Bacteria and Emerging Chemical Contaminants in the St. Clair River/Lake St. Clair Basin, Michigan

By Lisa R. Fogarty

Introduction

Since the enactment of the Clean Water Act in 1972, awareness of the quality of the Nation's water has continued to improve. Despite improvements to wastewater-treatment systems and increased regulation on waste discharge, bacterial and chemical contamination is still a problem for many rivers and lakes throughout the United States. Pathogenic microorganism and newly recognized chemical contaminants have been found in waters that are used for drinking water and recreation (Rose and Grimes, 2001; Kolpin and others, 2002).

This summary of bacteria and emerging-chemical-contaminant monitoring in the St. Clair River/Lake St. Clair Basin (fig. 1) was initiated by the Lake St. Clair Regional Monitoring Project (LSCRMP) in 2003, in cooperation with the Michigan Department of Environmental Quality (MDEQ), the Counties of Macomb, Oakland, St. Clair, and Wayne, and the U.S. Geological Survey (USGS).

Why Should We Care About Microorganisms In Surface Water?

Escherichia coli (*E. coli*) is a bacterium found in the intestinal tract of warm-blooded animals and is used as an indicator of fecal contamination. Most strains of *E. coli* are not harmful and typically do not cause disease; however, certain types of *E. coli* are pathogens (have the potential to cause disease) and pose a significant threat to human health. Pathogenic *E. coli* and other disease-causing microorganisms (pathogenic bacteria, viruses, and protozoa) have been identified as the causative agent for several waterborne *E. coli* outbreaks across the country. These organisms are commonly found in fecal waste. *E. coli* may not be a risk to human health itself but the presence of *E. coli* is used to indicate fecal contamination and the possible presence of bacterial, viral, and protozoan pathogens.

Several techniques are being developed to identify harmful pathogenic bacteria in the environment. Although these tools are helpful in assessing the health risk associated with drinking and recreational waters, methods to detect pathogens are still in their infancy and are often impractical because of cost and time. Therefore, the U.S Environmental Protection Agency (USEPA) recommends using *E. coli* and enterococci as indictor bacteria for disease-causing fecal waste (U.S Environmental Protection Agency, 1986). Microbial water-quality standards have been established on the basis of early studies showing increased risk of human illness with higher concentrations of these indicator organisms (Dufour, 1984). *E. coli* and enterococci are not necessarily reliable indicators of viruses and protozoa.

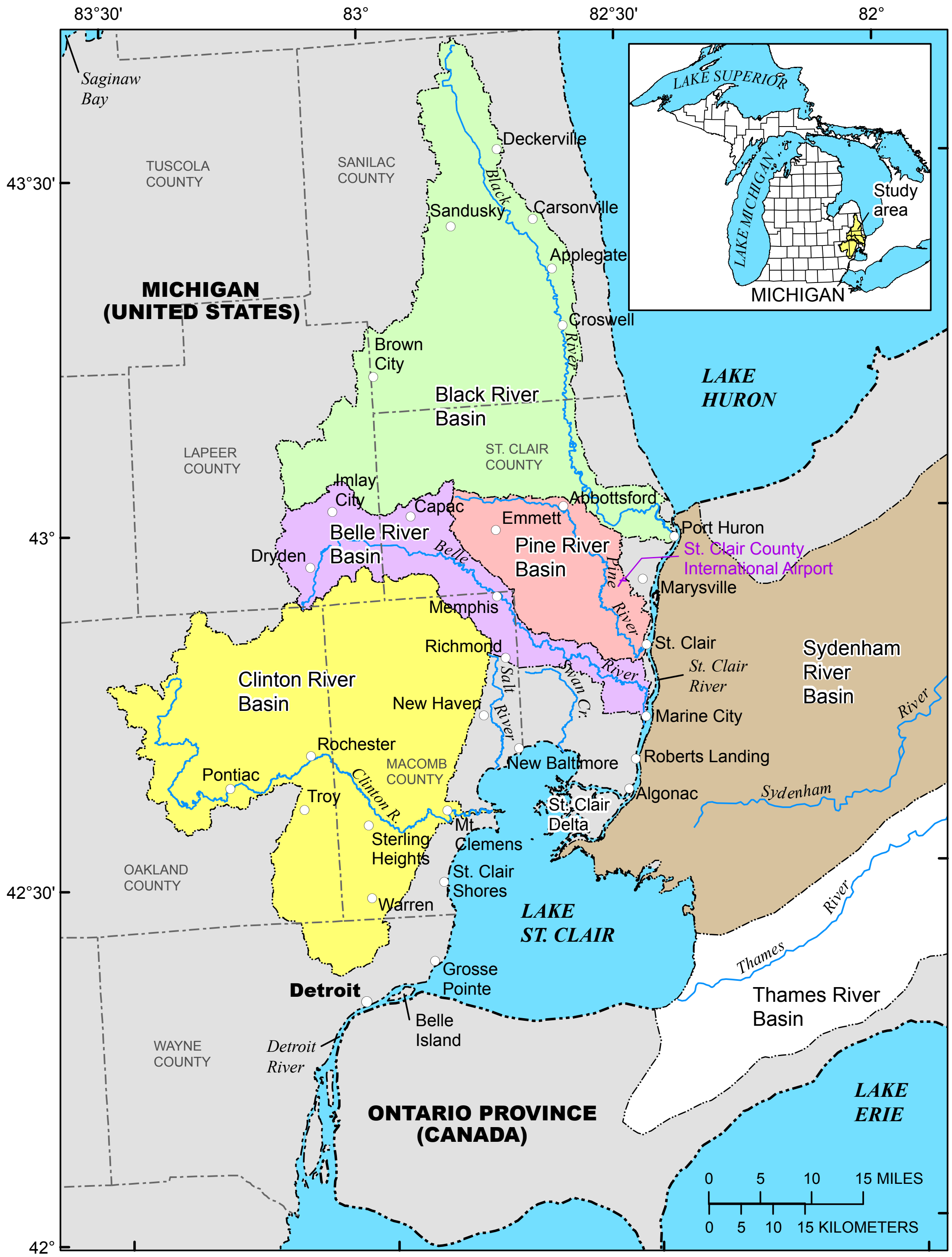
Microbiological Water-Quality Standards In Michigan

From May 1 to October 31 of each year, all surface waters in the State of Michigan are designated as total body contact recreational waters and shall be protected as such (Michigan's water-quality standard R323.1062 Rule 62). Total body contact recreation includes all activities that involve direct contact with water to the point of complete body submergence.

- No site should exceed 130 *E. coli* colony forming units (CFU) per 100 milliliters (mL) of water, as a geometric mean of all samples collected over a 30-day period.
- In a single sampling event, waters should not exceed 300 *E. coli* CFU per 100 mL of water, as a geometric mean based on three or more samples collected during that sampling event.
- If beach waters exceed these standards, an advisory or closure is implemented until standards are met.

Partial body contact waters (November 1 to April 30 of each year) are waters used for activities that involve some direct contact with the water but normally involve minimal submergence. These types of waters are not used for swimming, but rather are used for boating, fishing, or wading.

- The standard for partial body contact waters in the



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

Figure 1. Lake St. Clair, Michigan, with United States tributary drainage basins.

> State of Michigan is 1,000 *E. coli* colony forming units per 100 mL of water based on the geometric mean of at least three samples collected during a single sampling event.

For the protection of the public health, the Macomb County Health Department does not recommend contact with waters containing *E. coli* concentrations greater than 300 CFU per 100 mL regardless of the time of year.

Why Are We Concerned About Emerging Chemical Contaminants In Surface Waters?

"Emerging chemical contaminants" are chemicals that have not historically been considered environmental contaminants. Some of these chemicals are pharmaceuticals, antibiotics, pesticides, and other wastewater-derived chemicals. Emerging chemical contaminants have been detected in surface water throughout the Nation (Kolpin and others, 2002; Boyd and others, 2004; Metcalf and others, 2003, Gilliom and others, 2006). Although some of these chemicals may be new, hence the recent detections, others may have been released into the environment for several years but have only recently been discovered as new, more sensitive methods for detection have been developed.

Although concentrations of many emerging chemical contaminants detected in the environment are usually very low (typically parts per trillion), the effects of these chemicals at low levels on human and ecosystem health are not fully understood. Potential effects include disruption or changes in physiological processes, reproduction impairment, and increased bacterial resistances to antibiotics. These chemicals are commonly found in company with several other emerging contaminants. These chemical mixtures may have an even greater affect on human and ecosystem health (Matthiessen, 1998).

Where Do Bacteria And Emerging Contaminants Come From?

Different sources contribute different types of bacteria and emerging chemical contaminants that pose different risks to human health. Bacteria and emerging chemical contaminants can come from human and nonhuman sources.

"Human sources" are associated with wastewater effluents, septic system failures, industrial-waste discharges, combined-sewer overflows, sanitary-sewer overflows, biosolids, or runoff from urban landscapes. Human fecal sources often carry viruses that could cause mild to severe illnesses, especially in children or immune- compromised individuals. Glassmeyer and others (2005) identified a suite of chemicals typically found in wastewater effluents.

"Nonhuman sources" of contamination are those that originate from livestock and other domestic or wild animals; associated contaminants enter streams and lakes through runoff or direct inputs from grazing animals, wildlife (commonly waterfowl), or domestic animals standing in or near the water. *E. coli* O157:H7, commonly associated with fecal material from cattle, can cause severe disease in humans. Chemicals and antibiotics used in agriculture may seep into ground water or directly enter streams and lakes from surface runoff.

Where Do Bacteria Impair The Waters Of The St. Clair River/Lake St. Clair Basin?

The St. Clair River and Lake St. Clair (fig. 1) are an important waterway to Michigan, the United States, and Canada. These waters are the primary source of drinking water for millions of residents and serve as a recreational and economic resource to the surrounding communities. However, as of 2006, eight water bodies in Lake St. Clair area and nine water bodies in the St. Clair River Basin are listed as impaired under the USEPA 303d list. Seven Lake St. Clair areas, including four beaches, have been listed as impaired due to pathogens or *E. coli.* Of the nine impaired water bodies listed for the St. Clair River Basin, pathogens are listed as a cause for five.

The St. Clair River and Lake St. Clair are also affected by the quality of the major rivers and streams that discharge into them, such as the Bell, Black, Clinton, and Pine Rivers (fig. 1).

In the Clinton River Basin, 20 water bodies have been listed as concern areas; pathogens are the cause of impairment in five of them. Polychlorinated biphenyls (PCBs) and mercury are also listed as causes of impairment for waters in this area.

What Were the Results Of *E. coli* Monitoring In The Streams?

Water-quality monitoring is essential for managing the St. Clair River/Lake St. Clair Basin. Monitoring helps to identify problems and tracks the success of remediation efforts.

Macomb County has been monitoring streams and beaches in the county for indicator bacteria since 1947. Currently (2007), 57 stream sites, 4 Lake St. Clair beaches, and 2 inland lake beaches are routinely monitored by Macomb County Health Department for *E. coli*. Data that are summarized in the following paragraphs have been published online by the Macomb County Health Department (2007).

The Clinton River discharges directly into Lake St. Clair (fig. 1) and has potential to affect water quality of beaches along the shoreline. Although there are no public bathing beaches along the Clinton River, it is considered a recreational water body from May through October each year and can be used for total body contact recreation. Water-quality monitoring has identified several sites on the Clinton River and its tributaries where *E. coli* concentrations frequently were greater than water-quality standards.

E. coli sampling sites on the Clinton River are shown in figure 2. The median daily geometric mean for all samples collected May through October (2000-2005) from the Clinton River was as high as 601 colony forming units per 100 milliliters (CFU/100 mL) in 2000 and as low as 216 CFU per 100 mL in 2002. The median geometric mean concentration was greater than the single-sampling total body contact standard of less than 300 CFU/100 mL in 2000, 2001, and 2004 (fig. 3) and was always greater than the 30-day criterion of 130 CFU per 100 mL.

Of the Clinton River samples collected for the Macomb County Surface-Water-Quality Monitoring Program from 2000 to 2005, 46 percent had concentrations greater than the single-sampling total body contact standard and 23 percent had concentrations greater than the partial body contact standard of less than 1,000 CFU/100 mL. Concentrations in samples from individual site locations along the Clinton River were greater than total and partial body contact standards as frequently as 73 (site no. 75) and 36 (site no. 75) percent of time, respectively (fig. 4).

Identified as a major source of contamination to the Clinton River, the Red Run subbasin drains mainly urban and industrial land. Of the samples collected along Red Run, as part of the Macomb County Surface Water Quality Monitoring Program (2000 to 2005), 86 percent had concentrations greater than the single-sampling total body contact standard and 50 percent were greater than the partial body contact standard. *E. coli* concentrations as high as 240,000 CFU per 100 mL water were recorded.

An example of the effects of Red Run on the Clinton River can be seen in figure 5, in which *E. coli* concentrations on the Clinton River appear to increase downstream from the Red Run confluence. The percentage of samples in which concentrations were greater than microbial water-quality standards tends to be higher at sites downstream from Red Run (fig. 2, site 75) than upstream (fig. 2, site 62). Red Run is not the only site responsible for the high *E. coli* concentrations in the Clinton River Basin. *E. coli* concentrations have been greater than water-quality standards even upstream from Red Run, with more than 3 percent of samples upstream of Red Run being greater than the single-sampling total body contact standard and more than 10 percent greater than the partial body contact standard (fig. 4).

Because the Clinton River drains into Lake St. Clair, it has potential to influence the water-quality of the lake and shoreline beaches. Near the mouth of the Clinton River (site 95 in figure 2), *E. coli* concentrations were greater than 1,000 CFU per 100 mL in 16 percent of the samples collected from 2000 to 2005. Hydrodynamic and particle-tracking models show that particles coming out of the Clinton River do not flow far from the western shoreline of Lake St. Clair (Holtschlag and Koschik, 2004); therefore, the water quality along shoreline areas of Lake St. Clair may be affected by water draining out of the Clinton River.

Were There Seasonal And Spatial Patterns In *E. coli* Concentrations In Stream Waters?

The sample-collection efforts of the Macomb County Surface Water Quality Monitoring Program have resulted in more than 18,000 *E. coli* samples representing nearly the entire county from 2000 to 2005. The highest concentrations of *E. coli* typically occur in the recreational months of May through October (fig. 6). The reason for this increase in the summer months has not been fully investigated, but several factors may contribute to this seasonal pattern. Changes in human and animal activities may influence the amount of fecal pollution entering the basin. Weather may also influence the input of fecal waste into the environment. In addition, bacteria survival may differ between the summer and winter.

Spatial analyses may help identify potential source areas of high *E. coli* concentration. The Macomb County Health Department frequently collects several samples on the same sampling date. This type of data can then be visualized geographically where changes in concentrations along the river can be identified. The variability in *E. coli* concentrations across the county on two sampling dates in June 2005 is shown in figure 7. Some of this variation may be a result of changes in weather patterns or rainfall. For example, on average, samples collected on June 14 were influenced by greater rainfall than those collected on June 7 (average daily rainfall June 5–7, 0.19 inch; June12–14, 0.52 inch). A more thorough evaluation of the data is needed to better understand the effects rainfall has on *E. coli* concentrations in this area. Interestingly, samples collected near the mouth of the Clinton River appear to be much lower in *E. coli* concentrations than those from nearby upstream sites. These river-mouth sites may sometimes be affected by backwater from Lake St. Clair, thus diluting the *E. coli* concentrations for those samples. This dilution may result in total load calculations to Lake St. Clair that are artificially low.

Have Pathogens Been Found In The Basin?

E. coli is used as an indicator organism, but there is a small group of *E. coli* bacteria that has the potential to cause severe harm to humans. Identifying these organisms in the environment can be difficult, but several techniques are being

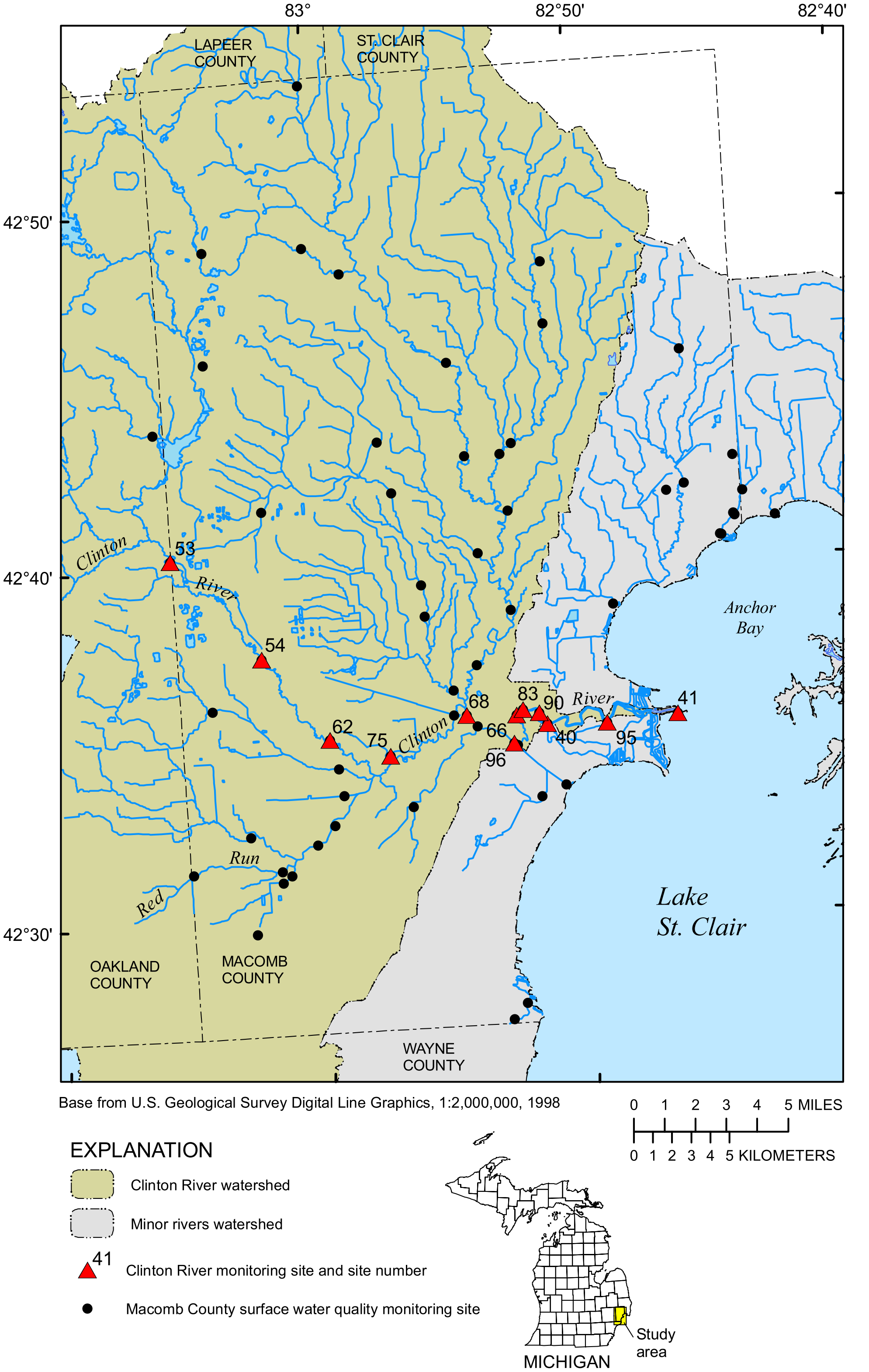


Figure 2. Location of Clinton River sites sampled as part of the Macomb County Surface Water Monitoring Program.

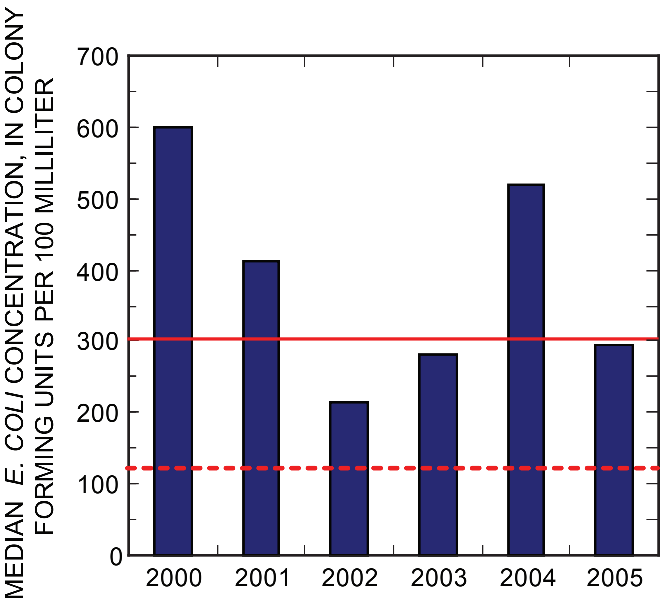


Figure 3. Median *E. coli* concentrations decreased from greater than the Michigan recreational water-quality single sample geometric mean standard of 300 CFU/100 ml (solid red line) in 2000 and 2001 to less than 300 CFU/100 ml in 2002 and 2003. In 2004 and 2005 the median value increased again to greater than 300 CFU/100 ml. Median concentration exceeded the Michigan water-quality 30-day geometric mean standard of 130 CFU/100 ml (dotted red line) each year. Data source: Macomb County Surface Water Monitoring Program.

used to detect toxin genes or surface proteins common to pathogenic *E. coli*. In a study in Oakland County, Mich., molecular and immunological assays detected markers for pathogenic *E. coli* in samples collected from the Clinton River (Fogarty and others, 2005). Molecular analyses have also detected genes associated with pathogenic *E. coli* in beach sand from Lake St. Clair beaches (Elizabeth Alm, Central Michigan University: oral commun., 2005).

What Emerging Chemical Contaminants Have Been Detected In The St. Clair River/Lake St. Clair Basin?

The USGS has detected several emerging chemical contaminants such as pharmaceuticals, detergents, and antibiotics in surface waters across the Nation. Many of these emerging contaminants have been detected at sites in Michigan, including sites in the Clinton River Basin.

Aichele and others (2005) reported detections of plasticizers, detergents and their metabolites, polyaromatic hydrocarbons, fire retardants, and detergents and musk fragrances (7-acetyl-1,1,3,4,4,6-hexamethyl-1,2,3,4-tetrahydronaphthalene (AHTN), and 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-2-benzopyran (HHCB)) at sites in the Clinton River Basin in Oakland County, Mich. Table 1 lists the most commonly detected wastewater chemicals in 2002 and 2003 at five sites in the Clinton River Basin (Aichele and others, 2005). Studies are ongoing to evaluate the presence of antibiotics at several sites in the Clinton River Basin.

Polybrominated diphenyl ethers (PBDEs) are an important class of brominated fire retardants that are added to plastics to reduce fire damage. They can be found in electronics, furniture padding, and appliances. PBDEs bioaccumulate in fish tissues and have also been found in elevated concentrations in human breast milk and in eggs from bald eagles. Studies have found an upward trend in PBDE concentrations in Great Lakes fish (Ling and Hites, 2004). Macomb County detected PBDEs in five nearshore water samples. The highest detected total PBDE concentration detected in aqueous samples was 23,210 picograms per liter (pg/L) at Irwin Drain. The total PBDE concentration detected from the Clinton River at the mouth was 450 pg/L and from the Clinton River Spillway was 4,230 pg/L (Macomb County Health Department, written commun., 2006).

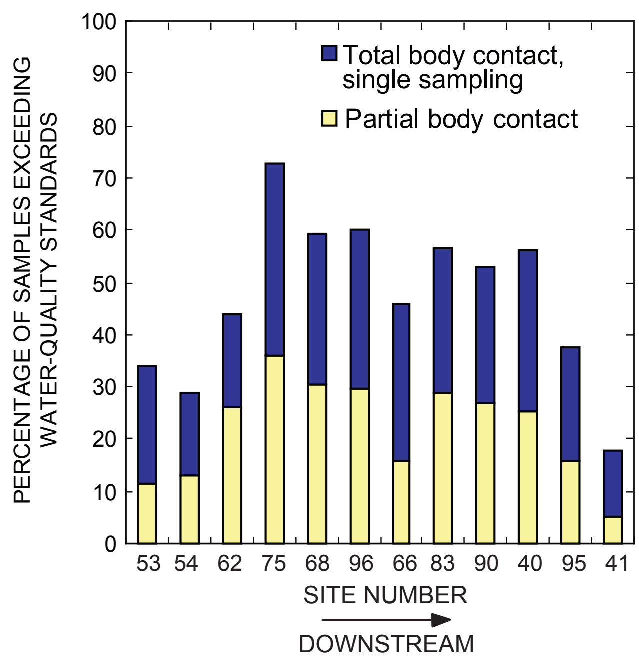


Figure 4. Sites along the Clinton River often did not meet Michigan's recreational water-quality standard (300 CFU/100 ml) and partial body contact standard (1000 CFU/100 ml) for *E. coli.* Data source: Macomb County Surface Water Monitoring Program. (See figure 2 for location of sites.)

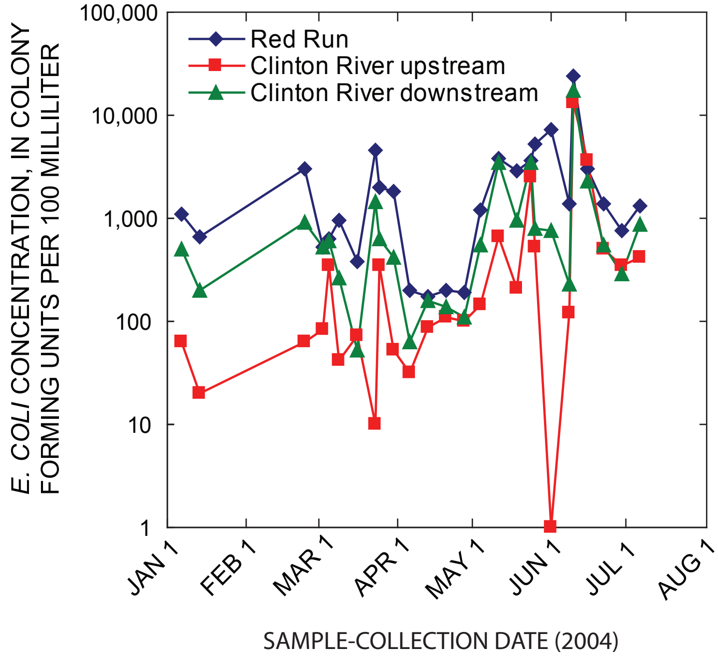


Figure 5. *E. coli* concentrations at sites located on Red Run just prior to discharge to the Clinton River and the Clinton River upstream and downstream of the Red Run. *E. coli* data obtained from the Macomb County Surface Water Monitoring Program.

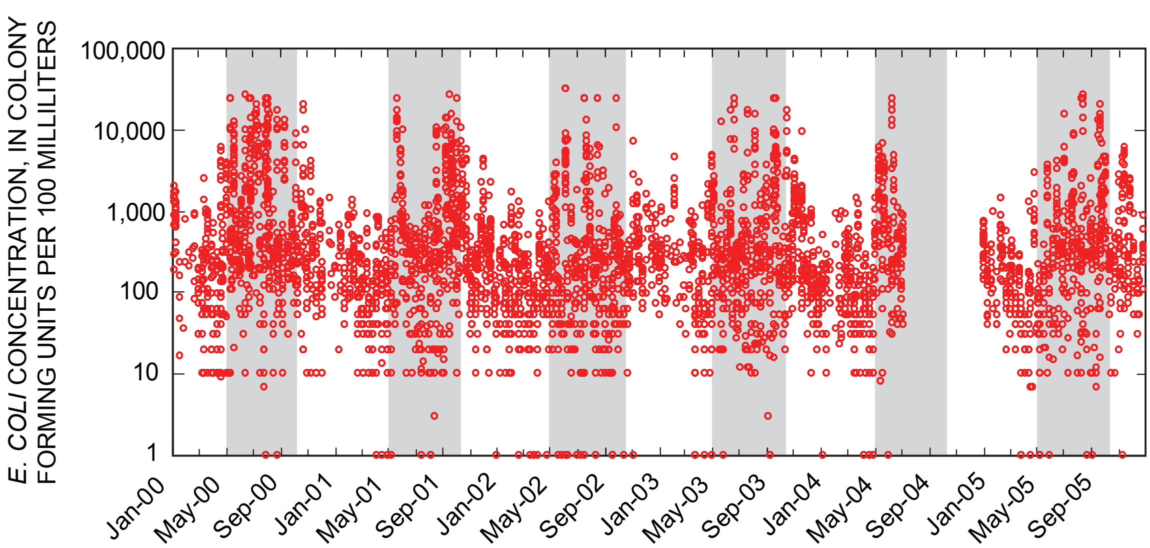


Figure 6. Seasonal variations in *E. coli* concentrations for samples collected from the Clinton River 2000-2005 as part of the Macomb County Surface Water Monitoring Program. Gray areas indicate the May 1 through October 31 time period during which recreational standards apply.

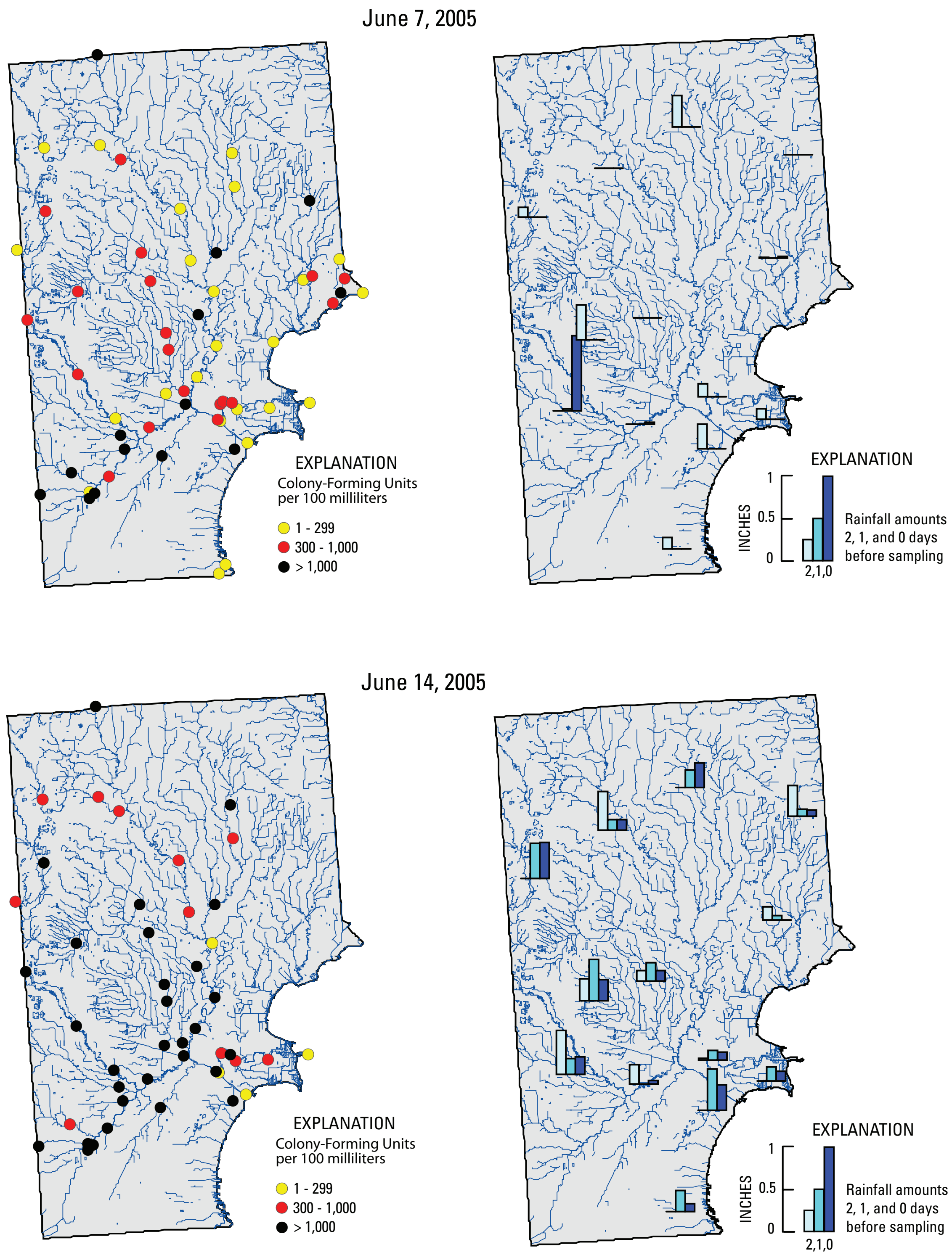


Figure 7. *E. coli* concentrations may vary upstream and downstream along the river and throughout the county. Rainfall may also influence the amount of *E. coli* detected as shown on June 14, 2005, in which *E. coli* concentrations are higher after three days of rainfall. *E. coli* data obtained from the Macomb County Surface Water Monitoring Program.

What Is Being Done To Protect The Beaches Of Lake St. Clair?

Beaches along Lake St. Clair and at inland lakes are important recreational areas in southeastern Michigan. High *E. coli* concentrations have forced closures or advisories for many of these beaches (fig. 8). Lake St. Clair beaches were closed more than 100 days in both 2004 and 2005 because concentrations were considered too high for recreation. Effective management of these beaches along Lake St. Clair requires an understanding of how the hydrologic system influences the beach. For many beaches, including those on Lake St. Clair, sources of *E. coli* are numerous, and so are the pathways that may transport *E. coli* to the beach. Several possible sources of *E. coli* to beaches are rivers, boaters, swimmers, waterfowl, surface runoff, or resuspension of *E. coli* residing in the sediment.

Beach monitoring programs help inform beachgoers when *E. coli* concentrations indicate a health risk. Methods currently used to measure *E. coli* concentrations take 12–24 hours and are not predictive of current conditions. The USEPA and other research groups are currently working on rapid methods that will be more predictive of real-time conditions. Models that use environmental data are being developed to help predict when conditions are unsafe at several Great Lake beaches (Francy, 2002; Nevers and Whitman, 2005). These models require extensive data collection for accurate model predictions and are beach-specific.

A particle-tracking model for Lake St. Clair is being used to help identify source areas of high *E. coli* at selected beaches under various wind directions. A hydrodynamic model of Lake St. Clair can map the path a particle may take once it enters the lake (Holtschlag and Koschik, 2004). This model can be used to improve understanding of where pollutants may come from and where they may end up.

Efforts are being made to protect the waters of the Lake St. Clair/St. Clair River Basin with improvements to wastewater treatment and discharge, elimination of combined-sewer overflows, and identification and elimination of illicit discharges. Although median *E. coli* concentrations have decreased from 2000 to 2005, the median concentration for 2005 was still almost 300 CFU per 100 mL. There has been no apparent increase or decrease in *E. coli* concentrations in beach waters from year to year; median and mean concentrations for the year have ranged from 23 to 42 and 80 to 145 CFU per 100 mL, respectively. Despite relatively low median and mean concentrations, the number of beach closures for Lake St. Clair beaches in Macomb County has fluctuated year to year from 2000 to 2005, with a low of 30 beach closures in 2001 to a high of 128 in 2004. Further studies and data evaluation would be necessary to fully understand the sources of *E. coli* in the Lake St. Clair/St. Clair River Basin.

Table 1. The most common wastewater chemicals detected in the Clinton River watershed in 2002 and 2003 (Aichele and others, 2005).

Chemical name	Percentage of samples with detection (n=26)	Possible source (Zaugg and others, 2001)
Benzophenone	70 %	Fixative in perfumes and soaps
Caffeine	50 %	Beverages and diuretic
Fluoranthene	40 %	Coal tar and asphalt
HHCB[1]	40 %	Musk fragrance
AHTN[2]	40 %	Musk fragrance
Phenanthrene	70 %	Disinfectant
Tributyl phosphate	40 %	Flame retardant

[1] HHCB, 1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-2-benzopyran.

[2] AHTN, 7-acetyl-1,1,3,4,4,6-hexamethyl-1,2,3,4-tetrahydronaphthalene.

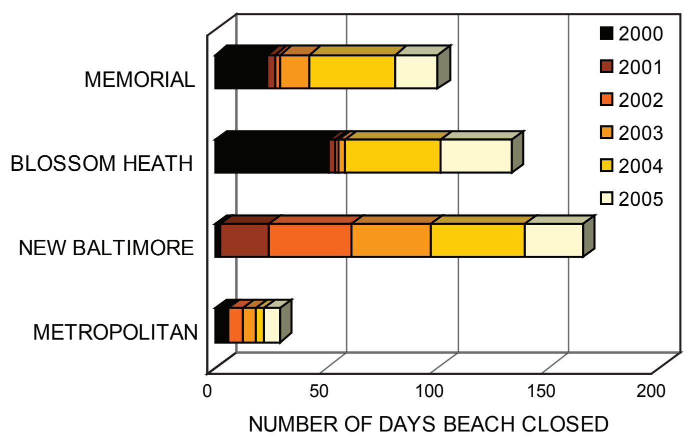


Figure 8. Beach closures have been a problem for four public beaches on Lake St. Clair. Data obtained from Macomb County Beach Monitoring Program.

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