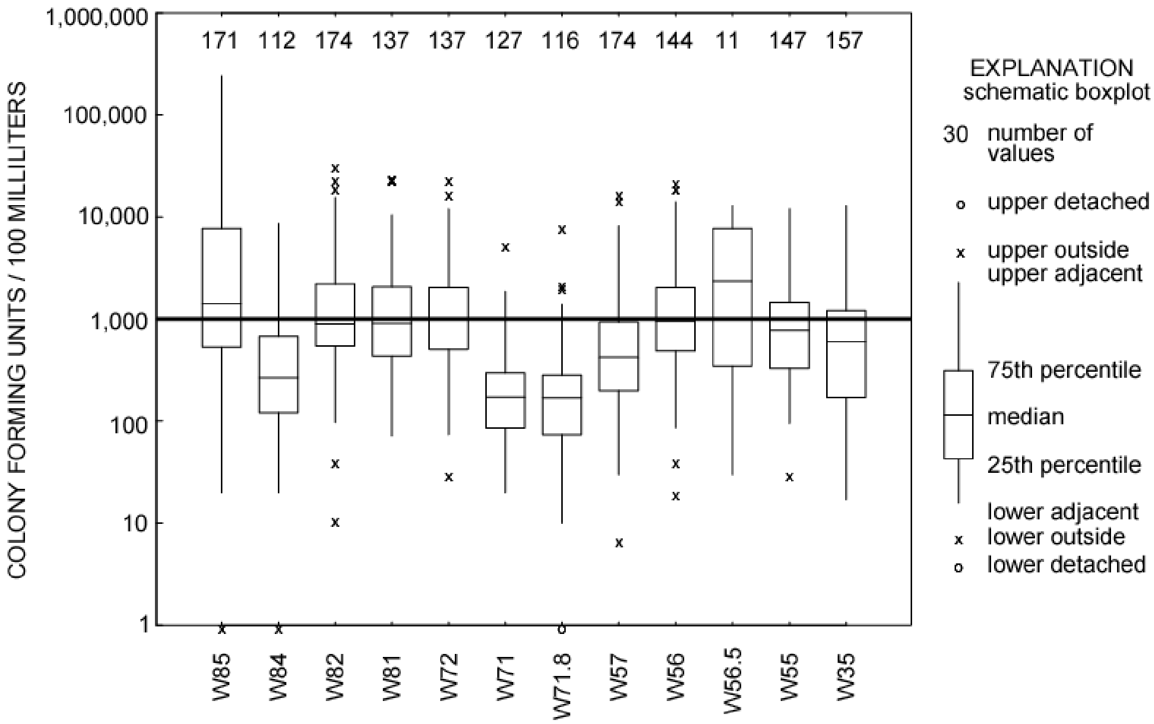

Figure 2–9. *Escherichia coli* concentrations for sites on Red Run and tributaries, November to April (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

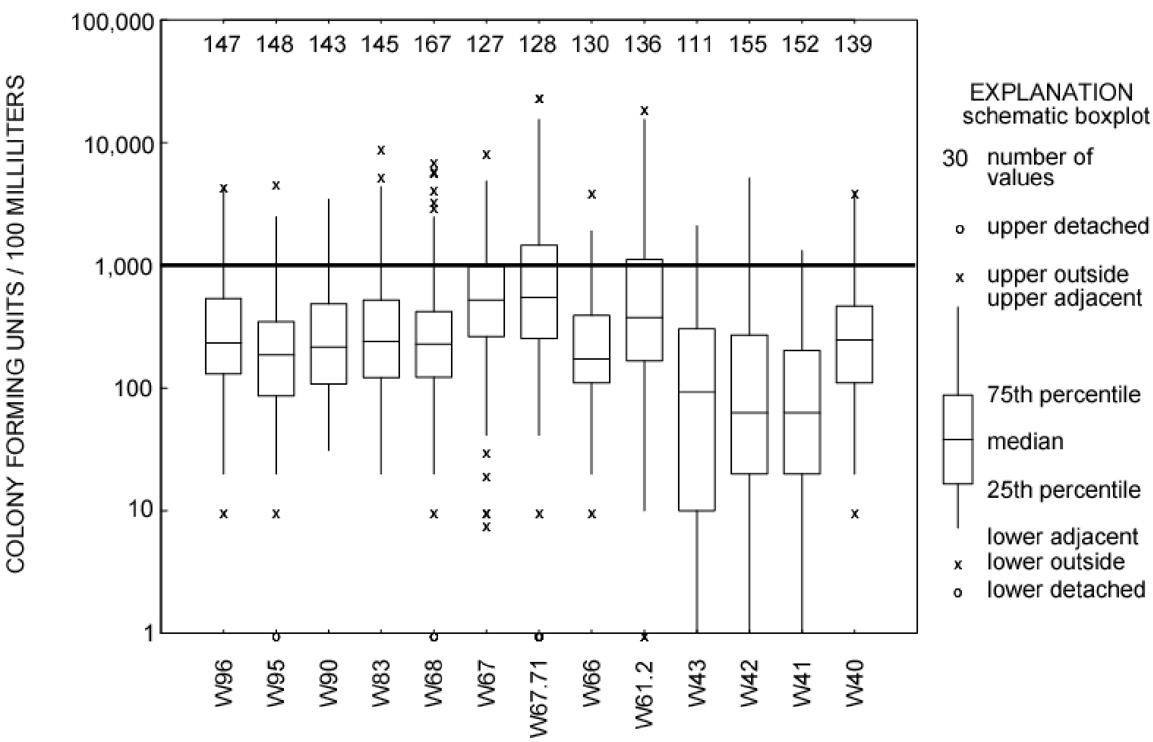

Figure 2–10. *Escherichia coli* concentrations for sites on the main stem Clinton River (East), November to April (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

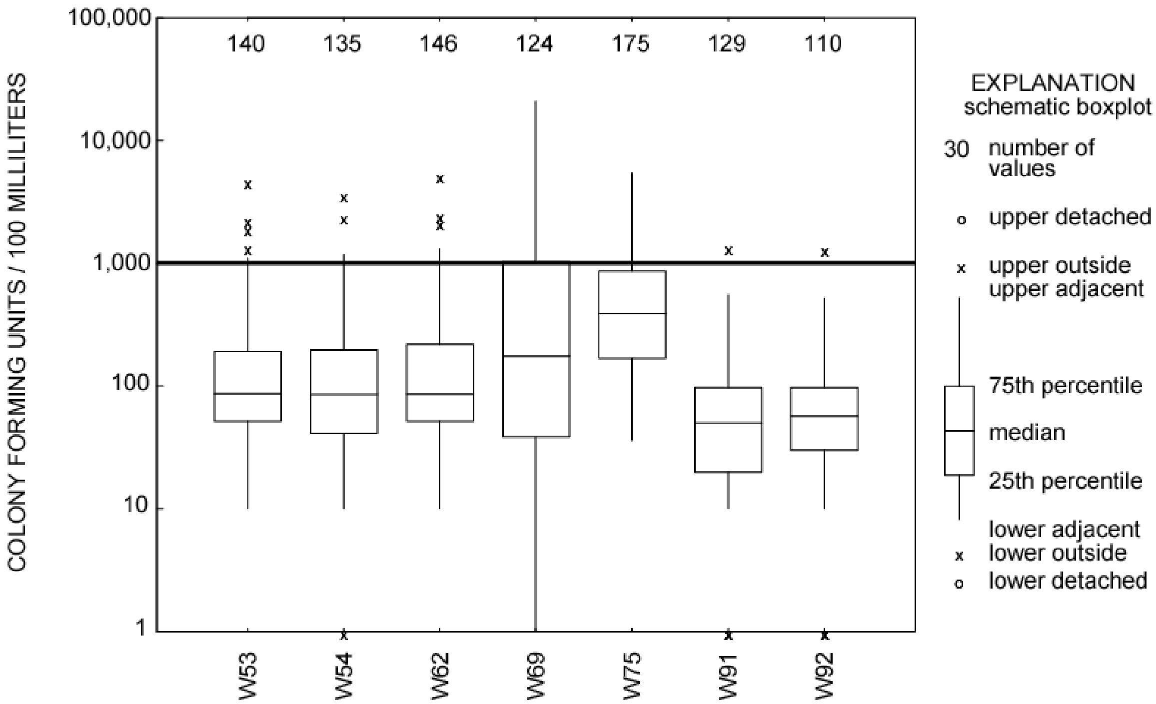

Figure 2–11. *Escherichia coli* concentrations for sites on the main stem Clinton River (West), November to April (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

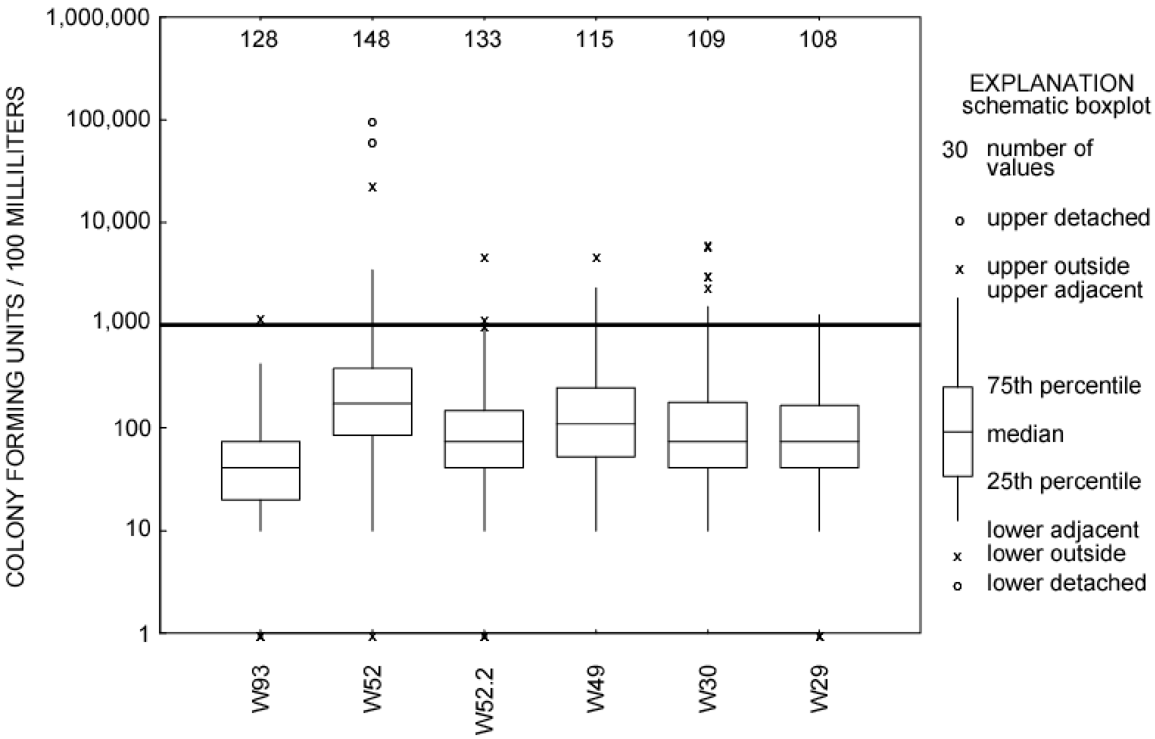

Figure 2–12. *Escherichia coli* concentrations for sites on the North Branch Clinton River (West), November to April (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

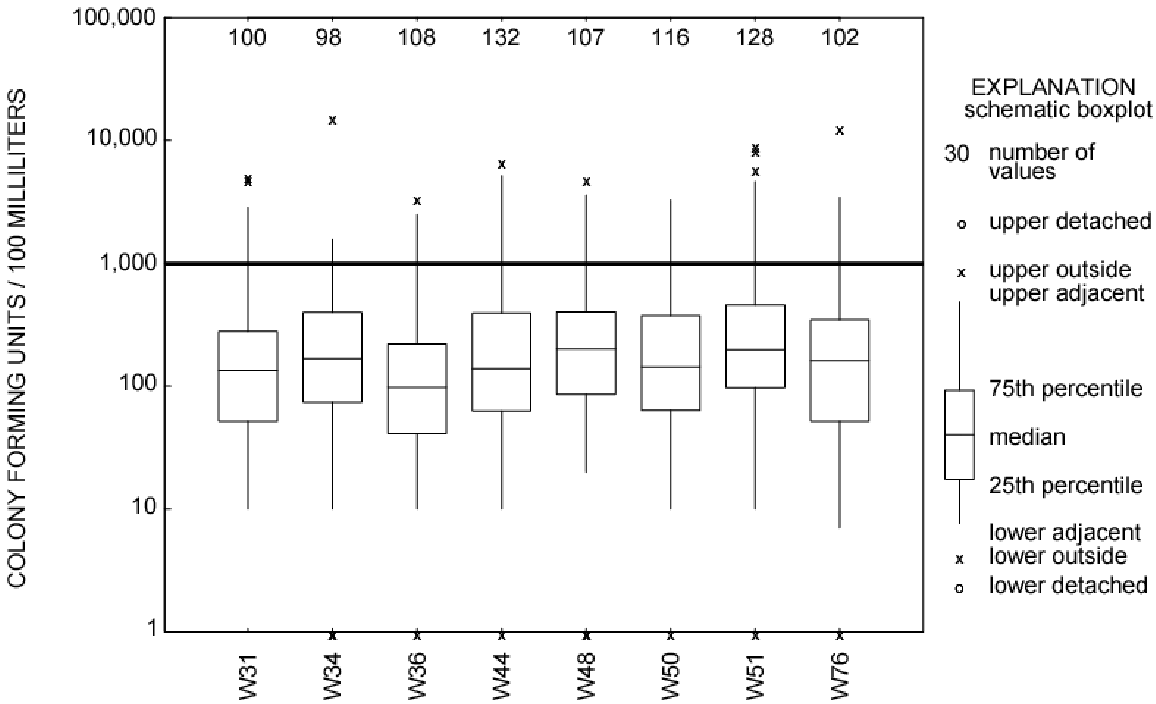

Figure 2–13. *Escherichia coli* concentrations for sites on the North Branch Clinton River, November to April (2000–05).

Appendix 2. *Escherichia coli* Concentrations—Continued

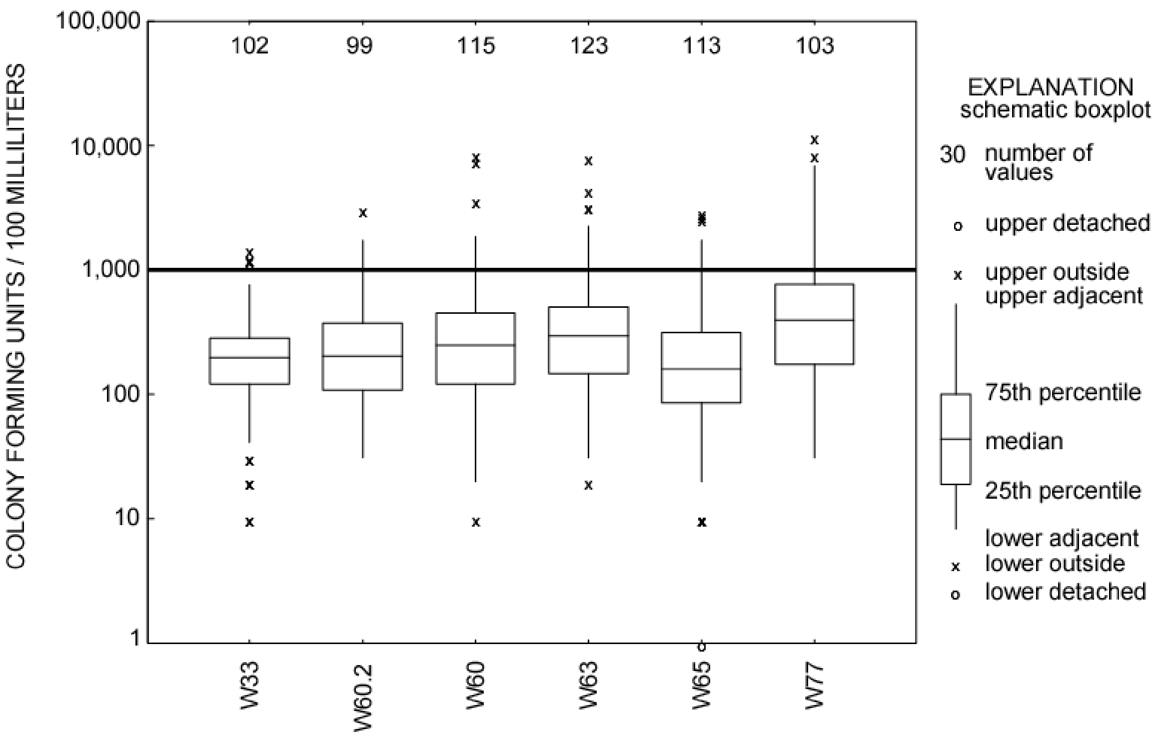

Figure 2–14. *Escherichia coli* concentrations for sites on the Middle Branch Clinton River, November to April (2000–05).

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Healy and others—**Water Quality of the St. Clair River, Lake St. Clair, and Their U.S. Tributaries, 1946–2005**—Scientific Investigations Report 2007–5172