State of Ohio
Environmental Protection Agency

Division of Surface Water

Biological and Water Quality Study of Fourmile Creek, Indian Creek, and Select Tributaries, 2005

Butler and Preble Counties

Fourmile Creek upstream from Camden-College Corner Road (RM 24.8)

April 3, 2008

Ted Strickland, Governor
Chris Korleski, Director

Biological and Water Quality Study of Fourmile Creek, Indian Creek, and Select Tributaries 2005

Preble and Butler Counties, Ohio

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NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio’s surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2006a. 2006 updates to Biological Criteria for the Protection of Aquatic Life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2006b. 2006 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2006c. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Ohio EPA Tech. Bull. EAS/2006-06-1. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

In addition to the preceding guidance documents, the following publications by the Ohio EPA should also be consulted as they present supplemental information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

Yoder, C.O. and M.A. Smith. 1999. Using fish assemblages in a State biological assessment and criteria program: essential concepts and considerations, pp. 17-63. in T. Simon (ed.). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

These documents and this report may be obtained by writing to:

Ohio EPA, Division of Surface Water
Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8798

or

www.epa.state.oh.us/dsw/formspubs.html

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Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us/dsw/document_index/psdindx.html) or may be available on CD from:

Ohio EPA
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FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 4-5 watersheds study areas with an aggregate total of 250-300 sampling sites.

The Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.,* NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure 1). The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or

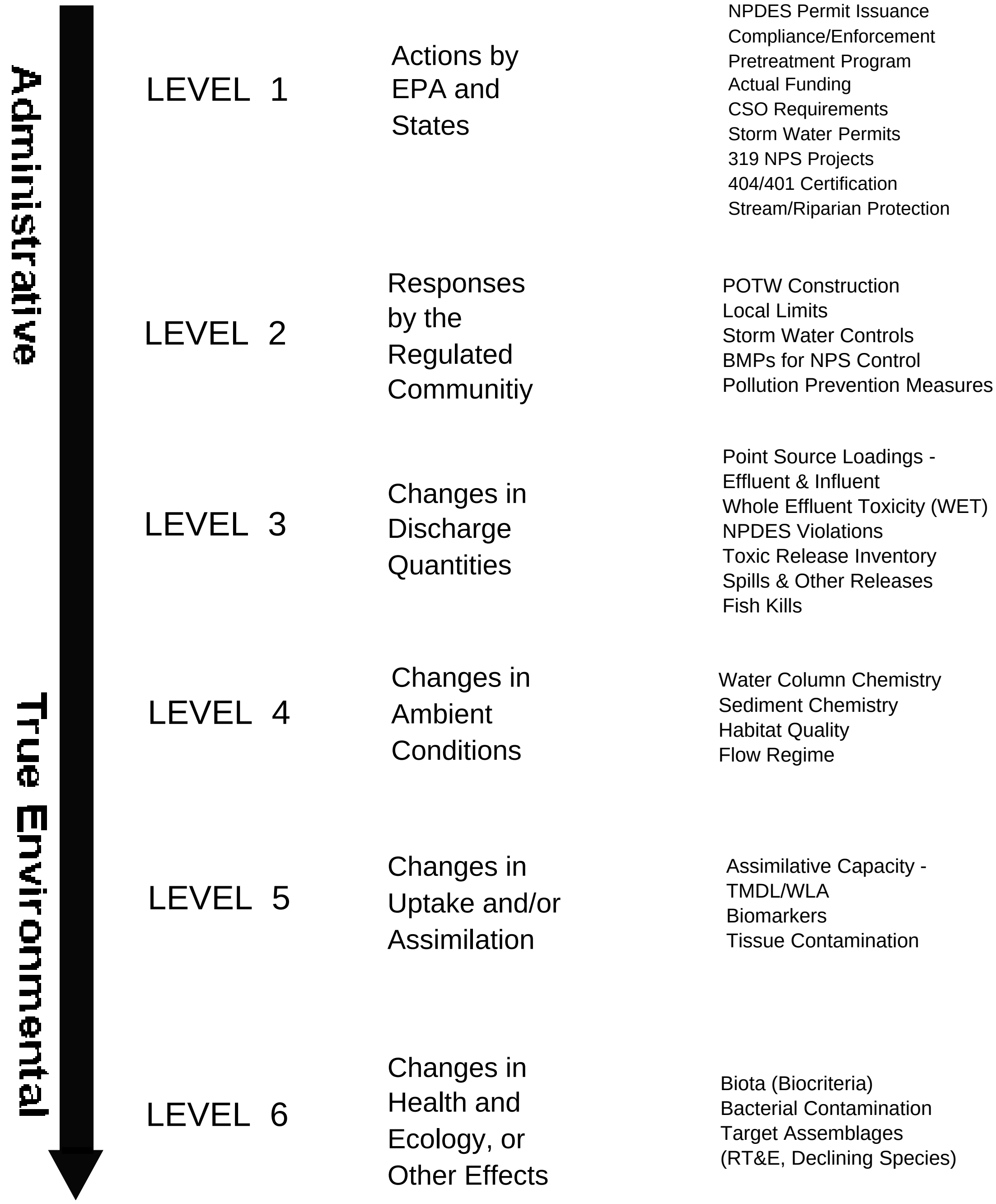

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental “results” (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition. Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio’s biological criteria. Other response indicators could include target assemblages, *i.e.,* rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreation uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio’s rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses. The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the “typical” warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.*

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support “unusual and exceptional” assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio’s best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic “runs” of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a “tiered” approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use can be having a water depth of at least one meter over an area of at least 100 square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Attainment of recreation uses are evaluated based on monitored bacteria levels. The Ohio Water Quality Standards state that all waters should be free from any public health nuisance associated with raw or poorly treated sewage (Administrative Code 3745-1-04, Part F). Additional criteria (Administrative Code 3745-1-07) apply to waters that are designated as suitable for full body contact such as swimming (PCR- primary contact recreation) or for partial body contact such as wading (SCR- secondary contact recreation). These standards were developed to protect human health, because even though fecal coliform bacteria are relatively harmless in most cases, their presence indicates that the water has been contaminated with fecal matter.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The AWS and IWS use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health.

MECHANISMS FOR WATER QUALITY IMPAIRMENT

The following paragraphs describe the various causes of impairment that were encountered during the Twin Creek study. While these perturbations are presented under separate headings, it is important to remember that they are often interrelated and cumulative in terms of the detrimental impact that can result.

Habitat and Flow Alterations

Habitat alteration, such as channelization, negatively impacts biological communities by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse. Indirect impacts include agricultural activities such as the removal of trees and shrubs adjacent to streams (described throughout this report as riparian vegetation/buffer) and field tiling to facilitate drainage. Urbanization impacts include removal of riparian trees, influx of stormwater runoff, straightening and piping of stream channels, and riparian vegetation removal.

Following a rain event, most of the water is quickly removed from tiled fields or urban settings rather than filtering through the soil, recharging groundwater, and reaching the stream at a lower volume and more sustained rate. As a result, small streams more frequently go dry or become intermittent.

Tree shade is important because it limits the energy input from the sun, moderates water temperature, and limits evaporation. Removal of the tree canopy further degrades conditions because it eliminates an important source of coarse organic matter essential for a balanced ecosystem. Riparian vegetation aids in nutrient uptake, may decrease runoff rate into streams, and helps keep soil in place. Erosion impacts channelized streams more severely due to the lack of a riparian buffer to slow runoff, trap sediment, and stabilize banks. Deep trapezoidal channels lack a functioning flood plain and therefore cannot expel sediment as would occur during flood events along natural watercourses. Additionally, the confinement of flow within an artificially deep channel accelerates the movement of water downstream, exacerbating flooding of neighboring properties.

The lack of water movement under low flow conditions can exacerbate degradation from organic loading and nutrient enrichment by limiting reaeration of the stream. The amount of oxygen soluble in water decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion, but channelization eliminates turbulence produced by riffles, meanders, and debris snags. Plant photosynthesis produces oxygen, but at night, respiration reverses the process and consumes oxygen. Conversely, oxygen concentrations can become supersaturated during the day, due to abnormally high amounts of photosynthesis, causing gas bubble stress to both fish and invertebrate communities. Oxygen is also used by bacteria that consume dead organic matter. Nutrient enrichment promotes the growth of nuisance algae that subsequently dies and serves as food for bacteria. Under these conditions, oxygen can be depleted unless it is replenished from the air.

Siltation and Sedimentation

Whenever the natural flow regime is altered to facilitate drainage, increased amounts of sediment are likely to enter streams either by overland transport or increased bank erosion. The removal of wooded riparian areas furthers the erosional process. Channelization keeps all but the highest flow events confined within the artificially high banks. As a result, areas that were formerly flood plains and facilitated the removal of sediment from the primary stream channel no longer serve this function. As water levels fall following a rain event, interstitial spaces between larger rocks fill with sand and silt and the diversity of available habitat to support fish and macroinvertebrates is reduced. Silt also can clog the gills of both fish and macroinvertebrates, reduce visibility thereby excluding obligate sight-feeding fish species, and smother the nests of lithophilic fishes. Lithophilic spawning fish require clean substrates with interstitial voids in which to deposit eggs. Conversely, pioneering species benefit. They are generalists and best suited for exploiting disturbed and less heterogeneous habitats. The net result is a lower diversity of aquatic species compared with a typical warmwater stream with natural habitats.

Sediment also impacts water quality, recreation, and drinking water. Nutrients absorbed to soil particles remain trapped in the watercourse. Likewise, bacteria, pathogens, and pesticides which also attach to suspended or bedload sediments become concentrated in waterways where the channel is functionally isolated from the landscape.

Nutrient Enrichment

The element of greatest concern is phosphorus because it is critical for plant growth and is often the limiting nutrient. The form that can be readily used by plants and therefore can stimulate nuisance algae blooms is orthophosphate (PO_4^{3-}). The amount of phosphorus tied up in the nucleic acids of food and waste is actually quite low. This organic material is eventually converted to orthophosphate by bacteria. The amount of orthophosphate contained in synthetic detergents is a great concern however. It was for this reason that the General Assembly of the State of Ohio enacted a law in 1990 to limit phosphorus content in household laundry detergents sold in the Lake Erie drainage basin to 0.5 % by weight. Inputs of phosphorus originate from both point and nonpoint sources. Most of the phosphorus discharged by point sources is soluble. Another characteristic of point sources is they have a continuous impact and are human in origin, for instance, effluents from municipal sewage treatment plants. The contribution from failed on-site wastewater treatment systems can also be significant, especially if they are concentrated in a small area. The phosphorus concentration in raw waste water is generally 8-10 mg/l and after secondary treatment is generally 4-6 mg/l. Further removal requires the added cost of chemical addition. The most common methods use the addition of lime or alum to form a precipitate, so most phosphorus (80%) ends up in the sludge.

A characteristic of phosphorus discharged by nonpoint sources is that the impact is intermittent and is most often associated with stormwater runoff. Most of this phosphorus is bound tightly to soil particles and enters streams from erosion, although some comes from tile drainage. Phosphorus input from urban stormwater is more of a concern if combined sewer overflows are involved. Phosphorus load from rural stormwater varies depending on land use and management practices and includes contributions from livestock feedlots and pastures and row crop agriculture. Crop fertilizer includes granular inorganic types and organic types such as manure or sewage sludge. Pasture land is especially a concern if the livestock have access to the stream. Large feedlots with manure storage lagoons create the potential for overflows and accidental spills. Land management is an issue because erosion is worse on streams without any riparian buffer zone to trap runoff. The impact is worse in streams that are channelized because they no longer have a functioning flood plain and cannot expel sediment during flooding. Oxygen levels must also be considered, because phosphorus is released from sediment at higher rates under anoxic conditions.

There is no numerical phosphorus criterion established in the Ohio Water Quality Standards, but there is a narrative criterion that states phosphorus should be limited to the extent necessary to prevent nuisance growths of algae and weeds (Administrative Code, 3745-1-04, Part E). Phosphorus loadings from large volume point source dischargers in the Lake Erie drainage basin are regulated by the National Pollutant Discharge Elimination System (NPDES). The permit limit is a concentration of 1.0 mg/l in final effluent. Research conducted by the Ohio EPA indicates that a significant correlation exists between phosphorus and the health of aquatic communities (Miltner and Rankin, 1998). It was concluded that biological community performance in headwater and wadeable streams was highest where phosphorus concentrations were lowest. It was also determined that the lowest phosphorus concentrations were associated with the highest quality habitats, supporting the notion that habitat is a critical component of stream function. The report recommends WWH criteria of 0.08 mg/l in headwater streams (<20 mi^2 watershed size), 0.10 mg/l in wadeable streams (>20-200 mi^2) and 0.17 mg/l in small rivers (>200-1000 mi^2).

Organic Enrichment and Low Dissolved Oxygen

The amount of oxygen soluble in water is low and it decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion. Drainage practices such as channelization eliminate turbulence produced by riffles, meanders, and debris snags. Although plant photosynthesis produces oxygen by day, it is consumed by the reverse process of respiration at night. Oxygen is also consumed by bacteria that decay organic matter, so it can be easily depleted unless it is replenished from the air. Sources of organic matter include poorly treated waste water, livestock waste, sewage bypasses, and dead plants and algae. Dissolved oxygen criteria are established in the Ohio Water Quality Standards to protect aquatic life. The minimum and average limits are tiered values and linked to use designations (Administrative Code 3745-1-07, Table 7-1).

Ammonia

Ammonia enters streams as a component of fertilizer and manure runoff and wastewater effluent. Ammonia gas (NH_3) readily dissolves in water to form the compound ammonium hydroxide (NH_4OH). In aquatic ecosystems an equilibrium is established as ammonia shifts from a gas to undissociated ammonium hydroxide to the dissociated ammonium ion (NH_4^{+1}). Under normal conditions (neutral pH 7 and 25°C) almost none of the total ammonia is present as gas, only 0.55% is present as ammonium hydroxide, and the rest is ammonium ion. Alkaline pH shifts the equation toward gaseous ammonia production, so the amount of ammonium hydroxide increases. This is important because while the ammonium ion is almost harmless to aquatic life, ammonium hydroxide is very toxic and can reduce growth and reproduction or cause mortality.

The concentration of ammonia in raw sewage is high, sometimes as much as 20-30 mg/l. Treatment to remove ammonia involves gaseous stripping to the atmosphere, biological nitrification and de-nitrification, and assimilation into plant and animal biomass. The nitrification process requires a long detention time and aerobic conditions like that provided in extended aeration wastewater treatment plants. Under these conditions, bacteria first convert ammonia to nitrite and then to nitrate. Nitrate can then be reduced by bacteria through the de-nitrification process and nitrogen gas and carbon dioxide are produced as by-products.

Ammonia criteria are established in the Ohio Water Quality Standards to protect aquatic life. The maximum and average limits are tiered values based on sample pH and temperature and linked to use designations (Administrative Code 3745-1-07, Tables 7-2 through 7-8).

Metals

Metals can be toxic to aquatic life and hazardous to human health. Although they are naturally occurring elements many are extensively used in manufacturing and are by-products of human activity. Certain metals like copper and zinc are essential in the human diet, but excessive levels are usually detrimental. Lead and mercury are of particular concern because they often trigger fish consumption advisories. Mercury is used in the production of chlorine gas and caustic soda and in the manufacture of batteries and fluorescent light bulbs. In the environment it forms inorganic salts, but bacteria convert these to methyl-mercury and this organic form builds up in the tissues of fish. Extended exposure can damage the brain, kidneys, and developing fetus. The Ohio Department of Health (ODH) issued a statewide fish consumption advisory in 1997 advising women of child bearing age and children six and under not to eat more than one meal per week of any species of fish from waters of the state because of mercury. Lead is used in batteries, pipes, and paints and is emitted from burning fossil fuels. It affects the central nervous system and damages the kidneys and reproductive system. Copper is mined extensively and used to manufacture wire, sheet metal, and pipes. Ingesting large amounts can cause liver and kidney damage. Zinc is a by-product of mining, steel production, and coal burning and used in alloys such as brass and bronze. Ingesting large amounts can cause stomach cramps, nausea, and vomiting.

Metals criteria are established in the Ohio Water Quality Standards to protect human health, wildlife, and aquatic life. Three levels of aquatic life standards are established (Administrative Code 3745-1-07, Table 7-1) and limits for some elements are based on water hardness (Administrative Code 3745-1-07, Table 7-9). Human health and wildlife standards are linked to either the Lake Erie (Administrative Code 3745-1-33, Table 33-2) or Ohio River (Administrative Code 3745-1-34, Table 34-1) drainage basins. The drainage basins also have limits for additional elements not established elsewhere that are identified as Tier I and Tier II values.

Bacteria

High concentrations of either fecal coliform bacteria or *Escherichia coli* (*E. coli*) in a lake or stream may indicate contamination with human pathogens. People can be exposed to contaminated water while wading, swimming, and fishing. Fecal coliform bacteria are relatively harmless in most cases, but their presence indicates that the water has been contaminated with feces from a warm-blooded animal. Although intestinal organisms eventually die off outside the body, some will remain virulent for a period of time and may infect humans. This is especially a problem if the feces contained pathogens or disease producing bacteria and viruses. Reactions to exposure can range from an isolated illness such as skin rash, sore throat, or ear infection to a more serious wide spread epidemic. Some types of bacteria that are a concern include *Escherichia*, which cause diarrhea and urinary tract infections, *Salmonella*, which cause typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which cause severe gastroenteritis or bacterial dysentery. Potential waterborne viruses that are a concern include polio, hepatitis A, and encephalitis. Disease causing parasitic microorganisms such as cryptosporidium and giardia are also a concern.

Since fecal coliform bacteria are associated with warm-blooded animals, there are both human and animal sources. Human sources, including effluent from sewage treatment plants or discharges by on-lot wastewater treatment systems, are a more continuous problem. Bacterial contamination from combined sewer overflows are associated with wet weather events. Animal sources are usually more intermittent and are also associated with rainfall, except when domestic livestock have access to the water. Large livestock farms store manure in holding lagoons and this creates the potential for an accidental spill. Liquid manure applied as fertilizer is a runoff problem if not managed properly as it may seep into field tiles or travel overland during precipitation events.

Bacteria criteria for the recreational use are established in the Ohio Water Quality Standards to protect human health. The maximum and average limits are tiered values and linked to use designation, but only apply during the May 1-October 15 recreation season (Administrative Code 3745-1-07, Table 7-13). The standards also state that streams must be free of any public health nuisance associated with raw or poorly treated sewage during dry weather conditions (Administrative Code 3745-1-04, Part F).

Sediment Contamination

Chemical quality of sediment is a concern because many pollutants bind strongly to soil particles and are persistent in the environment. Some of these compounds accumulate in the aquatic food chain and trigger fish consumption advisories, but others are simply a contact hazard because they can cause skin irritation, skin cancer and tumors. The physical and chemical nature of sediment is determined by local geology, land use, and contribution from manmade sources. As some materials enter the water column they are attracted to the surface electrical charges associated with suspended silt and clay particles. Others simply sink to the bottom due to their high specific gravity. Sediment layers form as suspended particles settle, accumulate, and combine with other organic and inorganic materials. Sediment is the most physically, chemically, and biologically reactive at the water interface because this is where it is affected by sunlight, current, wave action, and benthic organisms. Assessment of the chemical nature of this layer can be used to predict ecological impact.

Sediment chemistry results are evaluated by Ohio EPA using a dual approach, first by ranking relative concentrations based on a system developed by Ohio EPA (1996) and then by determining the potential for toxicity based on guidelines developed by

MacDonald et al. (2000). The Ohio EPA system was derived from samples collected at ecoregional reference sites. Classes are grouped in ranges that are based on the median analytical value (non-elevated) plus 1 (slightly elevated), 2 (elevated), 4 (highly elevated), and 8 (extremely elevated) inter-quartile values. The MacDonald guidelines are consensus based using previously developed values. The system predicts that sediments below the threshold effect concentration (TEC) are absent of toxicity and those greater than the probable effect concentration (PEC) are toxic.

Sediment samples collected by the Ohio EPA are measured for a number of physical and chemical properties. Physical attributes included % particle size distribution (sand ≥60 µ, silt 5-59 µ, clay ≤4 µ), % solids, and % organic carbon. Due to the dynamics of flowing water, most natural streams in Central Ohio do not contain a lot of fine grained sediment and samples often consist mostly of sand. Fine grained sediments are deposited in flood plains of natural streams during periods of high flow. This scenario changes if the stream is impounded by a dam or channelized. Chemical attributes included metals, volatile and semi-volatile organic compounds, pesticides, and poly-chlorinated biphenyls (PCBs).

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Fourmile Creek, Indian Creek, and Select Tributaries, 2005

Preble and Butler Counties

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INTRODUCTION

Ambient biological, water column chemical, and sediment sampling occurred in the Fourmile Creek and Indian Creek study areas from June through September, 2005. The Fourmile Creek watershed is located in southwestern Ohio with its headwaters originating in Preble County and Union County, Indiana, meandering south into Butler County, and passing through Acton Lake within Hueston Woods State Park and adjacent to the town of Oxford before joining the Great Miami River at the town of New Miami. The Sevenmile Creek sub-watershed was evaluated in 2002 (OEPA 2005). The Indian Creek watershed is adjacent to and directly south of the Fourmile Creek watershed. It originates in Union County, Indiana, and then flows through Butler County before joining with the Great Miami River. A list of the mainstem and tributary sites evaluated in this study are included in Table 1.

Objectives of the study were to:

1) Monitor and assess the chemical, physical and biological integrity of the water bodies within the Fourmile Creek and Indian Creek study areas;

2) Assess the physical conditions in streams listed in the study plan to identify their potential to support aquatic biological communities;

3) Characterize the amount of aquatic resource degradation attributable to various land uses including agricultural practices, rural development, urban and suburban community development;

4) Evaluate the biological potential to support the WWH use designation in any subsequently identified candidate WWH stream; and

5) Determine any aquatic impacts from known point sources including the Oxford WWTP.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g., NPDES permits, Director’s Orders, or the Ohio Water Quality Standards (OAC 3745-1)), and may eventually be incorporated into State Water Quality Management

Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c, 2006a, 2006b), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995, 2006c) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in Table 1.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 2) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the QHEI developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995, Ohio EPA 2006c). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently reflect habitat conditions which have the ability to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each location using decontaminated stainless steel scoops and excavated using nitrile gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with teflon® lined lids, placed on ice (to maintain 4^oC) in a cooler, and shipped to an Ohio EPA contract lab. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature. Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000) and Ohio Specific Reference Values (2003).

Recreational Use Assessment

Recreation use attainment was assessed by using fecal coliform and *E. coli* bacteria as test organisms. Their presence indicates that the water has been contaminated with feces from warm blooded animals. Counts are reported in colony forming units (CFU)/100 ml. To determine if criteria codified in OAC 3745-1-07 are met, a minimum of five samples must be collected within any 30-day period during the recreation season (May 1-October 15). Rules for the PCR use state that the fecal coliform geometric mean shall not exceed 1000 and not more than 10% of the samples shall exceed 2000 and that the *Escherichia coli* geometric mean shall not exceed 126 and not more than 10% of the samples shall exceed 298.

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). Stations with insufficient flow to place artificial substrates or where the artificial substrates were missing were only sampled qualitatively from the natural substrates. These stations were evaluated and assigned a narrative evaluation based on community attributes such as EPT (Ephemeroptera – mayfly, Plecoptera – stonefly, and Trichoptera – caddisfly) diversity and predominance, sensitive taxa diversity and predominance, and tolerant taxa predominance. Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b) and 2006 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities (Ohio EPA 2006b).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b) and 2006 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities (Ohio EPA 2006b).

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem “health” compared to human patient “health” (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

Table 1. Sampling locations for the Fourmile Creek and Indian Creek study areas, 2005. **M** - macroinvertebrate quantitative sample, M - macroinvertebrate qualitative sample, **F** - fish sample (2 passes), F - fish sample (1 pass), C - conventional water chemistry parameters (5 runs), B - bacteria (5 runs), S - sediment sample (conventional and organics), Pd - dissolved phosphorus, Chl -chlorophyll a, D-datasonde monitor, O-organic water chemistry (2 runs). Latitude/longitude coordinates are provided in WGS84 datum.

Stream RM*	Sample Type	Lat/Long (DD)	Location	USGS Quad
Fourmile Creek				
41.10	C,F,M	39.7609/84.7887	Farm lane upstream Weist Rd	New Paris
38.95	C,F,M	39.7365/84.7742	Concord-Fairhaven Rd	Fairhaven
35.62	C,B,S,**F**,**M**	39.6999/84.7696	Concord-Fairhaven Rd	Fairhaven
30.71	C	39.6558/84.7694	Paint Creek Fourmile Rd, upst Fairhaven	Fairhaven
28.90	C,B,S,O,D	39.6341/84.7745	Adj. Creek Rd; dst Fairhaven	Fairhaven
26.73	C,B,S,O,**F**,**M**	39.6115/84.7852	Junction Rd	College Corner
24.77	C,B,**F**,M	39.5919/84.7705	Camden-College Corner Rd	College Corner
20.25	C,B,S,O,D,M	39.5424/84.7371	Buckley Rd; Dst. Acton Lake	Oxford
18.75	C,B,**F**,**M**	39.5231/84.7339	Dst. Elams Run, Dst. SR 732	Oxford
16.40	C,B,S,O,D, **F**,**M**	39.4972/84.7158	Ust. Oxford WWTP	Millville
16.20	C,B,S,O,D,**F**,**M**	39.4966/84.7125	Dst. Oxford WWTP (outside mixing zone)	Millville
13.65	C,B,**F**,M	39.4817/84.6861	Lanes Mill Rd.	Millville
11.00	C,S,O,D,Pd,Chl **F**,**M**	39.4874/84.6531	SR 177	Millville
5.40	C,B,S,O,**F**,M	39.4631/84.5828	Eaton Rd.	Hamilton
0.35	C,S,O, D,**F**,**M**	39.4308/84.5440	Seven Mile Ave	Hamilton
Dixon Branch				
0.30	C,F,M	39.6998/84.7538	California School Rd	Fairhaven
East Fork Fourmile Creek				
5.22	C,O,F,M	39.6505/84.7415	SR 732	Eaton South
2.42	C,F,M	39.6197/84.7583	SR 177	College Corner
Paxton Branch				
1.00	C	39.5908/84.7817	Camden-College Corner Rd	College Corner
Little Fourmile Creek				
13.50	C,F,M	39.6762/84.8095	SR 177	Fairhaven
2.80	C,B,S,O,**F**,M	39.5830/84.7978	Upst Fairhaven College Corner Rd	College Corner
Fleisch Run				
0.72	C,B,F,M	39.6558/84.8074	Paint Creek Fourmile Rd	Fairhaven
Tributary to Fourmile Creek @ RM 23.57 (Morning Sun Tributary – north)				
0.60	C,B,F,M	39.5909/84.7554	Main Loop Rd (Hueston Woods St Prk) Dst. Morning Star	College Corner
Tributary to Fourmile Creek @ RM 23.57/0.25 (Morning Sun Tributary - south)				
0.35	C,B,F,M	39.5895/84.7505	Main Loop Rd (Hueston Woods St Prk) Dst. Morning Star	College Corner

Stream RM*	Sample Type	Lat/Long (DD)	Location	USGS Quad
Elams Run				
0.30	C,S,F,M	39.5211/84.7375	Upstream Corso Rd	Oxford
Harkers Run				
2.37	C,F,M	39.5393/84.7089	Somerville Rd, dst tributary	Oxford
Collins Creek				
0.56	C,F,M	39.4985/84.7293	US 27	Millville
Darrs Run				
2.13	C,B,S,O,D,F,M	39.5079/84.6623	SR 73	Oxford
Stony Run				
0.30	C,F,M	39.4681/84.6319	SR 177	Millville
Indian Creek				
23.95	C,S,O,D,**F**,M	39.5085/84.8148	Fairfield Rd, near-Ohio/Indiana border	College Corner
17.68	C,B,D,**F**,**M**	39.4485/84.7761	Indian Creek Rd-southern crossing	Reily
15.12	Flows only	39.4352/84.7601	SR 732	Reily
12.6	D	39.4179/84.7291	Garner Rd.	Reily
9.40	C,S,O,D,**F**,**M**	39.4021/84.6828	Adj. Reily-Millville Rd	Millville
6.80	C,B,S,O,D (7.6),**F**,**M**	39.3870/84.6463	Ust. Queen Acres WWTP	Millville
6.50	C,B,S,O,**F**,**M**	39.3846/84.6458	Dst. Queen Acre WWTP	Millville
4.30	C,D,**F**,M	39.3631/84.6436	Hamilton-New London Rd	Shandon
1.66	C,B,D	39.3374/84.6268	SR 128	Shandon
0.10 –1 sample	C,S,O	39.3226/84.6274	Gravel pit at mouth	Shandon
Little Indian Creek				
0.09	C,D,F,M	39.4291/84.7585	Sawmill Road at mouth	Reily
Reserve Run				
0.25	C,S,O,F,M	39.4296/84.6928	Adj. Reily-Millville Rd	Millville
Salmon Run				
1.90	C,F,M	39.4291/84.6950	Salmon Road	Millville
0.10	C,B,F,M	39.4047/84.6934	Adj. Reily-Millville Rd	Millville
Tributary to Salmon Run				
1.40	C	39.4467/84.6878	Hussey Road	Millville
0.10	C	39.4286/84.6941	Salmon Road	Millville
Lick Run				
0.90	C,F,M	39.3912/84.6790	Ross Rd	Millville
Beals Run				
0.10	C	39.3898/84.6493	Near mouth, Dst trib	Millville

* RM = River Mile of the sample. The RM in this table is for the chemistry sampling, the biological samples may have been conducted a few tenths of a mile upstream or downstream.

SUMMARY

A summary of monitoring results, attainment status for current or recommended aquatic life uses, and causes and sources of impairment or threats to attainment in the Fourmile Creek and Indian Creek study areas can be found in Table 2. Biological, physical habitat, and surface water chemistry information was collected from 26 stations in 12 streams in the Fourmile Creek watershed (excluding Sevenmile Creek) and from 11 stations in five streams in the Indian Creek basin. Of these, 18 were in full attainment (72%) and seven were partially attaining in the Fourmile Creek watershed and seven were in full attainment (64%), two were partially attaining, and one was not attaining in the Indian Creek watershed. Overall, the biological communities in these two basins were evaluated as good to exceptional. The majority of stream stations that were not in full attainment were impacted by low stream flow conditions. While the fish communities sampled were found to be intact and apparently adapted to the changes in flow regime, the macroinvertebrate communities did not fare as well. In these cases, most sensitive taxa that would normally be present in a flowing stream with riffle/run complexes were not found.

Bacteriological samples (fecal coliform and *E. coli*) were collected from 15 stations in the Fourmile Creek watershed and five stations in the Indian Creek watershed to evaluate attainment of the existing or recommended recreational use designations. Considering the entire Fourmile Creek watershed as a whole, the recreational use was met for the Primary Contact Recreation use designation. However, individual stations with at least one bacterial indicator not meeting the criteria included Fourmile Creek (RMs 35.62, 20.25), Fleisch Run (RM 0.72), and Morning Sun Tributary - South (RM 0.35). Fleisch Run, in particular, had the highest bacterial concentrations of the survey (medians of 3400 colonies/100ml fecal coliform and 1500 colonies/100ml *E. coli*). The Indian Creek watershed as a whole was meeting the Primary Contact Recreation use designation. However, individual stations with at least one bacterial indicator not meeting the criteria were found at three Indian Creek stations (RMs 17.68, 6.80, 6.50).

Fourmile Creek Mainstem

This study included 13 stations on the Fourmile Creek mainstem from the headwaters at Weist Road (RM 41.1) to near its confluence with the Great Miami River at Seven Mile Avenue (RM 0.3). Eleven stations were in full attainment of their aquatic life use designation, one was partially attaining, and one station only had qualitative macroinvertebrate sampling, so no attainment status was assigned. Overall, Fourmile Creek was supporting good to exceptional biological communities (Table 2).

The headwaters of Fourmile Creek at Weist Road (RM 40.9) was threatened by nutrient enrichment (median NO_3-NO_2 concentration of 7.03 mg/l) and habitat degradation (riparian removal, siltation, QHEI=44.5) from cattle with unrestricted access to the stream. While the fish community was found to be intact, the macroinvertebrate community was showing signs of degradation. Conditions were improved by the next station downstream.

Acton Lake was evaluated as hypereutrophic based on the Trophic State Index (TSI) values calculated from data collected during this survey. Water near the bottom of the impoundment near the dam was anoxic in the June sampling and near anoxic in October with elevated ammonia-N concentrations (1.01, 0.856 mg/l). The biological integrity in Fourmile Creek downstream from the Acton Lake outflow was threatened by high ammonia-N (range 0.191-4.46, median 3.71 mg/l), low dissolved oxygen (<4.0 mg/l 43% of time on July 5-7 and 78% of the time on September 12-14), and sedimentation. The fish community was not sampled at this station and while the macroinvertebrate community was evaluated as meeting WWH expectations, the presence of unusually high abundances of tolerant organisms and the absence of several sensitive taxa present at upstream and downstream stations were indications of degradation.

The city of Oxford discharges treated wastewater to Fourmile Creek at RM 16.36. The biological communities remained in full attainment of the WWH biocriteria upstream and downstream from the WWTP discharge. The fish communities in particular were performing in the exceptional range throughout this area. The macroinvertebrate communities, on the other hand, were exhibiting incremental declines in EPT and sensitive taxa diversity downstream from the WWTP discharge. Fourmile Creek's aquatic life use designation changes to EWH from Darrtown Road (RM 13.0) to Sevenmile Avenue (RM 0.4). The station at SR 177 (RM 11.0) was not fully meeting the EWH use due to the depressed macroinvertebrate community. The Oxford WWTP was the apparent cause of the gradual decline in the macroinvertebrate community performance. The city's sanitary and storm sewers are completely separate; however, the city's collection system has historically been subject to excessive infiltration and inflow (I/I) resulting in numerous overflows and/or WWTP bypasses during wet weather. In addition to these overflows and bypasses, the WWTP discharge elevated the phosphorus-T concentrations in the stream as far downstream as Eaton Road (RM 5.4).

Water samples from eleven sites in the Fourmile Creek watershed were analyzed for 59 volatile organic compounds, 53 semivolatile compounds, 41 pesticide compounds and seven polychlorinated biphenyl (PCB) congeners. Reflecting the agricultural nature of the watershed, the eleven organic compounds detected were pesticides or pesticide byproducts. The legacy insecticide dieldrin and α-hexachlorocyclohexane each accounted for 18% of the 97 detections, followed by atrazine (15% of detections), metolochlor (15% of detections), and heptachlor epoxide (13% of detections).

Biological community performance in Fourmile Creek has generally improved or remained comparable to previous sampling efforts. One exception was the decline in macroinvertebrate community performance downstream from the Oxford WWTP, which in the 1996 study recovered to upstream conditions, but remained depressed in 2005. Total phosphorus concentrations downstream from the WWTP have consistently remained elevated above the 90^{th} percentile reference concentration (0.22 mg/l) until becoming assimilated fifteen miles downstream near the mouth at RM 0.35. However, the median concentrations of total phosphorus immediately downstream from the Oxford WWTP have gradually declined from 2.38 mg/l in 1991 to 0.71 mg/l in 2005. On the other hand, total suspended solids concentrations were significantly higher downstream from the town of Oxford in 2005 compared to previous studies, with the highest median concentrations peaking at SR 177 (RM 11.0) and Eaton Road (RM 5.4), above the 75th percentile reference value (29 mg/l). This may be due to increases in suspended algae as the result of enrichment.

Fourmile Creek Tributaries

This study included 13 stations on 11 Fourmile Creek tributaries. Seven stations were in full attainment of their existing or recommended aquatic life use designation and six stations were in partial attainment (Table 2).

Fleisch Run (RM 0.7) was impacted by habitat degradation and water quality impairment from cattle with unrestricted access to the stream.

Morning Sun Tributary-South (RM 0.9) was supporting a depauperate fish assemblage. The macroinvertebrate community sampled on 27 July was, however, meeting WWH expectations. The fair fish results may be due to the small size of the stream (3.5 mi^2 watershed) which may be in transition between headwater and primary headwater and/or possibly subject to occasional interstitial flow.

Collins Creek (RM 0.6) is located south of the town of Oxford and receives urban runoff and sanitary sewer overflows. The macroinvertebrate community at this station was not meeting WWH expectations, apparently due to runoff from the town of Oxford. This station was sampled during rapidly rising flows on 30 August, when concentrations of copper (59 µg/l), iron (52,600 µg/l), and barium (241 µg/l) exceeded WQS criteria along with elevated concentrations of TSS (2360 mg/l), arsenic (9.6 µg/l), cadmium (0.59 µg/l), chromium (42 µg/l), lead (36 µg/l), nickel (55 µg/l), zinc (217 µg/l), and aluminum (30,000 µg/l). These values are an indication of the occasional slugs of pollutants that are associated with urban runoff and sanitary sewer overflows.

The macroinvertebrate communities in Harkers Run (RM 2.4), Darrs Run (RM 2.1), and Stony Run (RM 0.3) were impacted by low to interstitial stream flows. These low flows may in part be due to a natural seasonal drop in the water table.

Indian Creek Mainstem

This study included six biological stations on the Indian Creek mainstem from near the Indiana state line (RM 23.9) to Hamilton-New London Road (RM 4.3). All stations were in full attainment of the recommended WWH aquatic life use designation. Overall, Indian Creek was supporting good to exceptional biological communities (Table 2).

The biological index scores in Indian Creek began declining downstream from the community of Millville (RM 6.8) and further declined downstream from the Queen Acres WWTP (RM 6.5) and at Hamilton-New London Road (RM 4.3). Factors that may be contributing to this decline included increased phosphorus-T concentrations downstream from the Queen Acres WWTP, a history of bypassed wastewater from the Millville MHP WWTP into Beals Run and the Queen Acres WWTP, and elevated concentrations of arsenic-T and ammonia-N in the sediments downstream from the unsewered community of Millville, Beals Run, and the Queen Acres WWTP.

Indian Creek Tributaries

The macroinvertebrate communities in Little Indian Creek (RM 0.1), Reserve Run (RM 0.3), Salmon Run (RM 1.9), and Lick Run (RM 0.9) were impacted by low to interstitial stream flows. These low flows may in part be due to a natural seasonal drop in the water table.

Table 2. Aquatic life use attainment status for stations sampled in the Fourmile Creek and Indian Creek basins based on data collected June-October 2005. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Fourmile Creek (except Sevenmile Creek) Watershed Assessment Unit (WAS 05080002 070)							
Fourmile Creek (14-400) *ECBP Ecoregion - WWH Existing*							
41.1[H]/40.9	40	-	MG[NS]	44.5	FULL	Nitrate/nitrite, riparian removal, siltation	Unrestricted cattle access
38.9[H]	54	-	G	65.5	FULL		
35.9[H]	46	-	46	72.0	FULL		
26.7[W]/26.8	48	9.7	52	71.0	FULL		
24.8[W]	42	8.9	G	68.5	FULL		
20.3	-	-	G	-	-	Ammonia, D.O., sedimentation	Acton Lake outflow
18.7[W]	50	10.5	38	81.5	FULL		
16.4[W]	56	10.0	52	78.5	FULL		
16.2[W]	52	11.0	48	74.0	FULL		
13.7[W]/13.6	54	10.0	G	92.5	FULL		
ECBP Ecoregion - EWH Existing							
11.0[W]	52	10.2	40*	74.0	PARTIAL	Phosphorus	Oxford WWTP
5.4[W]	56	10.4	VG[NS]	83.0	FULL		
ECBP Ecoregion - WWH Existing							

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
0.3[B]	42	9.9	42	76.5	FULL		
Dixon Branch (14-406) *ECBP Ecoregion – Undesignated /* WWH Recommended							
0.3[H]	48	-	G	63.0	FULL		
East Fork Fourmile Creek (14-405) *ECBP Ecoregion - WWH Existing*							
5.2[H]	44	-	G	64.5	FULL		
2.4[H]	40	-	E	70.0	FULL		
Little Fourmile Creek (14-404) *ECBP Ecoregion - WWH Existing*							
13.5[H]	44	-	E	74.5	FULL		
2.8[W]	50	8.4	G	78.0	FULL		
Fleisch Run (14-426) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.7[H]	34*	-	G	41.5	PARTIAL	Channelization, riparian removal, siltation, D.O., ammonia, bacteria	Unrestricted cattle access
Morning Sun Trib – North (14-427) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.7[H]/0.6	58	-	G	79.5	FULL		
Morning Sun Trib – South (14-434) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.9[H]	28*	-	G	69.0	PARTIAL	Transition between headwater and primary headwater habitat	Natural
Elams Run (14-423) *ECBP Ecoregion - WWH Existing*							
0.3[H]/0.2	50	-	G	65.0	FULL		
Harkers Run (14-408) *ECBP Ecoregion - WWH Existing*							
2.4[H]	36[NS]	-	F*	67.5	PARTIAL	Low to interstitial stream flow	Natural

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Collins Creek (14-433) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.6[H]	50	-	F*	60.5	PARTIAL	Metals (Cu, Fe, Ba), increase in flow extremes (flashiness)	Urban runoff from Oxford
Darrs Run (14-424) *ECBP Ecoregion - WWH Existing*							
2.1[H]	44	-	F*	54.5	PARTIAL	Interstitial stream flow	Natural
Stony Run (14-432) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.3[H]	54	-	Low F*	52.0	PARTIAL	Interstitial stream flow	Natural
Indian Creek Watershed Assessment Unit (WAS 05080002 080)							
Indian Creek (14-010) *ECBP Ecoregion - EWH Existing / WWH Recommended*							
23.9[W]	38[NS]	9.7	VG	64.0	FULL		
17.7[W]/17.8	48	10.4	48	67.5	FULL		
9.4[W]/9.7	54	10.3	52	59.0	FULL		
6.8[W]/6.9	48	10.4	44	74.5	FULL		
6.5[W]/6.4	46	10.3	40	67.0	FULL	Phosphorus	Queen Acres WWTP
4.3[W]	42	10.8	G	55.5	FULL		
Little Indian Creek (14-198) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.1[H]	52	-	F*	65.0	PARTIAL	Interstitial stream flow	Natural
Reserve Run (14-197) *ECBP Ecoregion – Undesignated / WWH Recommended*							
0.3	-	-	Low F*	-	-	Interstitial stream flow	Natural
Salmon Run (14-011) *ECBP Ecoregion - EWH Existing / WWH Recommended*							
1.9[H]	44	-	P*	63.0	**NON**	Interstitial stream flow	Natural

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
0.1[H]	52	-	G	58.0	FULL		
Lick Run (14-198)	*ECBP Ecoregion – Undesignated / WWH Recommended*						
0.9[H]	50	-	F*	68.0	PARTIAL	Interstitial stream flow	Natural

Ecoregion Biocriteria: Eastern Corn Belt Plains

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters (H)	40	50	24				36	46	22
Wading (W)	40	50	24	8.3	9.4	4.0	36	46	22
Boat (B)	42	48	24	8.5	9.6	4.0	36	46	22

H Headwater site.

W Wading site.

B Boat site.

a MIwb is not applicable to headwater streams with drainage areas < 20 mi^2.

b A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

c Attainment status is given for the existing or, if a change is proposed, the recommended use designation.

ns Nonsignificant departure from biocriterion (<4 IBI or ICI units, or <0.5 MIwb units).

* Indicates significant departure from applicable biocriterion (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

RECOMMENDATIONS

Changes in Aquatic Life Uses

Current and recommended aquatic life, water supply and recreation uses are presented in Table 3. A number of the tributary streams evaluated in this study were originally assigned aquatic life use designations in the 1978 and 1985 Ohio WQS based largely on best professional judgment, while others were left undesignated. The current biological assessment methods and numerical criteria did not exist then. This study, as an objective and robust evaluation of beneficial uses, is precedent setting in comparison to the 1978 and 1985 designations. Several sub-basin streams have been evaluated for the first time using a standardized biological approach as part of this study. Ohio EPA is obligated by a 1981 public notice to review and evaluate all aquatic life use designations outside of the WWH use prior to basing any permitting actions on the existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

Fourmile Creek Watershed
Eight tributaries to Fourmile Creek were sampled for the first time by Ohio EPA during this study. Stony Run, Collins Creek, Morning Sun Tributary – North, Morning Sun Tributary – South, Little Fourmile Creek, Fleisch Run, East Fork, and Dixon Branch were all identified as having the potential to support WWH communities and have, thus, been recommended for the WWH aquatic life use designation. Elams Run was previously assigned the Secondary Contact Recreation use designation. However, using the current criteria and considering that the lower portion is accessible from a parking area and that housing development is increasing adjacent to the stream, the recreational use designation should be changed to Primary Contact Recreation.

Indian Creek Watershed
This study is the first time that the entire length of Indian Creek located in Ohio was sampled by the Ohio EPA. Based on the results of this study, WWH is recommended for the aquatic life use designation. The primary reason why EWH would not be appropriate was that only one station, out of all the sampling events over the years, was fully attaining the EWH biocriteria indexes for both organism groups (RM 9.4/9.7 in 2005). Additionally, the mean QHEI of 64.58 was below the target value of 75.0 generally considered adequate to support fully exceptional communities. Four tributaries to Indian Creek were sampled for the first time by Ohio EPA during this study. Lick Run, Salmon Run, Reserve Run, and Little Indian Creek were all identified as having the potential to support WWH communities and have, thus, been recommended for the WWH aquatic life use designation.

Improvements to Water Quality

Improvements may be made to water quality throughout the study area by addressing the causes and sources identified within the aquatic life use attainment table (Table 2).

The causes and sources associated with agricultural practices may be addressed by improving riparian buffers, proper fertilizer and pesticide application, and ceasing of traditional 'cleaning' of streams. Funding opportunities should be sought to improve agricultural practices and could include any of the above listed improvements. In particular, it would be beneficial to fence the cattle out of the headwaters of Fourmile Creek (RM 41.1) and Fleisch Run (RM 0.7). Urbanization impairments could be addressed through a combination of regulatory, educational and funding actions including improvements at each WWTP, management of failing septic systems, advances in storm water management, controlled development and alternatives to traditional stream channelization and riparian removal. One method to reduce polluted urban runoff would be to incorporate bioretention areas into existing and new infrastructure. A summery of these structures can be found in the fact sheet http://ohioline.osu.edu/cl-fact/1000.html .

Table 3. Waterbody use designations for the Fourmile Creek and Indian Creek basins. Designations based on Ohio EPA biological field assessments appear as a plus sign (+). Designated use based on the 1978 Water Quality Standards appear as an asterisk (*). Designations based on the 1978 and 1985 standards for which results of a biological field assessment are now available are displayed to the right of existing markers. Designated uses based on results other than Ohio EPA biological data are marked with a circle (o). A delta (Δ) indicates a new recommendation based on the findings of this report.

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Indian creek	*	Δ	*						*+	*+		*+		
Lick run		Δ							Δ	Δ		Δ		
Salmon run	*	Δ	*						*+	*+		*+		
Reserve run		Δ							Δ	Δ		Δ		
Little Indian creek		Δ							Δ	Δ		Δ		
Fourmile creek – headwaters to confluence with Acton lake	*	*+							*+	*+		*+		
- Darrtown rd. (RM 13.0) to Sevenmile ave. (RM 0.4)			+						+	+		+		
- all other segments		+							+	+		+		
Sevenmile creek – Paint creek (RM 15.2) to the mouth			+						+	+		+		
- all other segments		+							+	+		+		
Ninemile creek		*							*	*		*		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Big Cave run		+							+	+		+		
Rush run		+							+	+		+		
Paint creek	*	+							+	+		+		
Opossum run		*							*	*		*		
Sugar run		*							*	*		*		
Beasley run		+							+	+		+		
Pottenger run		+							+	+		+		
Rocky run		+							+	+		+		
Periwinkle run		+							+	+		+		
Becketts run		*							*	*		*		
Stony run		Δ							Δ	Δ		Δ		
Darrs run		+							+	+		+		
Collins creek		Δ							Δ	Δ		Δ		
Bull run		*							*	*		*		
Harkers run		+							*+	*+		*+		
Elams run (Tolland creek)		+							+	+		Δ	+	

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Spring (run)		*							*	*		*		
Morning Sun tributary - north		Δ							Δ	Δ		Δ		
Morning Sun tributary - south		Δ							Δ	Δ		Δ		
Little Fourmile creek	*	*+							*+	*+		*+		
Fleisch run		Δ							Δ	Δ		Δ		
East fork	*	*+							*+	*+		*+		
Dixon branch (Harris run)	*	*+							*+	*+		*+		

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

RESULTS

***Fourmile Creek Watershed Assessment* Unit (WAU 05080002 070)**

Study Area

Encompassing a total drainage area of 315 mi^2, the Fourmile Creek watershed drains 297 mi^2 in Preble and Butler counties in Ohio and 18 mi^2 in Wayne and Union counties in Indiana (ODNR 2001). The Indiana portion of the watershed is not included in this study. The largest tributary, Sevenmile Creek, enters the mainstem at RM 3.74 and drains 137 mi^2. This subwatershed (WAU 05080002 060) was surveyed in 2002 and 2004 and is not included in this current study (See Biological and Water Quality Study of the Sevenmile Creek Basin, 2002 – OEPA Technical Report EAS/2005-12-8; http://www.epa.state.oh.us/dsw/documents/2002SevenmileTSD.pdf). Tributaries studied in the 2005 assessment unit (Figure 2) include Dixon Branch (drainage area 5.4 mi^2, confluence RM 34.80), East Fork Fourmile Creek (drainage area 11.6 mi^2, confluence RM 24.82), Paxton Branch (drainage area 3.4 mi^2, confluence RM 24.32), Little Fourmile Creek (drainage area 16.9 mi^2 in Indiana and 13.6 mi^2 in Ohio, confluence with Acton Lake at RM 23.89), Fleisch Run, a tributary of Little Fourmile Creek (drainage area 5.6 mi^2, confluence RM 11.46), the two Morning Sun tributaries (combined drainage area 8.7 $mi^{2,}$ entering the upper reaches of Acton Lake near RM 23.57), Elams Run (drainage area 2.3 mi^2, confluence RM 18.80), Harkers Run (drainage area 7.7 mi^2, confluence RM 17.26), Collins Creek (drainage area 6.4 mi^2, confluence RM 16.60), Darrs Run (drainage area 9.6 mi^2, confluence RM 10.55), and Stony Run (drainage area 5.3 mi^2, confluence RM 8.68).

While agriculture is the predominant land use (Figure 3) with row crop and pasture respectively accounting for 66.5% and 10.6% of the total watershed area, a significant portion (18.2%) of the land is covered by deciduous forest (University of Cincinnati, 2001). Additionally, in the summer of 1956, an earthen dam was constructed across Fourmile Creek at RM 21.5, creating Acton Lake. With a length from inflow to spillway of 2.7 miles and a mean depth of 3.9 meters (12.8 feet), this 625-acre lake and its 8 miles of shoreline are surrounded by the 3,600-acre Hueston Woods State Park (ODNR 2007). The park includes a small resort lodge, nearly 500 camp sites, boating (10 hp limit), and a golf course. Acton Lake spans the Preble/Butler County line, effectively dividing the watershed into upper and lower reaches with drainage areas above and below the spillway of approximately 99 mi^2 and 79 mi^2, respectively (excluding Sevenmile Creek).

Encompassing 5.7 mi^2 in the northwestern corner of Butler County, the City of Oxford is the largest community in the watershed with a population of approximately 8,500 year-round residents and 16,000 Miami University students each academic year (City of Oxford, 2007). Other communities in the watershed include portions of the Villages of College Corner and New Miami, and the unsewered communities of Fairhaven, Morning Sun, and Darrtown.

During the 2005 survey, the aquatic life use designation in effect for the mainstem of Fourmile Creek was Exceptional Warmwater Habitat (EWH) from RM 13.0 to RM 0.4 and Warmwater Habitat (WWH) in all other segments. East Fork Fourmile Creek, Little Fourmile Creek, Elams Run, Harkers Run, and Darrs Run were designated WWH. With the exception of Elams Run which was designated Secondary Contact Recreation (SCR), the recreation use designation in effect for all of the above streams was Primary Contact Recreation (PCR). Dixon Branch, Paxton Branch, Fleisch Run, Collins Creek, Stony Run and the two Morning Sun tributaries were previously undesignated. Acton Lake is designated EWH, Bathing Water Recreation (BWR), and Public Water Supply (PWS). Acton Lake does not have any public water supply intakes and is designated PWS because all publicly owned lakes have a default PWS use.

There are several dischargers in the assessment unit (Table 14). The Ohio Department of Natural Resources (ODNR) operates three wastewater treatment plants (WWTPs) which discharge to Acton Lake in Hueston Woods State Park (Figure 12). Woodland Country Manor, a nursing home, discharges to an unnamed tributary which enters Harkers Run at RM 2.38. Effluent from the largest discharger in the assessment unit, the City of Oxford WWTP, enters Fourmile Creek at RM 16.36. Marshall Elementary School discharges at approximately RM 0.39 to an unnamed tributary which enters Culane Run at RM 0.82. The New Miami Local School District WWTP which discharged to Fourmile Creek at approximately RM 1.05 during the 2005 survey subsequently connected to the new Butler County New Miami WWTP (discharge to Fourmile Creek at RM 0.55) in late 2006.

Additionally, the City of Oxford's Sanitary Landfill lies south of the city on the north side of Collins Creek (near RM 1.3). Closure activities were completed in November 1995. The capped landfill has not accepted solid waste since the end of 1989. The facility, considered a Significant Industrial User (SIU), has an NPDES indirect discharge permit to discharge leachate to the City of Oxford WWTP. A stormwater collection system collects the stormwater from the landfill and the City's garage and discharges to a sedimentation pond.

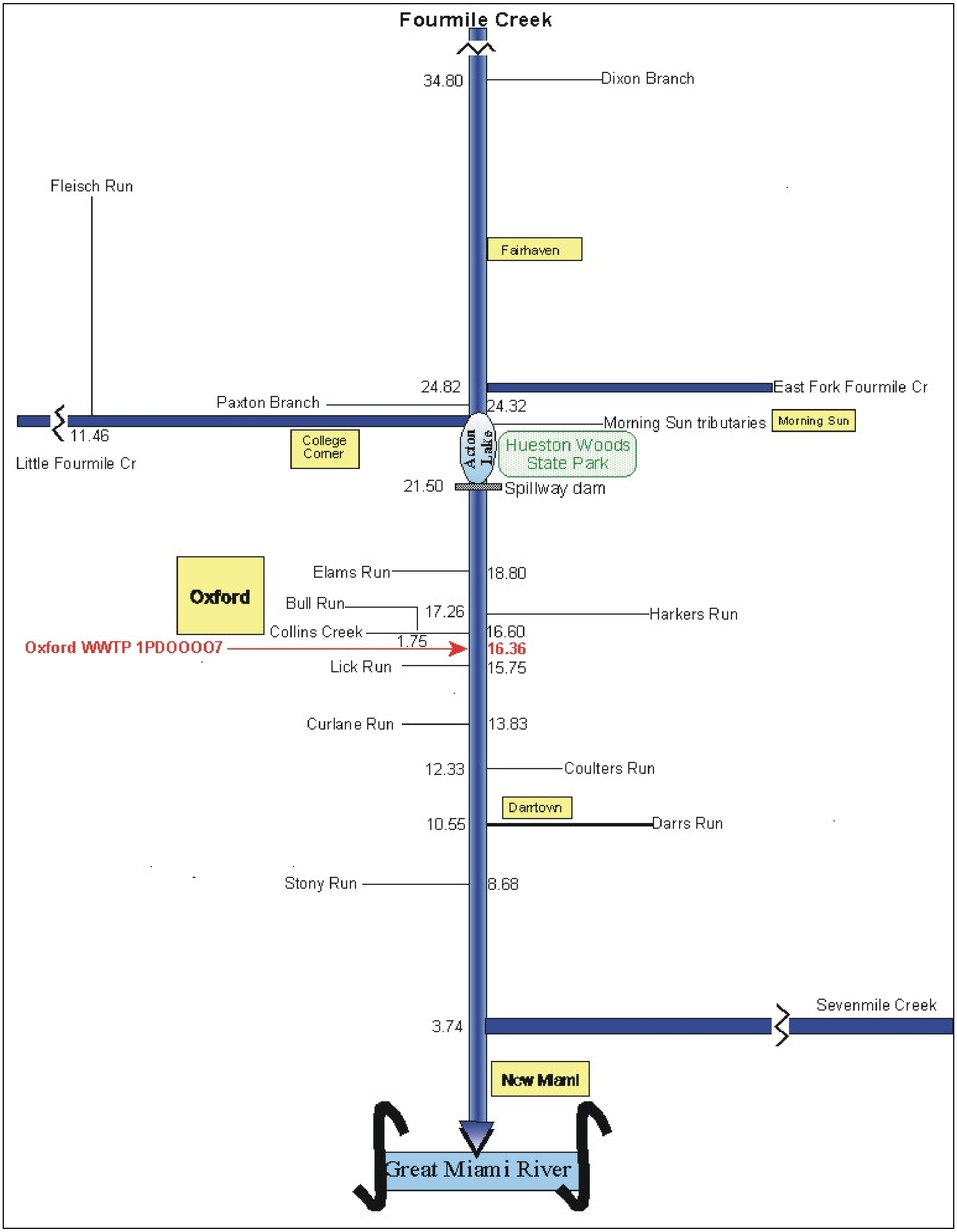


Figure 2. Schematic representation of the Fourmile Creek watershed.

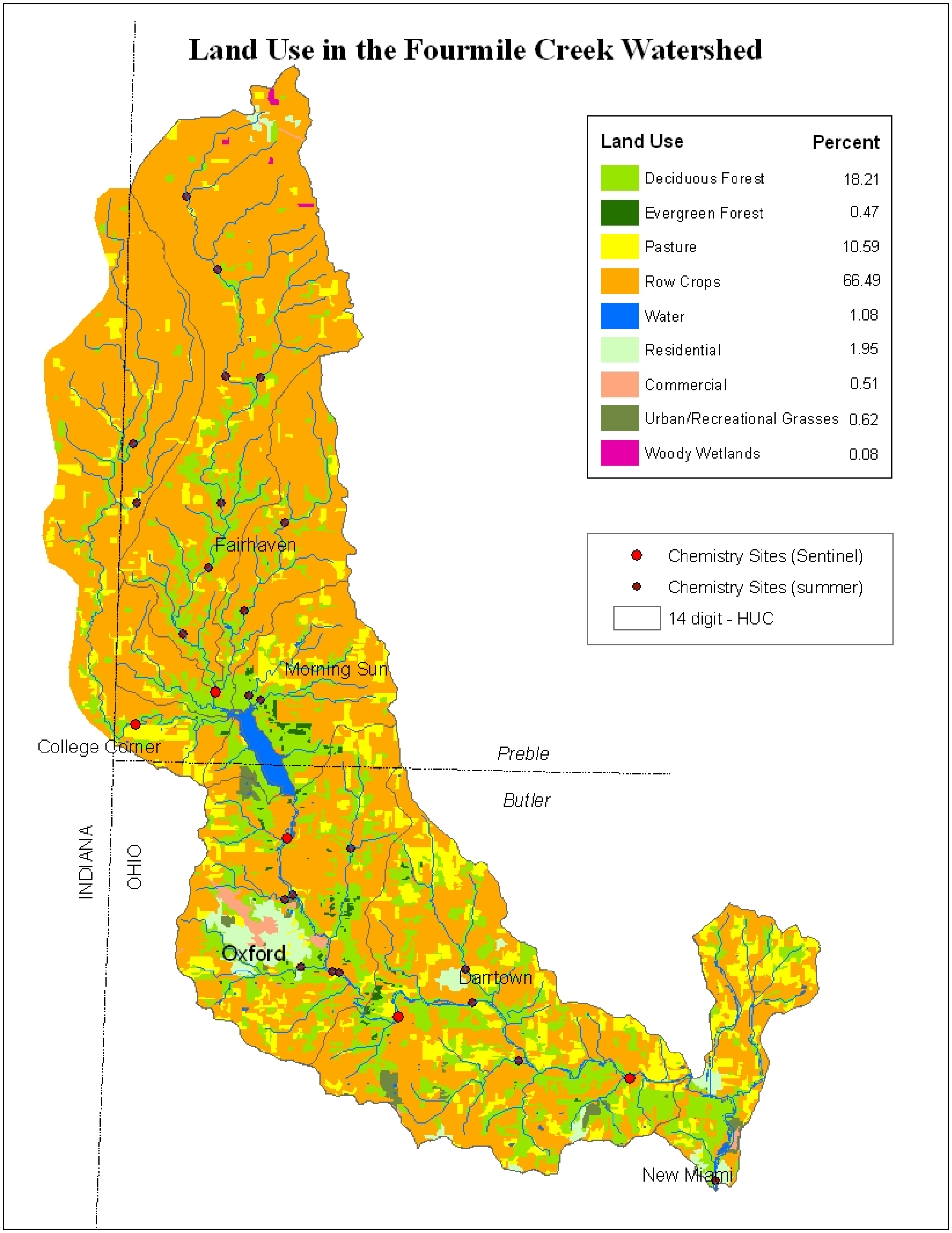


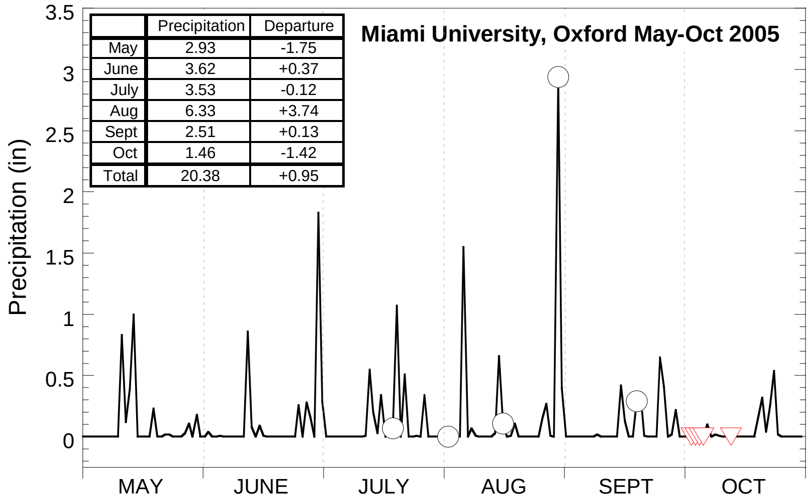
Figure 3. Land Use in the Fourmile Creek Watershed Assessment Unit (WAU 05080002-070).

Chemical Water Quality

Many of the graphs included with the following summaries include dotted lines representing percentile concentrations from least impacted regional reference sites of similar size (Ohio EPA 1999). Statistical data were segregated by ecoregion (all streams in the Fourmile Creek watershed are in the Eastern Corn Belt Plains (ECBP) ecoregion) and further stratified by three ranges of stream and river size for these analyses as follows: headwater streams (0-20 sq. mi.); wadable streams (> 20-200 sq. mi.); and small rivers (> 200-1000 sq mi.).

Inorganic water chemistry grab samples and field measurements were collected every other week (five times) at 15 sites in the mainstem of Fourmile Creek and at 14 sites in its tributaries from mid-July to mid September. All samples were analyzed for a variety of parameters including nutrients and metals (Appendix Table A-1). Eight of the mainstem sites and three of the tributary sites were also sampled for organic compounds twice during the summer survey (Table 6, Appendix Table A-4). Samples from these eleven sites were scanned for 59 volatile organic compounds, 53 semivolatile compounds, 41 pesticide compounds and seven polychlorinated biphenyl (PCB) congeners. Bacteria samples (fecal coliform and *E. coli*) were collected at 15 sites (10 mainstem and 5 tributaries) five times within a thirty-day period in order to determine recreational use attainment (Figure 7 & Figure 11, Table 5, Appendix Table A-2). Additionally, Datasonde® continuous monitors recorded hourly dissolved oxygen (D.O.) concentration, D.O. percent saturation, temperature, pH, and conductivity for a 48-hour period in July and again in September at six sites in the mainstem and at RM 2.13 in Darrs Run (Figure 5).

Total precipitation of 20.38 inches was recorded in Oxford on the Miami University campus from May through October 2005 (OARDC 2007), an inch above normal for the period (Figure 4). The greatest daily rainfall occurred on August 30 (2.94 inches) as the remnants from hurricane Katrina moved through the area. Localized showers and thunderstorms contributed to the Oxford station totals. By comparison, while not in the same watershed, Camden (nine miles northeast of Oxford) recorded only 13.6 inches and Collinsville (seven miles east of Oxford) recorded 18.3 inches for the same period (MCD 2007). There is no active stream flow gauging station in the watershed.



Data collected by remote sensors midnight to midnight.

Figure 4.

Daily precipitation recorded at Miami University in Oxford from May through October (OARDC, 2007). Open circles represent conventional water chemistry sampling days. Triangles represent bacteriological sampling days in the Fourmile Creek watershed.

Fourmile Creek mainstem

Water quality in the mainstem of Fourmile Creek was generally good (Figure 6). Water chemistry results from daytime grab samples which exceeded State of Ohio Water Quality Standards (WQS) criteria in the assessment unit are presented in Table 4. Dissolved oxygen hourly concentrations in the mainstem as measured by Datasonde® continuous monitors remained relatively stable longitudinally (upstream to downstream) with normal diurnal variation and the majority of values above applicable minimum WQS criteria. However, reflecting the impact of the Acton Lake impoundment 1.2 miles upstream, concentrations at Buckley Road (RM 20.25) dropped below the minimum criterion (4.0 mg/l) in 43% of the July measurements (20 of 47) and 78% (36 of 46) of September measurements (Figure 5). Dissolved oxygen saturations as measured by Datasonde® monitors from July 5-7 fluctuated widely from 35% to 96%. Similarly, multiple daytime grab dissolved oxygen concentrations also fell below the minimum WQS criterion. Field notes indicate that the water column was frequently green or cloudy. Additionally, concentrations of ammonia-N at the site exceeded criteria in 80% of samples (4 of 5) and remained elevated downstream at RM 18.75 (median 0.549 mg/l).

Mainstem nitrate-nitrite-N and phosphorus levels were generally low with respective overall medians of 2.5 mg/l and 0.06 mg/l for all samples collected. The highest nitrate-nitrite-N levels of the entire survey (median 7.03 mg/l) were recorded at the headwater site (RM 41.10). Phosphorus concentrations spiked downstream from the Oxford WWTP at RM 16.20 (median 0.73 mg/l) and remained elevated well above ECBP reference values before becoming assimilated near the mouth at RM 0.3 (median 0.04

mg/l). Total suspended solids (TSS) increased from an overall median concentration of 5.5 mg/l for samples collected upstream from Acton Lake to 19 mg/l for samples collected at downstream sites. Concentrations at SR 177 (RM 11.00) and Eaton Road (RM 5.40) were consistently elevated with TSS medians of 52 mg/l and 41 mg/l, respectively.

While most sampling on August 30 was completed during the morning, by early afternoon streams in the study area became increasingly elevated and turbid reflecting the impact of heavy rainfall from the aftermath of Hurricane Katrina. Field crews in the area of the Oxford WWTP observed rapidly rising stream levels within a 20 minute period. Total suspended solids increased from 67 mg/l downstream from the Oxford WWTP at RM 16.20 (sampled at 12:05 pm) to 1520 mg/l at RM 16.40 (sampled at 12:25 pm). Copper (64 µg/l), lead (38.5 µg/l), and iron (44100 µg/l) exceeded WQS criteria at RM 16.40. Additionally, while below WQS criteria, the highest mainstem concentrations of arsenic (8.7 µg/l), cadmium (0.49 µg/l), chromium (35 µg/l), nickel (43 µg/l), zinc (191 µg/l), barium (220 µg/l), and aluminum (28100 µg/l) were also documented at RM 16.40 on this day. Collins Creek, entering the mainstem at RM 16.60, was sampled at 12:45 pm and had similarly elevated parameters (see *Other Tributaries to Fourmile Creek* below). Parameters at RM 16.20, collected 20 minutes earlier than RM 16.40, were not elevated.

Eleven organic compounds were detected in the water column of the mainstem during the summer survey (Table 6, Appendix Table A-4). The most frequently detected compound, dieldrin, accounted for 18% of the total detections (13 of 72) with all concentrations above the non-drinking water human health WQS criterion. Atrazine, metolochlor, and alpha-hexachlorocyclohexane each accounted for another 15% of the detections. Concentrations of heptachlor epoxide and aldrin exceeded non-drinking water human health WQS criteria.

Bacteriological samples collected in the mainstem indicate that the Primary Contact Recreation use was easily attained (Table 5). All concentrations of fecal coliform and 94% of *E. coli* were less than applicable maximum criteria (Figure 7). The highest concentrations were measured in the upper mainstem at RM 35.62 (Concord-Fairhaven Road) and downstream from Acton Lake at RM 20.25 (Buckley Road).

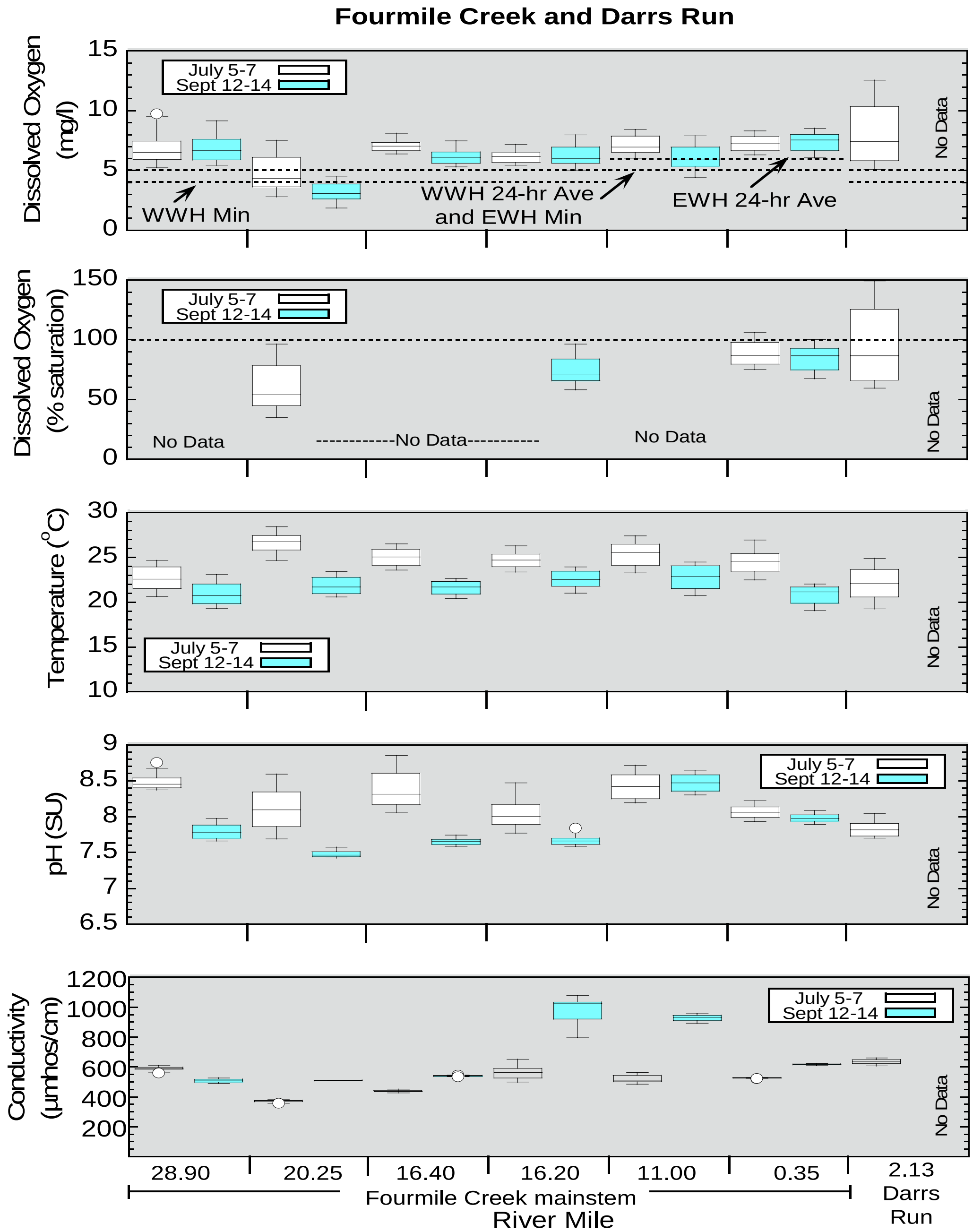


Figure 5. Distributions of dissolved oxygen (concentrations and saturations), temperature, pH, and conductivity recorded hourly with Datasonde® continuous monitors in Fourmile Creek and Darrs Run in 2005. (Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Any value outside of this range, called an outlier, is displayed as an individual point.)

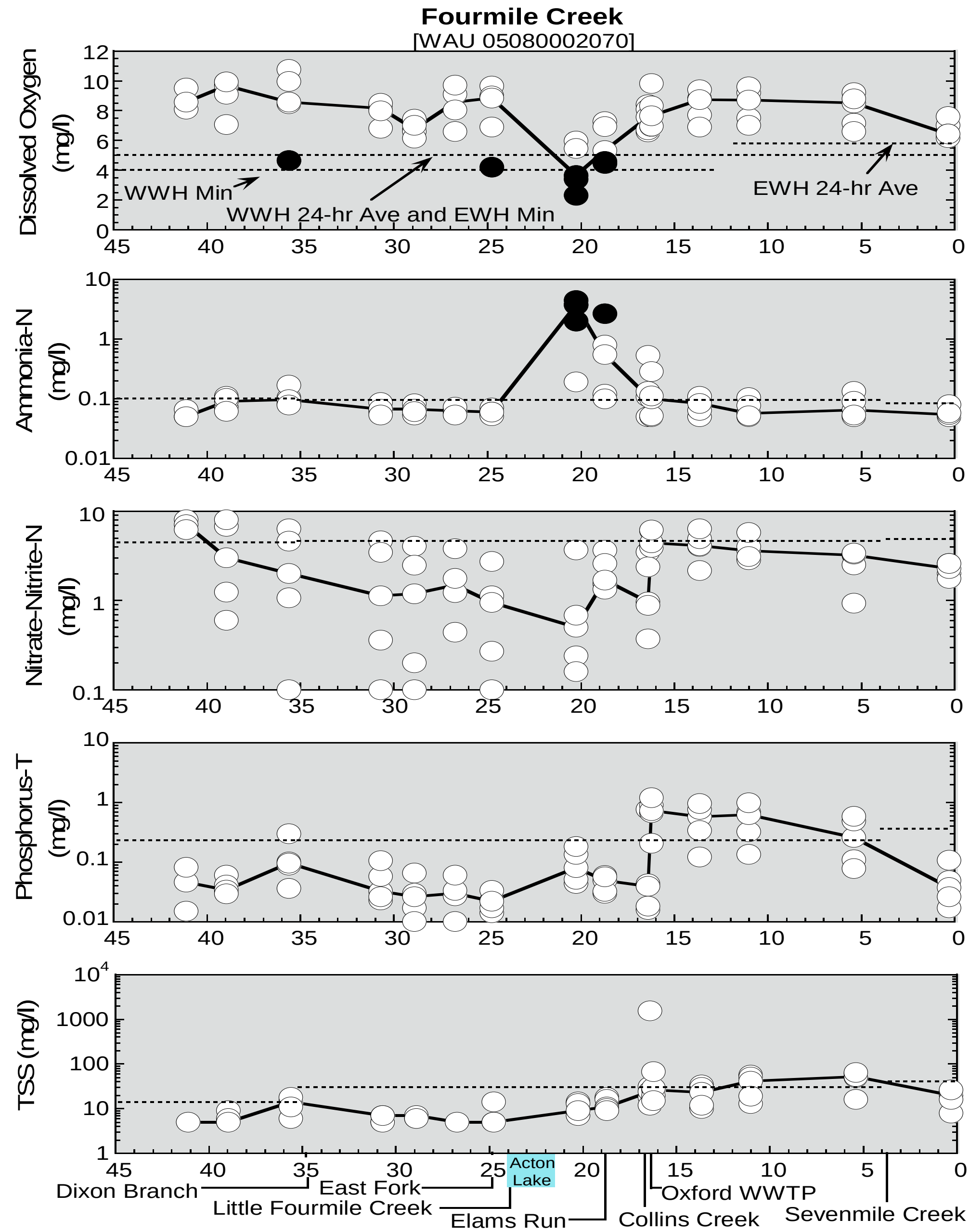


Figure 6. Longitudinal scatter plots of water chemistry daytime grabs in the mainstem of Fourmile Creek during the 2005 survey. Top to bottom: dissolved oxygen, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water Quality Standards criteria are shown in the dissolved oxygen plot. (Values not meeting criteria in the dissolved oxygen and ammonia-N plots are shown as solid circles.) Dotted lines in the other plots represent the 90th percentile concentration (75th percentile concentration for TSS) from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

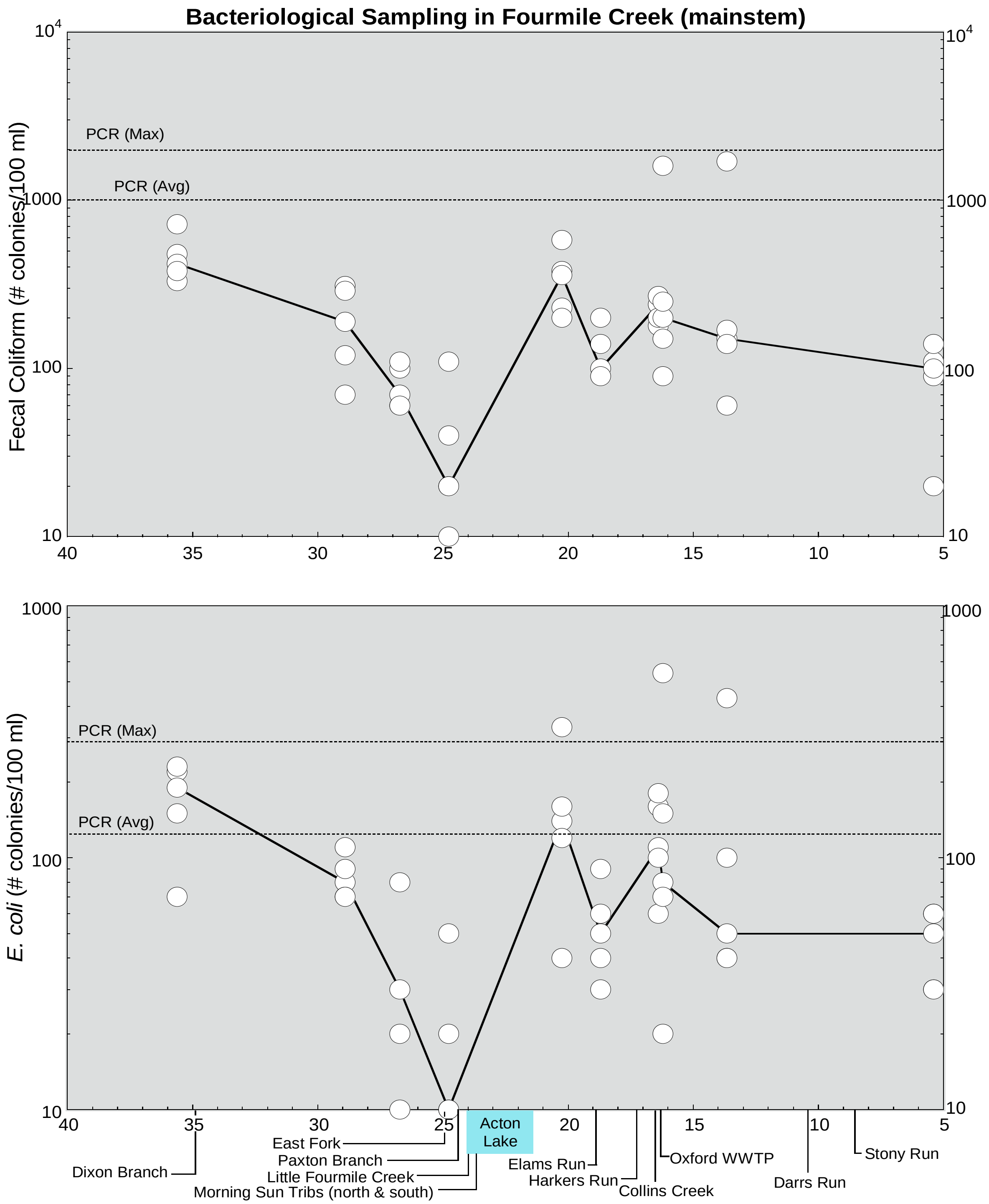


Figure 7. Longitudinal scatter plots of fecal coliform (top) and *E. coli* (bottom) concentrations in the mainstem of Fourmile Creek during the 2005 survey. Dotted lines represent Primary Contact Recreational (PCR) WQS criteria. The solid line depicts the median value at each river mile sampled.

East Fork Fourmile Creek
Two sites (RM 5.22 and RM 2.42) were sampled in East Fork Fourmile Creek (Figure 8). Ammonia, phosphorus, and TSS concentrations were all low and dissolved oxygen levels were above the WWH minimum criterion. While nitrate levels were significantly higher upstream at RM 5.22 (median 2.38 mg/l) compared to the downstream site (median 0.32 mg/l), all values were less than the ECBP reference value (4.6 mg/l). Only the upstream site was sampled for organics and five compounds were detected including metolochlor, heptachlor epoxide, atrazine, alpha-hexachlorocyclohexane, and dieldrin. Concentrations of heptachlor epoxide and dieldrin exceeded non-drinking water human health WQS criteria.

Little Fourmile Creek and Fleisch Run
Two sites were sampled in the mainstem of Little Fourmile Creek (RM 13.5 and RM 2.8) and one site (RM 0.72) was sampled in its tributary Fleisch Run (Figure 9, Figure 11). While the water quality in Little Fourmile Creek was relatively good, exceedences of criteria for dissolved oxygen and ammonia were documented in Fleisch Run. Total suspended solids concentrations at this site (median 28.5 mg/l) were consistently elevated above the ECBP reference value. Additionally, the highest bacteria concentrations of the survey were documented in Fleisch Run (medians of 3400 colonies/100ml fecal coliform and 1500 colonies/100ml *E. coli*). Field notes indicate that the stream bottom substrate was composed predominately of muck and that the water column was frequently brownish green. The site is immediately downstream from a cattle pasture.

The lower site in Little Fourmile Creek (RM 2.80) was also sampled for organic compounds. Six compounds were detected with concentrations of aldrin, dieldrin, and heptachlor epoxide exceeding non-drinking water human health WQS criteria.

Other Tributaries to Fourmile Creek
Water chemistry results for select parameters for nine other tributaries sampled during the 2005 survey are presented in Figure 10. Several daytime grab dissolved oxygen concentrations measured in Stony Run fell below WQS criteria. This stream was interstitial throughout much of the survey. Datasonde® monitors in Darrs Run (Figure 5) documented the widest diel fluctuation of the survey for dissolved oxygen with July concentrations and corresponding saturations ranging from 5.1 mg/l (59%) to 12.6 mg/l (149%). Field notes indicate that the water column at this site was typically somewhat murky and greenish throughout the survey and that flows became interstitial on at least one occasion (August 2). Ammonia levels were low in all of the tributaries with 90% of concentrations below the ECBP reference value of 0.1 mg/l. Nitrate-nitrite-N median concentrations ranged from 0.1 mg/l in Darrs Run and Stony Run to 3.03 mg/l in the Morning Sun tributary (south). Phosphorus levels were also generally low with medians ranging from 0.018 mg/l in Collins Creek to 0.085 mg/l in Stony Run.

Collins Creek, similar to the Fourmile Creek mainstem site upstream from the Oxford WWTP (RM 16.40), was sampled during rapidly rising flows on August 30. This small subwatershed (6.4 mi^2) drains most of the City of Oxford and has an impervious surface of almost 9% (Purdue 2007). Concentrations of copper (59 µg/l), iron (52600 µg/l), and barium (241 µg/l) exceeded WQS criteria. Elevated concentrations of TSS (2360 mg/l), arsenic (9.6 µg/l), cadmium (0.59 µg/l), chromium (42 µg/l), lead (36.5 µg/l), nickel (55 µg/l), zinc (217 µg/l), and aluminum (30000 µg/l) were also documented In Collins Creek on this day.

Bacteria samples were collected in the two Morning Sun tributaries and Darrs Run (Figure 11). Levels were generally low with the highest concentrations measured in the south Morning Sun tributary (medians of 450 colonies/100ml fecal coliform and 250 colonies/100ml *E. coli).* Darrs Run was also sampled for organic compounds. Six compounds were detected and concentrations of aldrin, dieldrin, and heptachlor epoxide were above non-drinking water human health WQS criteria.

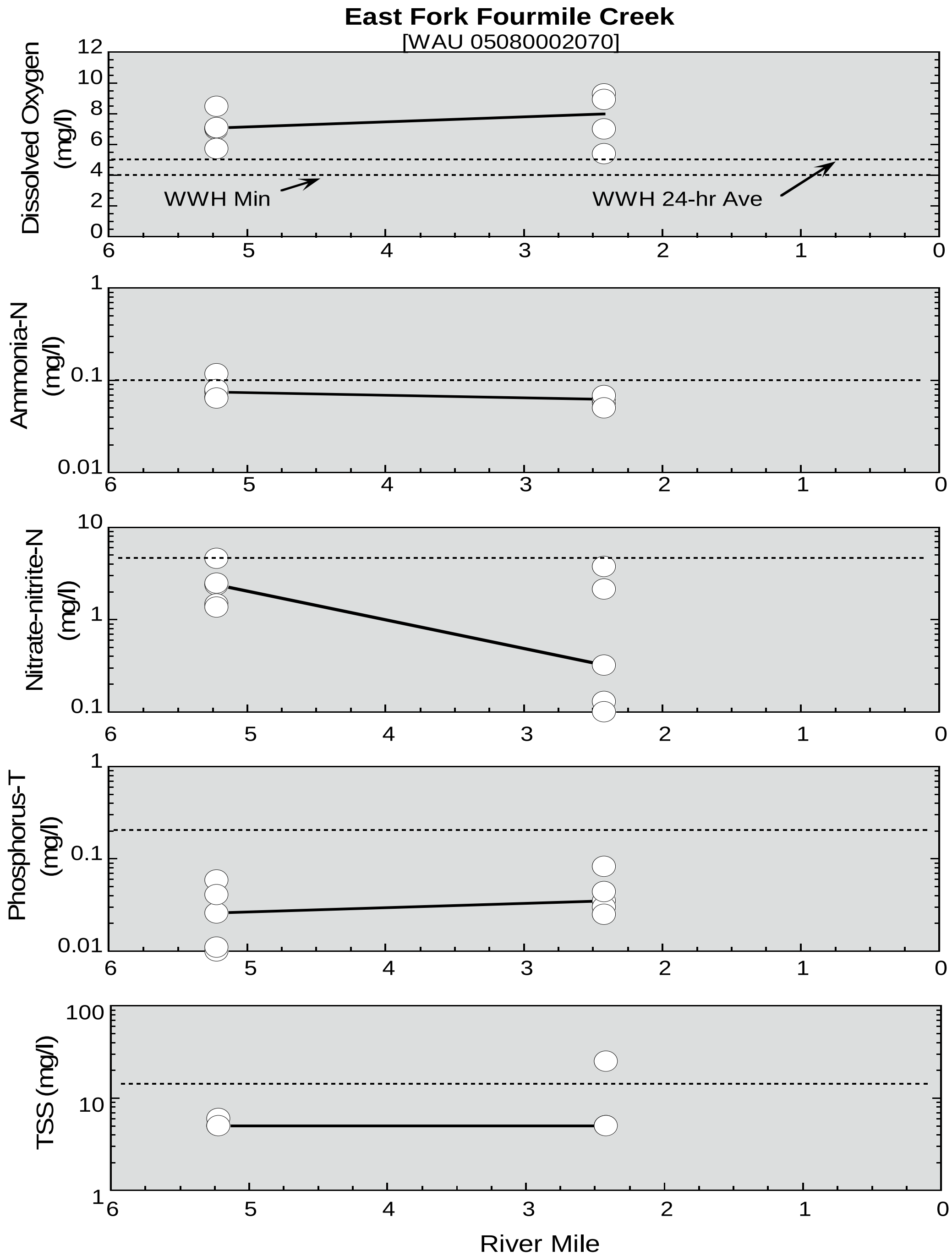


Figure 8. Longitudinal scatter plots of water chemistry daytime grabs in East Fork Fourmile Creek during the 2005 survey. Top to bottom: dissolved oxygen, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water Quality Standards criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration (75th percentile concentration for TSS) from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

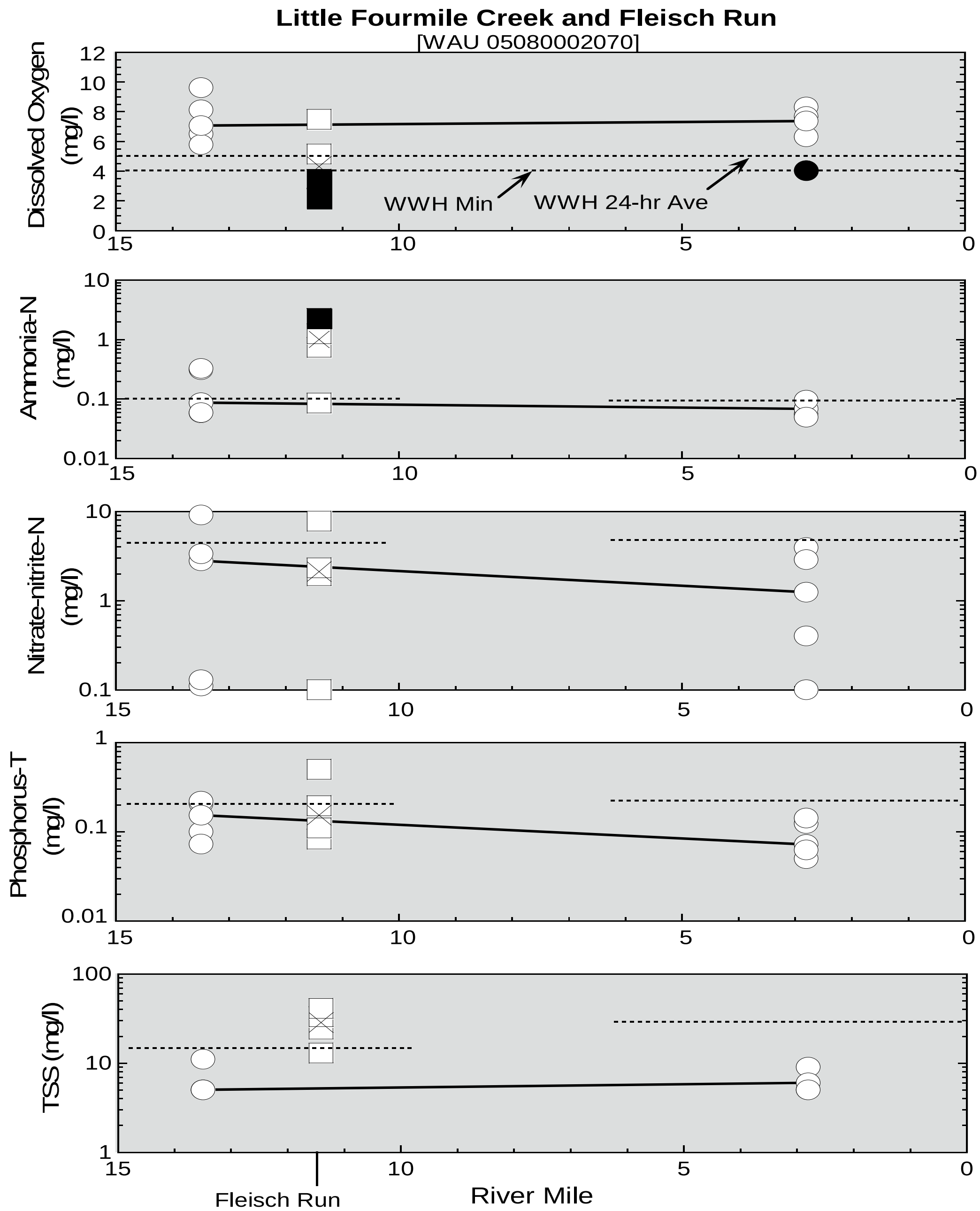


Figure 9. Longitudinal scatter plots of water chemistry daytime grabs in Little Fourmile Creek (circles), and Fleisch Run RM 0.72 (squares) during the 2005 survey. The solid line depicts the median value at each river mile sampled in Little Fourmile Creek while an 'X' depicts the median for Fleisch Run. Water Quality Standards criteria are shown in the dissolved oxygen plot. Values not meeting criteria in the dissolved oxygen and ammonia-N plots are shown as solid circles or squares. Dotted lines in the other plots represent the 90th percentile concentration (75th percentile concentration for TSS) from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

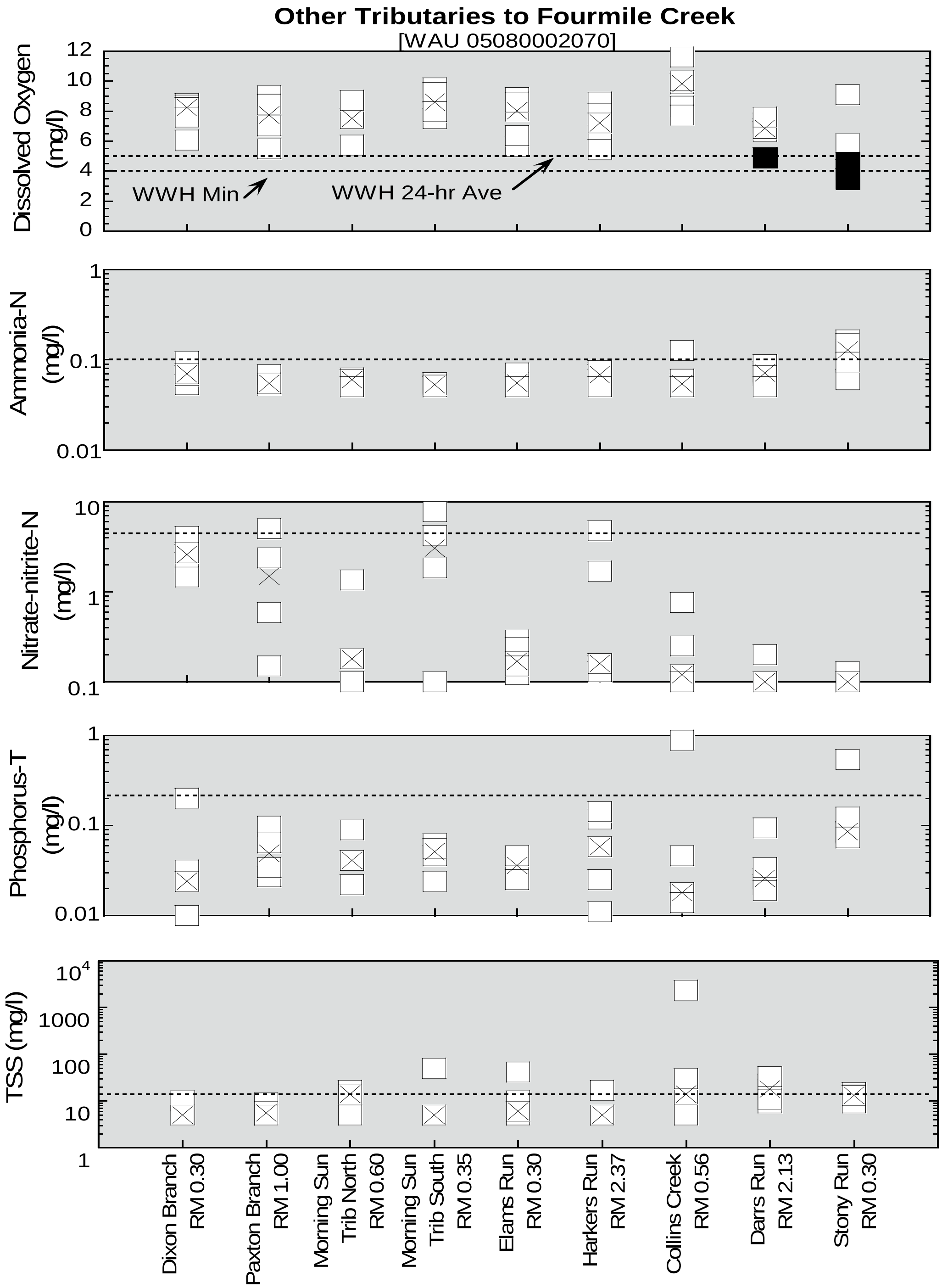


Figure 10. Scatter plots of water chemistry daytime grabs in tributaries to the mainstem of Fourmile Creek (squares) during the 2005 survey. Top to bottom: dissolved oxygen, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The median value at each site is depicted by an 'X'. Water Quality Standards criteria are shown in the dissolved oxygen plot. Values not meeting criteria are shown as solid squares. Dotted lines in the other plots represent the 90th percentile concentration (75th percentile concentration for TSS) from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

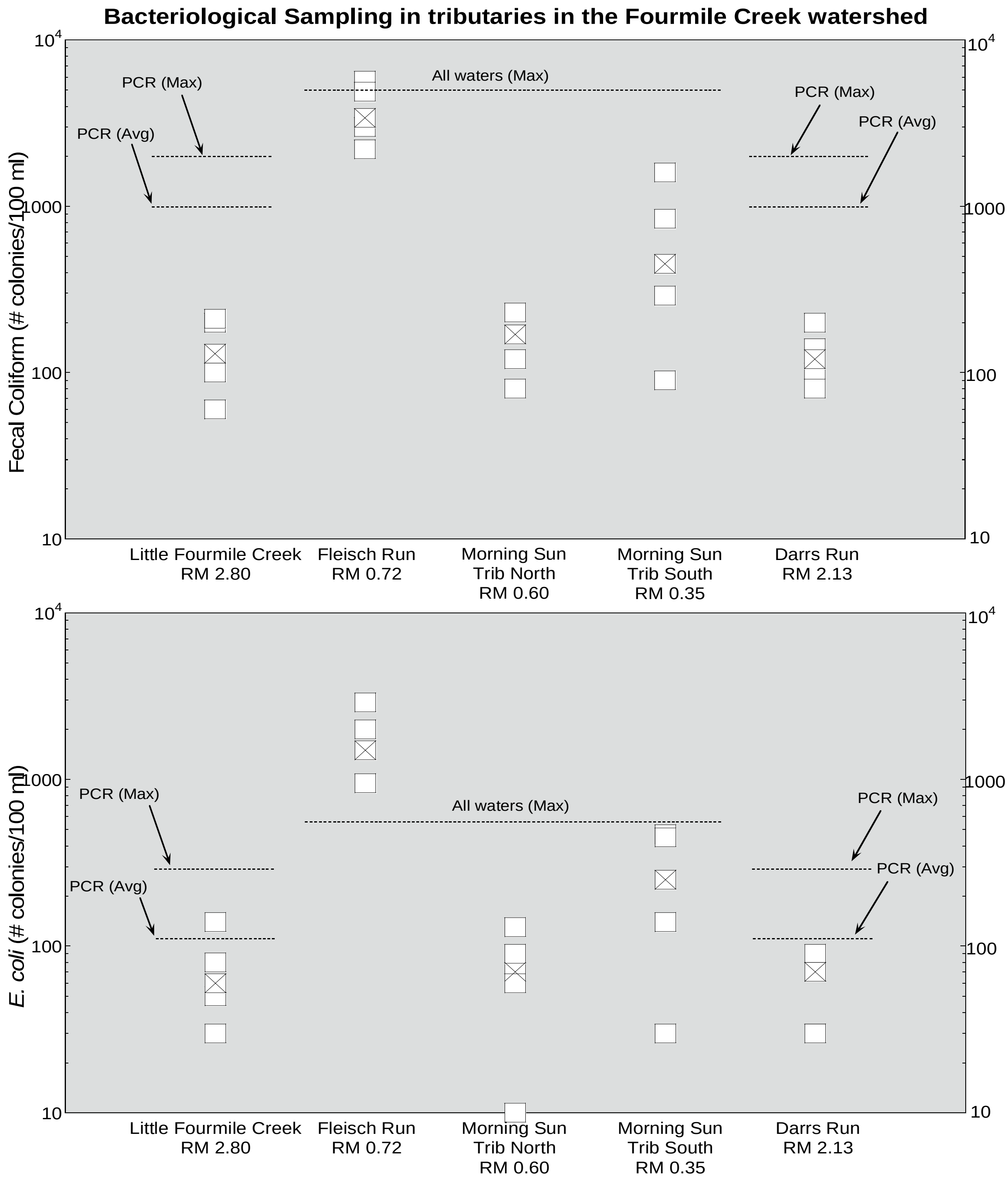


Figure 11. Fecal coliform (top) and *E. coli* (bottom) concentrations in select tributaries in the Fourmile Creek watershed during the 2005 survey. Dotted lines represent applicable Water Quality Standards criteria. The 'X' depicts the median value at the site sampled.

Table 4. Exceedences of Ohio Water Quality Standards criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Fourmile Creek study area during 2005 (units are µg/l for metals and organics, #colonies/100 ml for fecal coliform and *E. coli*, SU for pH, and mg/l for all other parameters).

Stream/Lake (*use designation* [a]) River Mile	Parameter [b] (value)
Fourmile Creek (mainstem) ***(Headwaters to confluence with Acton Lake:SRW, WWH, PCR, AWS, IWS; Darrtown Rd (RM 13.0) to Sevenmile Ave (RM 0.35): EWH, PCR, AWS, IWS; All other segments: WWH, PCR, AWS, IWS)***	
35.62	Dissolved Oxygen (4.65[‡]) *E. coli* (220[◊], 230[◊], 190[◊ JL], 150[◊ JL])
28.90	Aldrin (0.0030[#]) Dieldrin (0.0043[#], 0.0043[#]) Heptachlor epoxide (0.0034[#], 0.0046[#])
26.73	Dieldrin (0.0042[#], 0.0038[#]) Heptachlor epoxide (0.0034[#], 0.0027[#])
24.77	Dissolved Oxygen (4.2[‡])
20.25	Ammonia-N (2.00*, 3.78*, 4.46*, 3.71*) Dissolved Oxygen (3.4[‡‡], 3.65[‡‡], 2.32[‡‡]) Dieldrin (0.0037[#], 0.0039[#]) Heptachlor epoxide (0.0031[#]) *E. coli* (330[◊◊], 140[◊ JL], 160[◊ JL])
18.75	Dissolved Oxygen (4.46[‡], 4.6[‡]) Ammonia-N (2.66*)
16.40	Aldrin (0.0023[#]) Dieldrin (0.0033[#]) Heptachlor epoxide (0.0032[#]) Copper-T (64**) Iron-T (44100[∞]) Lead (38.5*) *E. coli* (160[◊ JL], 180[◊ JL])
16.20	Heptachlor epoxide (0.0024[#]) Dieldrin (0.0048[#]) Fecal coliform (1600[◊ JL]) *E. coli* (540[◊◊], 150[◊ JL])
13.65	Fecal coliform (1700[◊ JL]) *E. coli* (430[◊◊])
11.00	Dieldrin (0.0035[#]) Heptachlor epoxide (0.0026[#])
5.40	Dieldrin (0.0027[#], 0.0040[#])
0.35	Dieldrin (0.0027[#], 0.0022[#])

Stream/Lake (*use designation* [a]) River Mile	Parameter [b] (value)
East Fork Fourmile Creek *(SRW, WWH, PCR, AWS, IWS)*	
5.22	Dieldrin (0.0046[#]) Heptachlor epoxide (0.0025[#], 0.0038[#])
Little Fourmile Creek *(SRW, WWH, PCR, AWS, IWS)*	
2.80	Dissolved Oxygen (4.04[‡]) Aldrin (0.0029[#]) Dieldrin (0.0055[#], 0.0045[#]) Heptachlor epoxide (0.0031[#]) *E. coli* (140[◊ JL])
Fleisch Run *(undesignated)*	
0.72	Dissolved Oxygen (3.44[‡‡], 2.17[‡‡]) Ammonia-N (2.26*) Fecal coliform (5700[◊◊◊]) *E. coli* (2900[◊◊◊], 950[◊◊◊ JL], 2000[◊◊◊],1500[◊◊◊ JL],1500[◊◊◊ JL])
Collins Creek *(undesignated)*	
0.56	Temperature (28.1*) Copper-T (59**) Iron-T (52600[∞]) Barium-T (241*)
Darrs Run *(WWH, PCR, AWS, IWS)*	
2.13	Dissolved Oxygen (4.9[‡]) Aldrin (0.0034[#]) Dieldrin (0.0028[#]) Heptachlor epoxide (0.0032[#], 0.0029[#])
Stony Run *(undesignated)*	
0.30	Dissolved Oxygen (3.47[‡‡], 4.6[‡], 4.1[‡]) Temperature (28.2*)
Acton Lake *(SRW, EWH, BWR, PWS)*	
L-1 (near dam) surface	pH (9.09[Δ]) Lead-T (14.5*)
L-1 (near dam) bottom- 8m	Barium-T (249*) Atrazine (5.14[■]) Dieldrin (0.0048[#■], 0.0020[#■]) Heptachlor epoxide (0.0025[#■])
L-2 (near inlets)-surface	pH (9.29[Δ])
L-2 (near inlets)-bottom -2m	Lead-T (81*) Atrazine (4.03[■]) Dieldrin (0.0053[#■])

Stream/Lake (*use designation* [a]) River Mile	Parameter [b] (value)

a Use designations:
SRW - State Resource Water

Aquatic Life Habitat	Water Supply	Recreation
WWH - warmwater habitat	IWS - industrial water supply	PCR - primary contact
EWH - exceptional warmwater habitat	AWS - agricultural water supply	SCR - secondary contact
Undesignated	PWS - public water supply	BWR - bathing water

└ [WWH criteria apply to 'undesignated' surface waters.]

b Bacteriological data (fecal coliform, *E. coli*) are shown to gauge the potential for impacts to receiving waters. See Table 5 also.

- * exceedence of numerical criterion for prevention of chronic toxicity (CAC).
- ** exceedence of numerical criterion for prevention of acute toxicity (AAC).
- *** exceedence of numerical criterion for prevention of lethality (FAV).
- Δ exceedence of the pH criterion (6.5-9.0).
- # exceedence of numerical criterion for the protection of human health (non-drinking-protective of people against adverse exposure to chemicals via eating fish).
- ■ exceedence of numerical criterion for the protection of human health (drinking water-public water supply).
- ∞ exceedence of agricultural water supply criterion.
- ‡ value is below the EWH minimum 24-hour average D.O. criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O. criterion (5.0 mg/l) as applicable.
- ‡‡ value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) as applicable.
- ◊ value is above the average PCR criterion (fecal coliform 1000/100ml; *E. coli* 126/100ml)
- ◊◊ value is above the maximum PCR criterion (fecal coliform 2000/100ml; *E. coli* 298/100ml)
- ◊◊◊ value is above maximum criteria applicable to all waters (fecal coliform 5000/100ml; *E. coli* 576/100ml).
  [Requirements associated with the maximum criteria applicable to all waters include: samples must be collected during steady state flow representative of dry weather conditions; at least two or more samples must exceed criteria when five or fewer samples are collected, or criteria must be exceeded in more than twenty percent of the samples when more than five samples are taken.]
- JL The reported result is estimated because it has been computed using a colony count that is not within the acceptable counting range.

Table 5. Results of Ohio EPA bacteriological sampling collected from October 3-13 in streams in the Fourmile Creek study area (WAU 05080002-070) during 2005. For PCR designated streams, at least one of the two bacteriological standards (fecal coliform or *E. coli*) must be met. (Values above criteria are highlighted in red.)

	Entire Watershed* (15 sites)	Entire PCR Watershed (12 sites)**	Fourmile Creek mainstem (10 sites)
Recreational Use Attained?	YES	YES	YES
Primary Contact Recreation (Fecal coliform): Geometric mean fecal coliform content based on not less than five samples within a thirty-day period shall not exceed 1000 per 100 ml, *and* fecal coliform content shall not exceed 2000 per ml in more than ten percent of the samples taken during any thirty-day period.			
Geometric mean (#colonies/100ml)	194	146	150
% > max	6.7%	0%	0%
n =	75	60	50
Primary Contact Recreation (*E. coli*): Geometric mean *E. coli* content based on not less than five samples within a thirty-day period shall not exceed 126 per 100 ml, *and E. coli* content shall not exceed 298 per 100 ml in more than ten percent of the samples taken during any thirty-day period.			
Geometric mean (#colonies/100ml)	85	64	65
% > max	**13.3%**	5.0%	6.0%
n =	75	60	50

* includes in the calculation three sites that did not have a recreational use designation during the 2005 survey (Morning Sun tributaries and Fleisch Run)

** includes Fourmile Creek mainstem, Darrs Run, and Little Fourmile Creek

Table 6. Frequency of organic compounds detected in stream water samples collected in the Fourmile Creek study area (WAU 05080002-070) during 2005. Samples were collected at eleven sites twice during the summer survey (Number of Water Quality Standards criteria exceedences / Number of detections).

Parameter	**Fourmile Creek Mainstem** (8 sites)	**East Fork Fourmile Creek** (1 site)	**Little Fourmile Creek** (1 site)	**Darrs Run** (1 site)	**Total**
Acetochlor*	*/1	-	-	-	*/1
Aldrin	2/2	-	1/1	1/1	4/4
Atrazine*	*/11	*/1	*/2	*/1	*/15
α-Hexachlorocyclohexane	0/11	0/2	0/2	0/2	0/17
δ-Hexachlorocyclohexane*	*/5	-	-	-	*/5
γ-Hexachlorocyclohexane (Lindane)	0/6	-	-	-	0/6
bis(2-Ethylhexyl)phthalate	0/2	-	-	-	0/2
Dieldrin	13/13	1/1	2/2	1/1	17/17
Heptachlor epoxide	8/8	2/2	1/1	2/2	13/13
Metolachlor*	*/11	*/2	*/1	*/1	*/15
Simazine*	*/2	-	-	-	*/2
TOTAL	**23/72**	**3/8**	**4/9**	**4/8**	**34/97**

* No applicable WQS criteria available for parameter.

Sentinel Site Monitoring Program

Typically, OEPA sampling occurs within the critical low flow period of the year during the summer season when the attainment status for biological water quality criteria can be assessed. However, recognizing the impact of non-point pollution sources on streams and the lack of water chemistry data available under varying flow and seasonal conditions, OEPA developed a “sentinel site” approach in an effort to develop data sets over an annual period of varying climatic and flow conditions. In addition to assisting in the analysis of causes and sources of any observed non-attainment, the resulting data set supports water quality modeling efforts for pollutants where total maximum daily loads (TMDLs) may be necessary.

Sentinel site selection is based on several factors including proximity to the HUC watershed boundary, drainage area size ($\geq$ 20 mi^2), and varying land use (urban, agricultural, etc). If possible, locations are selected that have USGS flow stations. Typically, however, bridge to water measurements are taken at each site using a weighted tape in conjunction with periodic in-stream flow measurements in order to develop predictive gage height to stream flow relationships.

Five sites sampled during the intensive summer survey (July 19 - September 19) in the Fourmile Creek watershed were also sampled throughout the year as part of the sentinel site program (Fourmile Creek RMs 24.77, 20.25, 13.65, 5.40, and Little Fourmile Creek RM 2.80). An additional seven inorganic water chemistry samples and two organic samples (January 12 and June 1, 2006) were collected at these sites. Results for select parameters are presented in Table 7.

Nitrate-nitrite-N concentrations were elevated well above the ECBP reference value (4.84 mg/l) during the last five sampling events (December 6, 2005 through June 1, 2006) at all sites with the highest levels measured in Little Fourmile Creek (RM 2.80). Higher levels typically coincided with higher flows as represented by bridge to water measurements. Fourmile Creek at Lanes Mill Road (RM 13.65), downstream of the Oxford WWTP discharge at RM 16.36, experienced consistently elevated levels of nitrate-nitrite-N and total phosphorus throughout the period with recorded respective medians of 5.12 mg/l and 0.274 mg/l.

There were no exceedences of WQS criteria for inorganic parameters at the sentinel sites other than those previously noted for the regular summer survey.

Organic compounds and concentrations detected in the two additional sampling events were generally similar to the regular summer sampling (Appendix Table A-4). While the highest concentrations of atrazine were measured in June 2006, the compound was also detected at two of the five sentinel sites (RMs 20.25 and 13.65) on January 12, 2006. This day had the highest flow of any of the sampling days as represented by bridge to water measurements.

Table 7. Sampling results for select parameters at five sentinel sites in the Fourmile Creek watershed (July 19, 2005-June 1, 2006).*

Date	Bridge to water measurement (ft)**	Ammonia-N (mg/l)	Nitrate-nitrite-N (mg/l)	Phosphorus-T (mg/l)	TSS (mg/l)
Fourmile Creek @ Camden College Corner Rd, upstream Acton Lake (RM 24.77)					
7/19/05	na	0.054	2.72	0.014	5
8/2/05	18.40	0.070	1.12	0.017	5
8/16/05	18.44	0.059	0.27	0.023	5
8/30/05	na	0.051	0.10	0.033	14
9/19/05	18.23	0.059	0.95	0.022	5
10/6/05	na	< 0.05	1.32	0.014	< 5
11/8/05	17.92	< 0.05	1.84	0.030	< 5
12/6/05	17.82	0.055	7.48	0.044	< 5
1/12/06	17.47	< 0.05	8.70	0.038	< 5
2/2/06	17.82	< 0.05	7.82	0.010	< 5
4/26/06	17.59	0.05	5.75	0.011	5
6/1/06	17.76	0.05	8.36	0.026	5
Fourmile Creek @ Buckley Rd downstream Acton Lake, upstream Oxford (RM 20.25)					
7/19/05	na	0.191	3.69	0.044	14
8/2/05	27.40	**2.00**	0.50	0.051	13
8/16/05	27.32	**3.78**	0.24	0.080	7
8/30/05	27.16	**4.46**	0.68	0.133	9
9/19/05	27.10	**3.71**	0.16	0.181	9
10/6/05	na	0.366	0.58	0.114	12
11/8/05	24.25	0.174	0.9	0.022	12
12/6/05	24.35	0.142	6.44	0.125	6
1/12/06	24.03	0.062	8.99	0.080	5
2/2/06	24.20	< 0.05	8.73	0.031	6
4/26/06	24.32	0.055	5.58	0.033	15
6/1/06	24.23	0.187	6.13	0.060	6
Fourmile Creek @ Lanes Mill Road downstream Oxford (RM 13.65)					
7/19/05	na	0.050	4.00	0.121	34
8/2/05	na	0.063	4.09	0.577	10
8/16/05	na	0.093	2.16	0.339	30
8/30/05	na	0.109	4.89	0.769	23
9/19/05	na	0.083	6.32	0.965	12
10/6/05	na	0.080	5.09	1.580	13
11/8/05	na	0.083	2.82	0.719	20
12/6/05	na	0.082	5.90	0.155	6
1/12/06	na	< 0.05	8.14	0.142	5
2/2/06	na	< 0.05	7.89	0.147	5
4/26/06	na	0.050	5.15	0.044	5
6/1/06	na	0.095	6.05	0.209	8
Fourmile Creek @ Eaton Road (RM 5.40)					
7/19/05	na	0.050	3.19	0.108	50
8/2/05	24.10	0.064	0.93	0.077	16
8/16/05	23.90	0.131	2.5	0.259	60
8/30/05	23.95	0.090	3.32	0.489	52
9/19/05	24.05	0.053	3.37	0.585	64
10/13/05	24.00	< 0.05	3.43	0.878	11

Date	Bridge to water measurement (ft)**	Ammonia-N (mg/l)	Nitrate-nitrite-N (mg/l)	Phosphorus-T (mg/l)	TSS (mg/l)
11/8/05	23.88	< 0.05	1.26	0.755	< 5
12/6/05	23.50	0.08	5.76	0.192	18
1/12/06	23.03	< 0.05	6.95	0.102	6
2/2/06	23.35	< 0.05	6.87	0.114	< 5
4/26/06	23.29	0.05	3.84	0.057	5
6/1/06	23.41	< 0.05	5.43	0.112	13
Little Fourmile Creek @ Fairhaven-College Corner Rd (RM 2.80) upstream Acton Lake					
7/19/05	na	0.07	3.91	0.072	9
8/2/05	25.30	0.055	2.89	0.050	5
8/16/05	25.25	0.068	0.4	0.124	6
8/30/05	25.65	0.096	0.1	0.063	6
9/19/05	25.25	0.05	1.24	0.142	5
10/6/05	25.20	< 0.05	2.95	0.076	< 5
11/8/05	24.85	< 0.05	3.17	0.027	< 5
12/6/05	24.60	0.053	10.1	0.040	9
1/12/06	24.25	< 0.05	9.59	0.045	< 5
2/2/06	24.57	< 0.05	9.39	0.035	< 5
4/26/06	24.59	0.05	9.24	0.015	5
6/1/06	24.37	0.065	13.00	0.053	5

* Exceedences of water quality criteria for ammonia-N are in **red**. Values above 90th percentile concentrations (75th percentile concentration for TSS) from reference sites of similar size in the ECBP ecoregion are highlighted in yellow.

** While actual flow measurements are not available, relative flows are inversely related to bridge to water measurements (i.e. the greater the bridge to water measurement, the lower the flow and vice-versa).

Acton Lake
Water samples were collected on June 8 and October 3 in Acton Lake (Figure 12) near the spillway (L-1) and in the northern part of the lake closer to the inlets of Fourmile Creek and Little Fourmile Creek (L-2). Secchi disc depth was recorded and field measurements of temperature, dissolved oxygen, pH, and conductivity were collected at fixed intervals through the water column at both sites (Table 8 & 9). Inorganic water chemistry samples (Appendix Table A-3) were taken at the surface (0.5 meters) and near the lake bottom. Surface samples were also analyzed for bacteria and bottom water samples were analyzed for organic compounds (Appendix Table A-5). Surface samples were collected in triplicate for chlorophyll-a analysis at both Sites L-1 and L-2. Sediments were collected at Site L-2 in October.

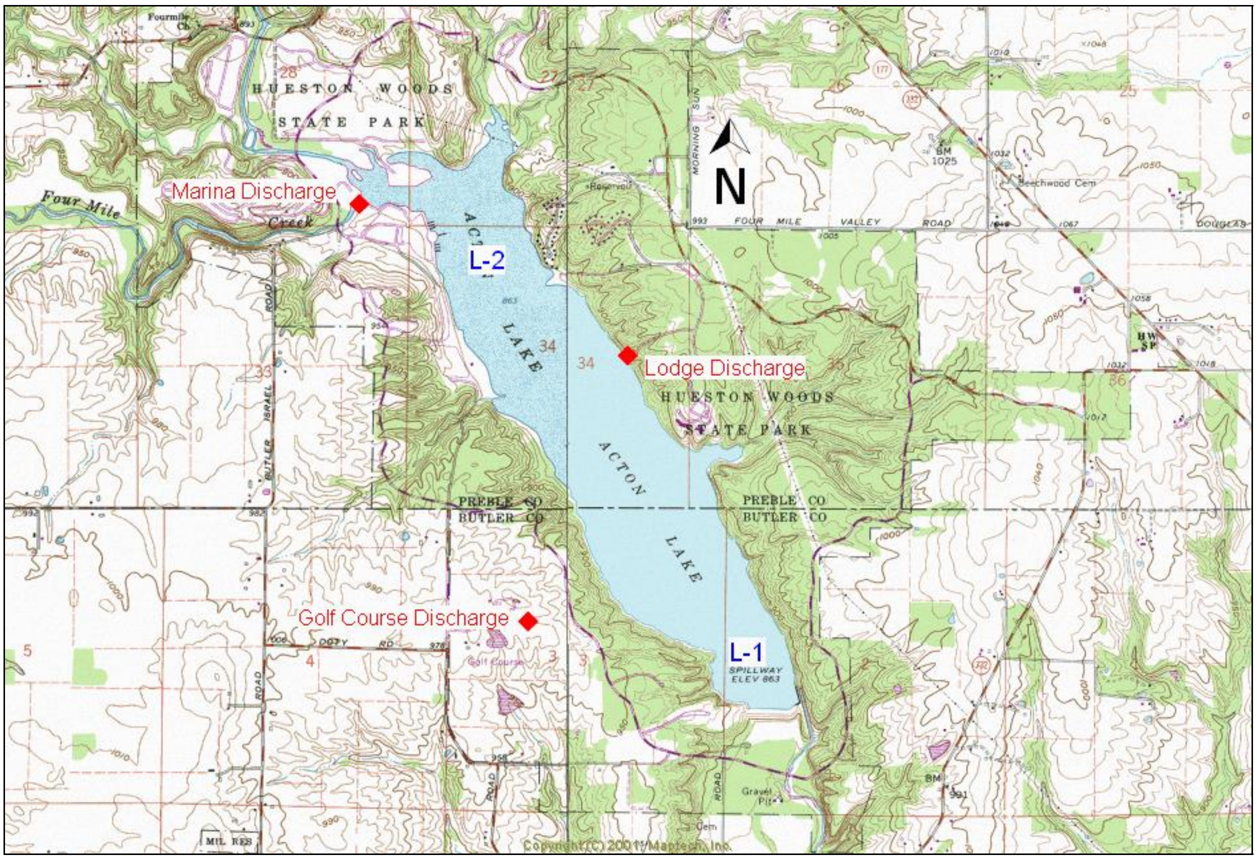


Figure 12. Acton Lake 2005 approximate sampling locations (L-1 and L-2) and NPDES dischargers in Hueston Woods State Park.

The Ohio Department of Natural Resources (ODNR) operates and maintains three wastewater treatment facilities in Hueston Woods State Park which discharge to Acton Lake, including the beach and marina, the lodge and cabins, and the golf course (see *Point Source Evaluations*).

Very low levels of dissolved oxygen (≤ 2.0 mg/l) were measured in June near the dam (L-1) at depths below 2.5 meters (8.2 ft) with concentrations falling to zero at 4.5 meters (14.8 ft). Oxygen depletion in the bottom waters of a lake typically results from bacteria respiration as dead organic matter, mostly algae and aquatic plant biomass, is decomposed when it falls to the lake bottom. A small thermocline, where the warm surface water separates from the colder bottom water, was present at L-1 between the 1.5 and 2.5 meter depth in June (Table 8). This thermal energy barrier can prevent surface water oxygen from mixing into the bottom waters of the lake. October dissolved oxygen levels at L-1 diminished more gradually through the water column and remained above 2.0 mg/l to a depth of six meters while the temperature change from surface to bottom was only one degree. Supersaturated dissolved oxygen levels (≥ 18.5 mg/l) were found in June in the shallower waters near the inlets (L-2) at all depths. June temperatures and pH were also significantly higher at L-2.

The results for trophic state measures are summarized in Table 9. Carlson (1977) Trophic State Index (TSI) values calculated from chlorophyll data indicate that Acton Lake was hypereutrophic (TSI > 66) during the 2005 survey. Chlorophyll-a concentrations were significantly higher nearer the stream inflows at Site L-2 in both June and October. Additionally, Site L-2 became more eutrophic from June to October compared to L-1. Both total phosphorus and chlorophyll-a increased at L-2 and Secchi depth transparency decreased. Knoll et al (2003) took a total of 25 samples in Acton Lake between April and October from 1998 through 2000 at similar locations (i.e. near the stream inlets and near the dam). The 3-year means for all results of total phosphorus (129.9 µg/l) and chlorophyll-a (56.3 µg/l) were also indicative of hypereutrophic conditions (TSI TP of 74 and TSI Chl-a of 70). In Knoll's study both total phosphorus and phytoplankton biomass (chlorophyll-a) were higher at the inflow site compared to the dam site. Nutrient release from sediments and excretion of nutrients into the water column by sediment-feeding fish (gizzard shad) particularly in the summer are other potential sources of nutrients in Acton Lake (Schaus et al. 1997). This steady and continual supply of nutrients may help to maintain high phytoplankton productivity during periods when external nutrient loading is reduced.

Phosphorus is typically the limiting nutrient in freshwater lakes (i.e. the plants deplete all available phosphorus before depleting other nutrients). Nitrogen to phosphorus ratios above 17:1 generally indicate that phosphorus availability limits the growth of algae (Smith 1981). Exceptionally high nitrogen to phosphorus ratios measured in June at both Acton Lake sites likely reflect the predominance of cropland in the upstream watershed and the spring application and subsequent runoff of fertilizers which typically have a high N:P ratio. October nitrogen concentrations and hence N:P ratios were much lower. Nitrate-nitrite concentrations in the Acton Lake stream inlet samples collected in Fourmile Creek at RM 24.12 (5.51 mg/l) and Little Fourmile Creek at RM 0.10 (8.23 mg/l) on June 8 were elevated well above the ECBP reference value of 4.84 mg/l. Total phosphorus levels, however, remained low (0.013 mg/l in Fourmile Creek and 0.029 mg/l in Little Fourmile Creek). Concentrations of nitrate-nitrite and total phosphorus measured during the regular summer sampling (July 19 - September 19) in

Fourmile Creek at RM 24.77 and in Little Fourmile Creek at RM 2.80 were all low. However, samples collected at these two sites as part of the sentinel sampling program (Table 7) indicate nitrate-nitrite-N concentrations elevated well above the ECBP reference value (4.84 mg/l) during the last five sampling events (December 2005 through June 1 2006) especially in Little Fourmile Creek. Higher levels typically coincided with higher flows.

Lead and pH exceeded WQS criteria (Table 4) in surface samples at Site L-1 near the dam in June while elevated levels of ammonia-N (near 1 mg/l) were documented in the deeper bottom waters (8 meters) in both June and October. Lead, frequently elevated near the stream inlets at Site L-2, exceeded its criterion in the shallow bottom waters (2 meters) in June.

Bacteria (fecal coliform and *E. coli*) surface samples collected at L-1 and L-2 were all well below Bathing Water Recreation (BWR) criteria. Additionally, of the five *E. coli* samples collected during the summer months at the park swimming beach through the Bathing Beach Monitoring Program (a cooperative effort of the Ohio Department of Health and the Ohio Department of Natural Resources), one sample was greater than the single sample maximum standard of 235 colonies/100 ml (ODH 2007).

Nine organic compounds were detected in the bottom water samples collected in Acton Lake (Appendix Table A-5). June concentrations of atrazine exceeded the maximum contaminant level (MCL) under the Safe Drinking Water Act at both L-1 and L-2. Dieldrin and heptachlor epoxide also exceeded criteria. While Acton Lake is not used as a drinking water source, all publicly owned lakes and reservoirs are designated public water supply.

While the quality of sediments collected at Site L-2 was generally good (Table 11 & 12), ammonia-N concentrations (120 mg/kg) were elevated above the Ontario sediment disposal guideline (100 mg/kg).

Historically, Acton Lake has experienced significant sedimentation. During 2005, approximately 70,000 cubic yards of dredged material was taken out of Acton Lake using a suction dredge (Snow 2007). However, Renwick (2005) found that sedimentation rates in Acton Lake have declined dramatically in recent years and largely attributes the improvement to the adoption of soil conservation practices in the watershed, most notably conservation tillage. Renwick notes that while there has been little change in the amount of row-crop agriculture in Preble County over the years, the portion of cropland in conservation tillage increased from 14 percent to 75 percent between 1989 and 2001.

Table 8. Chemical field measurements at two sites in Acton Lake during 2005.

Depth (m)	**Temp (C)**	**D.O. (mg/l)**	**pH (SU)**	**Conductivity (umhos/cm)**
Acton Lake L-1 (near dam) Lat/long: 39.55986/84.73748				
June 8, 2005				
0.5	26.0	11.0	8.52	425
1.0	25.0	9.0	8.24	425
1.5	24.4	10.0	8.23	425
2.0	22.9	5.2	7.76	425
2.5	21.1	2.0	7.49	425
3.0	20.5	1.0	7.43	425
3.5	20.1	0.5	7.41	425
4.0	19.7	0.2	7.37	425
4.5	19.1	0	7.32	425
5.0	18.8	0	7.27	425
5.5	17.6	0	7.40	425
6.0	16.8	0	7.42	425
6.5	16.4	0	7.43	425
7.0	16.4	0	7.41	425
7.5	16.1	0	7.41	425
8.0 bottom	16.2	0	7.39	425
October 3, 2005				
0.5	22.6	10.0	8.71	*
1.0	22.9	9.6	8.71	*
1.5	22.3	8.4	8.73	*
2.0	22.8	7.5	6.92	*
2.5	22.4	7.5	6.92	*
3.0	22.2	6.4	6.92	*
3.5	21.9	6.0	6.92	*
4.0	21.7	4.6	6.91	*
4.5	21.6	3.8	6.91	*
5.0	21.8	3.0	6.91	*
5.5	21.6	2.0	6.91	*
6.0	21.6	2.0	6.91	*
6.5	21.5	1.2	6.91	*
7.0	21.5	1.2	6.91	*
8.0 bottom	21.6	0.2	6.91	*
Acton Lake L-2 (near the inlets) Lat/long: 39.58013/84.75315				
June 8, 2005				
0.5	29.4	18.5	9.19	410
1.0	29.9	20.0	9.17	410
1.5	28.6	19.0	9.13	410
2.0 bottom	28.1	19.0	9.06	410
October 3, 2005				
0.5	22.1	11.4	8.88	*
1.0	21.8	10.6	8.87	*
1.5 bottom	21.8	7.0	8.50	*

* meter malfunction

Table 9. Concentrations of trophic state parameters collected at two sites in Acton Lake during 2005.*

Location	----------Date Sample Collected----------			
	6/08/05		**10/03/05**	
	Surface	Bottom	Surface	Bottom
Acton Lake L-1 (near dam)				
Secchi (m)	0.46	--	0.44	--
TSI SD	71.2		71.8	
Chl-a (µg/l)	52.45 - 63.80	--	56.26 - 59.01	--
TSI Chl-a	69 - 71		70 - 71	
NO^2NO^3 (µg/l)	6440	2970	< 100	< 100
TKN (Kjeldahl-N)(µg/l)	1070	1560	670	1540
Total Nitrogen (µg/l) (NO^2NO^3 + TKN)	7510	4530	720 **	1590 **
T. Phosphorus (µg/l)	25	33	28	101
TSI TP	51	55	52	71
N/P Ratio	300:1	137:1	26:1	16:1
Acton Lake L-2 (near inlets)				
Secchi (m)	0.40	--	0.32	--
TSI SD	73.2		76.4	
Chl-a (µg/l)	67.72 - 71.59	--	85.89 - 114.31	--
TSI Chl-a	72 - 73		74 - 77	
NO^2NO^3 (µg/l)	6480	5780	< 100	< 100
TKN (Kjeldahl-N)(µg/l)	1110	660	1010	980
Total Nitrogen (µg/l) (NO^2NO^3 + TKN)	7590	6440	1060 **	1030 **
T. Phosphorus (µg/l)	15	17	64	66
TSI TP	43	45	64	65
N/P Ratio	506:1	379:1	17:1	16:1

* Carlson (1977) Trophic State Index (TSI) values were calculated using the following equations:

Secchi Disk TSI = 60 - 14.41 [ln (SD meters)]
Total Phosphorus TSI = 14.42 [ln (TP µg/l)] + 4.15
Chlorophyll-a TSI = 9.81 [ln (Chl-a µg/l)] + 30.6

** a value of ½ the detection limit was used for the NO2NO3 portion of total N

Chemical Sediment Quality

Sediment grab samples were collected from the upper four inches of bottom material at 12 locations in the Fourmile Creek watershed using stainless steel scoops. Whenever possible, composite samples from a cross-section of the stream channel were collected with silts and clays comprising at least 30% of the sample. Sediments composed of sand and larger sized particles (>60 microns) are often stable inorganic silicate minerals and not usually associated with contaminants. Given that the finer grained silts and clays (<60 microns) are much more chemically, physically and biologically interactive, collection efforts were biased toward collecting these finer grain types of sediments. Samples were analyzed for metals, nutrients (ammonia and phosphorus), volatile and semivolatile organic compounds, organochlorine pesticides, polychlorinated biphenyl compounds (PCBs), and particle size.

Sediment evaluations were conducted using guidelines established in MacDonald et al. (2000), Ohio EPA Sediment Reference Values (SRV) (2003), and Ontario Sediment Quality Guidelines (Persuad 1993).

Consensus-based sediment quality guidelines (SQGs) for freshwater ecosystems were derived for 28 chemicals by MacDonald et al. (2000) from numerous previously published SQGs which used a variety of approaches. The previously published guidelines were used to develop two consensus-based SQGs for each contaminant, including a threshold effect concentration (TEC) below which adverse effects on sediment-dwelling organisms are not expected to occur, and a probable effect concentration (PEC) above which adverse effects are expected to occur more often than not. The consensus-based SQGs provide a unifying synthesis of the existing guidelines, reflect causal rather than correlative effects, and are predictive of toxicity in sediments containing mixtures of contaminants but do not consider the potential for bioaccumulation in aquatic organisms.

Ohio Sediment Reference Values (SRVs) were developed by Ohio EPA to identify representative background sediment metal concentrations for lotic (flowing) water bodies. Sediment samples were taken from reference areas throughout the state that have been used historically to develop the biological criteria as part of the State of Ohio's Water Quality Standards. These reference locations were selected as being representative of the least impacted areas in the watershed. The Ohio SRVs are site-specific background metal concentrations based upon ecoregions and are used to identify whether a site has been contaminated. Ohio SRVs are guidelines, not Ohio EPA standards or criteria.

The Ontario Severe Effect Level (SEL) guidelines (Persuad 1993) were used to evaluate total organic carbon and total phosphorus. Sediment ammonia was evaluated using the Persuad open water disposal guidelines (100 mg/kg). Ohio and MacDonald SQGs do not have nutrient sediment parameter guidelines.

Sediment was evaluated at nine sites in the mainstem of Fourmile Creek and in three of its tributaries (Little Fourmile Creek RM 2.80, Elams Run RM 0.30, and Darrs Run RM 2.13) (Table 10, 11, & 12). Sediment quality in the entire watershed was generally very good.

Concentrations of arsenic and manganese in Fourmile Creek at Junction Road (RM 26.73) were minimally elevated above guidelines. Manganese (862 mg/kg) was above the Ohio SRV at the site while arsenic (12.7 mg/kg) was between the MacDonald TEC and PEC but less than the Ohio SRV. Ammonia concentrations (120 mg/kg) in the mainstem at Eaton Road (RM 5.40) were elevated above the Ontario sediment disposal guideline (100 mg/kg). Ammonia concentrations in water samples at the site were not elevated. Three samples collected in the mainstem (RMs 28.90, 20.25, and 16.40) and the Little Fourmile Creek sample (RM 2.80) fell below the 30% fine grain material (FGM) particle size goal.

Fluoranthene, a polycyclic aromatic hydrocarbon (PAH), was found in the sediments at three mainstem sites (RMs 16.40, 16.20, 11.00) and in Elams Run (RM 0.30) at concentrations between the MacDonald TEC and PEC. The PAH compounds are products of combustion and can be associated with deposition of particulate matter from automobile and diesel exhaust, other combustion sources, asphalt paving of highways, and parking lot and driveway sealcoat. All four sites where fluoranthene was detected in the sediments are in the Oxford area.

The compound 3&4 methylphenol (m&p cresol) was also detected in the mainstem sediments at three locations (RMs 11.00, 5.40, and 0.35). Sources of mixed cresols in ambient air include car exhaust, electrical power plants, and municipal solid waste incinerators. Cresols are used as disinfectants, preservatives, and wood preservatives. There is no sediment guideline for this compound.

PCBs (31.4 µg/kg) detected in mainstem sediments downstream of Fairhaven (RM 28.90) were less than the MacDonald TEC (adverse effects are not likely to occur).

Table 10. Concentrations (mg/kg unless otherwise noted) of metals and nutrients in sediment samples collected in the mainstem of Fourmile Creek during 2005. Parameter concentrations were evaluated based on Ohio EPA sediment metal reference sites (2003), MacDonald (2000) Sediment Quality Guidelines (SQG) and Persuad (1993). Values above guidelines are highlighted.

Parameter	Fourmile Creek Mainstem River Mile									***Reference***	
	35.62	28.90	26.73	20.25	16.40	16.20	11.00	5.40	0.35		
										Ohio	**MacDonald** TEC -PEC
Al-T [O]	22200	10800	23600	8910	8250	8480	10700	16400	11800	39000	*
As-T [OM]	8.48	6.85	12.7#	5.64	5.11	4.87	6.21	8.18	6.89	18	9.79-33
Ba-T [O]	161	67.2	174	57	55	56.1	69.5	94.8	75.8	240	*
Ca-T [O]	73200	67000	118000	76200	49900	59000	61100	82100	90600	120000	*
Cd-T [OM]	0.363	0.109	0.381	<0.108	0.169	0.117	0.130	0.166	0.357	0.9	0.99-4.98
Cr-T [OM]	24	15	<38	<16	<17	<14	15	21	<18	40	43.4-111
Cu-T [OM]	11.6	7.7	14.6	6.8	<5.5	10	11.3	14.3	9.5	34	31.6-149
Fe-T [O]	17900	12700	25400	11900	9500	10000	12900	18900	13400	33000	*
Hg-T [OM]	<0.045	<0.028	<0.064	<0.031	<0.026	<0.026	<0.029	<0.036	<0.037	0.12	0.18-1.06
K-T [O]	4490	3520	6350	2530	1760	2330	3340	4770	3340	11000	*
Mg-T [O]	19900	19800	29200	22400	12400	16900	17200	23900	25000	35000	*
Mn-T [O]	495	400	862 +	373	298	382	466	574	401	780	*
Na-T *	<3930	<2090	<6330	<2700	<2750	<2390	<2110	<2810	<2960	*	*
Ni-T [OM]	<31 ?	<17	<51 ?	<22	<22	<19	<17	<22	<24 ?	42	22.7-48.6
Pb-T [OM]	<31	<17	<51 ?	<22	<22	<19	<17	<22	<24	47	35.8-128
Se-T [O]	<1.57	<0.84	<2.53 ?	<1.08	<1.10	<0.96	<0.84	<1.12	<1.18	2.3	*
Sr-T [O]	188	78	223	101	92	69	83	108	140	390	*
Zn-T [OM]	89.5	32.5	87.6	22.1	30.4	39.1	46.8	60.6	43.7	160	121-459
										Ohio	**Persuad**
NH_3-N [P]	75	55	95	21	65	80	92	120 [L]	55	*	100
TOC(%) [P]	4.6	5.0	7.1	5.5	4.4	5.4	5.5	4.7	6.2	*	10.0%
pH (SU) *	7.5	7.8	7.4	7.7	7.8	7.8	7.5	7.5	7.6	*	*
P-T [P]	777	641	982	728	432	1030	930	1240	832	*	2000
%FGM [O]	39.3	26.9↘	57.2	12.0 ↘	25.5↘	30.7	35.5	46.6	43.4	30.0%	*

↘ Below the goal of 30% Fine Grain Material in sample
%FGM Percent Fine Grain Material in sediment sample (<60 micron or >30 seconds settling time)
NA Compound not analyzed. * Not evaluated
O Evaluated by Ohio EPA (2003) M Evaluated by MacDonald (2000) P Evaluated by Persuad (1993)
? Detection limit is greater than guideline

Ohio Sediment Reference Values (SRV) Guidelines (2003)
\+ above background for this area

Ontario Sediment Guidelines (Persuad 1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.
▲ > severe effect level (disturbance in benthic community can be expected)

MacDonald (2000) Sediment Quality Guidelines (SQG)
\# **>** TEC (Threshold effect concentration) and ≤ PEC (Probable effect concentration)
Adverse effects frequently occur
■ **> PEC (**Probable effect concentration)
Adverse effects usually or always occur

Table 11. Concentrations (mg/kg unless otherwise noted) of metals and nutrients in sediment samples collected in select tributaries in the Fourmile Creek watershed (WAU 05080002-070) and in Acton Lake (L-2) during 2005. Parameter concentrations were evaluated based on Ohio EPA sediment metal reference sites (2003), MacDonald (2000) Sediment Quality Guidelines (SQG) and Persuad (1993). Values above guidelines are highlighted.

Parameter	Tributary (River Mile) Little Fourmile Creek (RM 2.80)	Elams Run (RM 0.30)	Darrs Run (RM 2.13)	Acton Lake L-2	***Reference***	
					Ohio	**MacDonald** TEC-PEC
Al-T [O]	9950	11400	20400	26900	39000	*
As-T [OM]	4.04	5.76	7.14	NA	18	9.79-33
Ba-T [O]	66.4	80.7	106	166	240	*
Ca-T [O]	55000	63000	79500	63200	120000	*
Cd-T [OM]	0.136	0.147	0.138	NA	0.9	0.99-4.98
Cr-T [OM]	13	16	23	32	40	43.4-111
Cu-T [OM]	5.2	11.0	11.7	17.7	34	31.6-149
Fe-T [O]	9830	12400	16700	20700	33000	*
Hg-T [OM]	<0.018	<0.028	<0.033	0.046	0.12	0.18-1.06
K-T [O]	2930	3300	5840	6110	11000	*
Mg-T [O]	12900	16200	18400	21000	35000	*
Mn-T [O]	314	409	388	455	780	*
Na-T *	<1760	<2530	<2860	<2780	*	*
Ni-T [OM]	<14	<20	<23 ?	22	42	22.7-48.6
Pb-T [OM]	<14	<20	<23	<22	47	35.8-128
Se-T [O]	<0.71	1.01	<1.14	NA	2.3	*
Sr-T [O]	65	75	104	99	390	*
Zn-T [OM]	32.2	40.8	51.7	85.2	160	121-459
					Ohio	**Persuad**
NH_3-N [P]	22	25	41	120 [L]	*	100
TOC (%) [P]	4.3	4.9	4.4	3.9	*	10.0%
pH (SU) *	7.6	7.5	7.7	NA	*	*
P-T [P]	386	504	636	729	*	2000
%FGM [O]	25.0 ↘	35.4	38.1	75.1	30.0%	*

↘ Below the goal of 30% Fine Grain Material in sample
%FGM Percent Fine Grain Material in sediment sample (<60 micron or >30 seconds settling time)
NA Compound not analyzed. * Not evaluated
[O] Evaluated by Ohio EPA (2003) [M] Evaluated by MacDonald (2000) [P] Evaluated by Persuad (1993)
? Detection limit is greater than guideline

<u>Ohio Sediment Reference Values (SRV) Guidelines (2003)</u>
\+ above background for this area

<u>Ontario Sediment Guidelines (Persuad (1993)</u>
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH_3-N only.
▲ > severe effect level (disturbance in benthic community can be expected)

<u>MacDonald (2000) Sediment Quality Guidelines (SQG)</u>
\# **>** TEC (Threshold effect concentration) and ≤ PEC (Probable effect concentration)
Adverse effects frequently occur
■ **> PEC (**Probable effect concentration)
Adverse effects usually or always occur

Table 12. Concentrations of organic compounds (priority pollutant scan) detected in stream sediments in the Fourmile Creek watershed (WAU 05080002-070) and in Acton Lake (L-2) during 2005. Individual compounds were evaluated by the MacDonald (2000) Sediment Quality Guidelines (SQG).

Stream (Lake) / Rivermile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Fourmile Creek / RM 35.62 Concord-Fairhaven Rd TOC= 4.6% Fine Grain Material = 39.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Fourmile Creek / RM 28.90 Adj. Creek Rd (Dst Fairhaven) TOC= 5.0% Fine Grain Material = 26.9%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 PCB-1254 **Total PCB**	BDL BDL BDL 31.4 µg/kg * 31.4 µg/kg +
Fourmile Creek / RM 26.73 Junction Rd TOC= 7.1% Fine Grain Material = 57.2%	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Fourmile Creek / RM 20.25 Buckley Rd (Dst Acton Lake) TOC= 5.5% Fine Grain Material = 12.0%	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Fourmile Creek / RM 16.40 Upstream Oxford WWTP TOC= 4.4% Fine Grain Material = 25.5%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Fluoranthene **Total PAH**	BDL 0.64 # 0.64 + BDL BDL
Fourmile Creek / RM 16.20 Downstream Oxford WWTP TOC= 5.4% Fine Grain Material = 30.7%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Fluoranthene **Total PAH**	BDL 0.84 # 0.84 + BDL BDL
Fourmile Creek / RM 11.00 SR 177 TOC= 5.5% Fine Grain Material = 35.5%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Fluoranthene **Total PAH** 3&4-Methylphenol	BDL 0.85 # 0.85 + 2.67 * BDL BDL
Fourmile Creek / RM 5.40 Eaton Rd TOC= 4.7% Fine Grain Material = 46.6%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 3&4-Methylphenol	BDL 1.59 * BDL BDL

Stream (Lake) / Rivermile Location	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Fourmile Creek / RM 0.35 Seven Mile Rd TOC= 6.2% Fine Grain Material = 43.4%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 3&4-Methylphenol	BDL 1.84 * BDL BDL
Little Fourmile Creek / RM 2.80 Fairhaven College Corner Rd TOC= 4.3% Fine Grain Material = 25.0 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Elams Run / RM 0.30 Upstream Corso Rd TOC= 4.9% Fine Grain Material = 35.4%	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Fluoranthene **Total PAH**	BDL 0.57 # 0.57 + BDL BDL
Darrs Run / RM 2.13 SR 73 TOC= 4.4% Fine Grain Material = 38.1%	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Acton Lake L-2 **(near inlets)** TOC= 3.9% Fine Grain Material = 75.1%	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL

* Not evaluated
BDL Below Detection Limit
TOC Total Organic Carbon

1) Volatile Organic Compounds (VOC) U.S. EPA Method 8260B
2) Base Neutral & Acid Extractibles (BNA) U.S. EPA Method 8270
3) Pesticides U.S. EPA Methods 8082A
4) Polychlorinated biphenyls (PCBs) U.S. EPA Method 8082A

Percent Fine Grain Material in sediment sample (<60 micron or >30 seconds settling time)

MacDonald (2000) Sediment Quality Guidelines (SQG)
+ **≤** TEC (Threshold effect concentration)
Harmful effects are unlikely to be observed
>TEC and ≤ PEC (Probable effect concentration)
Adverse effects frequently occur
■ **> PEC (**Probable effect concentration)
Adverse effects usually or always occur

Point Source Evaluations

ODNR Hueston Woods State Park Beach and Marina WWTP
Acton Lake
Permit # 1PP00002*CD
Latitude/Longitude (DD): 39.5833770/ 84.7638412

The ODNR Hueston Woods State Park beach and marina WWTP, built in 1959 and serving the park beach, marina, campground, park office and nature center, discharges to Acton Lake near the inlet streams (Figure 12). The average daily flow rate calculated from facility monthly operating reports (MORs) from January 2000 through December 2005 was 0.02 mgd. The plant is designed for 0.05 mgd. Treatment consists of a bar rack, aeration tank, clarifier, an upflow filter where chlorine is added, a dosing tank, four surface sand filters, and a chlorine contact tank used as a dechlorination system. Sludge is hauled to a sanitary landfill.

A total of 865 numeric violations (concentration and loading) of NPDES permit limits were reported through the Ohio EPA Surface Water Information Management System (SWIMS) for the final effluent from 2000 through 2005. As with the discharge from the lodge and cabins WWTP (see below), almost all (97%) of the violations were residual chlorine violations due to an inadequate dechlorination system. In November, 2005 ODNR indicated their intention to submit a PTI for the installation of a dechlorination system to address this problem. They have further noted their intention to completely evaluate the wastewater systems in the park and replace or rehabilitate as necessary upon approval of the next capital budget.

ODNR Hueston Woods State Park Lodge and Cabins WWTP
Acton Lake
Permit # 1PP000005*CD
Latitude/Longitude (DD): 39.5755595/ 84.7457886

The treatment system for the Hueston Woods State Park 94-room lodge and restaurant and 37 cabins was built in 1966 with modifications in 1982 (Figure 12). Current treatment consists of a flow equalization tank, bar rack, an aeration tank, two clarifiers, a rapid sand filter, and a chlorination / dechlorination system. Sludge is disposed of at a sanitary landfill. The average design flow is 0.08 mgd and the average daily flow rate from January 2000 through December 2005 was 0.02 mgd with a peak daily flow rate of 0.08 mgd.

A total of 856 numeric violations (concentration and loading) of NPDES permit limits were reported through the Ohio EPA Surface Water Information Management System (SWIMS) for this facility's final effluent from 2000 through 2005. Almost all (97%) of the violations were residual chlorine violations due to an inadequate dechlorination system.

ODNR Hueston Woods State Park Golf Course WWTP
Unnamed tributary to Acton Lake
Permit # 1PP00004*AD
Latitude/Longitude (DD): 39.5621699/ 84.7496510

The ODNR golf course pro shop WWTP, built in 1970 with a design flow of 0.005 MGD, discharges to an unnamed tributary of Acton Lake (Figure 12). A review of the facility MORs from March 2004 through December 2005 indicates an average daily flow rate of 1,174 gpd and a peak daily flow rate of 1,730 gpd. Treatment consists of a bar rack, an aeration tank, a clarifier, and chlorination. Sludge is hauled to the Beach and Marina WWTP. No NPDES violations were reported for this facility since the inception of the NPDES permit (May 1, 2003) through 2005.

Woodland Country Manor WWTP
Unnamed tributary to Harkers Run (RM 2.38)
Permit # 1PX00041*BD
Latitude/Longitude (DD): 39.5450000 / 84.6975000

Woodland Country Manor is a 50 bed nursing home near Somerville. The original treatment system designed for 0.008 mgd and approved by the Ohio Department of Health in 1971, consisted of a septic tank used as a trash trap, an aeration tank, a clarifier, and a polishing lagoon. The facility was subsequently issued an NPDES permit which became effective in January 2004 and included a compliance schedule for upgrades to the WWTP. The discharge is to an unnamed tributary which enters Harkers Run at RM 2.38.

In September 2005, OEPA issued a permit to install (PTI) authorizing Woodland Country Manor to upgrade and expand the treatment facility to 0.0122 mgd (peak design 0.061 mgd). The upgrades included a new influent pump station, two flow equalization basins, four aeration tanks, two clarifiers, a dosing tank, two surface sand filters, and an ultraviolet disinfection system. These upgrades were completed and the treatment plant was operational on March 31, 2006. The facility did not submit MORs from June 2005 through February 2006, blaming the failure on computer problems. Since completion of the construction of the new plant, the WWTP has been in compliance with the issued NPDES permit. Woodland Country Manor is currently adding an additional eleven residential units, resulting in an estimated additional 1,350 gpd of wastewater. The additional flow will be within the WWTP design.

City of Oxford WWTP
Fourmile Creek (RM 16.36)
Permit # 1PD00007*KD
Latitude/Longitude (DD): 39.4972402 / 84.7151860

The City of Oxford discharges treated wastewater to Fourmile Creek at river mile 16.36. The treatment plant, constructed in 1968 with an average design flow of 3.0 million gallons per day (mgd), was modified in 1989, increasing average daily design flow to 4.2 mgd and peak flow capacity to 8.0 mgd. It serves a population of approximately 25,000 including the Miami University student population. Current average daily flow varies from approximately 1.5 mgd when Miami University is not in session to 2.5 mgd when the university is in session. The collection system is 100% separate and all of the service area has sewers. Significant contributions to the system include waste from Miami University food services, Schneider Electric Oxford Plant (Square D), and leachate from the closed Oxford Sanitary Landfill. Treatment processes at the plant currently include a mechanical bar screen, grit tank, flow equalization, primary clarification, activated bio-filtration, secondary settling, ultraviolet disinfection, and cascade aeration. Until 1996, sludge was treated by anaerobic digestion, thickening, and drying beds and then land applied. Historically, the facility experienced numerous NPDES violations due in part to inadequacies in the solids handling process. In September of 1995, a Permit to Install (PTI) was issued for a belt filter press and sludge storage pads. These improvements, completed in March of 1996, helped to eliminate suspended solids violations after May of 1996. More recently, in December 2006, Oxford was granted a PTI for modifications and improvements to the solids handling facilities, aeration system, and hydraulics through the secondary clarifier flow splitter box. Improvements include replacing the existing jet aeration system with new surface disk aerators, replacing the existing gravity sludge thickening tank with a new gravity sludge belt thickener, refurbishing the primary settling tanks, and modifying the secondary settling tank flow splitter box to improve flow splitting. Construction will begin March, 2007 and is scheduled to be completed in September, 2008.

Historically, the city's collection system has been subject to excessive infiltration and inflow (I/I) resulting in numerous overflows and/or WWTP bypasses during wet weather. During storm events the combination of sanitary flow and I/I frequently exceeded the hydraulic capacity of the system with the excess flow either released along the collection system at several locations or bypassed at the headworks of the plant and discharged untreated directly to Fourmile Creek.

In response to numerous violations of the requirements of the NPDES permit, consent orders were filed in September 1987 and February 1989 requiring the City of Oxford to operate its wastewater treatment plant and sewer system in compliance with its NPDES permit. Although the city upgraded its facility in 1989, effluent violations, overflows, and bypasses continued. While the Hester Road pump station, a significant overflow site, was eliminated in November of 1995, a third Modified Consent Decree was filed in April 1997, again ordering the city to complete projects needed to bring the plant into compliance with its NPDES permit and prohibiting bypasses and overflows after May 31, 1998. In response the city constructed a new raw sewage screening and pumping station (17.5 mgd peak capacity), dual 8.75 mgd vortex grit removal chambers (17.5 mgd total), and two 2.5 million gallon flow equalization basins (5.0 mgd total). In conjunction with the City's ongoing I/I removal projects, these improvements were designed to prevent bypasses during periods of wet weather by providing temporary storage of wastewater.

However, while the City was required to eliminate all bypasses from the sewage collection and treatment systems by May 31, 1998, unauthorized discharges and bypasses continue to be reported (Table). An evaluation of the last six years (2000 through 2005) reveals approximately 15 collection system overflows (total volume > 100,000 gallons) and 10 bypass incidents at the WWTP itself (total volume > 9,000,000 gallons). The largest bypass of this period was reported in early January 2005, the result of snowmelt in conjunction with significant rainfall in a short period of time, when the facility bypassed an extraordinary 5,663,757 gallons from the flow equalization basins.

Numeric violations (concentration and loading) of NPDES permit limits for the final effluent (NPDES station 1PD00007001) were evaluated from 2000 through 2005 as reported through the Ohio EPA Surface Water Information Management System (SWIMS). The Oxford WWTP reported a total of 36 numeric violations for the six-year period. Violations of the minimum pH limit (6.5 SU) occurred from March through May 2001 and accounted for the majority of violations (61%). (Investigation by the entity indicated that incorrect calibration of the pH transducer caused the low pH readings.) Other constituents violating the numeric permit limits included ammonia-N (11 violations), total suspended solids (2 violations), and copper (1 violation). There were no numeric violations reported in SWIMs for Oxford in 2005. Additionally, there were a total of 109 monitoring frequency violations reported through SWIMS for the period for Outfall 001, the majority of which were for failure to meet the measurement frequency requirements for oil and grease (73%).

Ohio EPA conducted three bioassays on Oxford's final effluent, upstream, and mixing zone waters within the last ten years (April 2001, November 2005, and June 2006). Additionally, Oxford conducted numerous bioassays from November 1997 through April of 2001. The results of these bioassays indicate that the tested effluents and the instream samples were not acutely toxic to either test species (*P. promelas* and *C. dubia*).

Given the variability of flows to the plant dependent on the presence of the Miami University student population, both annual and third quarter flow and loading graphs are presented in Figure 13 - Figure 15. Peak flows at the plant, as represented by the 95th percentiles, are within the peak daily design flow of 8.0 mgd while median flows remained well below the average daily design flow of 4.2 mgd for the sixteen year period (1989-2004). For comparison purposes, graphs for third quarter ammonia-N,

$CBOD_5$, and total suspended solids (TSS) include a line depicting the NPDES summer monthly loading limits (the most restrictive time period for discharge limitations in the permit). Median loadings for all three parameters remained well below these monthly limits.

Improvements to the solids handling processes in 1996 are reflected in the subsequent reduction in median TSS and $CBOD_5$ loadings. Median annual TSS loadings declined from 107 kg/day in 1996 to 43 kg/day in 2004, a sixty percent (60%) decline. A smaller reduction occurred in median annual $CBOD_5$ loadings with values dropping from 30 kg/day in 1996 to 23 kg/day in 2004, a 23 percent reduction. Comparable improvements were noted for third quarter loadings for both parameters. Phosphorus monitoring, begun in 2000, indicates a decrease in annual median loadings from 34 kg/day in 2000 to 23 kg/day in 2004 while third quarter medians, more variable, have ranged from 16 kg/day in 2001 to 25 kg/day in 2002.

Monthly monitoring upstream and downstream from the outfall (1989-2004) indicates that downstream concentrations of ammonia-n and fecal coliform are generally somewhat higher than upstream concentrations (Figure 16). Medians recorded for ammonia-N both upstream and downstream of the plant were generally below the ECBP reference value of 0.096 mg/l while fecal coliform medians were generally below primary contact recreation criteria.

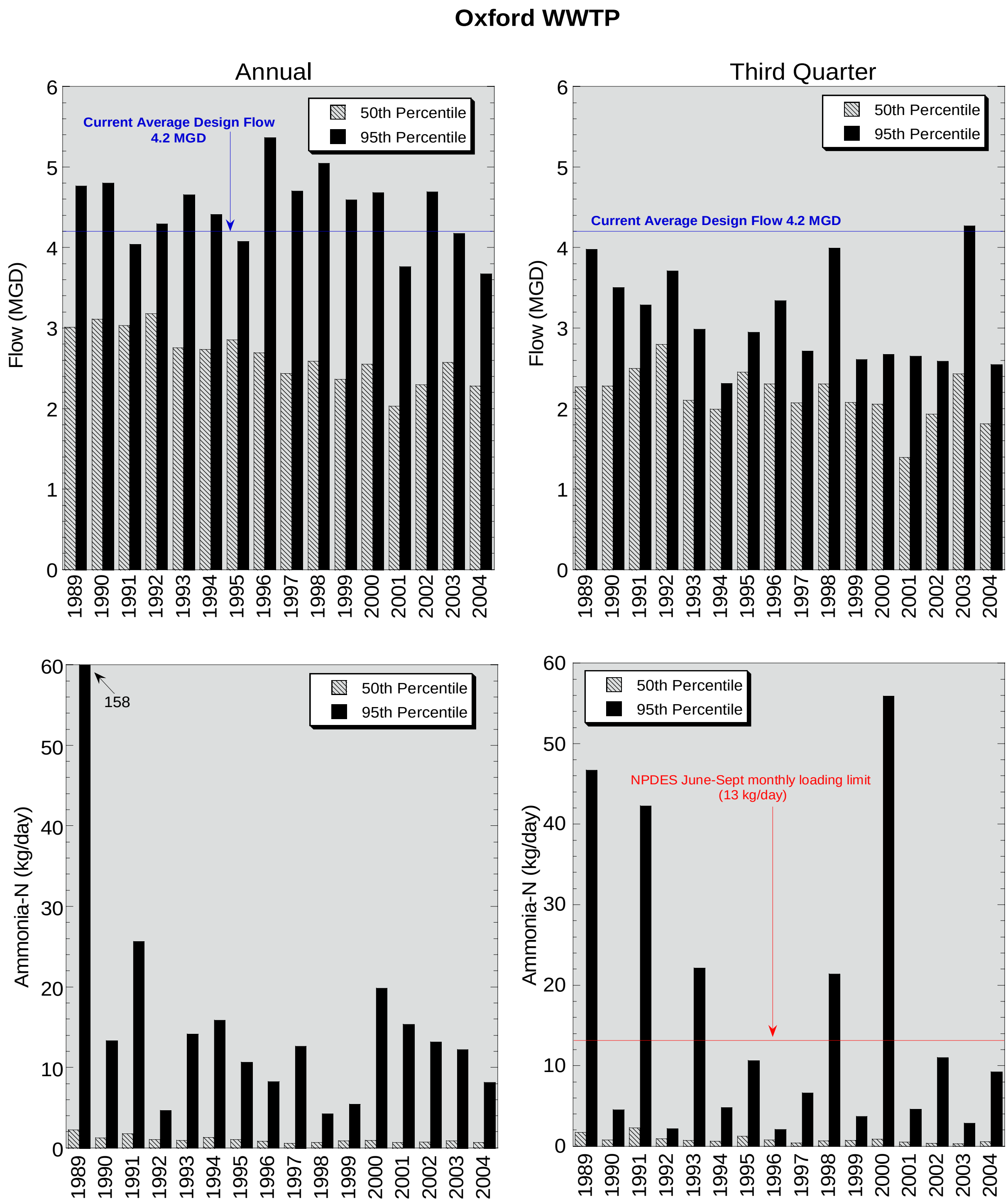


Figure 13. Oxford WWTP Outfall 001 annual (left side) and third quarter (right side) 50th and 95th percentile conduit flows (MGD), and ammonia-N loadings (kg/day) from 1989 - 2004.

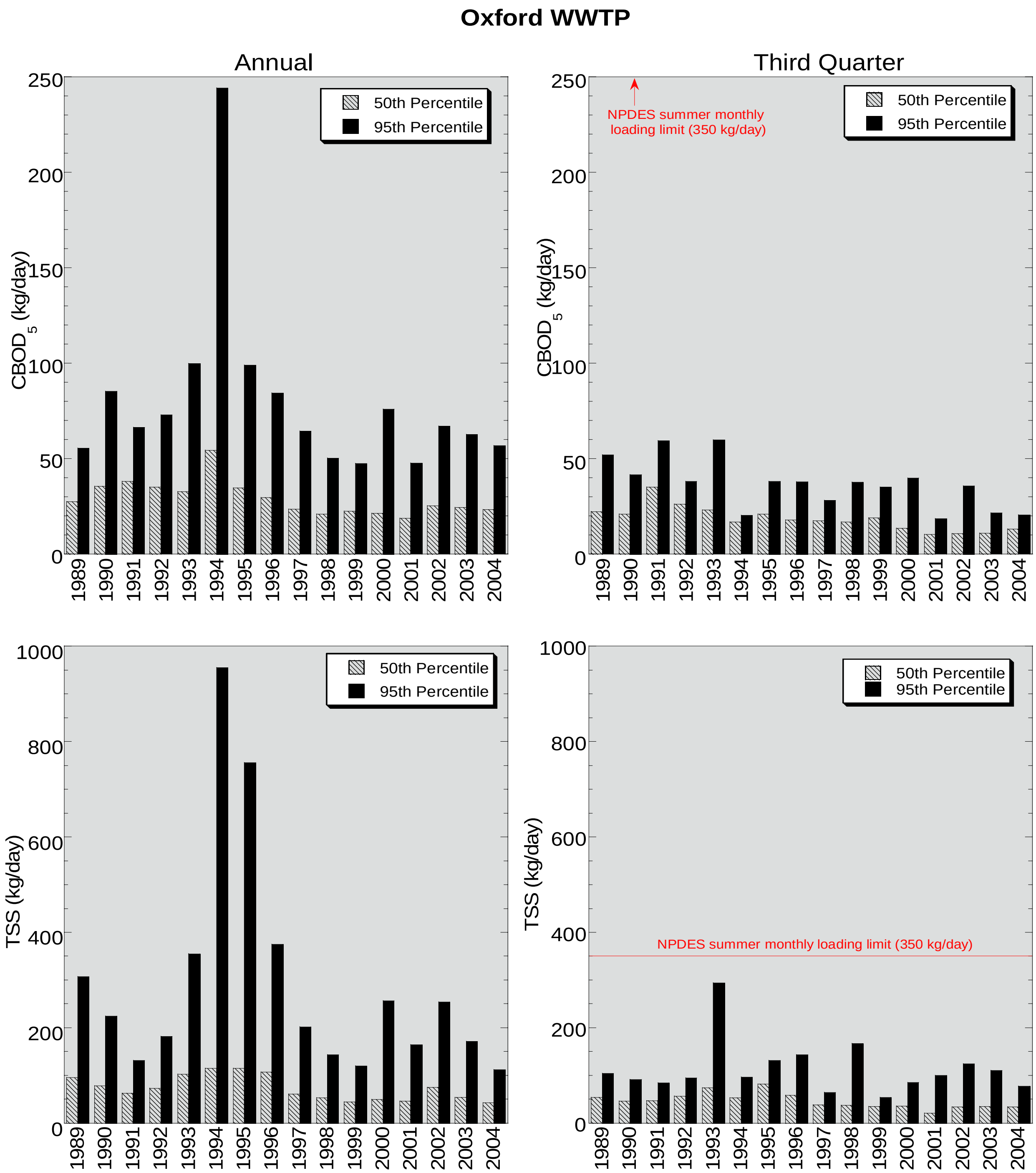


Figure 14. Oxford WWTP Outfall 001 annual (left side) and third quarter (right side) 50th and 95th percentile loadings (kg/day) of $CBOD_5$ and total suspended solids (TSS) from 1989 - 2004.

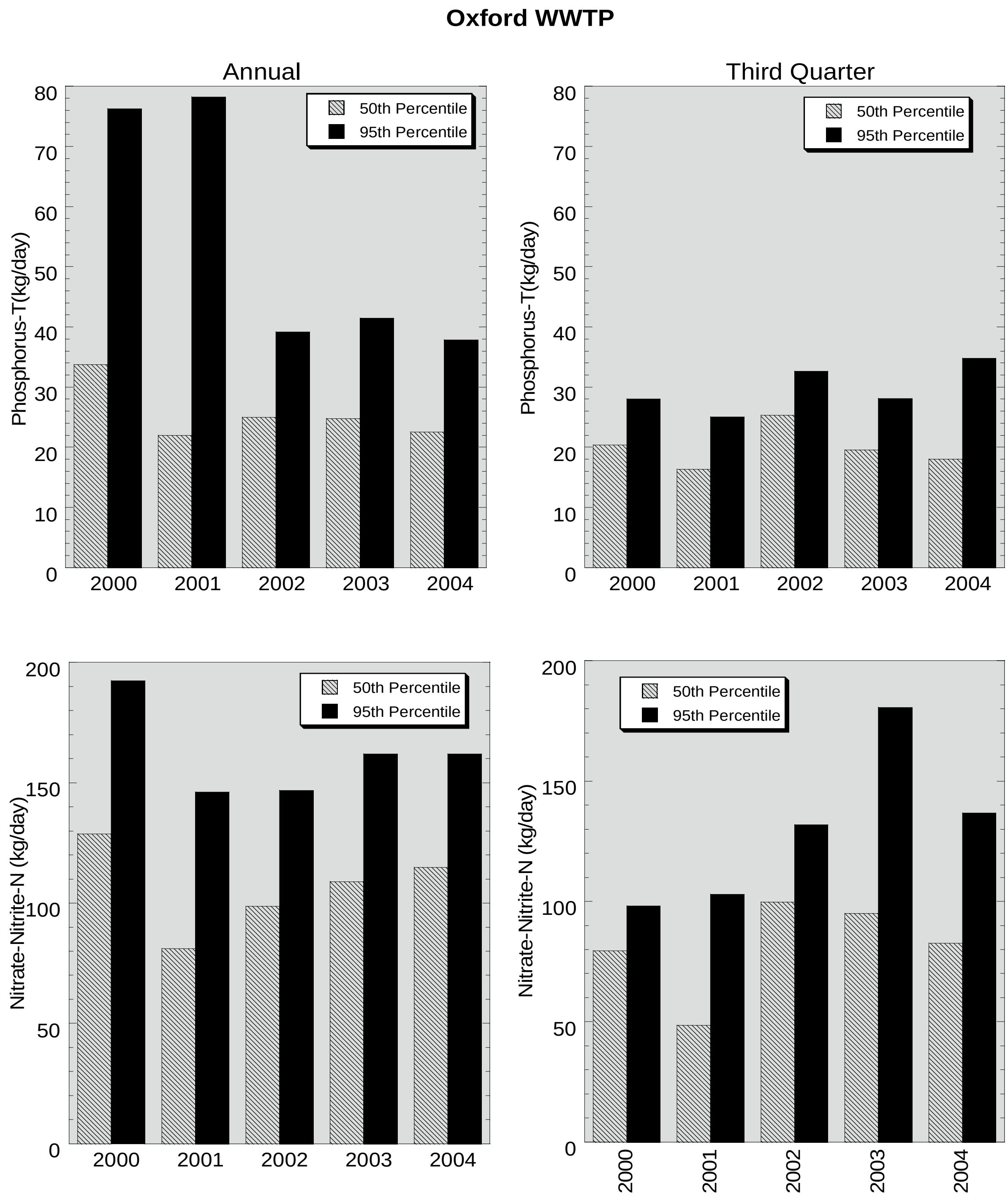


Figure 15. Oxford WWTP Outfall 001 annual (left side) and third quarter (right side) 50th and 95th percentile loadings (kg/day) of total phosphorus and NO3-NO2-N from 2000 - 2004.

Oxford WWTP

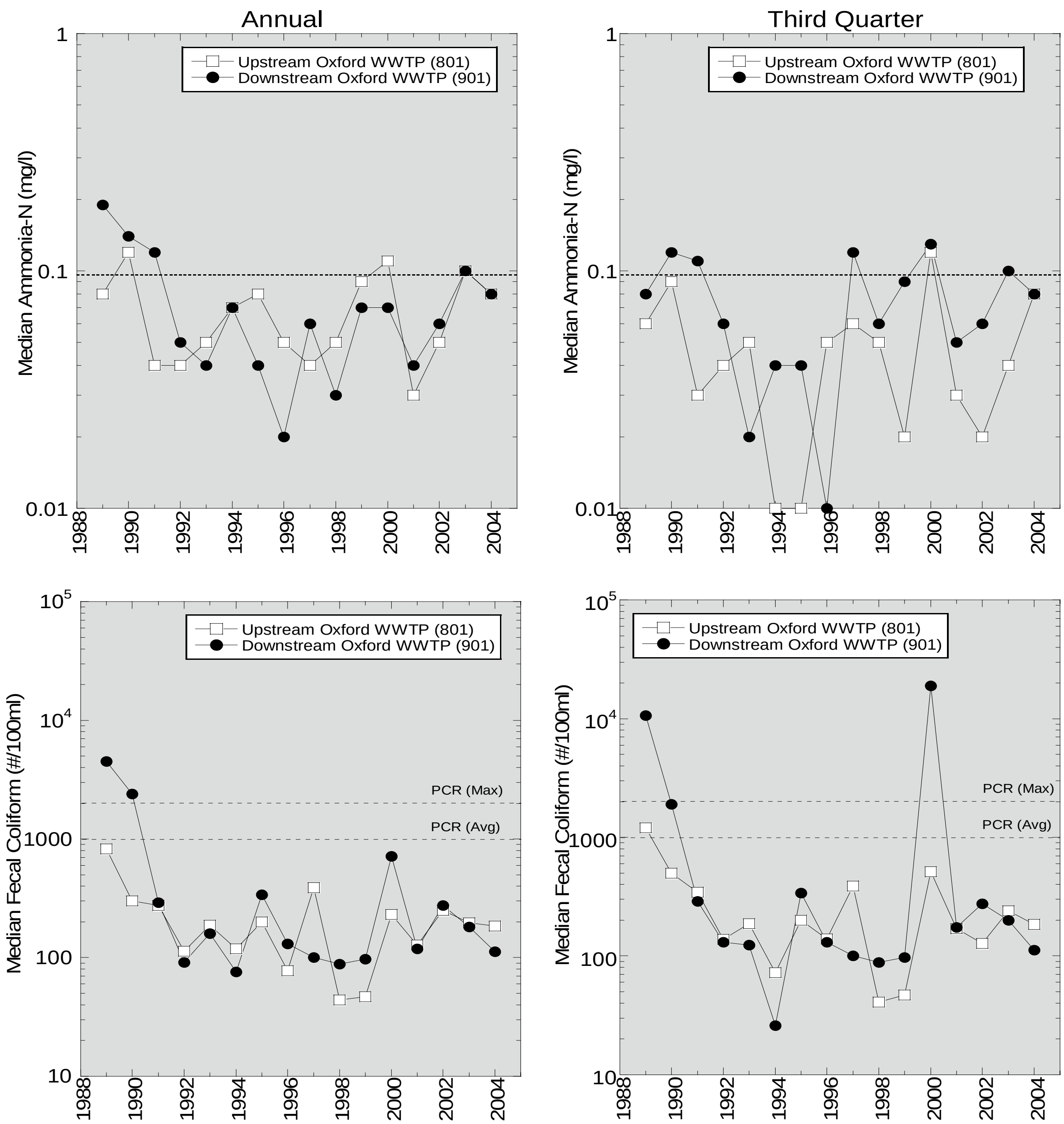


Figure 16. Oxford WWTP annual (left side) and third quarter (right side) median instream ammonia-N and fecal coliform concentrations at Oxford upstream (801) and downstream (901) monitoring stations in Fourmile Creek from 1989 – 2004. (The dotted line in the ammonia-N graphs represents the 90th percentile concentration from reference sites of similar size in the ECBP ecoregion while the PCR water quality criteria are depicted in the fecal coliform graphs.)

Talawanda Board of Education - Marshall Elementary School WWTP
Unnamed tributary of Culane Run (RM 0.39/0.82)
Permit # 1PT00067*DD
Latitude/Longitude (DD): 39.4702777 / 84.7016666

Marshall Elementary WWTP discharges to an unnamed tributary at RM 0.39 which then enters Curlane Run at RM 0.82. Current treatment consists of a grease trap, comminutor, flow equalization tank, extended aeration tank, secondary clarifier, dosing chamber, two surface sand filters, chlorine contact tank, and post aeration. An aerated sludge holding tank is also provided and sludge is hauled to the LeSourdesville WWTP. The average design flow is 0.0075 mgd and the average daily flow as calculated from facility MORs from February through December 2005 was 0.0031 mgd. A February 2005 OEPA inspection report noted fourteen effluent limit NPDES violations and numerous monitoring frequency violations from March 2000 through December 2004. No violations (limit or monitoring frequency) were reported for the school in 2005 through SWIMs.

New Miami Local School District WWTP
Fourmile Creek (RM 1.05)
Permit # 1PT00000*ED (NPR effective December 1, 2006)
Latitude/Longitude (DD): 39.4386111/ 84.5386111

The New Miami Local School District (LCD) discharged treated sewage to Fourmile Creek at RM 1.05 from 1959 until late 2006. The system, with an average daily design of 0.03 mgd and an average daily flow rate of 0.005 mgd, provided sewage treatment for a total of approximately 1,180 students and employees at the high school, middle school and elementary school. Treatment consisted of a septic tank, extended aeration and clarification. Sludge was hauled to the LeSourdesville WWTP. In 1997, the facility installed a chlorination/dechlorination system and replaced the influent pumps.

A total of 95 numeric violations (concentration and loading) of NPDES permit limits were reported through the Ohio EPA Surface Water Information Management System (SWIMS) for the final effluent from 2000 through 2005 for the New Miami LCD. Total suspended solids accounted for the majority of violations (60%) followed by $CBOD_5$ (40%). Additionally, there were a total of 398 monitoring frequency violations reported through SWIMS for the period, the majority of which were for failure to meet the measurement frequency requirements for flow (93%).

The discharge from this facility was eliminated and the permit revoked effective December 1, 2006 when the school system connected to the new Butler County Department of Environmental Services New Miami WWTP.

Butler County Department of Environmental Services New Miami WWTP
Fourmile Creek (RM 0.55)
Permit # 1PB00023*FD
Latitude/Longitude (DD): 39.4334022 / 84.5438280

The Butler County Department of Environmental Services (BCDES) New Miami WWTP discharges treated wastewater to Fourmile Creek at RM 0.55. The original treatment plant, constructed in the early 1970s, served the Cherokee Park subdivision and had a capacity of 0.12 mgd. Treatment consisted of two aeration tanks, two clarifiers and an ultraviolet disinfection system. The collection system is 100% separate. In September 2004, BCDES received a Permit to Install (PTI) to construct a new treatment facility and install new sanitary sewers to serve the unsewered portions of the community. Effective November 2004 the Village of New Miami transferred ownership and operational responsibilities for the treatment and collection system to BCDES.

The current plant, which was completed and placed in operation on April 27, 2006, has a design flow rating of 0.8 mgd. The plant treats wastewater from more than 650 homes and businesses in the Village of New Miami and the Cherokee Park subdivision and has an average annual daily flow rate of 0.155 mgd. Treatment consists of a fine screen with a manual bar rack, two vertical loop activated sludge tanks, two secondary clarifiers, an ultraviolet disinfection system, and a post cascade aeration system. Waste activated sludge is stabilized in two interchange bioreactor selector tanks. The stabilized biosolids are either returned to the WWTP influent or hauled to the LeSourdesville WWTP. While infiltration and inflow have historically been a problem for the New Miami sewage collection system, BCDES continues to identify and reduce infiltration and inflow, particularly in the Cherokee Park subdivision. Currently (2007), BCDES is seeking funding to connect the Village of Seven Mile (located north of New Miami and east of Sevenmile Creek near RM 1.3) and areas of Wayne and St. Clair townships to the new treatment plant by sewer extensions. It is estimated that this would eliminate approximately 500 failing septic systems.

Numeric violations (concentration and loading) of NPDES limits for the final effluent (NPDES station 1PB00023001) were evaluated from 2000 through 2005 as reported through the Ohio EPA Surface Water Information Management System (SWIMS).

Table 13. Number of NPDES numeric permit violations (concentration and loading) for the Village of New Miami WWTP from 2000 through 2005.

Parameter	2000	2001	2002	2003	2004	2005	Total
DO	52	-	-	-	29	5	86
CBOD5	2	-	1	-	8	4	15
Ammonia-N	-	-	-	-	8	-	8
pH	2	32	19	8	-	-	61
TSS	2	5	2		23	14	46
Fecal coliform	1	-	-	-	-	-	1
Total	59	37	22	8	68	23	217

During this period the old plant was still on line and the facility reported a plethora of violations (217) for the six-year period (Table). Violations were attributed to the lack of sludge storage, high flow events, and the general age of the facility. Additionally, there were a total of 72 monitoring frequency violations reported through SWIMS for the period for Outfall 001, the majority of which were for failure to meet the measurement frequency requirements for ammonia-N (71%). During the nine months the new facility has been operational (May 2006 through January 2007), there has only been one numeric violation reported in SWIMs (TSS 7-day loading violation on June 8). No bioassays have been conducted at either the old or new facility.

Annual flow and loading graphs presented in Figure 17 indicate median flows approached or exceeded the average daily design flow of 0.12 mgd for much of the 16-year period (1989-2004), corroborating the need for the increased capacity provided by the subsequent construction of the new treatment system. More recent loading information applicable to the new facility is not currently available.

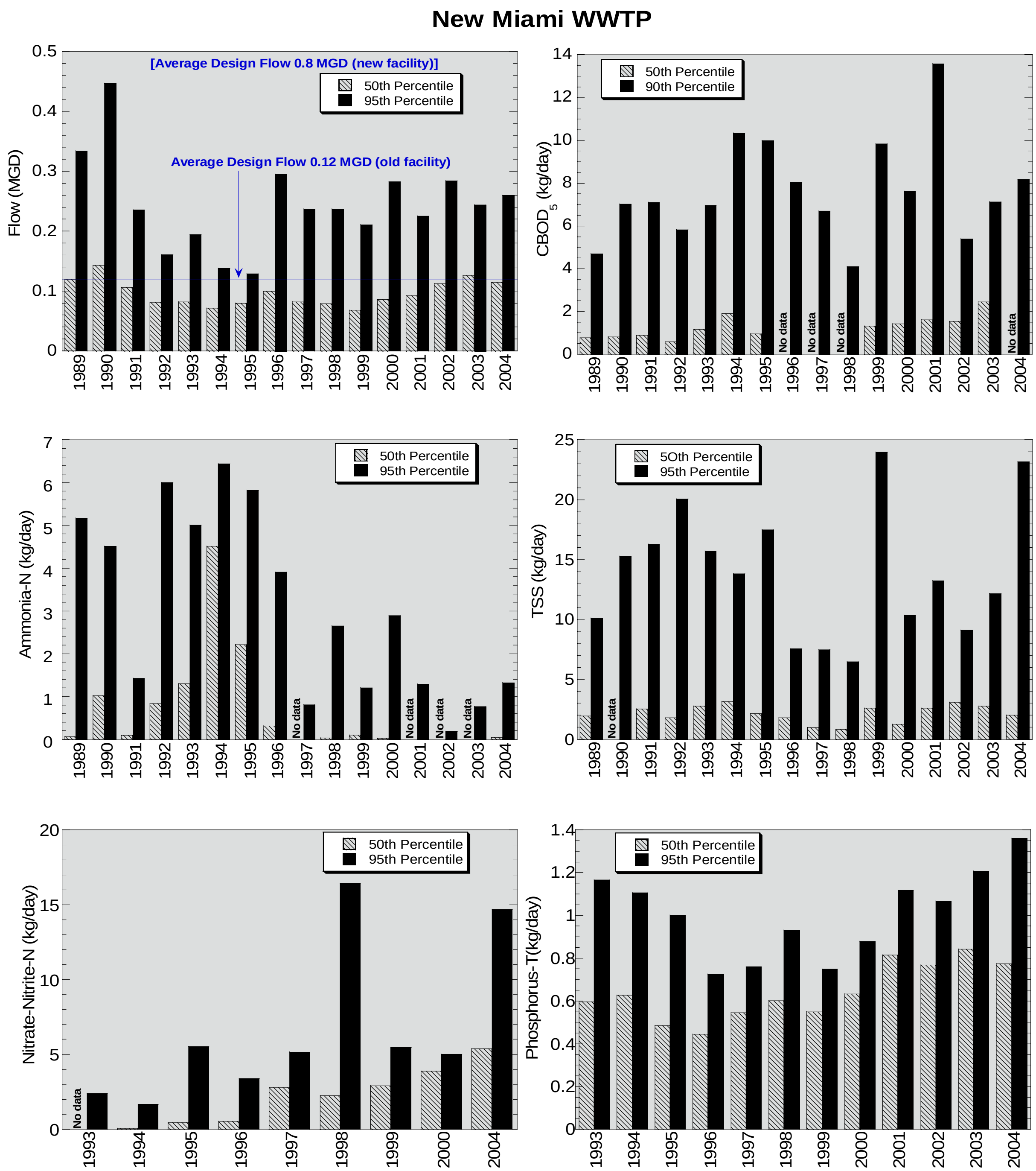


Figure 17. New Miami WWTP Outfall 001 annual 50th and 95th percentile conduit flows (MGD), and annual loadings (kg/day) of $CBOD_5$, ammonia-N, total suspended solids (TSS), nitrate-nitrite-N, and total phosphorus from 1989-2004 (1993-2004 for the latter two graphs).

Table 14. Dischargers in the Fourmile Creek watershed during 2005.

Facility Name	Ohio EPA Permit No.	Receiving Stream (River mile)	Average Design Flow (MGD)	Treatment
Preble County				
Hueston Woods State Park Beach and Marina	1PP00002*CD	Acton Lake	0.050	bar rack, aeration tank, clarifier, upflow filter where chlorine is added, four surface sand filters, a chlorine contact tank used as a dechlorination system
Hueston Woods State Park Lodge and Cabins	1PP00005*CD	Acton Lake	0.080	flow equalization, bar rack, aeration tank, two clarifiers, rapid sand filter, chlorination / dechlorination
Butler County				
Hueston Woods State Park Golf Course	1PP00004*AD	Unnamed tributary to Acton Lake	0.005	bar rack, aeration tank, clarifier, chlorination
Woodland Country Manor	1PX00041*BD	Unnamed tributary to Harkers Run (RM 2.38)	0.008	flow equalization, four aeration tanks, two clarifiers, a dosing tank, two surface sand filters, ultraviolet disinfection
City of Oxford WWTP	1PD00007*JD	Fourmile Creek (RM 16.36)	4.2	mechanical bar screen, grit tank, flow equalization, primary clarification, activated bio-filtration, secondary settling, ultraviolet disinfection, cascade aeration
Marshall Elementary School	1PT00067*DD	Unnamed tributary to Culane Run (RM 0.39/0.82)	0.0075	grease trap, comminutor, flow equalization, extended aeration, secondary clarifier, dosing chamber, two surface sand filters, chlorine contact tank, post aeration
New Miami Local School District	1PT00000*ED (NPR Dec. 2006)	Fourmile Creek (RM 1.05)	0.03	Extended aeration, chlorination/dechlorination
New Miami WWTP	1PB00023*FD	Fourmile Creek (RM 0.55)	0.12 (0.8 as of April 2006)	New plant: bar rack, two vertical loop activated sludge tanks, two secondary clarifiers, ultraviolet disinfection, post cascade aeration

Spills, Overflows and Unauthorized Releases

Pollutant discharges from spills, overflows, and other unauthorized releases can be significant sources of lethal and sublethal stresses to the aquatic communities in the watershed (Table 15).

The Oxford wastewater treatment plant and collection system released over 9.2 million gallons of sewage, accounting for 25 of the 30 releases documented in the entire watershed from 2000 through 2005. The three largest bypasses at the plant occurred in Jan 2005 (5.7 million gallons), July 2003 (3.3 million gallons), and June 2000 (168,000 gallons). Respectively, the reported causes of these three incidents were excessive rain and snowmelt, a generator transfer switch gear error, and power failure. The majority of collection system overflows were a result of I/I problems or blockages.

Petroleum related materials (oil, gasoline and diesel fuel) accounted for the remainder of spills in the watershed.

Table 15. Spills, overflows, and unauthorized releases in the Fourmile Creek watershed from 2000 through 2005. (*Releases are listed whether or not it is certain the substance actually reached a waterway*.)

Date of Spill	Entity	Location of Spill	Substance spilled	Quantity (gallons)	Waterway
2005					
March 28	Oxford WWTP	325 W. High St	Sewage	6,400	Collins Cr
Jan 5-7	Oxford WWTP	501 McKee Ave	Sewage	5,663,757*	Fourmile Cr
Jan 5	Oxford WWTP	325 W. High St	Sewage	21,000	Collins Cr
2004					
Aug 6	Oxford WWTP	Chestnut St	Sewage	1000	Storm to trib to Collins Cr
April 13	Oxford WWTP	501 McKee Ave	Sewage	300	Fourmile Cr
April 4	Oxford WWTP	501 McKee Ave	Sewage	1,500	Fourmile Cr
Feb 9	Oxford WWTP	501 McKee Ave	Sludge	150	Fourmile Cr
Jan 3-4	Oxford WWTP	501 McKee Ave	Sewage	unknown	Fourmile Cr
Jan 3	Oxford WWTP	325 High St	Sewage	72,000	Collins Cr
2003					
Oct 14	Oxford WWTP	501 McKee Ave	Sewage	8,160	Fourmile Cr
July 4-5	Oxford WWTP	501 McKee Ave	Sewage	3,270,000*	Fourmile Cr
June 30	Unknown	Eaton Oxford Rd	Used Oil	2	Morning Sun trib
June 15	Oxford WWTP	501 McKee Ave	Sewage	unknown	Fourmile Cr
June 2	Oxford WWTP	97 Acorn Circle	Sewage	1,000	Collins Cr
May 9-11	Oxford WWTP	501 McKee Ave	Sewage	10,000	Fourmile Cr
Jan 7	Dairy Mart	327 W. Spring St	Gasoline	3	Storm to trib to Collins Cr
2002					
June 7	Benjamin Steel	SR 725 and SR 177	Diesel Fuel	150	Trib to East Fk Fourmile Cr
May 8	Oxford WWTP	5110 Bonham Rd	Sewage	500	Fourmile Cr
May 7	Oxford WWTP	S. Locust St	Sewage	2,000	Fourmile Cr
2001					
Dec 20	Oxford WWTP	Corn Circle	Sewage	unknown	Collins Cr
Dec 17	Oxford WWTP	S. Locust St	Sewage	unknown	Collins Cr
June 2	Rumpke	Rt 177/Preble-Butler Rd	Diesel	30	Ditch
April 30	Oxford WWTP	S. Locust St	Sewage	1,500	Collins Cr
Jan 29	Oxford WWTP	S. Locust St	Sewage	1,200	Collins Cr
2000					
July 18	Unknown	2 S. Campus	Oil	Unknown	Storm
June 17	Oxford WWTP	501 McKee Ave	Sewage	168,000*	Fourmile Cr
May 27	Oxford WWTP	S. Locust St	Sewage	300	Collins Cr
April 15	Oxford WWTP	N. Locust St	Sewage	300	Collins Cr
Jan 18	Oxford WWTP	220 W. Sycamore St	Sewage	Unknown	--
Jan 12	Oxford WWTP	Emerald Woods Dr	Sewage	100	Collins Cr

*Reported causes: Jan 5-7, 2005: rain, snowmelt
July 4-5, 2003: generator transfer switch gear error
June 17, 2000: power failure

Chemical Water Quality Changes

Past biological and water quality surveys of the Fourmile Creek watershed were conducted by the Ohio EPA in 1996 and 1991. Water samples were collected in the mainstem at ten (10) sites in 1996 from August through October and at eight (8) sites in 1991 from July through September. Additionally, three sites were sampled in Elams Run in 1996 (RMs 2.15, 2.08, and 0.01) to assess the impact of the discharge from Square D on the stream. Square D (Schneider Electric Oxford Plant) produces electrical distributing equipment. Prior to 2001, the facility discharged effluent from the painting, boiler room, plating and powder coating operations directly to Elams Run at RM 2.11 via a direct discharge NPDES permit. In July 2001, Square D was issued an NPDES indirect discharge permit to discharge all wastewater to the Oxford WWTP.

Precipitation records for Miami University in Oxford for the three survey years are presented in Figure 18 (OARDC 2007). There are no stream flow gauging stations in the watershed. Precipitation from May through October 1991 (14.81 inches) was well below normal (19.43 inches) and field notes indicate that stream flows steadily diminished throughout the survey. While significantly more precipitation was measured in 1996 for the May through October period (24.81 inches), most of this rainfall (16.45 inches) occurred from May through July before survey sampling began in August. Precipitation in August and October of 1996 was below normal and field notes indicate lower stream flows during much of the 1996 survey also. Total precipitation of 20.38 inches was recorded in 2005 from May through October. However, precipitation records and field notes indicate that rainfall in 2005 may have been more localized with areas downstream from Oxford in the lower portion of the watershed receiving more precipitation than the upper watershed.

A comparison of 2005, 1996, and 1991 median water chemistry results for select parameters in the mainstem of Fourmile Creek and in Elams Run (near the mouth) are presented in Figure 19 and Figure 20. Given that the most upstream sampling location in the mainstem in the previous two surveys was at Camden-College Corner Road (RM 24.77), the figures below include only the nine mainstem sites in 2005 from this point to the mouth.

Elevated ammonia concentrations and multiple exceedences of WQS criteria were recorded in the mainstem downstream from the Acton Lake spillway in all surveys with medians ranging from 1.83 mg/l (1991) to 3.71 mg/l (2005). Lower dissolved oxygen levels were also observed here, most notably in 2005.

Total phosphorus levels were generally lower in 2005 compared to previous surveys. Median phosphorus concentrations immediately downstream from the Oxford WWTP decreased from 2.38 mg/l in 1991 to 0.73 mg/l in 2005. Similar longitudinal patterns were observed downstream from this facility in all three surveys with phosphorus elevated well above the 90^{th} percentile reference concentration (0.22 mg/l) before becoming assimilated fifteen miles downstream near the mouth at RM 0.35.

Total suspended solids were significantly higher in the mainstem during the 2005 survey compared to previous surveys. The overall median TSS concentration for all mainstem sites downstream from Acton Lake in 2005 was 19 mg/l compared to 7.5 mg/l in 1996 and 7 mg/l in 1991. Levels were especially elevated at RM 11.00 (SR 177) and RM 5.40 (Eaton Rd) in 2005 with medians well above the 75th percentile reference value. The highest levels in 1996 also occurred at RMs 11.00 and 5.40. Additionally, while overall levels were lower in previous surveys, TSS increased in a remarkably similar pattern longitudinally in all survey years from RM 18.75 (SR 732 downstream from Elams Run) to RM 5.40 (Eaton Road) before decreasing near the mouth (RM 0.35) after the confluence of Sevenmile Creek. The consistency of this pattern may warrant further investigation.

Water quality in Elams Run has improved since Square D no longer discharges directly to the stream. A comparison of 2005 and 1996 water chemistry results for Elams Run near the mouth indicates lower levels of nitrate-nitrite-N, total phosphorus, and conductivity in 2005. While no elevated concentrations were recorded in Elams Run near the mouth during either the 2005 or 1996 surveys, elevated concentrations of copper, ammonia-N, nitrate-nitrite-N, and total phosphorus were recorded in 1996 downstream from Square D in Elams Run at RM 2.08.

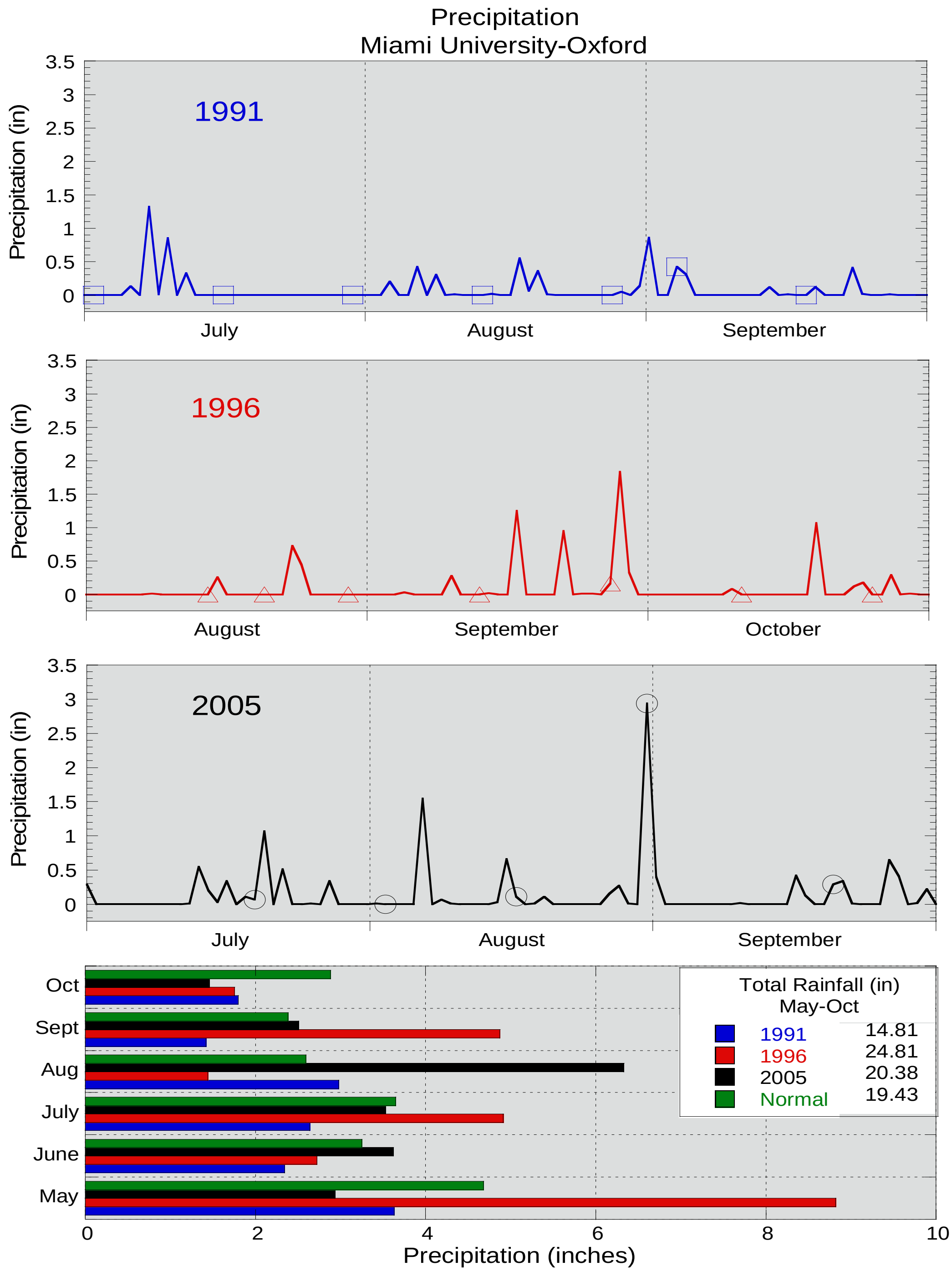


Figure 18. Upper three graphs: Daily precipitation recorded at Miami University in Oxford during survey months in 1991, 1996, and 2005 (OARDC, 2007). The markers (squares, triangles, circles) in each of the upper three graphs represent water chemistry sampling days in each respective survey. Lower graph: Monthly precipitation totals versus normal recorded at Miami University in Oxford for May through October in 1991, 1996, and 2005 (OARDC, 2007).

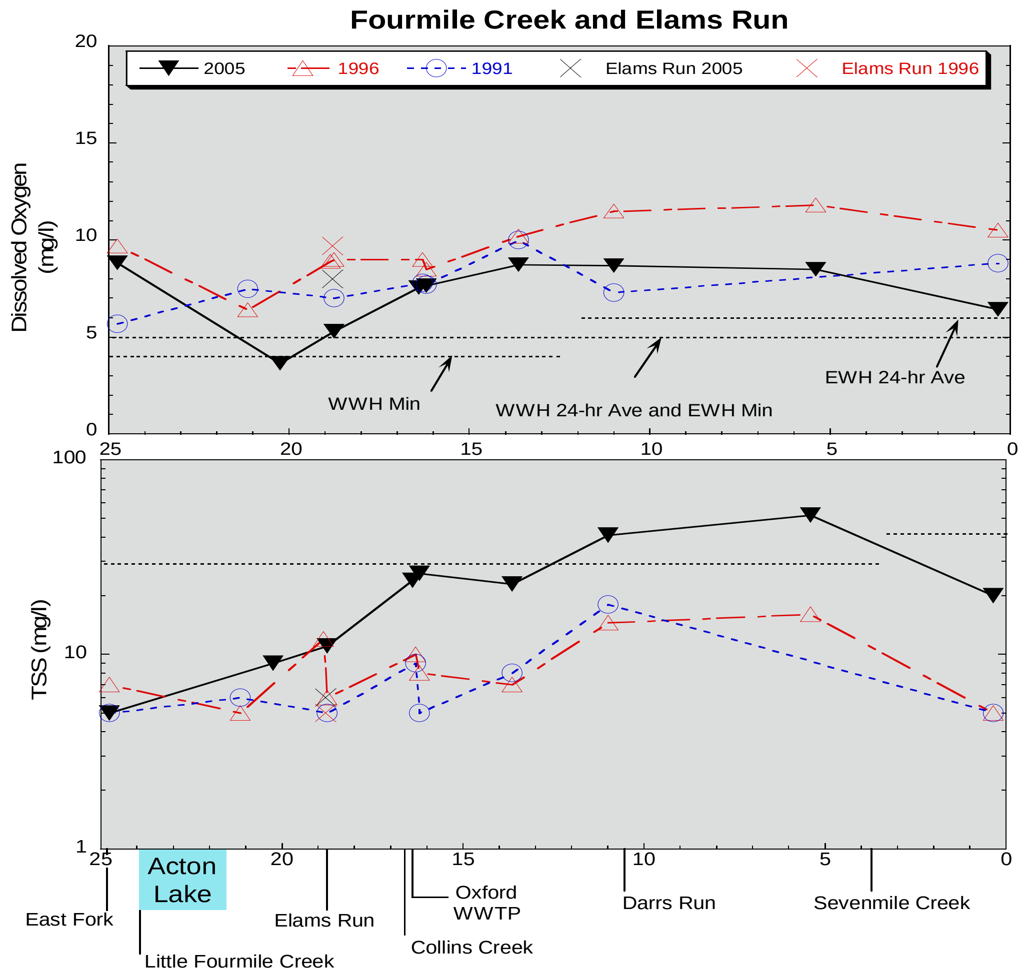


Figure 19. Median concentrations of dissolved oxygen and total suspended solids in the mainstem of Fourmile Creek (2005, 1996, and 1991) and in Elams Run near the mouth (2005 and 1996). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in the TSS plot represent the 75th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

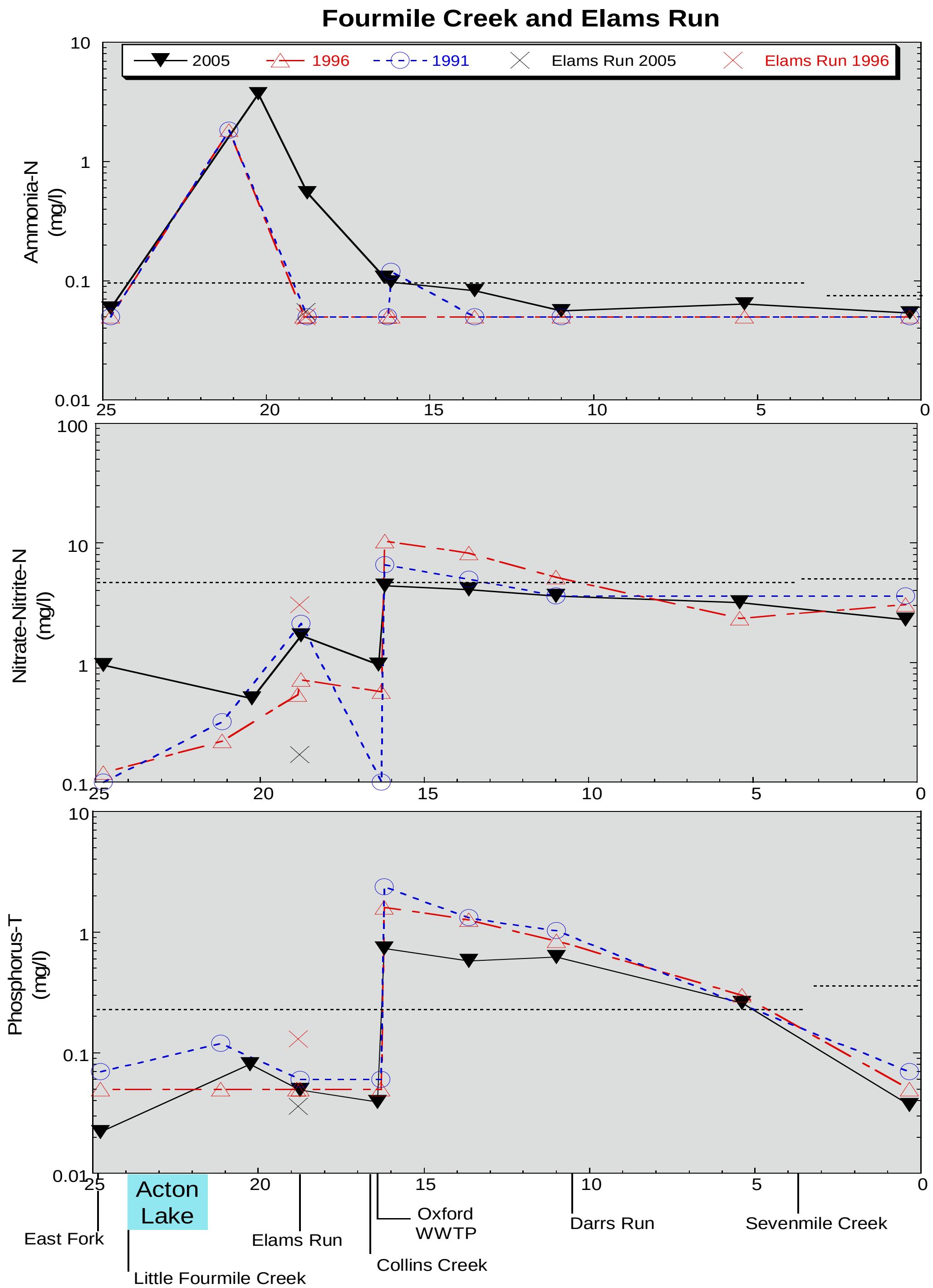


Figure 20. Median concentrations of ammonia-nitrogen, nitrate-nitrite-nitrogen, and total phosphorus in the mainstem of Fourmile Creek (2005, 1996, and 1991) and in Elams Run near the mouth (2005 and 1996). Dashed horizontal lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Physical Habitat for Aquatic Life

Fourmile Creek (mainstem)

The assessment of the influence of physical stream features and riparian conditions on ambient biological performance for the Fourmile Creek basin will proceed in a longitudinal manner (upstream to downstream). The discussion of tributaries will either be treated in the aggregate, or if sufficiently large, tributaries or sub-basins will be broken-out separately for discussion. For the purposes of continuity, this longitudinal reporting structure will also be applied to the assessment of ambient biological performance throughout this document.

As part of the 2005 fish sampling effort, the quality of near and in-stream macrohabitats of the Fourmile Creek mainstem were evaluated at 12 sampling locations, assessing approximately 42 miles of the mainstem, between RM 41.1 (Weist Rd.) and RM 0.3 (at mouth). QHEI values ranged between 92.5 and 44.5, with a mean score of 73.4 (±11.63 SD). Longitudinal performance of the QHEI and a matrix of macrohabitat features, by station, are presented in Table 16 and Figure 21.

Mean QHEI values from rivers or river segments equal to or greater than 60.0 generally indicate a level of macrohabitat quality sufficient to support an assemblage of aquatic organisms fully consistent with the WWH aquatic life use designation. Average reach values greater than 75.0 are generally considered adequate to support fully exceptional (EWH) communities (Rankin 1989 and Rankin 1995). Values between 55 and 45 indicate limiting components of physical habitat are present and may exert a negative influence upon ambient biological performance. However, due to the potential for compensatory stream features (e.g., strong ground water influence) or other watershed variables, QHEI scores within this range do not necessarily preclude WWH or even EWH assemblages. Values below 45 indicate a higher probability of habitat derived aquatic life use impairment.

Presently, two aquatic life use designations, affecting three segments of Fourmile Creek are in place. The WWH use is applicable from the headwaters to Acton Lake, downstream from Acton Lake to Darrtown Road (RM 13.0), and the lowest reach between RM 0.4 (Sevenmile Rd.) and the mouth. The intervening 12.6 miles, between RM 13.0 (Darrtown Rd.) and RM 0.4 is designated EWH. In nearly every instance the quality of near and in-stream macrohabitat throughout the entire length of Fourmile Creek appeared fully capable of supporting diverse, functionally organized, and well-structured assemblages of aquatic organisms, consistent with its existing WWH and EWH aquatic life uses. Most sites contained a full compliment of positive channel, substrate, and riparian features, displaying classic channel form and function typical of high quality till-plains streams of central and west-central Ohio. The channel configuration of the mainstem was generally in a natural or recovered state, displaying a high degree of sinuosity. Riffle and run complexes were commonly observed throughout.

Table 16. A matrix of macrohabitat features and QHEI scores for the Fourmile Creek study area, 2005.

Key: QHEI Components

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Overall Embeddedness	Max Depth > 40 cm	Low/Normal Riffle Embeddedness	Total WWH Attributes	MWH Attributes, High Influence: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(14-400) Fourmile Creek																																		
Year: 2005																																		
41.1	44.5	10.31	■	■			■						3		●	●	●	●	4		●			●			●	●	●		●	6	1.25	2.75
38.9	65.5	9.01	■	■			■	■			■	■	6		●				1		●			●				●	●			4	0.29	0.86
35.6	72.0	12.05	■	■		■	■	■			■	■	7						0		●			●				●	●	●		5	0.13	0.75
26.7	71.0	14.29	■	■		■	■	■		■	■	■	8				●		1					●	●			●				3	0.22	0.56
24.8	68.5	41.67	■			■	■	■		■		■	6					●	1					●		●		●				3	0.29	0.71
18.7	81.5	9.35	■	■		■	■	■	■	■	■	■	9						0		●								●			2	0.10	0.30
16.4	78.5	9.26	■	■		■	■	■	■		■	■	8						0		●			●					●	●		4	0.11	0.56
16.2	74.0	9.26	■	■		■	■	■	■		■		7				●		1		●			●					●	●		4	0.25	0.75
13.7	92.5	10.99	■	■		■	■	■	■	■	■	■	9						0		●											1	0.10	0.20
11.0	74.0	15.63	■			■	■	■	■	■	■	■	8						0		●											1	0.11	0.22
5.4	83.0	10.53	■	■		■	■	■	■	■	■	■	9						0		●								●			2	0.10	0.30
0.3	76.5	7.10	■	■		■	■	■		■	■	■	8						0	●								●	●			3	0.11	0.44
(14-404) Little Fourmile Creek																																		
Year: 2005																																		
13.5	74.5	15.38	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
2.8	78.0	17.54	■	■		■	■	■		■	■	■	8						0		●			●	●			●				4	0.11	0.56
(14-405) East Fork Fourmile Creek																																		
Year: 2005																																		
5.2	64.5	25.00	■							■	■	■	4			●	●		2					●				●				2	0.60	1.00
2.4	70.0	27.78	■	■		■	■	■		■	■		7				●		1		●		●	●				●		●		5	0.25	0.88
(14-406) Harris Run (Dixon Branch)																																		
Year: 2005																																		
0.3	63.0	15.63	■		■					■	■	■	5			●	●		2					●				●				2	0.50	0.83
(14-426) Fleisch Run																																		
Year: 2005																																		
0.7	41.5	11.49									■		1	●	●	●	●		4	●	●			●				●	●	●		6	2.50	5.50
(14-427) Trib. to Fourmile Creek (RM 23.57)																																		
Year: 2005																																		
0.7	79.5	30.43	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22

Table 16. Continued.

Key: QHEI Components

WWH Attributes

River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes
(14-408) Harkers Run													
Year: 2005													
2.4	67.5	29.41	■	■			■	■		■		■	6
(14-423) Elams Run													
Year: 2005													
0.3	65.0	52.63	■	■	■	■	■			■	■	■	8
(14-424) Darrs Run													
Year: 2005													
2.1	54.5	37.04		■							■		2
(14-432) Stony Run													
Year: 2005													
0.3	52.0	45.45	■	■		■	■			■			5
(14-433) Collins Creek													
Year: 2005													
0.6	60.5	23.81		■						■	■		3
(14-434) Trib. to Fourmile Creek (23.57/0.25)													
Year: 2005													
0.8	69.0	35.71	■	■	■	■	■			■	■	■	8

MWH Attributes — *High Influence*

River Mile	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes
(14-408) Harkers Run, 2005: 2.4			●	●	●	3
(14-423) Elams Run, 2005: 0.3			●	●		2
(14-424) Darrs Run, 2005: 2.1			●	●		2
(14-432) Stony Run, 2005: 0.3				●	●	2
(14-433) Collins Creek, 2005: 0.6			●	●		2
(14-434) Trib. to Fourmile Creek (23.57/0.25), 2005: 0.8				●		1

MWH Attributes — *Moderate Influence*

River Mile	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(14-408) Harkers Run, 2005: 2.4		●			●				●				3	0.57	1.00
(14-423) Elams Run, 2005: 0.3					●				●				2	0.33	0.56
(14-424) Darrs Run, 2005: 2.1	●	●			●				●	●	●		6	1.00	3.00
(14-432) Stony Run, 2005: 0.3					●				●			●	3	0.50	1.00
(14-433) Collins Creek, 2005: 0.6	●				●				●		●		4	0.75	1.75
(14-434) Trib. to Fourmile Creek (23.57/0.25), 2005: 0.8					●				●				2	0.22	0.44

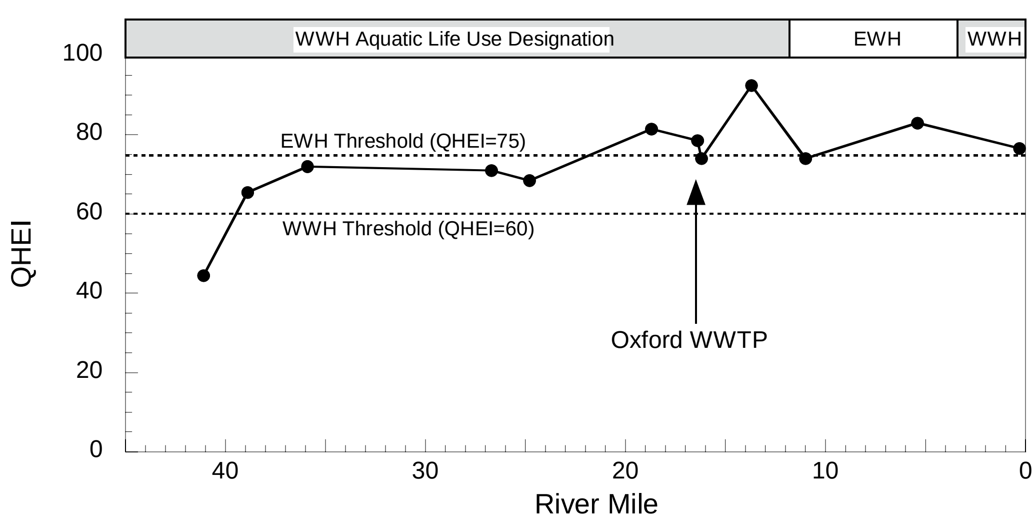


Figure 21. Longitudinal performance of the QHEI for the Fourmile Creek mainstem, 2005.

Where evidence of previous channel modification was found, the process of natural restoration or recovery of complex channel features, although incomplete, appeared well underway. Trench and lateral scour pools were regularly observed and often found well-structured with woody debris and fallen timber. Dominant substrates were coarse glacial till which was generally unencumbered with extensive deposits of clayey silts. Riparian areas at most sites were vegetated, more often wooded, attenuating sunlight and providing in-stream structure in the form of woody debris and rootwad formations.

Degraded, diminished or otherwise substandard habitat on the mainstem was documented at the uppermost site only (RM 41.1, Weist Rd.). Fourmile Creek at this station courses through an open pasture, where livestock access is unrestricted. As such, this reach displayed the various and sundry physical impacts typically associated with pasture streams: little or no riparian vegetation, false banks, embedded substrates, and monotonous development. High and moderate influence modified habitat attributes were overwhelmingly dominant at this site (Table 16). The combined influence of these features yielded a *poor* habitat score (QHEI=44.5).

Several factors can diminish the anticipated negative effects of the locally degraded conditions. Typically, sustained inputs from the water table to surface waters results in greater sustained surface flow, cooler in-stream temperatures, and improved chemical water quality. It has been regularly observed, state-wide, that the deleterious effects of degraded macohabitat on ambient biological performance in small headwater streams can be largely mitigated by the influence of ground water. This phenomenon appeared operative in the headwaters of Fourmile Creek.

It is also important to consider the aggregate macrohabitat condition of Fourmile Creek. Poor conditions documented at the uppermost site are truly anomalous, in comparison with all remaining downstream stations (Figures 22 and 23). Previous statewide investigations have found that measures of macrohabitat quality, and their power to predict ambient biological performance, are best viewed and most informative when analyzed in the aggregate (Rankin 1989).

In the absence of a profound disruption (e.g., large impoundments), ambient biological performance does not directly parallel measures of macrohabitat quality on a station or small reach scale. Rather, community performance generally reflects the aggregate or typical conditions of large contiguous stream segments, with deficient sites or reaches serving as biological *sinks*, and high quality sites or reaches functioning as biological *sources*. For sufficiently large data sets, the operative variable is the proportion of sink and source habitat. This phenomenon has been described and found to operate in other ecological settings (Pulliam 1988).

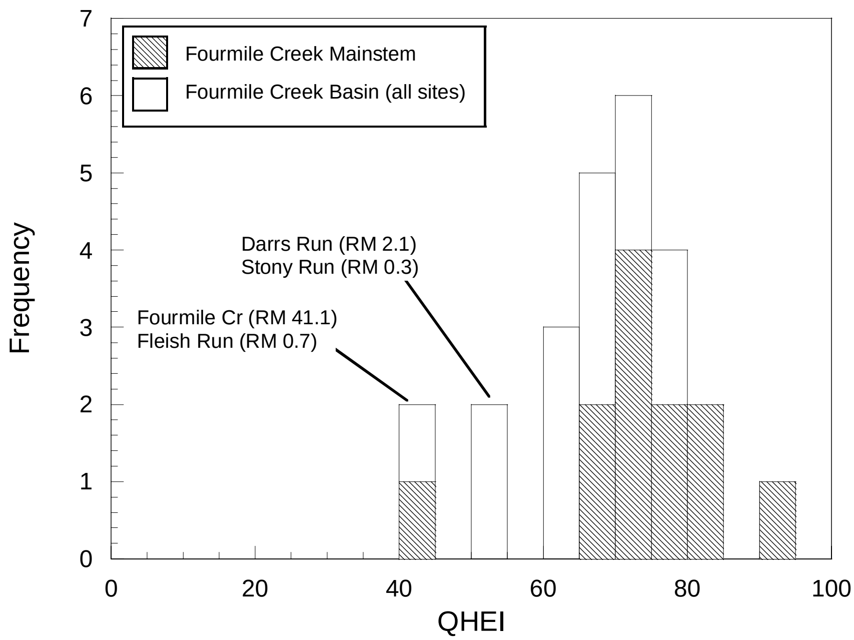


Figure 22. Distribution of QHEI scores for all monitoring stations within the Fourmile Creek study area, 2005.

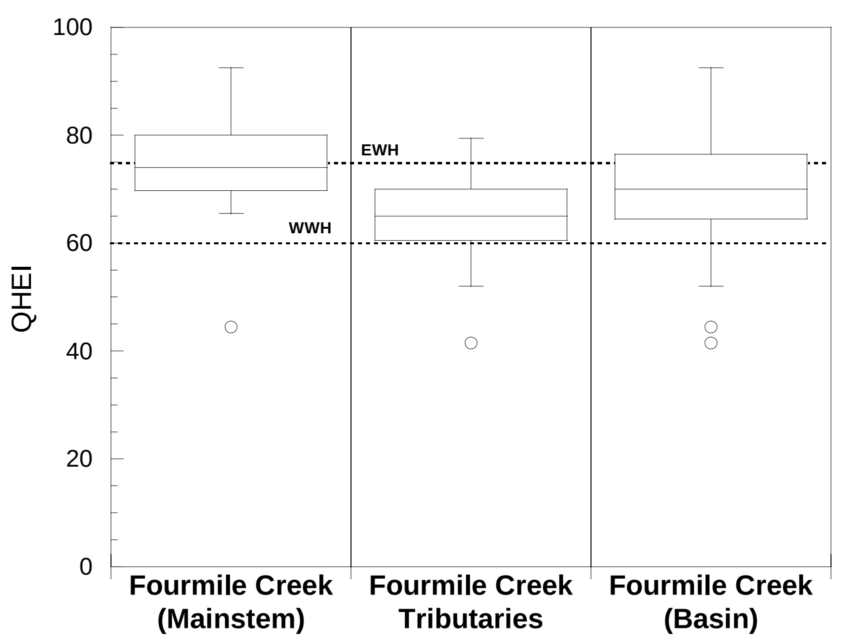


Figure 23. Aggregated and categorized Qualitative Habitat Evaluation Index (QHEI) values from the Fourmile Creek study area, 2005.

Ultimately, in light of the abundance of macrohabitat at or greater than the WWH thresholds, the small segments of sub-par habitat found in the uppermost reaches of Fourmile Creek would potentially have a limited effect on the performance of the local aquatic fauna. Furthermore, the positive and often mitigating effects of groundwater, as described above, would further reduce the likelihood of habitat related impairment within the headwaters or readily explain community performance far greater than that predicted from the QHEI alone. Therefore, departure from the applicable ambient biological criteria, derived solely from or associated with deficient, degraded or otherwise simplified macrohabitat were not anticipated. In the absence of significant water quality problems, the near and in-stream physical features of Fourmile Creek appeared capable of supporting aquatic communities consistent with the applicable biological criteria.

Fourmile Creek Tributaries

Eleven direct and indirect Fourmile Creek tributaries were surveyed and assessed as part of the 2005 field sampling effort. Thirteen sampling stations were deployed to these waters, evaluating the macrohabitat quality of 32 cumulative linear stream miles. QHEI values for these tributaries ranged between 79.5 and 41.5, with a mean score of 64.58 ($\pm$10.69 SD).

Areas of deficit habitat were limited to three streams, representing 15.6% (five miles) of the 32 monitored tributary miles. Specifically, these streams included Fleisch Run, Stony Run, and Darrs Run. QHEI score from these sites were 41.5, 52.0 and 54.5, respectively (Table 16 and Figure 23).

Serious or otherwise significant macrohabitat degradation was evident only on Fleisch Run (QHEI=41.5). The majority of the segment evaluated in 2005 coursed through open pasture. The stream was obviously channelized in the past and displayed most of the negative channel form and substrate features attendant to this activity. As such, high and moderate influence modified habitat features were dominant, yielding a QHEI narrative of poor. Given the absence of mitigating or otherwise compensatory stream features, the level of habitat simplicity for Fleisch Run appeared severe enough to explain the aquatic life use impairment.

Deficient macrohabitat quality for Stony Run and Darrs Run were by no means profound, and as such did not appear to serve as a significant impediment to the maintenance of WWH communities.

Stony Run was found in a natural, unmodified state. No obvious evidence of anthropogenic modification was observed. The waterbody possessed a typical set of features common to small limestone bedrock streams of southwestern Ohio. As a group, streams so characterized are often over-wide and shallow. Because the streambed is resistant to degradation, erosive forces responsible for channel maintenance and formation are only able to act laterally. The resulting wide and generally shallow channels of bedrock streams often lack important habitat features and are also prone to dewatering during periods of drought. In the case of Stony Run, the natural homogeneity coupled with observed emphemerality, resulted in a QHEI score in the fair range. The channel was largely dry in September of 2005, surface water being reduced to residual pools. However, Stony Run appeared interstitial, as the residual pools were adequate to serve as drought refuge, due to the influence of hyporheic flow. The absence of flow dependant channel features (riffles and runs) and the natural simplicity of small bedrock streams, as a category, negatively affected the QHEI, thus the sub-goal habitat score (QHEI=52.0). However, the interpretation of the observation detailed above suggest that overall habitat conditions of Stony Run appeared more compatible with WWH communities, than the QHEI would predict alone.

The fair macrohabitat quality observed for Darrs Run was principally a result of previous direct channelization. The original hydromodification was not recent, and as such, much recovery was observed. However, channel development, sinuosity, and substrate composition were still affected or otherwise controlled by the artificial and entrenched nature of Darrs Run's active channel. The level of physical recovery (albeit incomplete) and the compensatory nature of persistent surface flow appeared adequate to support WWH communities, despite a sub-goal habitat score.

Fish Community

<u>Fourmile Creek</u> (mainstem)

A total of 22,309 fish comprising 43 species and four hybrids was collected from Fourmile Creek between July and September, 2005 (Appendix Table A-7). The fish sampling effort included 12 stations, evaluating 42 miles of the mainstem, between RM 41.1 (Wiest Rd.) and RM 0.3 (at mouth).

Based on aggregated catch statistics, numerically predominant species (No./0.3km) included central stoneroller (17.7%), bluntnose minnow (15.8%), northern hog sucker (10.5%), sand shiner (9.0%), striped shiner (6.6%), and spotfin shiner (6.1%). In terms of relative biomass (kg/0.3km), dominant species were common carp (30.5%), northern hog sucker (13.5%), black redhorse (8.8%), smallmouth bass (7.4%), and central stoneroller (6.1%). Nearly 20% of the numerically dominant species and 30% of fish biomass were composed of environmentally sensitive species. Remarkably, over 40% of all fish captured from the mainstem were environmentally sensitive taxa.

No fish species classified as rare, threatened, endangered, or otherwise recognized for special conservation status by the Ohio DNR (2007) were observed. However, highly intolerant, declining or otherwise ecologically significant species included mimic shiner, rosyface shiner, silver shiner, southern redbelly dace, banded darter, slenderhead darter, and black redhorse (Ohio EPA 1987 and 1996). Although not presently imperiled, species so defined have experienced a significant reduction in their historical distributions statewide or have been found to be extremely sensitive to a wide range of environmental disturbance, and therefore are considered associates of the best riverine habitats in Ohio.

Community indices and accompanying narrative evaluations for Fourmile Creek ranged between exceptional (IBI=56/MIwb=11.0) and good/very good (IBI=40/MIwb=8.9). Overall, the fish assemblage of Fourmile Creek was characterized as very good/exceptional. Longitudinal performance of the IBI, MIwb, and other relevant indicators are presented in Figure 24. Summarized index scores and community statistics by station are presented in Table 17.

As measured by the IBI and MIwb (where applicable), community performance through its entire length was found fully consistent with the existing EWH and WWH biocriteria. Every station was found to support an assemblage of fish possessing the expected structure, functional organization, and species richness, comparable to the reference conditions within the ECBP ecoregion. Environmentally sensitive taxa were well-represented and made-up a significant proportion of the catch from each fish sampling station. The occurrence of serious disease or other external anomalies was typically at or below expected levels. Collectively, the incidence of Deformities, Eroded fins, Lesions, and Tumors (DELT) anomalies reached an elevated level (1.0%) at only one station, at RM 0.3. This principally took the form of external lesions in redhorse (Figure 25). Given the elevated occurrence was limited to the mouth of Fourmile Creek, the rise in the incidence of DELT anomalies likely represented fish moving into Fourmile Creek from the impounded, and thus stressful, segment of the Great Miami River.

As measured by the performance of the fish community, in every instance point and non-point source pollutant loads currently delivered to Fourmile Creek appeared safely assimilated.

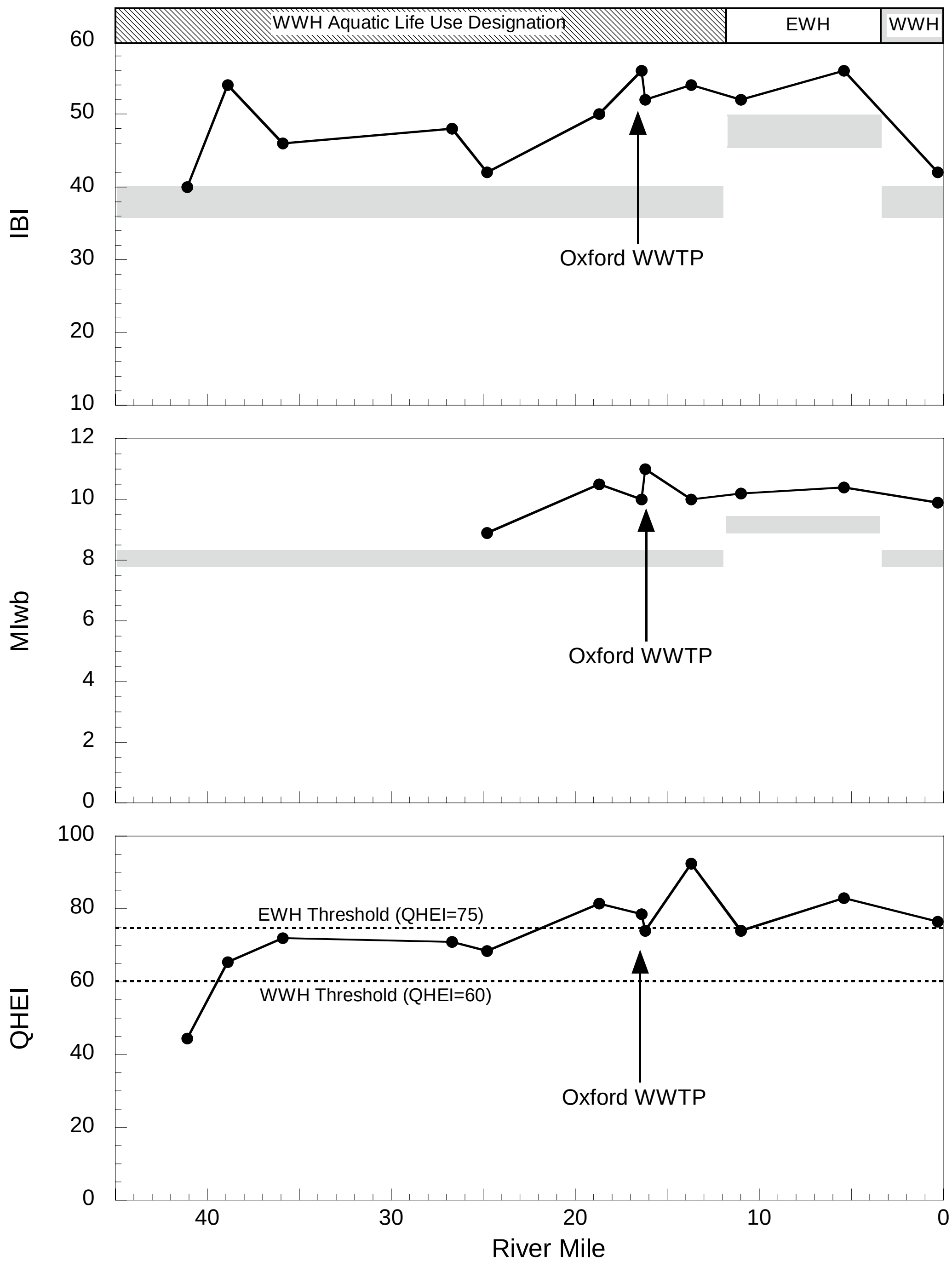


Figure 24. Longitudinal performance of the Index of Biological Integrity (IBI), Modified Index of well-being (MIwb), and Qualitative Habitat Evaluation Index (QHEI) for Fourmile Creek (mainstem), 2005. Shaded areas represent biocriteria and areas of nonsignificant departure for the EWH aquatic life use. Dashed lines represent QHEI values associated with WWH and EWH communities. Arrows identify points of discharge for significant NPDES permitted entities.

Table 17. Fish community and descriptive statistics from the Fourmile and Indian Creek study area, 2005.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)[a]	Mean Rel. Wt. (Wt./km)[a]	Mean IBI	Mean MIwb	QHEI	Narrative Evaluation[b]
Fourmile Creek (2005) [14-400]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
41.1[H]	18.0	18	1460.0	4.0	40	NA	44.5	Good
38.9[H]	22.0	22	4396.5	123.9	54	NA	65.5	Exceptional
35.9[H]	27.0	27	5061.0	79.0	46	NA	72.0	Very Good
26.7[W]	26.0	26	2887.5	16.5	48	NA	71.0	Very Good
24.8[W]	21.0	21	4239.0	13.3	42	8.9	68.5	Good/V.Good
18.7[W]	23.0	23	2056.5	48.0	50	10.5	81.5	Exceptional
16.4[W]	32.0	32	4399.5	36.4	56	10.0	78.5	Exceptional
16.2[W]	30.0	30	2635.5	63.8	52	11.0	74.0	Exceptional
13.7[W]	30.0	30	1795.7	22.0	54	10.0	92.5	Exceptional
Eastern Corn Belt Plain (ECBP)-EWH Use Designation (Existing)								
11.0[W]	27.0	27	1692.0	35.2	52	10.2	74.0	Exceptional
5.4[W]	29.0	29	2392.5	55.8	56	10.4	83.0	Exceptional
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
0.3[W]	29.0	29	964.0	62.1	42	9.9	76.5	Good/Excpt.
Dixon Branch (2005) [14-406]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.3[H]	21.0	21	2134.5	12.9	48	NA	63.0	Very Good
East Fork Fourmile Creek (2005) [14-405]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
5.2[H]	11.0	11	4918.5	12.7	44	NA	64.5	Good
2.4[H]	10.0	10	2217.0	15.8	40	NA	70.0	Good
Little Fourmile Creek (2005) [14-404]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
13.5[H]	16.0	16	5096.0	35.1	44	NA	74.5	Good
2.8[W]	18.0	18	934.5	19.1	50	8.4	78.0	Excpt./Good
Fleisch Run (2005) [14-426]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.7[H]	13.0	13	1118.0	5.1	34*	NA	41.5	Fair
Morning Sun Tributary-North (2005) [14-427]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.7[H]	22.0	22	957.0	8.1	58	NA	79.5	Exceptional

Table 17. continued.

Stream **River Mile**	**Mean Number Species**	**Cumul-ative Species**	**Mean Rel. No. (No./km)** [a]	**Mean Rel. Wt. (Wt./km)**[a]	**Mean IBI**	**Mean MIwb**	**QHEI**	**Narrative Evaluation**
Morning Sun Tributary-South (2005) [14-434]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)[c]								
0.9 [H]	4.0	4	666.4	1.0	28*	NA	69.0	Fair
Elams Run (2005) [14-423]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
0.3 [H]	11.0	11	2012.0	7.1	50	NA	65.0	Exceptional
Harkers Run (2005) [14-408]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
2.4 [H]	6.0	6	2250.0	4.5	36[ns]	NA	67.5	Marginally Good
Collins Creek (2005) [14-433]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.6 [H]	18.0	18	3454.5	13.9	50	NA	60.5	Marginally Good
Darrs Run (2005) [14-424]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Existing)								
2.1 [H]	16.0	16	7623.0	21.0	44	NA	54.5	Good
Stony Run (2005) [14-432]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.3 [H]	22.0	22	2767.5	7.9	54	NA	52.0	Exceptional
Indian Creek (2005) [14-010]								
Eastern Corn Belt Plain (ECBP)-EWH/WWH Use Designation (Recommended/Existing)								
23.9 [W]	29.0	29	5667.0	57.6	38[ns]	9.7	64.0	M.Good/Exceptional
17.7 [W]	27.0	27	4018.0	37.3	48	10.4	67.5	V.Good/Exceptional
9.4 [W]	26.0	26	3934.0	42.9	54	10.3	59.0	Exceptional
6.8 [W]	33.0	33	3585.6	123.9	48	10.4	74.5	V.Good/Exceptional
6.5 [W]	24.0	24	3424.5	52.5	46	10.3	67.0	V.Good/Exceptional
4.3 [W]	27.0	27	9055.7	78.5	42	10.8	55.5	Good/Exceptional
Little Indian Creek (2005) [14-198]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.1 [W]	17.0	17	2940.0	4.5	52	NA	65.0	Exceptional
Salmon Run (2005) [14-011]								
Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)								
1.9 [H]	10.0	10	694.0	3.2	44	NA	63.0	Good
0.1 [H]	24.0	24	2156.0	12.6	52	NA	58.0	Exceptional

Table 17. continued.

Stream River Mile	Mean Number Species	Cumul-ative Species	Mean Rel. No. (No./km) [a]	Mean Rel. Wt. (Wt./km)[a]	Mean IBI	Mean MIwb	QHEI	Narrative Evaluation
Lick Run (2005) [14-198]								
	Eastern Corn Belt Plain (ECBP)-WWH Use Designation (Recommended)							
0.9 [H]	18.0	18	1432.1	7.8	50	NA	68.0	Exceptional

a - Relative abundance and relative weight estimate normalized to 0.3km.
b - Narrative biological performance.
c - Candidate for Primary Headwater Designation in lieu of WWH
H - Headwaters: sites draining areas < 20 miles^2.
W - Wadable Streams: sites draining areas > 20 miles^2.
ns- Nonsignificant departure from the biocriteria (<4 IBI units or <0.5 MIwb units).
* - Significant departure from the biocriteria (>4 IBI units or >0.5 MIwb units).

Ecoregional Criteria (OQC 3745-1-07, Table 7-14)
Eastern Corn-belt Plain (ECBP)

Index-Site Type	WWH	EWH	MWH[d]
IBI - Headwater/Wading	40	50	24
MIwb – Wading	8.3	9.4	6.2

d - Modified Warmwater Habitat (MWH) for channel modified areas.

Figure 25. External lesions on a black redhorse. Such lesions were the most commonly observed anomaly on Fourmile Creek, at RM 0.4, near its confluence with the Great Miami River.

Fourmile Creek Tributaries

The fish assemblages of the eleven direct and indirect tributaries that comprise the principal drainage network of Fourmile Creek were surveyed and assessed in 2005.

Thirteen sampling stations were deployed among these tributaries, evaluating 42 linear stream miles.

Like the mainstem, no fish species classified as rare, threatened, endangered, or otherwise recognized for special conservation status by the Ohio DNR (2007) was observed. However, highly intolerant, declining or otherwise ecologically significant species included southern redbelly dace, rosyface shiner, and stonecat (Ohio EPA 1987 and 1996). In particular, eight of the eleven tributaries (over 70%) were found to support southern redbelly dace, a declining headwater species. The catch and distribution of the rosyface shiner and stonecat were limited to a few individuals from two streams.

Community indices and accompanying narrative evaluations from these waters ranged between exceptional (IBI=58) and fair (IBI=28). Taken together, the fish assemblages of Fourmile Creek tributaries can be collectively characterized as *good*. Summarized index scores and community statistics by stream and by station are presented in Table 17.

The existing or recommended Aquatic Life Use for all Fourmile Creek tributaries is WWH. Nine of the eleven tributaries were found to support fish assemblages fully consistent with the applicable biocriteria. These streams included, Dixon Branch, East Fork Fourmile Creek, Little Fourmile Creek, Morning Sun North Tributary, Elams Run, Harkers Run, Collins Creek, Darrs Run, and Stony Run. Community performance below the minimum WWH ECBP biocriteria was limited to two water bodies: Fleisch Run and Morning Sun South Tributary.

Although impairments on both Fleisch Run and Morning Sun South Tributary were directly related to habitat quality, the specifics for each stream were distinct. Habitat deficiencies documented on Fleisch Run were typical of hydromodification, specifically channelization. Community performance by no means indicated profound degradation, rather the condition of the fish assemblage remained in the high fair range. Basic structural measures were consistent with WWH communities (species richness, number of sensitive species, number of lithophilic species, etc.). However, proportional metrics had a strong and negative influence on the resulting IBI score. Despite adequate diversity and the presence of some environmentally sensitive species, these taxa made up only a small proportion of the fish assemblage. Numerically, over 70% of the community was composed of environmentally tolerant, ecological generalists, and pioneering species. The dominance of these tolerant taxa appeared reflective of the monotonous or otherwise simple habitat that typified Fleish Run.

Impairment of the fish community in the Morning Sun South Tributary appeared related to emphemerality. Although the waterbody was sampled at a time when surface flow appeared normal, the evaluated reach supported surprisingly few fish. The majority of the catch (97%) was composed of two highly tolerant taxa (northern creek chub and blacknose dace). The depauperate assemblage prompted an examination of the stream bed for evidence of in-stream productivity or other macro-indicators of a perennial or functional interstitial stream. These efforts found rocks, boulders or other bed material nearly devoid of attached or encrusting algae and aquatic invertebrates. Over the course of this substrate investigation, multiple two-lined salamanders were observed. This taxon is a stream obligate, and is indicative of primary headwaters or transitional areas representing the cline between headwaters and primary headwaters. Primary headwaters typically support only a transient fish population, due to their ephemeral nature. Taken together, these observations suggest that despite adequate flow observed at the time of the sampling event, this tributary is truly intermittent and incapable of supporting a resident fish community, and thus is a likely candidate for primary headwater designation.

Trend Assessment: Fish Community

Through the biosurvey survey process and reference site re-sampling efforts, the fish fauna of the Fourmile Creek basin have been surveyed and assessed by Ohio EPA since 1981. Prior field worked included all or portions of the mainstem and selected tributaries. For the purposes of trends assessment, the 1991 and 1995 results will be compared against conditions documented in 2005, as sampling prior to 1991 was fragmentary and more limited in scope.

In order to succinctly summarize and compare survey results between field years, analysis of trends will take two forms: 1) aggregated annual trends, examining cumulative performance from each field year through time, and 2) comparative longitudinal trends, relative to the principal associated stressors. The only significant difference between the three survey years (1991, 1995, and 2005) were modest variations in the station density and length of the mainstem reach evaluated. Given this, these data provide an excellent opportunity to evaluate meaningful changes, or lack thereof, in the environmental conditions of Fourmile Creek over the last 14 years. Historically, very little sampling effort was allocated to the tributaries of Fourmile Creek. As such, the 2005 sampling represented the first systematic evaluation of the drainage network of Fourmile Creek. Where historical data exists for these tributaries, the result will be discussed in a narrative form.

Aggregate Community Performance: 1991-2005

Annualized cumulative community performance, summarized by box and whisker plots of the IBI, MIwb, and sensitive species (number of taxa and proportion) for Fourmile Creek is presented in Figure 26. To ensure comparability, the 1991 and 2005 data were truncated, or normalized, to compare with the smaller mainstem reach evaluated in 1995. All box and whisker plots contained in Figure 26 include aggregated sampling results from the mainstem reach between RM 24.8 (Camden-College Rd.) and the mouth. Taken together, median, 75th percentile, 25th percentile, maximum, and minimum values for these indicators displayed a step-wise improvement through time. This pattern was readily apparent for the IBI and the number and proportion of sensitive species. Performance of the MIwb showed a marked improvement in 2005, compared against the 1991 and 1995 results.

<u>Longitudinal Trends:</u> 1991-2005
As observed for the aggregated analysis, longitudinal trends for Fourmile Creek indicated improvement through time (Figure 27). Community indices from stations common to all field years either advanced or remained comparable to historical results. As indicated by the performance of the fish community, the limited areas of impairment documented in the past were fully recovered in 2005. Presently, all stations now support an assemblage of fish well in excess of the prescribed biocriterion.

Relevant historical data for Fourmile Creek tributaries are limited and available from single stations located on each of the following streams: Elams Run, Harker Run, and Darrs Run. In addition to the 2005 sampling effort, Elams Run was sampled in 1996 and both Harkers Run and Darrs Run were sampled in 1994. Although the historical stations do not perfectly match with the recent effort, the stations were close enough to warrant a brief summary of trends. Considering both natural and temporal variation associated with disparate location and field year, historical performance from these tributaries were consistent with the WWH designation. Similarly, conditions documented in 2005 were also in accordance with the WWH use.

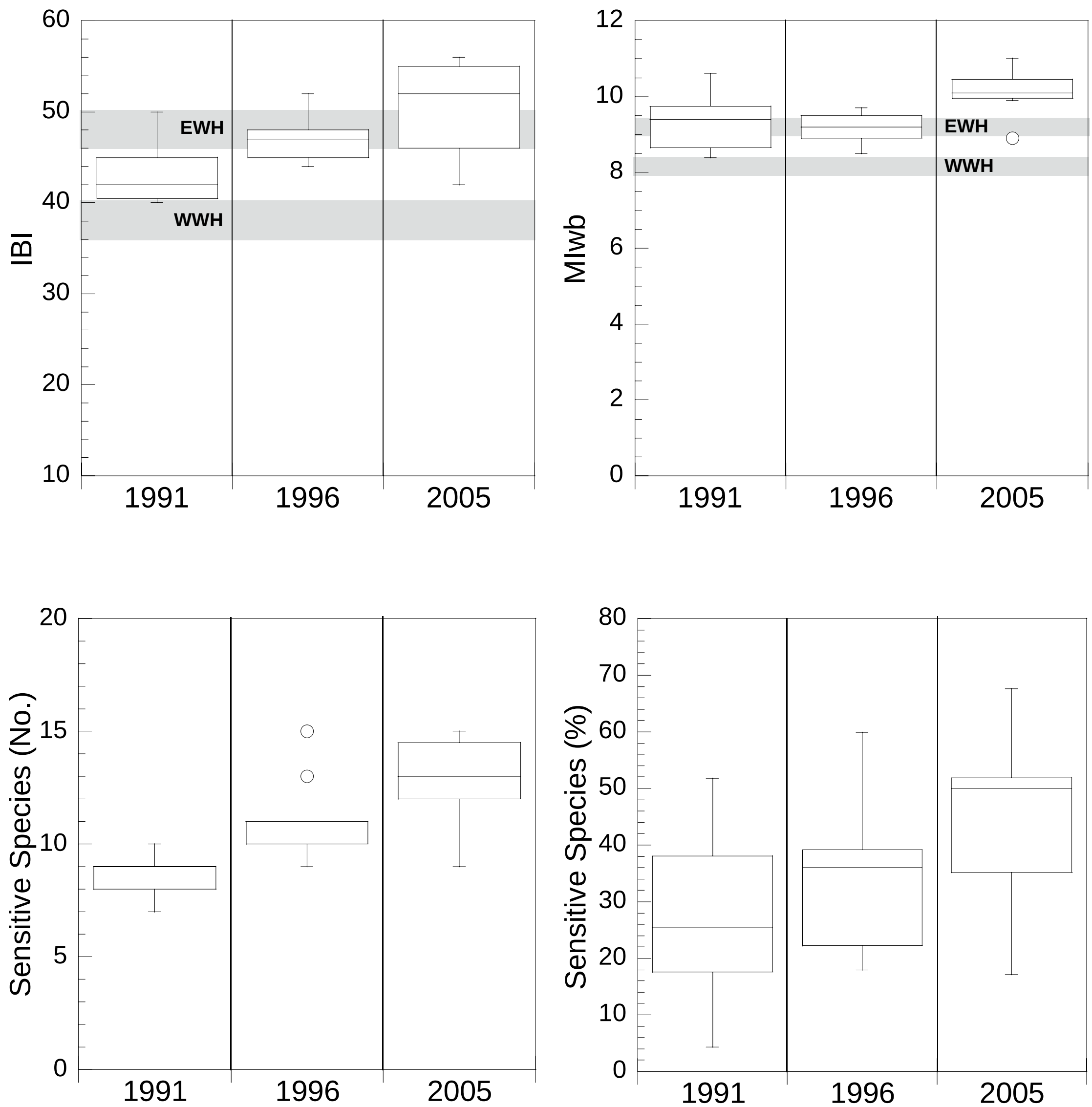


Figure 26. Aggregated Index of Biotic Integrity (IBI) and Modified Index of well-being scores, and the number and percentage of environmentally sensitive fish species, Fourmile Creek (mainstem), 1991, 1995 and 2005. Shaded areas in upper figures represent the EWH and WWH biocriteria and area of nonsignificant departure for the Eastern Corn Belt Plains (ECBP) ecoregion. To ensure comparability, only data between RM 24.8 (Camden-College Rd.) and the mouth were selected for the aggregate trends assessment.

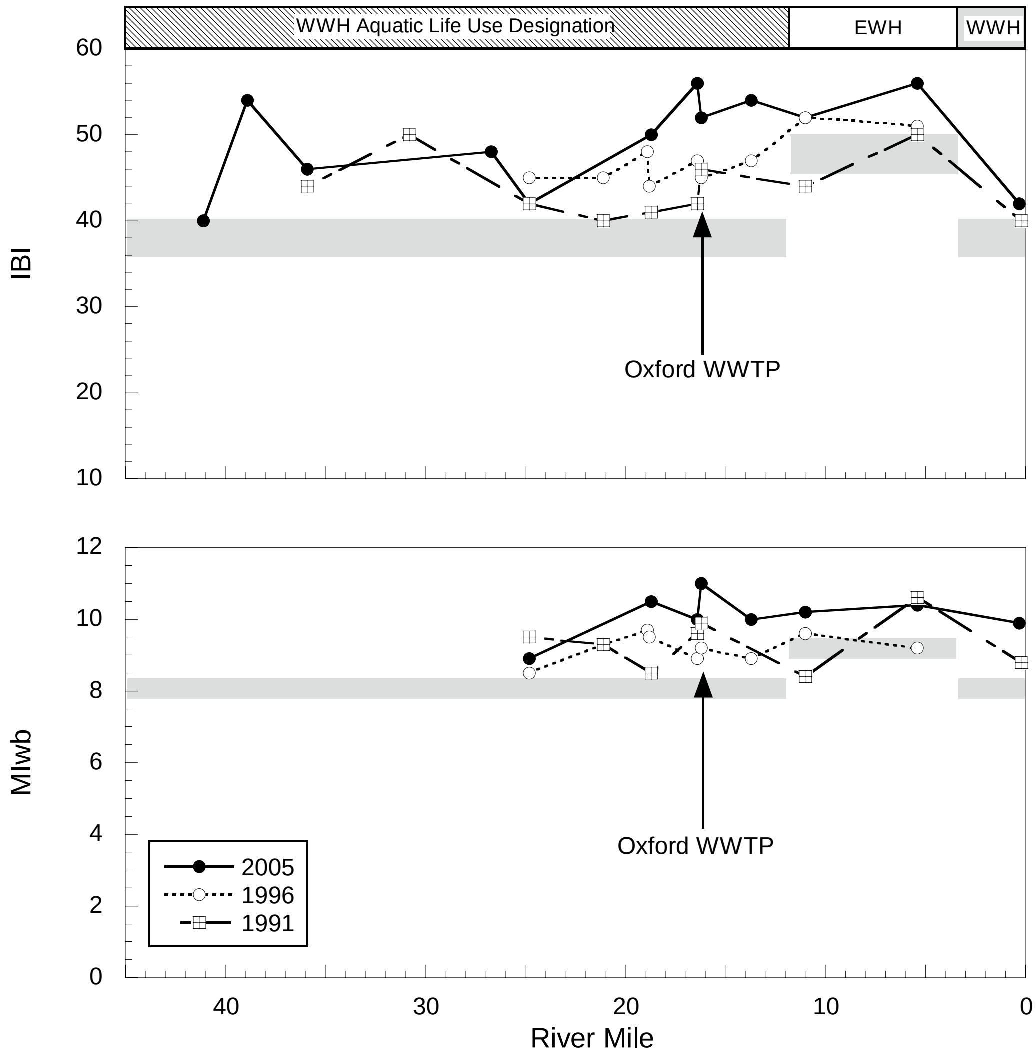


Figure 27. Longitudinal performance of the Index of Biotic Integrity (IBI) and the Modified Index of well-being (MIwb) from Fourmile Creek (mainstem), 1991, 1996, and 2005. Shaded areas represent the applicable biocriteria in support of the existing EWH Aquatic life use, Eastern Corn Belt Plains (ECBP) ecoregion. Arrows identify points of discharge for significant NPDES permitted entities.

Macroinvertebrate Community

Macroinvertebrate communities were evaluated at 26 stations in the Fourmile Creek assessment unit (Table 18, Appendix Table A-8). The community performance was evaluated as exceptional at six stations, very good at two, good at 13, marginally good at one, and fair at four stations. The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT) was on Fourmile Creek upstream from the Oxford WWTP (RM 16.4) with 27 taxa. The station with the highest number of total sensitive taxa was on Fourmile Creek at Junction Road (RM 26.8) with 40 taxa. Sensitive taxa found in this assessment unit, which are noteworthy because they are not commonly collected, were the mayflies *Acentrella turbida* in Fourmile Creek (RMs 26.8, 18.7); *Diphetor hageni* in "Morning Sun Trib.-South" (RM 0.9); and *Maccaffertium mediopunctatum* in Fourmile Creek (RMs 26.8, 24.8, 18.7, 16.4, 0.3), and Little Fourmile Creek (RM 2.8); and the midges *Polypedilum (C.) ontario* in Fourmile Creek (RM 18.7, 16.4, 11.0); and *Sublettea coffmani* in Fourmile Creek (RMs 35.9, 26.8). The state threatened crayfish, *Orconectes sloanii,* was collected at nine stations in this assessment unit with drainage areas ranging from 1.6 to 50 mi^2.

Fourmile Creek

Macroinvertebrate community performance in Fourmile Creek was generally good to exceptional (Table 18, Fig. 28). The farthest upstream station (RM 40.9) was only marginally meeting WWH expectations. In particular, sensitive mayflies were completely absent at this station and the community was primarily predominated by facultative taxa. Observed siltation and excessive algal and aquatic macrophyte growths were indications of nutrient enrichment and sediment runoff from the open pasture located upstream from this site. The station upstream from Acton Lake with the highest diversity of EPT and sensitive taxa was at Junction Road (RM 26.8). The apparent decline in community performance at the station just upstream from Acton Lake (RM 24.8) was considered to be due to a change in substrate from gravel to predominantly bedrock, which may have hampered collection efficiency, rather than an indication of any additional impairment from pollution or anthropogenic habitat alterations.

The macroinvertebrate station located downstream from the Acton Lake outflow, located at Buckley Road (RM 20.3), was considered to be meeting WWH expectations based on the collection of 18 EPT taxa in the qualitative part of the sample. However, unusually high abundances of the tolerant midges *Glyptotendipes (G.) sp.* and *Polypedilum (P.) illinoense* and facultative flatworms in association with the loss of several taxa of sensitive mayflies present at upstream and downstream stations were indications of a nutrient enrichment impact from the Acton Lake outflow. Excessive siltation was also observed at this station, which may be deposits of biosolids from Acton Lake acting as fine sediments. Community performance improved at downstream stations until an exceptional community was achieved at the station upstream from the Oxford WWTP (RM 16.4) comparable to the Junction Road station

(RM 26.8). This is the highest achieving station downstream from Acton Lake. Downstream from the Oxford WWTP the community performance gradually declined and never recovered to the same level as the station upstream from the WWTP. Nutrient enrichment from the Oxford WWTP, possibly in conjunction with the stream channel becoming wider which may be facilitating increased water temperatures, appears to be reducing EPT, sensitive, and overall taxa diversity.

Tributaries Upstream from Acton Lake
The tributaries that confluence with Fourmile Creek upstream from Acton Lake or into Acton Lake were all evaluated as good to exceptional (Table 18). EPT and sensitive taxa diversity ranged from 13 to 23 and 15 to 26, respectively. Fleisch Run (RM 0.7) was meeting WWH macroinvertebrate expectations; however, unrestricted cattle access upstream from Paint Creek - Fourmile Road was a potential threat to the stream's resource quality.

Tributaries Downstream from Acton Lake
Four out of the five sampled tributaries that confluence with Fourmile Creek downstream from Acton Lake were not meeting their WWH expectations (Table 18). Harkers Run (RM 2.4), Darrs Run (RM 2.1), and Stony Run (RM 0.3) were apparently limited by low to interstitial flows. Collins Creek, which appeared to maintain flow during the summer, was probably impacted by urban runoff from the town of Oxford. The macroinvertebrate community collected from Elams Run (0.2) was evaluated as good; however, the lack of any sensitive mayfly taxa was an indication of at least mild impairment.

Trend Assessment: Macroinvertebrate Community

The macroinvertebrate community was evaluated in the mainstem of Fourmile Creek starting in 1981. Quantitative data was available for only the years 1996 and 2005. The longitudinal trend for ICI, number of EPT taxa, and number of sensitive taxa is presented in Figure 29. Generally, the macroinvertebrate community during the present study (2005) was performing at a comparable level or higher than previous studies. Compared to the 1996 study, community performance improved downstream from Acton lake to the area around the Oxford WWTP discharge. Both EPT and sensitive taxa diversity were consistently higher. Community performance has improved substantially since 1981.

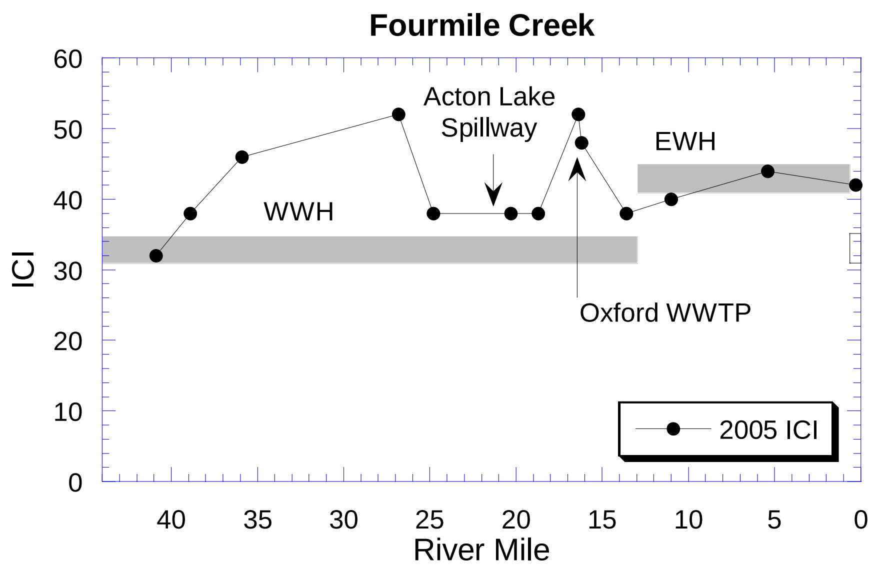
Table 18. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Fourmile Creek study area, July to October, 2005.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Fourmile Creek (14-400)										
40.9	4.4	-	59	12	10	M-H	0	Hydropsychid caddisflies (F), heptageniid mayflies (F), *Physella* snails (T)	-	Marg. Good
38.9	12.2	-	60	16	17	M	0	Hydropsychid caddisflies (F,MI),riffle beetles (F), *Helicopsyche* caddisflies (MI)	-	Good
35.9	17.3	15	66	18 / 18	23 / 28	M / 451	1	Riffle beetles (F), midges (MI,F)	46	
26.8	38.0	15	66	21 / 23	29 / 40	M-H / 314	1	Hydropsychid caddisflies (MI,F), *Chimarra* caddisflies (MI), midges (MI,F)	52	I
24.8	50	-	46	16	17	M	0	Baetid mayflies (F), midges (F), hydropsychid caddisflies (MI,F)	-	Good
20.3	100	6,8,13	64	18 / 19	13 / 15	M-H / 778	0	Midges (T,F,MI)	(22)[a]	Good
18.7	106	-	46	20 / 21	21 / 23	H / 735	0	*Rheotanytarsus* midges (MI), hydropsychid caddisflies (F,MI)	38	
16.4	122	-	63	22 / 27	26 / 34	H / 1148	1	*Rheotanytarsus* midges (MI), hydropsychid caddisflies (MI,F), *Chimarra* caddisflies (MI)	52	
16.2	122	-	60	17 / 20	20 / 25	M-H / 2091	0	*Rheotanytarsus* midges (MI), hydropsychid caddisflies (F,MI), *Chimarra* caddisflies (MI)	48	
13.6	132	-	52	15	17	M	0	*Chimarra* caddisflies (MI), midges (MI,F), hydropsychid caddisflies (MI,F)	-	Good
11.0	137	4	41	16 / 17	20 / 24	M-H / 1354	0	*Rheotanytarsus* midges (MI)	40	

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
5.4	163	-	42	19	18	M	0	Baetid mayflies (F), hydropsychid caddisflies (F,MI), *Chimarra* caddisflies (MI)	-	Very Good
0.3	315	-	39	12 / 20	12 / 24	L-M / 1310	0	Midges (F,MI)	42	
Dixon Branch (14-406)										
0.3	5.5	-	53	15	23	M	0	Hydropsychid caddisflies (F,MI), *Rheotanytarsus* midges (MI), riffle beetles (MI,F)	-	Good
East Fork Fourmile Creek (14-405)										
5.2	4.9	-	58	17	23	M	2	Midges (F,MI), hydropsychid caddisflies (F,MI)	-	Good
2.4	9.8	-	55	21	26	M	1	Hydropsychid caddisflies (F,MI), *Rheotanytarsus* midges (MI)	-	Exceptional
Little Fourmile Creek (14-404)										
13.5	5.0	-	57	23	21	M	1	Hydropsychid caddisflies (F), riffle beetles (F,MI), *Helicopsyche* caddisflies (MI)	-	Exceptional
2.8	27.8	9	38	13	15	L-M	0	Water penny beetles (MI)	-	Good
Fleisch Run (14-426)										
0.7	4.6	-	58	17	19	M-H	1	Hydropsychid caddisflies (F), *Helicopsyche* caddisflies (MI), baetid mayflies (F,I)	-	Good
Tributary to Fourmile Creek (RM 23.57) "Morning Sun Trib. – North" (14-427)										
0.6	4.4	-	54	15	21	M	1	Hydropsychid caddisflies (F), baetid mayflies (F), *Helicopsyche* caddisflies (MI)	-	Good
Tributary to Fourmile Creek (RM 23.57, 0.25) "Morning Sun Trib. – South" (14-434)										
0.9	3.5	-	53	16	22	L-M	2	Baetid mayflies (F), blackflies (F), hydropsychid caddisflies (F)	-	Good

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Elams Run (14-423)										
0.2	1.6	-	47	12	16	M	3	Midges (MI,F), baetid mayflies (F)	-	Good
Harkers Run (14-408)										
2.4	5.0	-	32	6	12	L-M	0	Flatworms (F), midges (MI,F), craneflies (F,MI)	-	Fair
Collins Creek (14-433)										
0.6	5.4	-	29	7	7	M	0	Hydropsychid caddisflies (F), baetid mayflies (F)	-	Fair
Darrs Run (14-424)										
2.1	5.1	9	33	9	8	L-M	0	Riffle beetles (F), hydropsychid caddisflies (F), water penny beetles (MI)	-	Fair
Stony Run (14-432)										
0.3	4.8	9	13	4	4	M	0	Heptageniid mayflies (F), *Helicopsyche* caddisflies (MI)	-	Low Fair

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 4=2 HD Only, 5=3 HD Only, 6=4 HD Only, 8=Non-Detectable Current, 9=Intermittent or Near-Intermittent Conditions, 13=Suspected Disturbance by Vandalism, 15=Current >0.0 fps but <0.3 fps.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
CW: Coolwater/Coldwater.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant
[a] ICI values in parentheses are invalidated due to insufficient current speed over the artificial substrates. The station evaluation is based on the qualitative sample narrative evaluation.



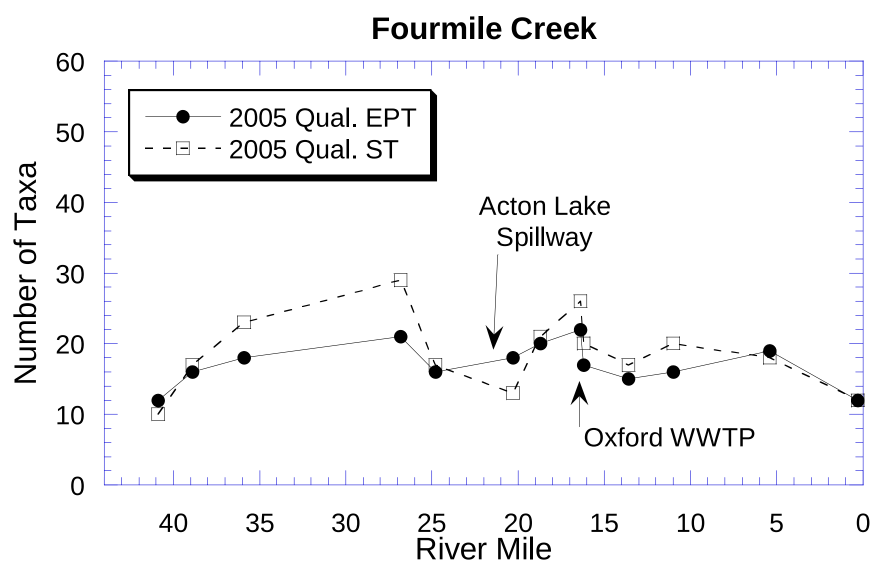


Figure 28. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in Fourmile Creek, 2005. ICI equivalent values were used for RMs 40.9, 38.9, 24.8, 20.3, 13.6, and 5.4 based on the qualitative narrative evaluation.

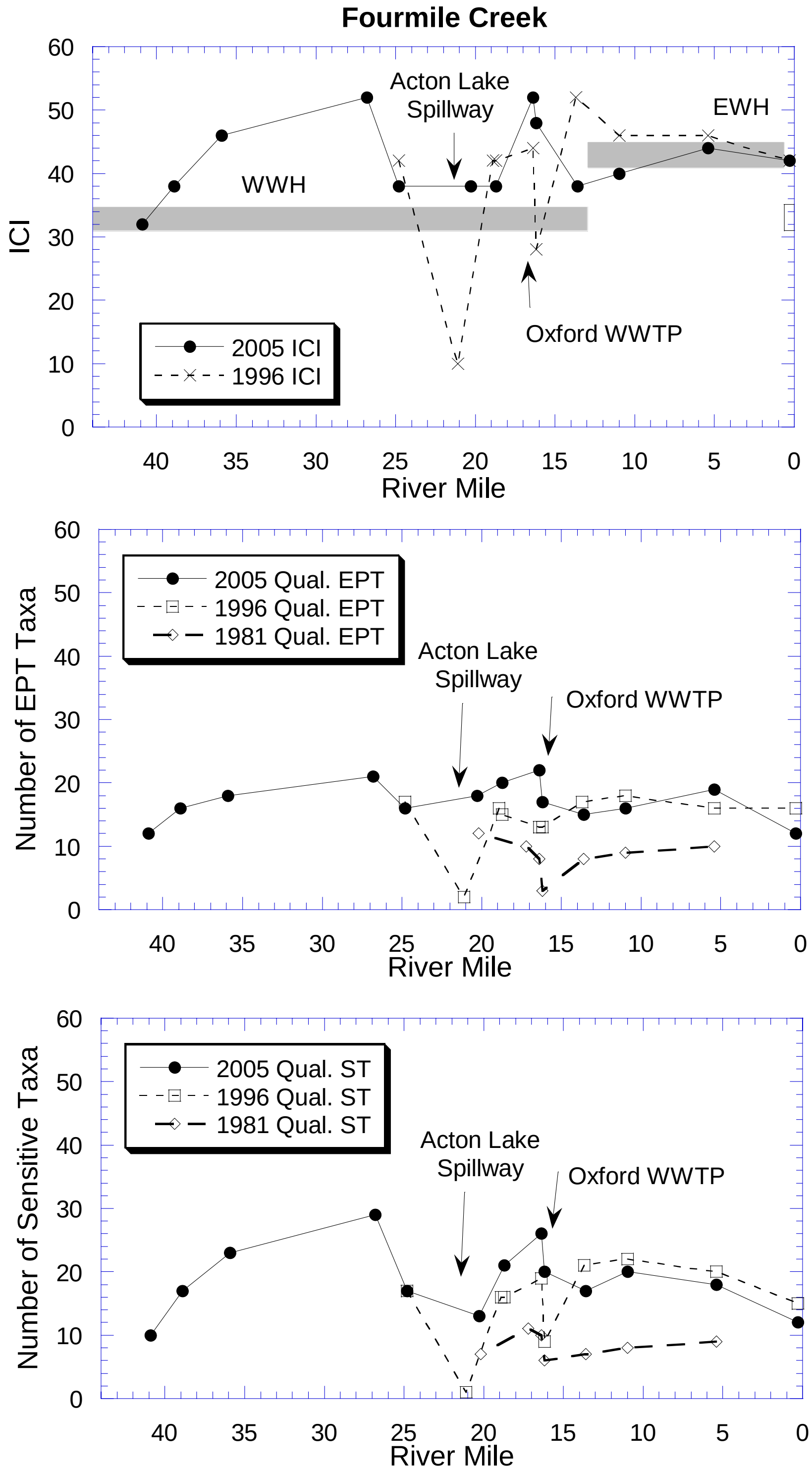


Figure 29. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in Fourmile Creek, 1981-2005. ICI equivalent values were used for RMs 40.9, 38.9, 24.8, 20.3, 13.6, and 5.4 in 2005 and RMs 24.8, 18.9, 18.7, and 11.0 in 1996 based on the qualitative narrative evaluation.

Indian Creek Watershed Assessment **Unit (WAU 05080002 080)**

Study Area

The Indian Creek watershed is located in portions of Union County, Indiana and Butler County, Ohio. This basin is located in the Eastern Cornbelt Plains (ECBP) ecoregion. The Indian Creek watershed assessment unit encompasses a drainage area of 106 mi^2 (34.4 mi^2 in Indiana). The area includes the Indian Creek mainstem from the headwaters in Indiana to the confluence with the Great Miami River at RM 27.7.

The largest communities in this watershed are the central and southern portions of West College Corner, the community of Reily, and the Village of Millville.

Tributaries in the assessment unit include Little Indian Creek (drainage area 7.42 mi^2, confluence RM 14.70), Reserve Run (drainage area ~3 mi^2, confluence RM 13.73), Salmon Run (drainage area 4.86 mi^2, confluence RM 10.18), unnamed tributary to Salmon Run (drainage area <2 mi^2, confluence RM 0.39), Lick Run (drainage area ~5 mi^2, confluence RM 7.9) and Beals Run (drainage area ~5 mi^2, confluence RM 7.16). The town of Reily, is unsewered and there are no plans for sewering this area. The Village of Millville is not served by the Queen Acres WWTP nor are there any plans to sewer this area.

Indiana has a few known dischargers in the Indian Creek Watershed including the Indian Hills Mobile Home Park WWTP located approximately 2.5 miles south of West College Corner, Indiana on Brookville Road. They operate under an NPDES Permit (IN0038911) discharging 0.0108 million gallons per day (MGD) of treated sanitary wastewater into the mainstem of Indian Creek in Union County. Tributaries in Indiana include Cottage Grove Creek, Sand Run, and Brandywine Creek. Indian Creek within Indiana has a fish consumption advisory for mercury. Indian Creek at Cottage Grove and Sand Run are listed on the 303 (d) List of Impaired Waters for mercury. The railway system and US Hwy 27 both have had transportation with loss of materials incidents in the Indian Creek Watershed. Indiana's farm employment exceeds non-farm employment in Union and Franklin Counties. Farm earnings in the basin are highest in Union County. Cropland, the major land use in the Whitewater River Basin, is particularly widespread in Union and Wayne Counties.

While agriculture is the predominant land use (Figure 30) with row crop and pasture/hay accounting for 72%, collectively, of the total watershed area, a significant portion (23%) of the land is covered by deciduous forest (University of Cincinnati, 2001). Urbanization of the Interstate 75 corridor between Cincinnati and Dayton is changing the ratio of agricultural land to urban land in Butler and Warren counties. Current statistics show 1,040 farms with an average size of 132 acres; total land in farms is 137,000 acres.

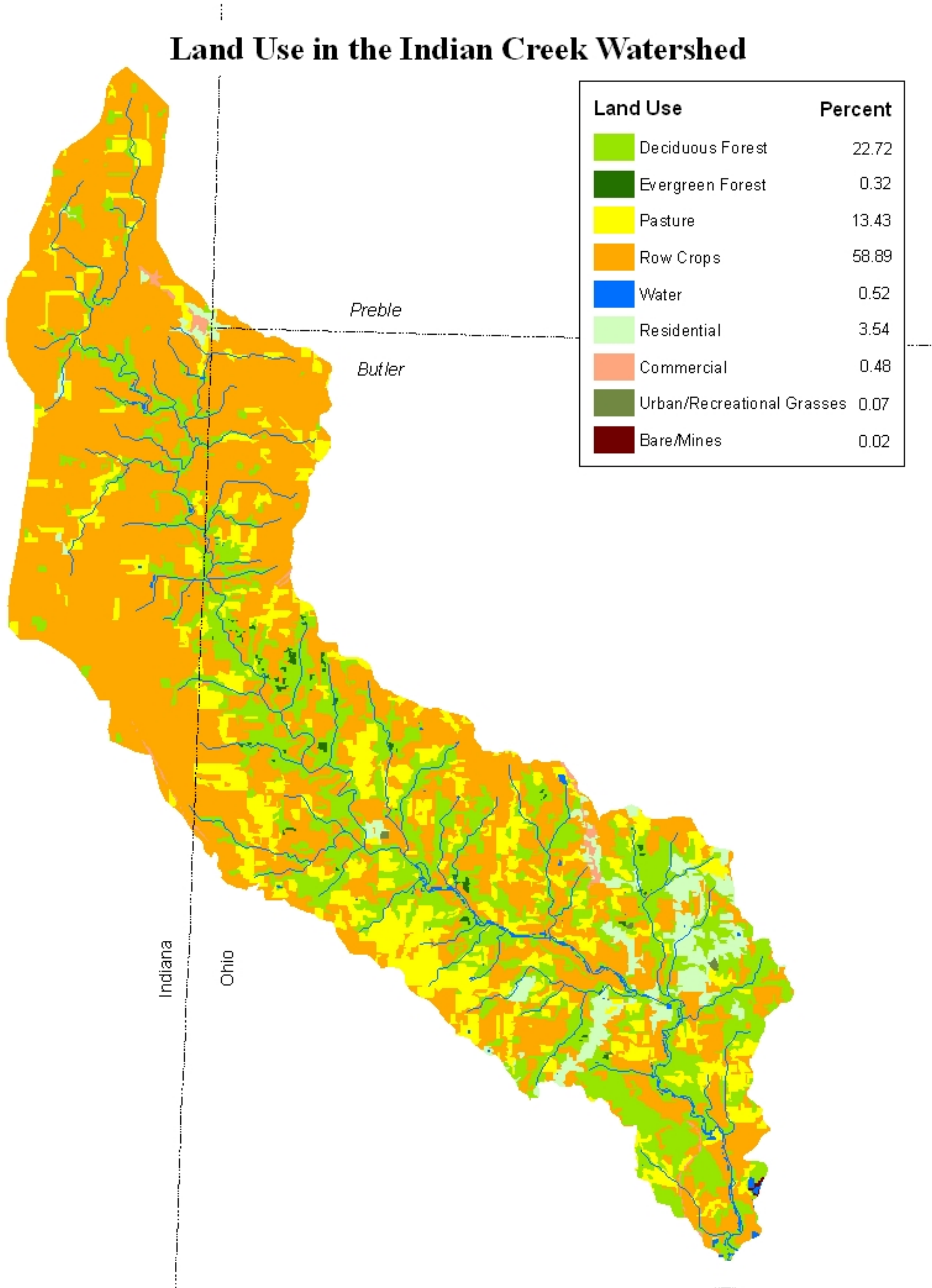


Figure 30. Land Use Map for the Indian Creek Watershed based on Landsat-7 Level analysis.

The Ohio State Extension office tallied farm data for Butler County comparing chronological increases or decreases in numbers and size of farms. Table 19 reveals slight annual fluctuations in totals with a decreasing trend since the 1980's which most likely can be extrapolated as a countywide pattern. Decade shifts from the 1980's to the 1990's indicate a greater reduction in farm and farm size than the decade shift from the 1990's into the millennium. A corresponding trend is observed with farm reduction and livestock numbers for all livestock categories from the 1980's until recent.

Table 19. Statistical Farm trend information for Butler County, Ohio showing reductions in farm size and animal units for ten years (Ohio Agricultural Statistics, Ohio Crop Reporting Service-Ohio State University, 2006).

Year	Number of Farms	Average Farm Size acres	Land in Farms acres	Hogs &Pigs head	Sheep head	Dairy Cattle head	Cattle and Calve head
1994	1,040	144	150,000	21,000	1,200	2,700	19,100
1995	1,030	144	148,000	21,500	--	2,700	20,800
1996	1,010	145	146,000	13,000	--	2,600	20,300
1997	1,020	143	146,000	14,000	--	2,600	20,400
1998	990	143	142,000	13,500	--	2,500	21,200
1999	1,010	141	142,000	13,700	--	2,300	19,100
2000	1,020	138	141,000	13,900	--	2,200	18,600
2001	1,020	137	140,000	11,100	--	2,000	18,300
2002	1,050	134	141,000	8,800	--	1,800	17,100
2003	1,050	133	140,000	9,300	--	1,600	17,000
2004	1,050	133	140,000	8,700	--	1,600	15,500

This basin, with the exception of the southern tip, lies within the Till Plains section of the Central Lowland physiographic province [Spieker 1968; Ohio Department of Natural Resources (ODNR) 2004]. The topography consists of flat to rolling hills, and was greatly influenced by glaciations during the Pleistocene Epoch [U.S. Department of Agriculture (USDA) 1976; USDA 1980]. Major aquifer systems within Indian Creek include alluvial and sand and gravel buried valley aquifers associated with the Great Miami River. The thickness of buried valley aquifer deposits in the Indian Creek Watershed vary to a considerable extent.

The geology of upland portions of the Indian Creek watershed consists of glacial till overlying Ordovician-age bedrock. The till is often less than 30 feet thick and may contain scattered sand and gravel lenses. Bedrock within the Indian Creek watershed is comprised of interbedded shale and limestone. The shale and limestone bedrock is not a good aquifer resource and often yields less than two or three gallons of water per minute (MCD, 2004).

All of the dischargers in this assessment unit discharge to tributaries to the Indian Creek mainstem (Figure 31). Half of the point source dischargers are upstream from the Village of Millville, or originating in Indiana and include Island Lake MHP, the Golden Years Healthcare WWTP and Butler County Queen Acres Water Reclamation Facility WWTP. Millville Mobile Home Park and LayHigh Estates discharge downstream from the Village of Millville into Beals and Lick Run, respectively.

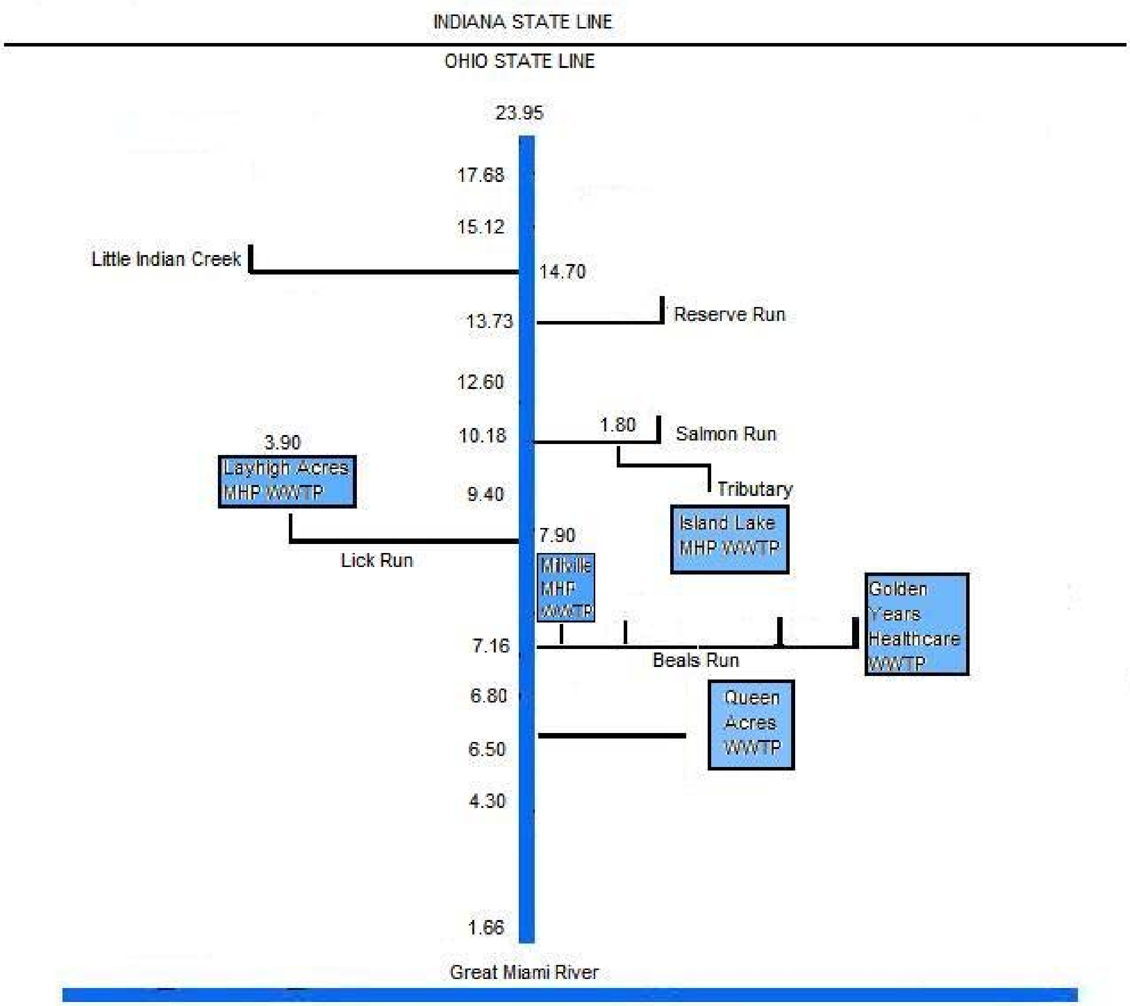


Figure 31. Watershed schematic for the Indian Creek Survey, 2005.

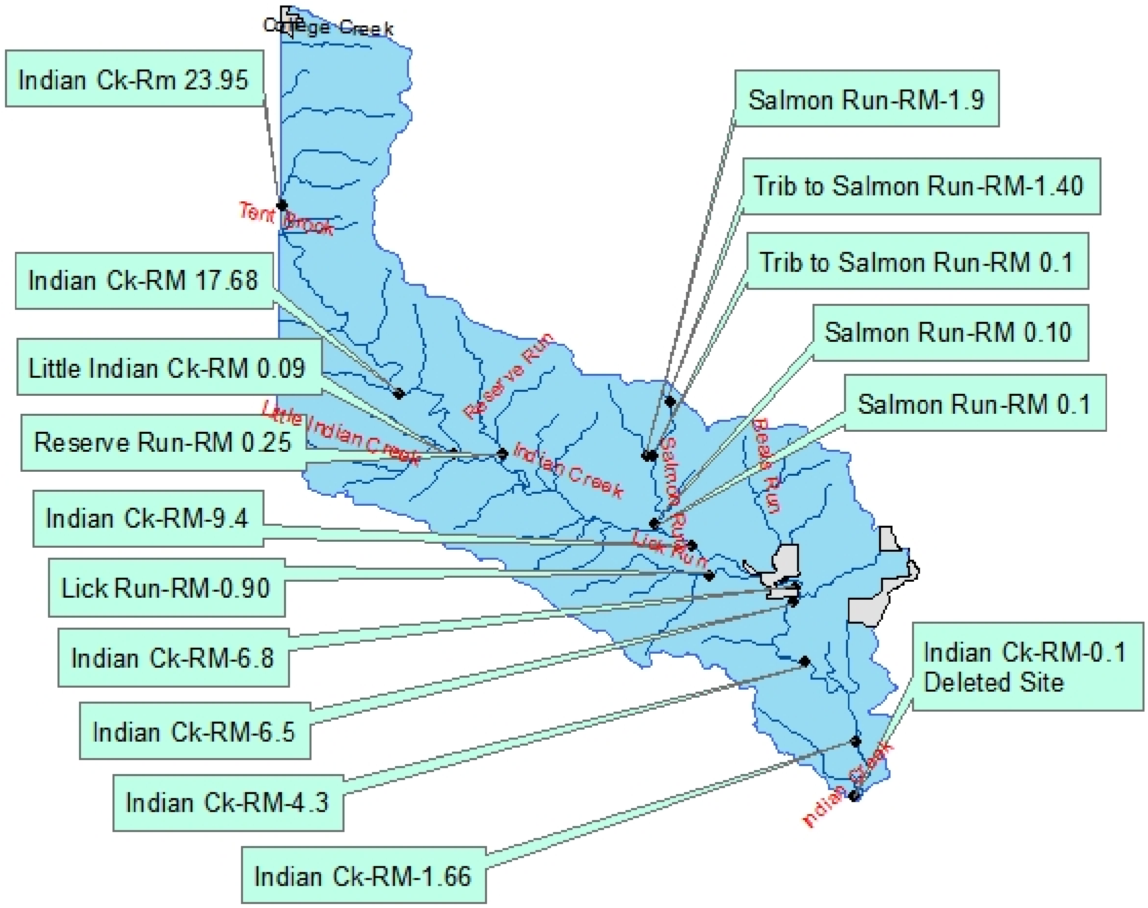


Figure 32. Ohio EPA survey stations in the Indian Creek basin, 2005.

Chemical Water Quality Summary

Chemistry grab samples and field measurements were collected at sixteen sites in the Indian Creek Watershed (Table 1, Figure 32). Water samples were taken at two-week intervals (five times) from mid-June to mid-August and were analyzed for a variety of parameters including nutrients and metals (Appendix Table A-1). Six sites were also sampled for organic compounds during the survey (Table 22, Appendix Table A-6). Bacteria samples (fecal coliform and *E. coli*) were collected at five sites, five times within a thirty-day period in order to determine Recreational Use Attainment (Table 21, Figures 40 and 41 and Appendix Table A-2). Datasonde® continuous monitors were deployed in the Indian Creek mainstem at eight sites in July and August of 2005 (Figures 36 and 37). Sediment was collected at five select sites, four in the mainstem and one in a tributary (Table 24).

Water chemistry results which exceeded Ohio Water Quality Standards (WQS) criteria codified in Ohio Administrative Code (OAC) Chapter 3745-1 in the Indian Creek watershed are presented in Table 20 and Figure 35. Out of 48 total exceedences, 73% were attributed to either low dissolved oxygen (D.O.) or bacteria. Iron exceedences of the agricultural water supply criteria were also recorded from RM 9.4 to the confluence with the Great Miami River. One ammonia-N value resulted in a WQS exceedence occurring in the Tributary to Salmon Run at RM 1.40, downstream of the Island Lake MHP wastewater facility.

Ohio EPA results for fecal coliform levels were highest near the Indiana border site, suggesting Indiana as a possible contributor of pollutants to the watershed. Bacteria results for *E. coli* in June, 2005 ranged from 6,937 to 214,000 #/100ml at Indiana's wastewater facilities. Indiana has two wastewater facilities in the watershed; West College Corner WWTP and Indian Hills MHP. Both facilities experienced numeric permit violations of ammonia during the 2005 survey year.

Nutrients were evaluated using the 90th percentile for ammonia-N, nitrate-nitrite-T, and phosphorus-T and the 75th percentile for total suspended solids from reference sites in the Eastern Corn Belt Pains ecoregion found in the Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams appendix tables (Ohio EPA, 1999). Ammonia-N was most elevated in the Indian Creek mainstem near the Indiana border and downstream from the confluence of point source dischargers. The mainstem values exceeded the target value in 23% of the samples; however, the median value remained below the target at all stations. Five of the eight tributary stations sampled exceeded the 90th percentile target value for ammonia-N in at least one sample. The Tributary to Salmon Run (RM 1.81) at RM 1.40, downstream from the Island Lake MHP WWTP, was the only tributary site with the median ammonia-N concentration (0.128 mg/l) above the target value (0.10 mg/l). Median phosphorus-T levels were above the target value for headwater streams (0.206 mg/l) in Lick Run (0.21 mg/l) and the tributary to Salmon Run at RM 1.40 (0.239 mg/l) downstream from WWTPs and above the target value for wadable streams (0.220 mg/l) in the Indian Creek mainstem at RM 6.50 (0.40 mg/l) downstream from the Queen Acres WWTP.

The highest nitrate-nitrite-N levels were recorded on June 15, 2005 for all mainstem sites, a sampling date with less average rain for that region (Miami Conservancy District, 2005). These high concentrations documented on June 15th, support a point-source origin over non-point source. Suspended solids (TSS) were elevated from background conditions from Reily-Milleville Rd (RM 9.40) to downstream of Queen Acres WWTP Improvements in point source management practices could address this concern.

Stream Flow

Stream flow data for the survey were extracted from two sources; the United States Geological Service (USGS) and the Ohio EPA, DSW, Modeling Section. The USGS gage station in Hamilton, Ohio 2005 (#03274000 Great Miami River at Hamilton, Ohio, coordinates: -39.391111/84.572222) was utilized for average daily stream flows from June through August **(**www.waterdata.usgs.gov**)**.

The Ohio EPA, DSW, Modeling Section conducted flow measurements in the mainstem of Indian Creek at State Route (SR) 732, RM 15.12, in July, August and October of 2005 (Figure 33). As expected, the stream velocity decreased over time as the summer temperatures and evaporation increased. In August, field crews reported walking up from the mouth of the mainstem where Indian Creek was dry. In addition to natural causes, gravel operations in that area may also influence the interstitial nature of the stream due to groundwater draw-down.

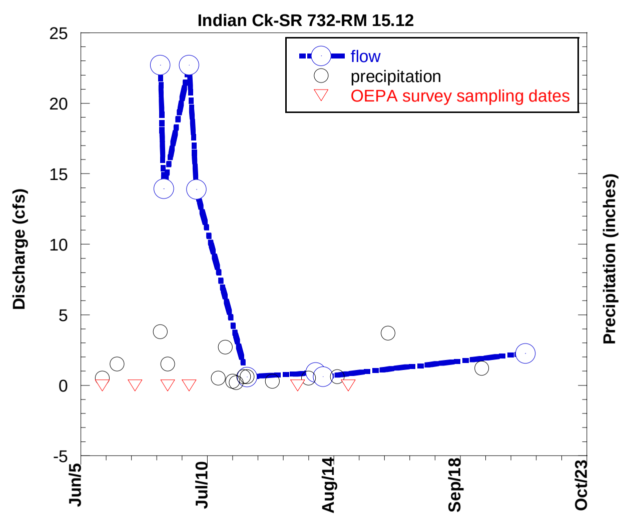


Figure 33. Relationship between stream flow, precipitation and sampling dates for the Indian Creek Watershed.

An average of 39 inches of precipitation falls on Butler County annually. Around June 12th, the remnants of Tropical Storm Arlene contributed 0.40 to 0.80 inches of rain to this region of the Ohio Valley. A June 27th rain event produced a much more significant precipitation in the upper portion of the basin than the lower. The July 13-15th residual rains from Hurricane Dennis soaked portions of the Ohio River Valley by adding almost a half an inch of rain to the region. Additional rainfall accumulations of two to six inches accompanied Hurricane Katrina across the study area by August 29-30th, 2005. These significant rain events impacted the sampling dates of June 12, June 28, July 13, July 15, July 21, August 3, and August 29-30, 2005. In spite of these heavy precipitation events, the difference between long term precipitation average trends and total precipitation for the June-August 2005 sampling period resulted in a deficiency of just over an inch of rain (www.miamiconservancy.org).

Recreational Use Attainment
In order to assess the bacteriological data collected from the Indian Creek Assessment Unit, the geometric mean and 90th percentile were determined (Table 21). Data was collected during the recreational season (May 1 through October15) and compared to the Primary Contact Recreation use (PCR) water quality criteria in WQS to determine attainment. Taken as a whole, this watershed was in attainment of the PCR use. However, 28 % of the *E. coli* samples had counts above the PCR maximum criterion. On bacteria sample collection days (October 3, 4, 5, 6, 13) no rain was recorded at either the Oxford or Hamilton precipitation logs and average daily stream flows declined gradually from 1,990 cfs to 1,140 cfs by October 13, 2005. Bacteria results demonstrated increases in concentration at RMs 17.68, 6.80, 6.50, and 1.66 (Figure 40) during this same time period which could indicate direct access of livestock to the stream, failing onsite home sewage treatment systems, and point source human waste disposal. However, isolated showers that do not reflect in localized rain gauging stations can also indicate a non-point source contribution.

Dissolved Oxygen
Sixty-eight in-stream measurements (instantaneous) for *dissolved oxygen* were taken in mainstem and tributary sites. Of the total readings taken, twenty-six percent (26%) of readings fell below WQS minimums for their respective Aquatic Life Use and only one percent (1%) of those was recorded in the mainstem. Two mainstem sites, RM 23.95 and 6.50 (near the Indiana state line and downstream Queen Acres wastewater treatment plant respectively) had the most frequent readings below D.O. water quality standards.

Datasonde® Continuous Monitor Data
Datasonde® continuous monitors are data-gathering instruments that record various parameter concentrations over a designated time period. Datasondes® were placed in the mainstem of Indian Creek at locations indicated in Figures 36 and 37. All values for RM 1.66 in August are not validated as the monitor was air-exposed due to low stream flow.

Extreme ranges of *oxygen* levels in the Indian Creek watershed were not detected in this survey. Stream oxygen ranges predictably reached highest and lowest values in August for the two sites near the mouth and at RM 7.6, falling below the EWH minimum for the stream. The acceptable ranges of dissolved oxygen observed over 24-hr monitoring in the Indian Creek Watershed are indications of adequate flow regimes and low impacts from both agricultural runoff and home septic inputs.

Datasonde® pH values for July and August ranged from 7.0 to 8.81 (Figure 36). Typically, during daylight hours, aquatic plants have a net alkalizing affect, while sundown brings a net acidifying affect. In July, this pattern occurred for all sites except RMs 23.9, 12.6 and 7.6, where pH values remained alkaline and stable through 24 hrs.

Comparing diurnal readings for all sites after midnight until sunrise (when dissolved oxygen levels typically decrease), only RM 4.3 declined below the EWH minimum of 5 mg/l. Not coincidentally, heavy algal growth was noted at this site.

Indian Creek Mainstem

Mainstem values for ammonia-N ranged from 0.05 to 0.149 mg/l but did not exceed WQS standards (Figures 34 and 39). Most mainstem sites experienced highest ammonia-N concentrations uniformly on the highest flow day of June 28th, 2006. Median ammonia-N values were most elevated from the Indiana border to RM 6.5, reducing gradually toward the mouth. River mile 9.4, located below the confluence of Salmon Run, revealed the highest median value for the mainstem (0.079 mg/l). Phosphorus concentrations followed the same pattern as ammonia relative to stream flow. The median phosphorus level increased downstream from the Queen Acres WWTP to above the target value.

Two sampling events (June 28th and July 21st) at RM 1.66 with similar rainfall amounts were used for comparison. The highest ammonia-N value was 0.107 mg/l occurring on June 28, 2005, twice the ammonia-N concentration of July 21, 2005. The doubling of ammonia-N concentration on June 28th also held true for mainstem sites at RM's 23.95, 17.68 and 6.80.

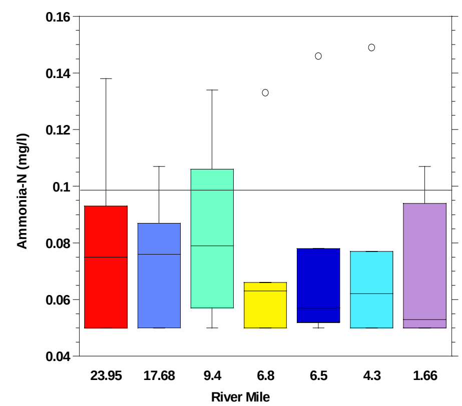


Figure 34. Indian Creek mainstem ammonia-N values.

The difference is theorized to be variant rainfall amounts leading up to ten days prior to each sampling event. The July event logs recorded a total of 1.65 inches of rain over ten days prior to the sampling event. The June event logs showed minimal to no rain leading up to the sampling event. Variables that can skew concentration outcomes are a localized rain event an unknown or non-verifiable discharge prior to the sampling dates.

Ohio EPA's Sentinel Data Program was developed to evaluate water chemistry at select sites during variable flow regimens. The Indian Creek Watershed sentinel station is located on the mainstem at Indian Creek Road, RM 17.68. Ammonia–N values remained at the detection limit for 67% of samples (Figure 38).

In 2004, The Miami Conservancy District (MCD) published the 2004 Water Quality Assessment of the Lower Great Miami River conducting a limited assessment of the tributaries of the Lower Great Miami River which included Indian Creek. Indian Creek was sampled once on July 8, 2004 at the SR 128 bridge (RM 1.66). This was a relatively dry precipitation period (0.26 inches of rain up to 10 days prior) validated by receding flows on the Great Miami. MCD's ammonia-N concentrations at RM 1.66

during July, 2004 was 0.049 mg/l. The ammonia concentration from Ohio EPA's water sample in July, 2005 at RM 1.66 was 0.053 mg/l. Nitrate data showed similar concentrations (approximately 1 mg/l) from both agencies' studies at this site. Of the six tributaries in the MCD study, Indian Creek water chemistry demonstrated the third lowest concentration of nitrates.

The mainstem water quality had numerous metals above analytical detection limits; however, only iron, lead and copper exceeded WQS (Table 20). Iron surpassed Agricultural WQS from river mile 9.4 to the mouth while lead and copper were elevated at river miles, 6.80 to 4.30.

Although not exceeding Water Quality Standards, fifty-eight total organic compound concentrations above analytical detection were recorded in the water column during the survey (Table 22, Appendix Table A-6). Twenty-four different compounds were detected (including tentatively identified compounds). More than half of the compounds were herbicides (54%), followed by pesticides and semi-volatiles. The majority of June detections were at higher concentrations and appeared with greater frequency in the water column. Higher herbicide levels were typically detected in the June sampling, mostly likely due to spring application of herbicides in concert with greater volumes of precipitation transporting chemicals through field tiles and then directly to waterways. The most frequently detected compounds for herbicides were atrazine, acetachlor, dieldrin and metolachlor. Atrazine was identified at all sites in July and at 67% of sites in August.

The greatest numbers of organic compounds were detected near RMs 6.80 and 6.50. Aldrin and Heptachlor epoxide were detected at RM 9.40 to 6.50. Bis-(2-Ethylhexyl) phthalate, atrazine and acetochlor had the highest values of all the organic compounds at RM 23.90. Results from a study conducted by the Miami Conservancy District in 2004 reflected similar patterns of organic compound detection. Inter-state collaboration of land management practices should be encouraged to minimize cross-boundary transfer of nutrients and organic compounds from agricultural and urban areas.

Indian Creek Tributaries

Nutrient data for tributaries of Indian Creek Watershed were evaluated for nitrate-nitrite, ammonia-N and phosphorus. Select tributaries are represented graphically in Figure 42. Tributary streams were found to contain considerably lower nitrate-nitrite levels than the mainstem of Indian Creek. The Tributary to Salmon Run at RM 0.10 had the highest one-day value for nitrate-nitrite (9.72 mg/l) of all tributary sites, followed by Little Indian Creek (3.56 mg/l) and Beals Run (3.55 mg/l). The Tributary to Salmon Run location was located downstream from the Island Lake MHP WWTP.

For all sampling dates in 2005, slightly higher concentrations of ammonia-N in the mainstem were noted downstream from the confluence of the tributaries Salmon, Beals and Lick Runs. Ammonia-N values generally remained below the target value of 0.10 mg/l in the tributary sites except for individual elevated values in Little Indian Creek (0.110 mg/l), Salmon Run at RM 1.9 (0.101 mg/l), Lick Run (0.159, 0.128 mg/l), and Beals Run (0.17 mg/l); and generally elevated values in the Tributary to Salmon Run at

RM 1.4 (max. 0.334, min. 0.091, median 0.128 mg/l) which is located immediately downstream from the Island lake MHP WWTP. The maximum concentration reported at this site of 0.334 mg/l was a violation of the WQS criterion.

Phosphorus values remained below the target value of 0.206 mg/l in all the tributary sites except for elevated values in the Tributary to Salmon Run at RM 1.4 (max. 0.256, min. 0.122, median 0.239 mg/l) which is located immediately downstream from the Island lake MHP WWTP and Lick Run at RM 0.90 (max. 0.494, min, 0.079, median 0.21 mg/l) which is located about three miles downstream from the Layhigh Estates MHP WWTP. Little Indian Creek consistently had the lowest phosphorus values of all the tributaries.

The Indian Creek tributaries of Salmon Run, Beals Run, and Lick Run incurred most of the in-field dissolved oxygen WQS exceedences, with values frequently falling below WWH standards. Most of these values were connected to either interstitial or turbid flow regimes, however, streamside piles of residential grass clippings were noted at the Beal Run sampling station.

Metals did not appear in concentrations above state water quality standards in the tributaries of Indian Creek.

Organic compounds appeared above detection limits in both tributaries selected for sampling (Reserve Run and Little Indian Creek), possibly either through air deposition or via unknown discharges. Reserve Run showed the greatest occurrence of organics, particularly phthalates (used in plasticizers) and the widely used herbicide atrazine.

Stream Alteration Projects

Stream alteration projects in the Indian Creek Watershed require a Clean Water Act 401 permit. In 1997, Martin Marietta Materials of Cincinnati relocated 1200 feet of Indian Creek to allow for the expansion of its sand and gravel operation at 3900 Krause Lane in the town of Ross (approximate RM-1.66). In 2001, a section of Indian Creek Park along Indian Creek Road was altered and 500 ft of gabion wall placed to prevent road washout (Approximate RM 20.00). In 2004, Ross Estates in Millville performed a relocation of 1000 ft of a Class II primary headwater stream in an unnamed tributary to Indian Creek (approximate location RM 7.2).

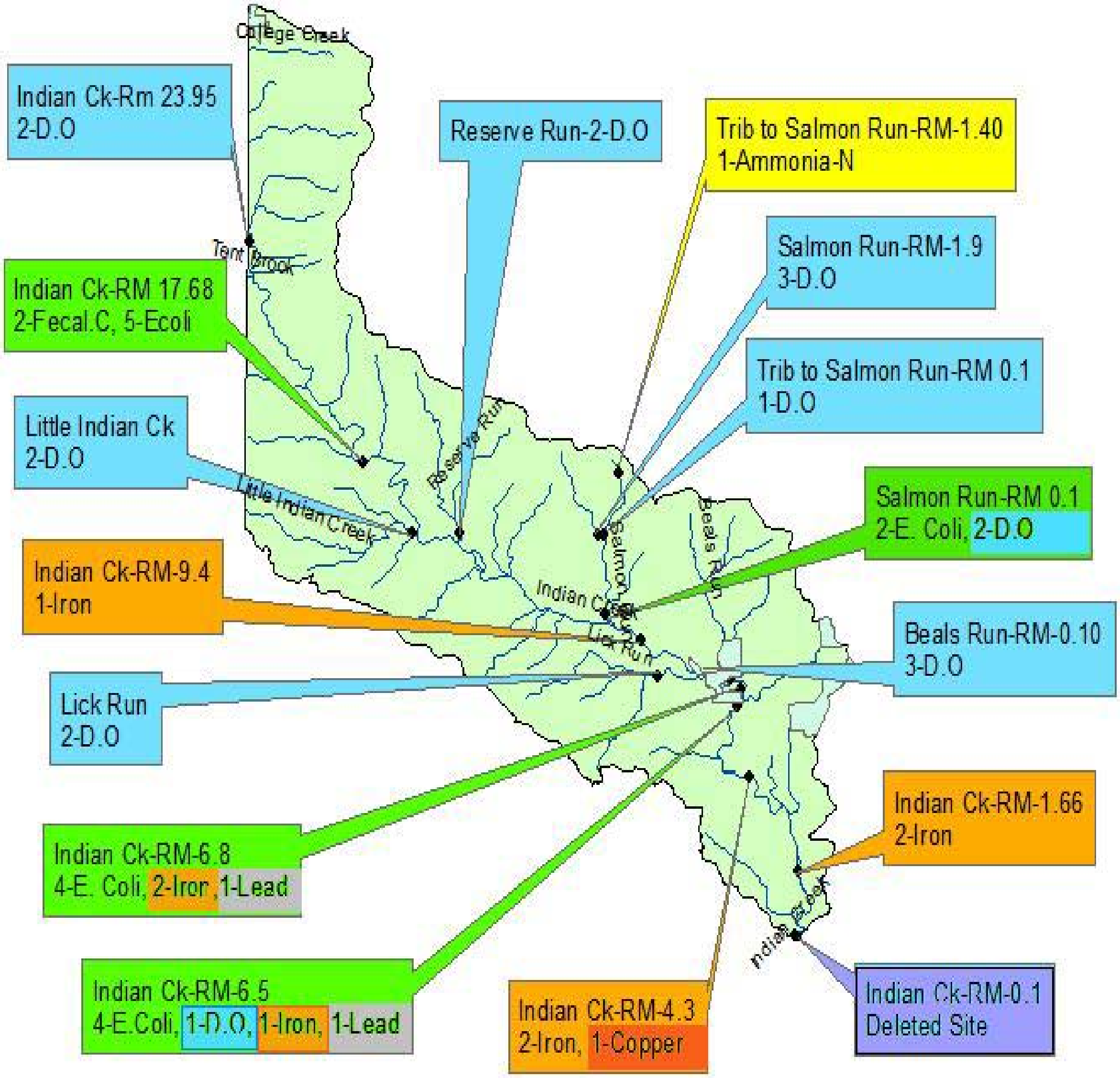


Figure 35. Water Quality Standard Exceedences by survey sampling site, 2005.

Table 20. Exceedences of Ohio EPA water quality criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Indian Creek study area during 2005 (units are µg/l for metals and organics, #colonies/100 ml for Fecal coliform and *E. coli*, SU for pH, and mg/l for all other parameters). Exceeded Tier II limits in samples are not included in the table[b]. Indian Creek and Salmon Run were evaluated with the existing EWH aquatic life use designation, but please note that these streams are recommended to be changed to the WWH aquatic life use.

Stream (*use designation* [a]) **River Mile**	**Parameter (value)**
WAU: 05080002-080	
Indian Creek	***(SRW, EWH, AWS, IWS, PCR)***
23.95	Dissolved oxygen **(**4.89[‡‡], 5.29[‡‡] **)**
17.68	Fecal coliform [b] (1200[◊], 1400[◊]) *E. coli* [b] (200[◊], 210[◊], 150[◊], 860[◊◊], 1200[◊◊])
9.4	Iron-T (8860[∞])
6.80	*E. coli* [b] (180[◊], 220, 270[◊], 340[◊◊]) Iron-T (5040[∞], 13,800[∞]) Lead-T (11.5*)
6.50	*E. coli* [b] (210[◊], 300[◊◊]370[◊◊] 440[◊◊]) Dissolved oxygen (5.60[‡]) Iron-T (14400[∞]) Lead-T (11.6*)
4.30	Iron-T (6840[∞], 20100[∞]) Copper-T (17*)
1.66	Iron-T (10800[∞], 14200[∞])
0.1	Iron-T (11200[∞])
Little Indian Ck (undesignated [a])	
0.09	Dissolved oxygen (2.81[‡‡], 3.50[‡‡])
Reserve Run (undesignated [a])	
0.25	Dissolved oxygen (3.37[‡‡] 4.0[‡‡])

Salmon Run (**SRW, *EWH, AWS, IWS, PCR)***

1.90	Dissolved oxygen **(**1.5 ‡‡**,** 4.0‡‡**,** 4.4‡‡**)**
0.10	*E. coli* [b] (280◊, 420◊◊) Dissolved oxygen **(**2.81‡, 5.60‡‡**)**

Trib to Salmon (undesignated [a])

1.40	Ammonia-N (0.334*)
0.10	Dissolved oxygen (4.9‡‡)

Lick Run (undesignated [a])

0.90	Dissolved oxygen (3.0‡‡, 4.9‡‡)

Beals Run (undesignated [a])

0.10	Dissolved oxygen (1.57‡‡, 3.1‡‡, 3.3‡‡)

---

a **Use Designations:** SRW - State Resource Water

Aquatic Life Habitat	Water Supply	Recreation
EWH - Exceptional warmwater habitat	IWS - industrial water supply	PCR – primary contact
WWH - Warmwater habitat	AWS - agricultural water supply	

(WWH criteria apply to "undesignated" surface waters)

b Bacteriological data (Fecal coliform, *E. coli*) is applied to estimate the potential for human health impacts to receiving waters. See Table ___ also.

* exceedence of numerical criteria for prevention of chronic toxicity (CAC).

∞ exceedence of agricultural water supply criterion.

‡ value is below the below the EWH minimum 24-hour average D.O. criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O. criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O. criterion (4.0 mg/l) as applicable.

‡‡ value is below the EWH minimum at any time D.O. criterion (6.0 mg/l) or value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the MWH minimum at any time D.O. criterion (3.0 mg/l) as applicable.

◊ value is above the average PCR criteria (fecal coliform 1000/100ml; *E. coli* 126/100ml)

◊◊ value is above the maximum PCR criteria (fecal coliform 2000/100ml; *E. coli* 298/100ml) or value is above the maximum SCR criteria (fecal coliform 5000/100ml; *E. coli* 576/100ml) as applicable.

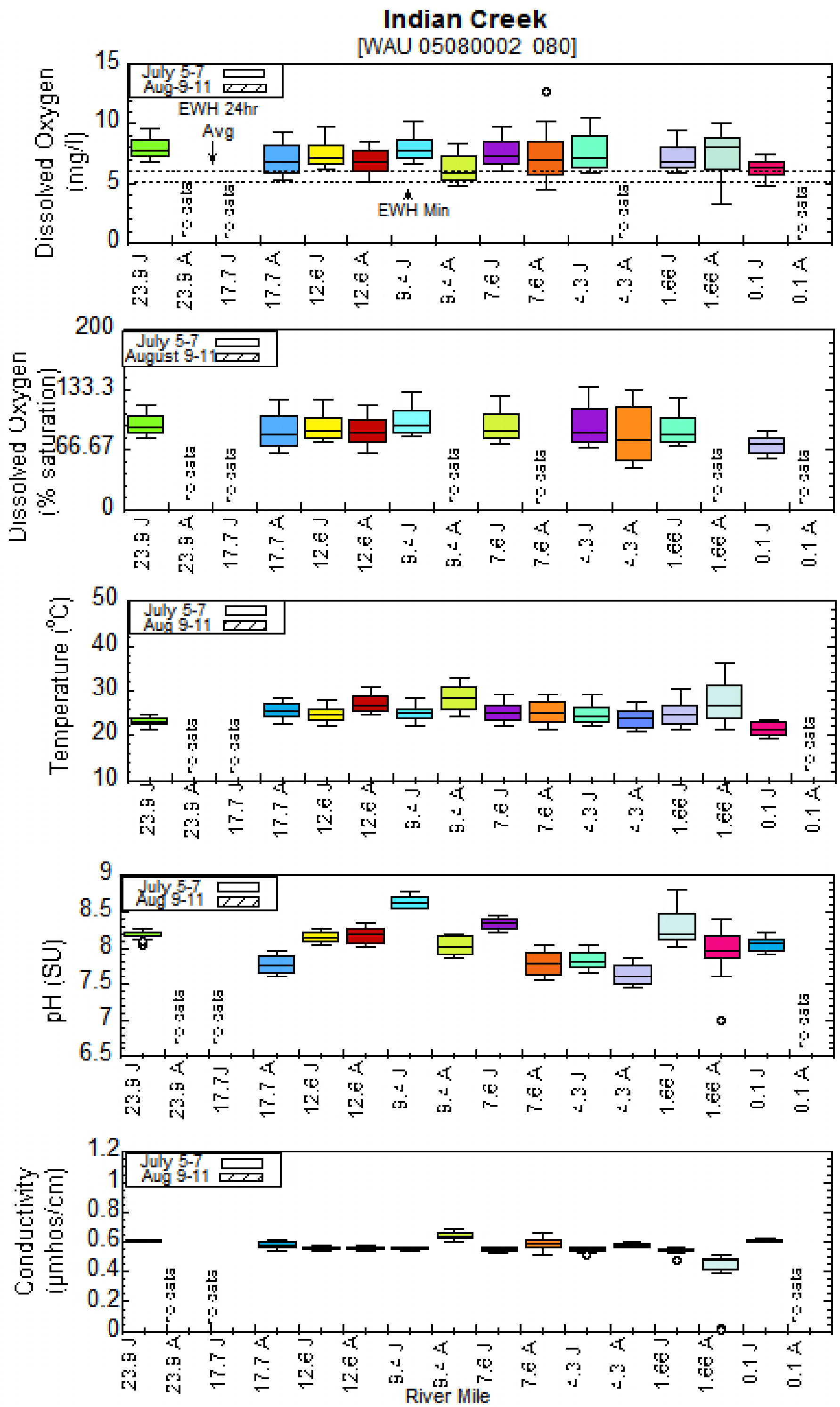


Figure 36. Multiprobe Data Loggers continuous recorders deployed by Ohio EPA Modeling Section in the Indian Creek mainstem, 2005.

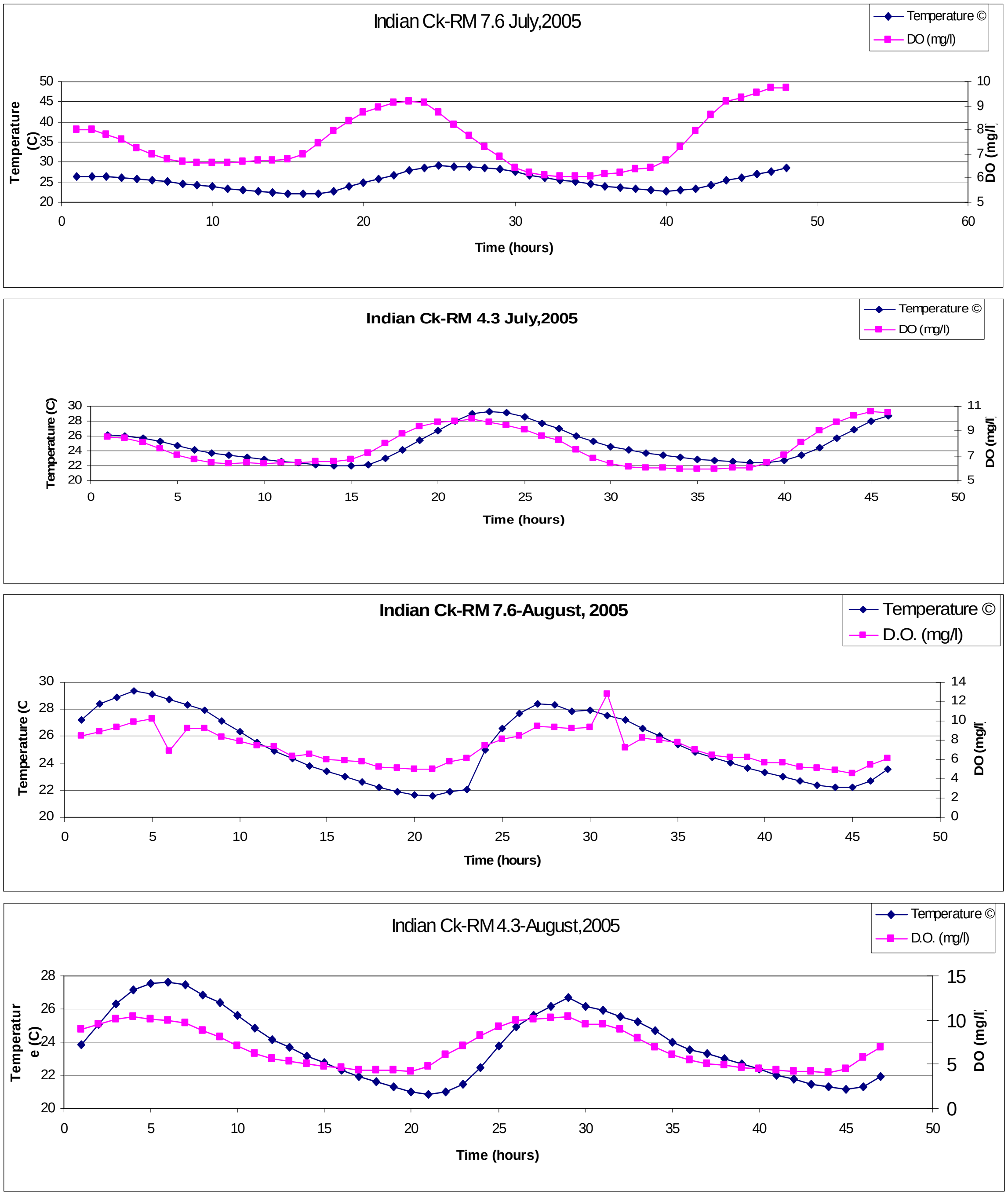


Figure 37. Multiprobe Datalogger temperature and dissolved oxygen two month comparisons at RM 7.6 and 4.30.

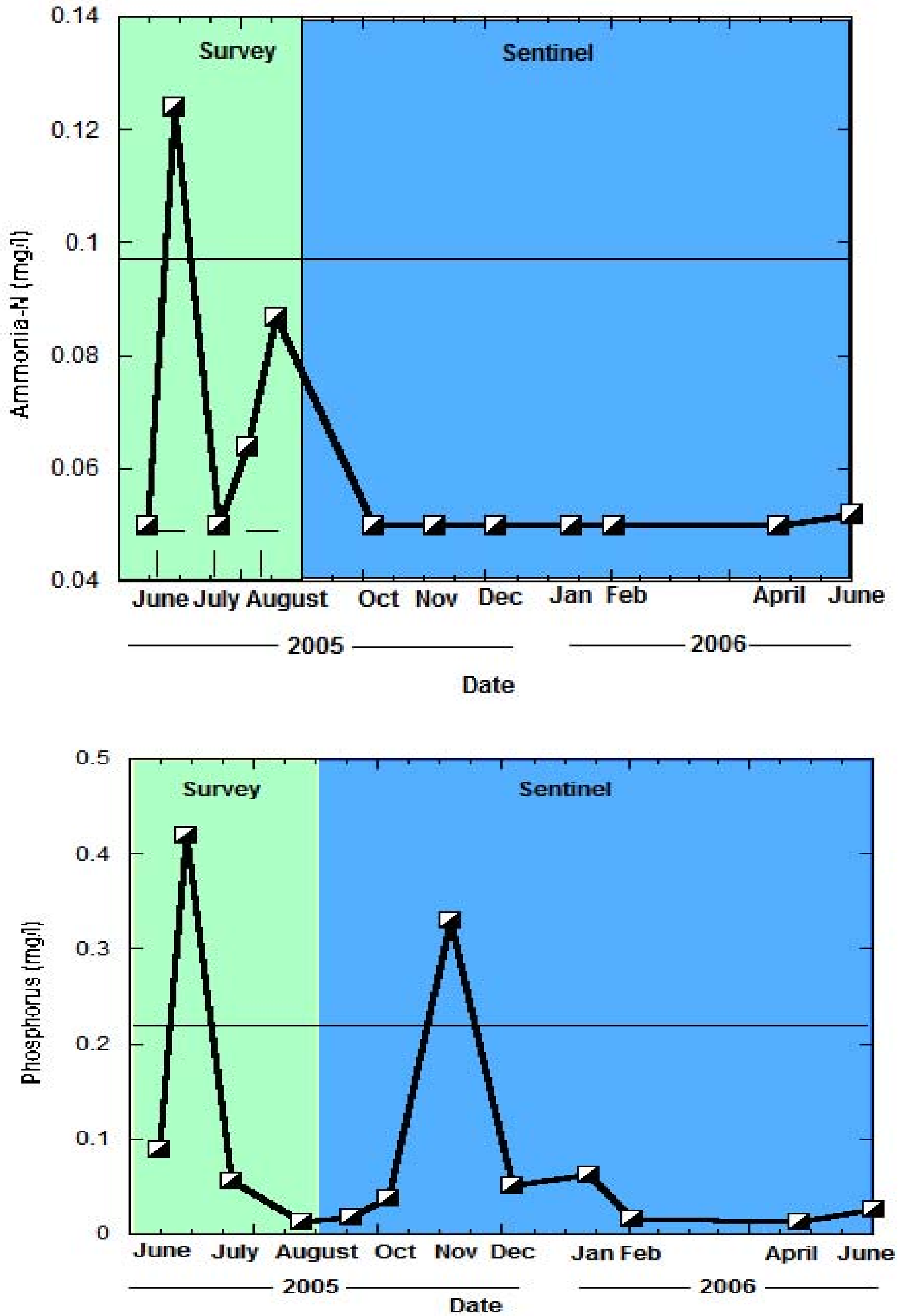


Figure 38. Indian Creek mainstem sites survey and sentinel survey mean data for ammonia-N and phosphorus.

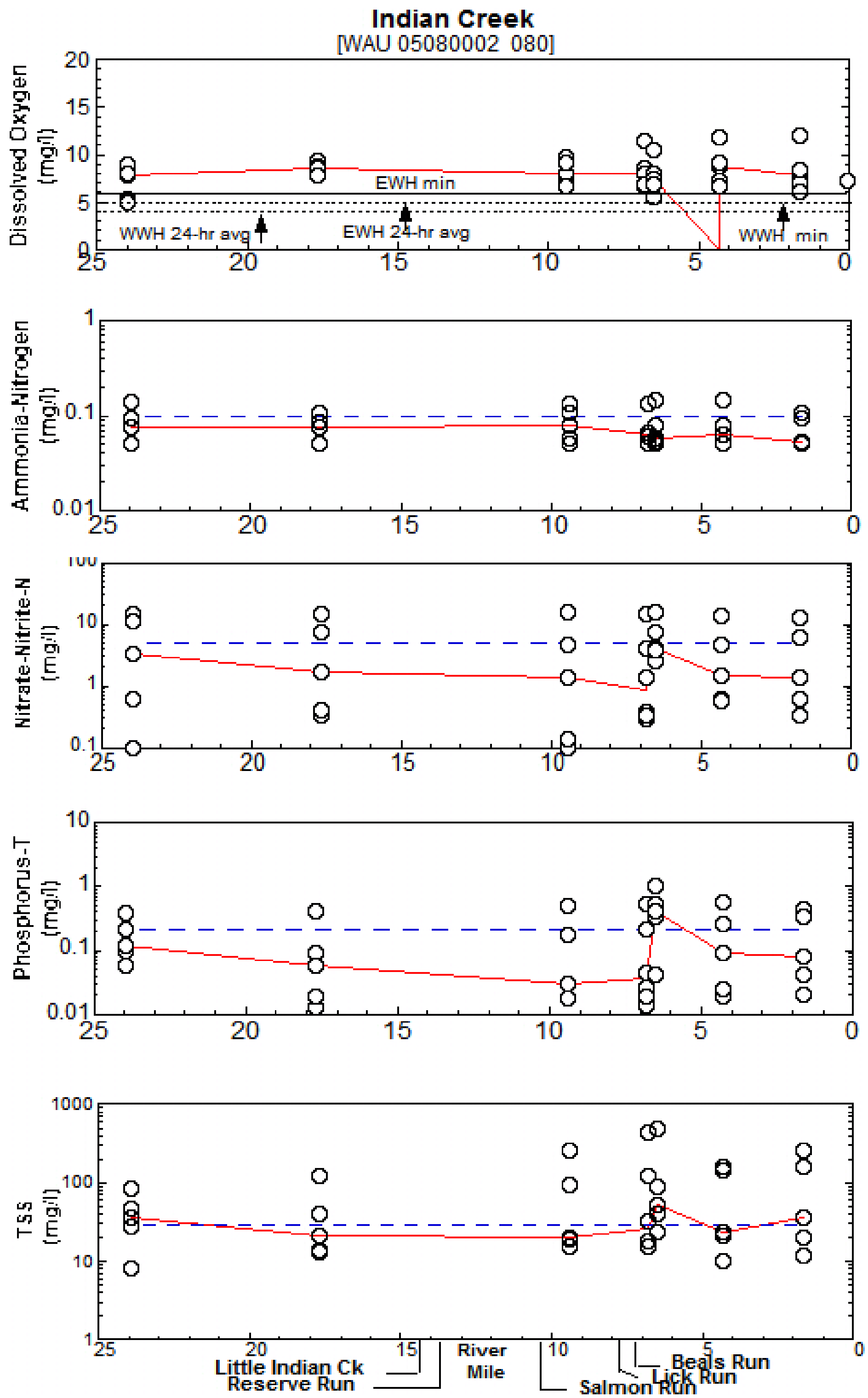


Figure 39. Longitudinal plots of chemical results Indian Creek mainstem during the 2005 survey. Dotted lines represent target values. The solid line depicts the median value at each river mile sampled.

Table 21. Exceedences of Ohio EPA bacteriological water quality criteria (OAC 3745-1-07) during 2005 in the Indian Creek study area by watershed assessment unit (WAU). Five samples were collected from 5 selected sites from October 3-13th. Criteria above Recreational limits are highlighted in red.

Primary Contact Recreation (*Fecal coliform*): Geometric mean fecal coliform content based on not less than five samples within a thirty-day period shall not exceed 1000 per 100 ml, and fecal coliform content shall not exceed 2000 per ml in more than ten percent of the samples taken during any thirty-day period.	
Geometric mean (#colonies/100ml)	237
% of samples > 2000	0%
n =	25
Primary Contact Recreation *(E. coli)*: Geometric mean E. coli content based on not less than five samples within a thirty-day period shall not exceed 126 per 100 ml, and E. coli content shall not exceed 298 per 100 ml in more than ten percent of the samples taken during any thirty-day period.	
Geometric mean (#colonies/100ml)	122
% of samples > 298	28%
n =	25

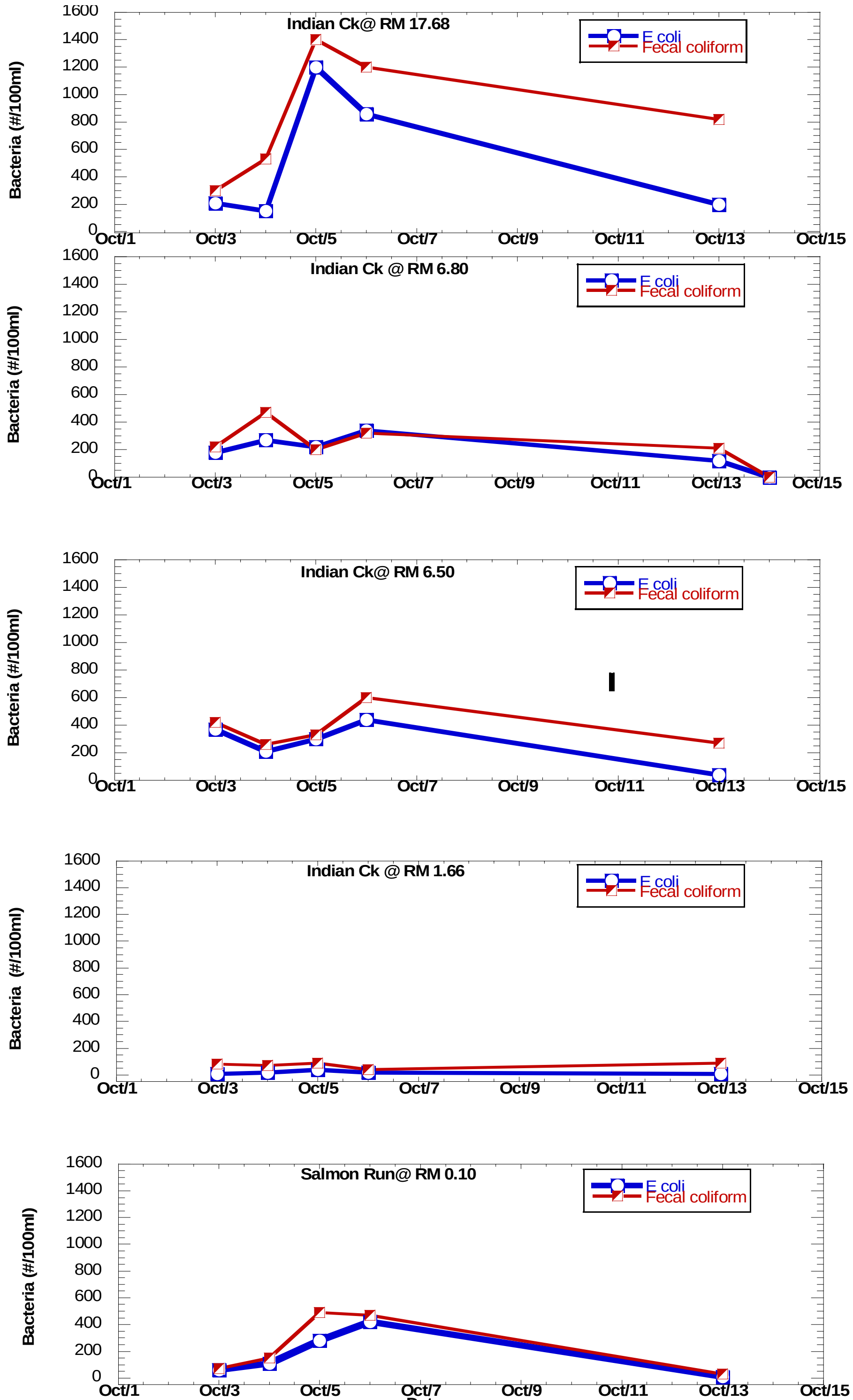
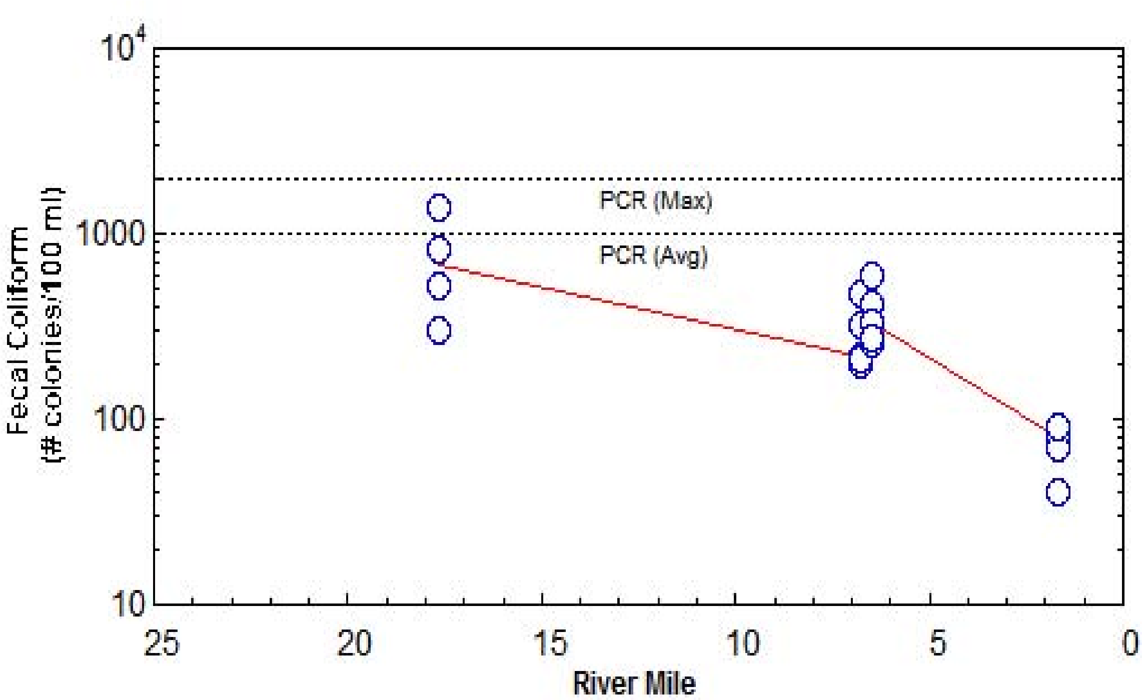


Figure 40. Longitudinal plots of E *coli* and Fecal Coliform daytime grabs in the Indian Creek watershed for five select sites.



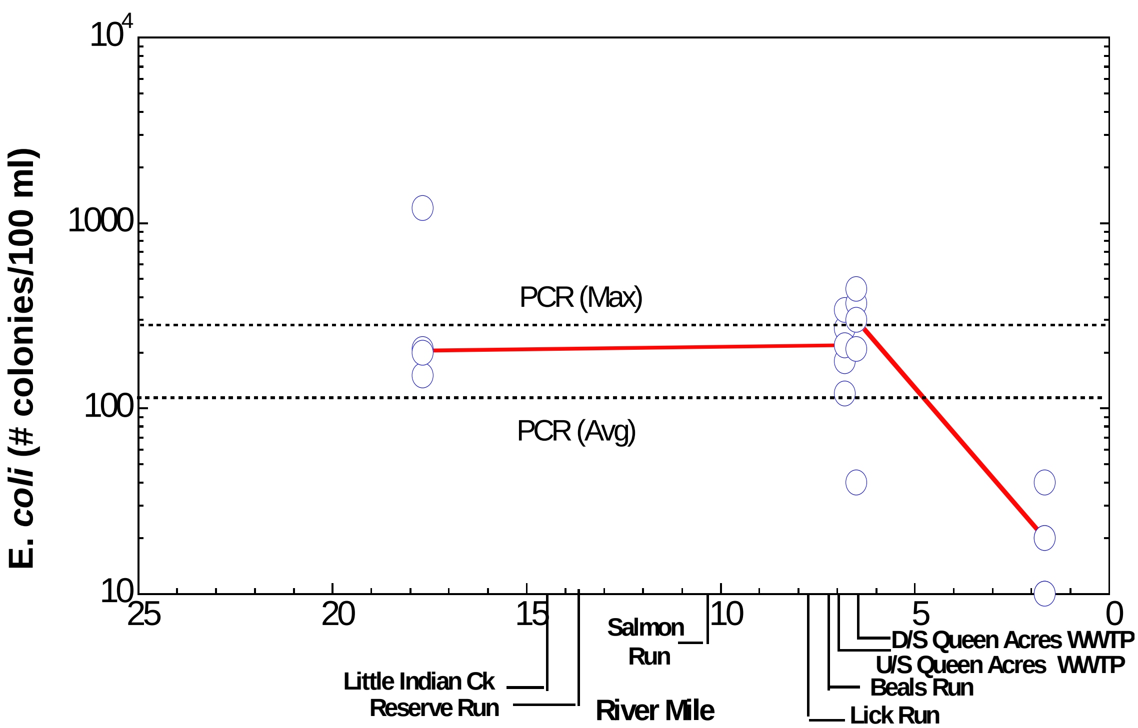


Figure 41. Longitudinal plots of median fecal coliform (top) and *E. coli* (bottom) bacteria results in the Indian Creek mainstem during the 2005 survey. Dotted lines represents WQS Recreational Use criteria. The solid line depicts the median value at each river mile sampled.

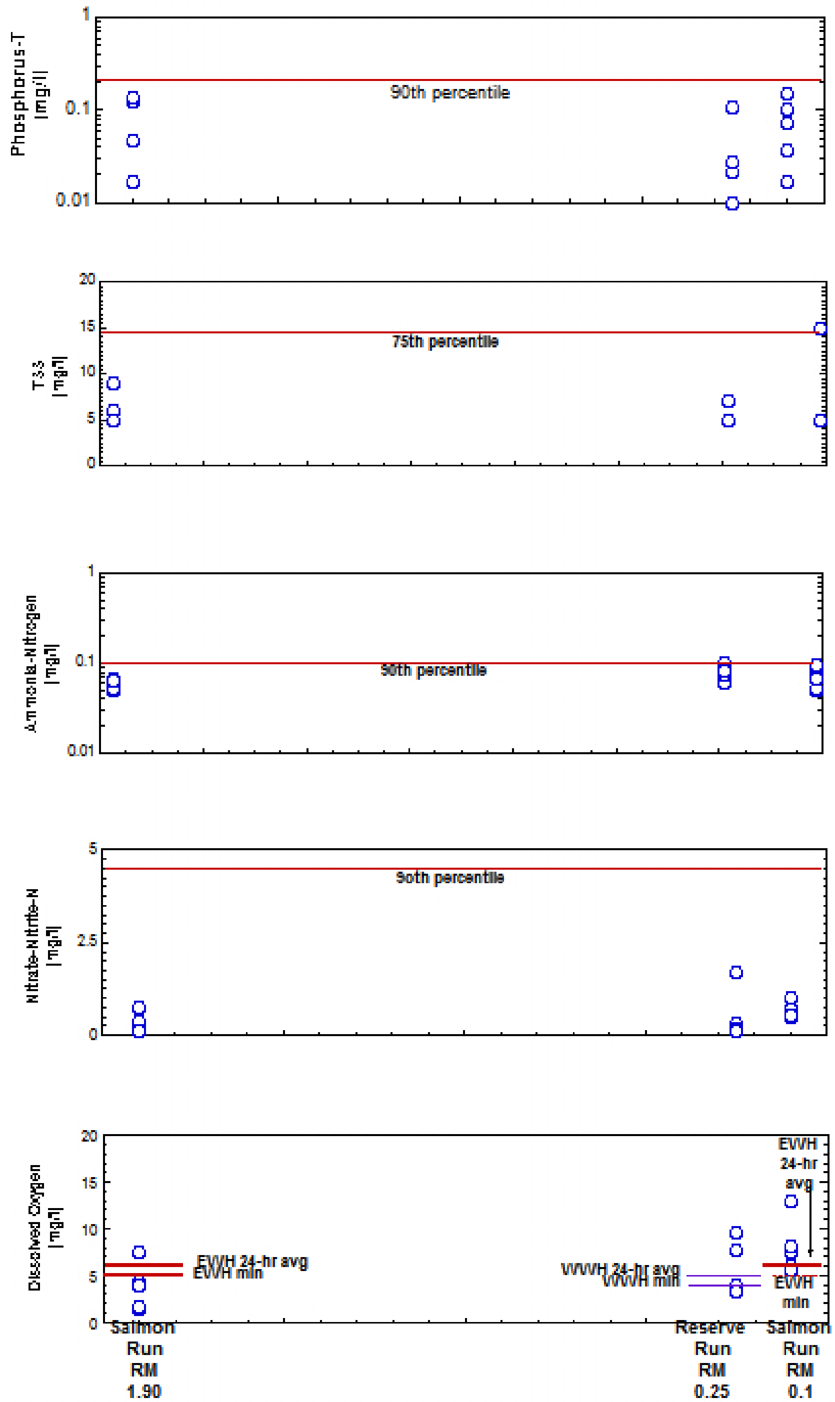


Figure 42. Per sampling event plots of three sites in two tributaries during the 2005 survey. The solid red line depicts the target values at each river mile sampled. Dissolved oxygen solid lines are Use designation Criteria limits.

Table 22. Frequency of 13 identified water organic compounds collected from six sites in the Indian Creek Study Area during 2005.

Parameter	Frequency/ Number of Organic Sites
a-BHC*	5/6
d-BHC*	1/6
y-BHC*	2/6
Acetochlor*	4/6
Alachlor	2/6
Aldrin	3/6
Atrazine*	6/6
bis(2-Ethylhexyl) phthalate	5/6
Dieldrin	4/6
Heptachlor epoxide	4/6
Hexachlorobenzene	1/6
Metolachlor*	4/6
Simazine*	3/6
TOTAL	44/78

* No applicable water quality criteria available for parameter.

Loadings Section

Table 23. Dischargers in the Indian Creek watershed during 2005.

Facility Name	County	Ohio EPA Permit #	Lat/Long	Receiving Stream	River Mile Discharge, Receiving Stream	Design Flow (MGD)
Golden Years Healthcare WWTP	Butler	1PT00079	39^{0}26’05” 84^{0}38’41”	Unnamed tributary of Beals Run	2.23; 7.16	0.0225
Island Lake MHP	Butler	1PV00080	39^{0}26’57”; 84^{0}11’16	Unnamed tributary of Salmon Run	1.80; 1.40	0.040
Millville MHP WWTP	Butler	1PV00124	39^{0}23’25” 84^{0}39’09”	Beals Run	7.06; 0.20	0.003
Layhigh Estates MHP WWTP	Butler	1PZ00002	39^{0}22’49” 84^{0}42’49	Unnamed tributary of Lick Run	3.09; 0.90	0.045
Queen Acres Water Reclamation Facility WWTP	Butler	1PG00043	39^{0}23’48” 84^{0}38’20”	Indian Creek	6.67	0.600

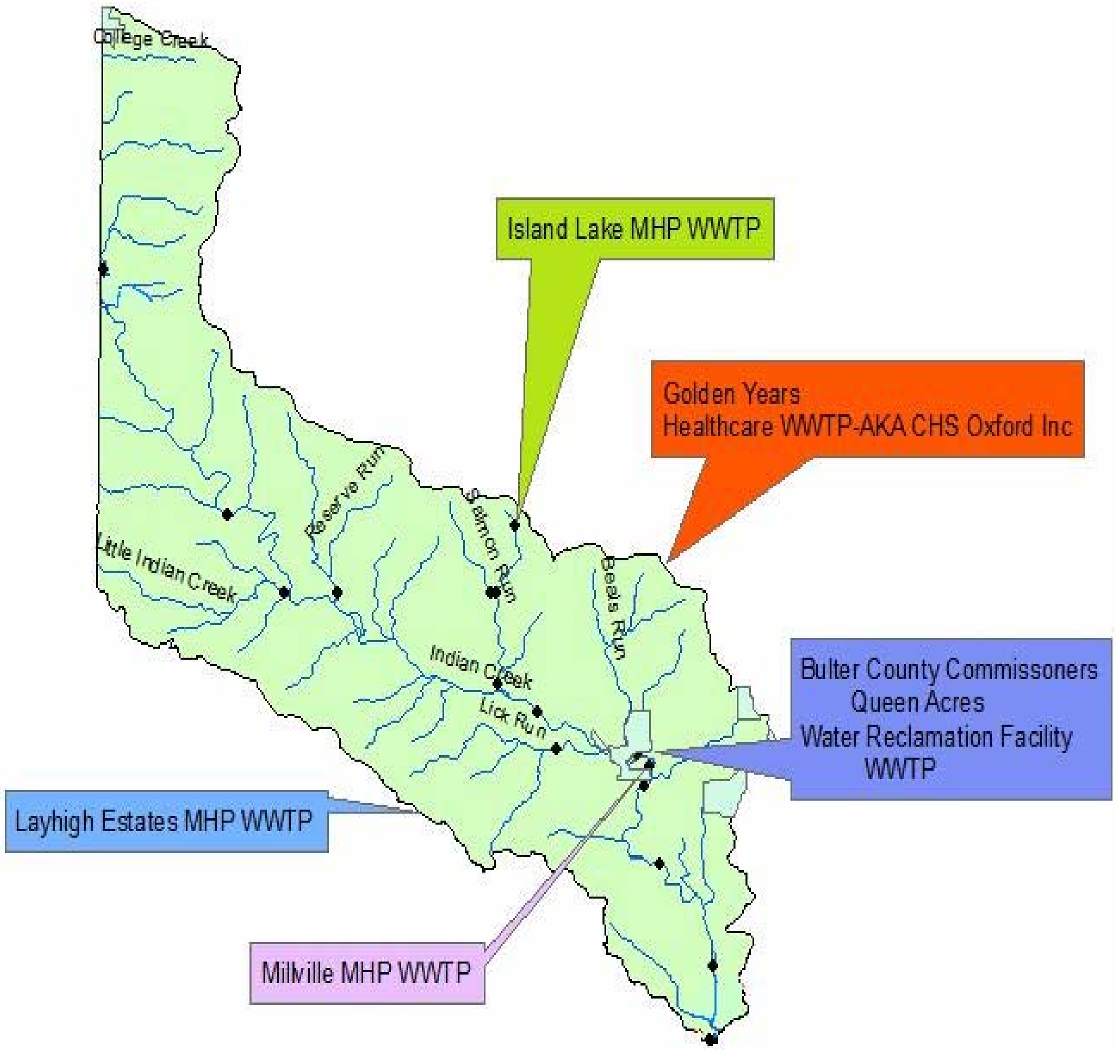


Figure 43. Location of permitted dischargers in the Indian Creek Watershed.

Island Lake MHP-a.k.a-**JGR Properties, Inc**-lake to unnamed tributary of Salmon Run-RM 1.50; 1.80
Permit #-1PV00080
Lat: 39.449167; Long: 84.187778

The Island Lake MHP is located in Butler County at 2315 Millville-Oxford Road, Oxford, Ohio. The Ohio EPA issued the 70 unit facility a wastewater permit in August of 1973. Treatment consisted of a comminutor, bar screen, flow equalization tank, aeration tank, aerated sludge holding tank, secondary clarifier, rapid sand filters, and a chlorine contact tank. The facility is designed for an average daily flow of 0.040 MGD. Upgrades completed by 2004 included the installation of a new dosing tank, four surface sand filters, a chlorine contact tank, post aeration, dechlorination and two new aerated sludge holding tanks.

Numeric violations of the National Pollutant Discharge Elimination System (NPDES) were evaluated for part of 2001 through February of 2006. For the nearly 5.5 years of data evaluated through SWIMS (Surface Water Information Management System) approximately 112 violations were reported. Ohio EPA NPDES permit violations were composed of the typical wastewater constituents of suspended solids (TSS), $cBOD_5$, ammonia-N and bacteria listed from the greatest to least frequent.

Violations dropped notably after the upgrade in service in 2004 with three violations reported in 2005. Eighty-five percent (85%) of the documented violations occurred between 2000 and 2002. Ohio EPA permit violations have reportedly been attributed to excessive precipitation events and various treatment equipment being offline for service or cleaning. Monitoring or frequency violations (Ohio EPA permit violations documented for failure to comply with permit reporting requirements) generally increased for numerous parameters from 2002 to 2005 with the exception of 2004.

Golden Years Healthcare WWTP-AKA-CHS Oxford, Inc- unnamed tributary of Beals Run-RM (headwater region)
Permit #-1PT00079
Lat: 39.434722;Long: 84.644722

The Golden Years Healthcare WWTP is located in Butler County at 2436 Old Oxford Road, Hanover Township, Ohio. This facility has been discharging wastewater since 1965 and brought under an Ohio EPA permit in 2001. The facility was an extended aeration plant with a design flow of 6,000 gpd and consisted of a trash trap, aeration tank, and clarifier.

Due to frequent NPDES violations, caused by the facility's inability to handle peak flows, an upgrade was completed and online as of August 16, 2005. Construction was completed August 10, 2005 for an average daily flow of 22,500 gpd. Current treatment consists of a bar rack, anoxic tank, aeration tank, upflow sludge blanket filter clarifier, aerated sludge holding tank, a chlorine contact tank, and dechlorination tank. The sludge is hauled to another wastewater facility for processing and is not land applied.

Numeric Violations of the National Pollutant Discharge Elimination System (NPDES) were evaluated for part of 2000 through a portion of 2006. For the nearly 6 years of data evaluated through SWIMS, (Surface Water Information Management System) approximately 224 violations were reported. Ohio EPA permit violations were composed of the typical wastewater constituents of suspended solids (TSS), $cBOD_5$, dissolved oxygen and ammonia-N listed from the greatest to least frequent.

Violations were primarily seasonal until 2005 when all seasons produced violations most likely linked to upgrade activities. Violations from 2001 to 2005 increased and occurred predominately within the first week and second weeks of the month. Thirty-eight percent (38%) of violations were TSS and were consistently reported as approximately four violations per month. Fifty-six percent (56%) of the numerical violations occurred in 2005. No sanitary sewer overflows were reported for this period. Ammonia-N concentrations reduced drastically after the upgrade jumping twice in June and July of 2006 to (10 and 28 mg/l respectively) while fecal coliform reached record lows and highs post upgrade the highest values were six digits and occurred near the rain events (Figure 44). Sampling is conducted approximately the same range of dates monthly so larger rain events were missed. Daily flow rates were identical fluctuating incrementally annually remaining unchanged until the upgrade of 2005 when reliable flow monitoring equipment was installed.

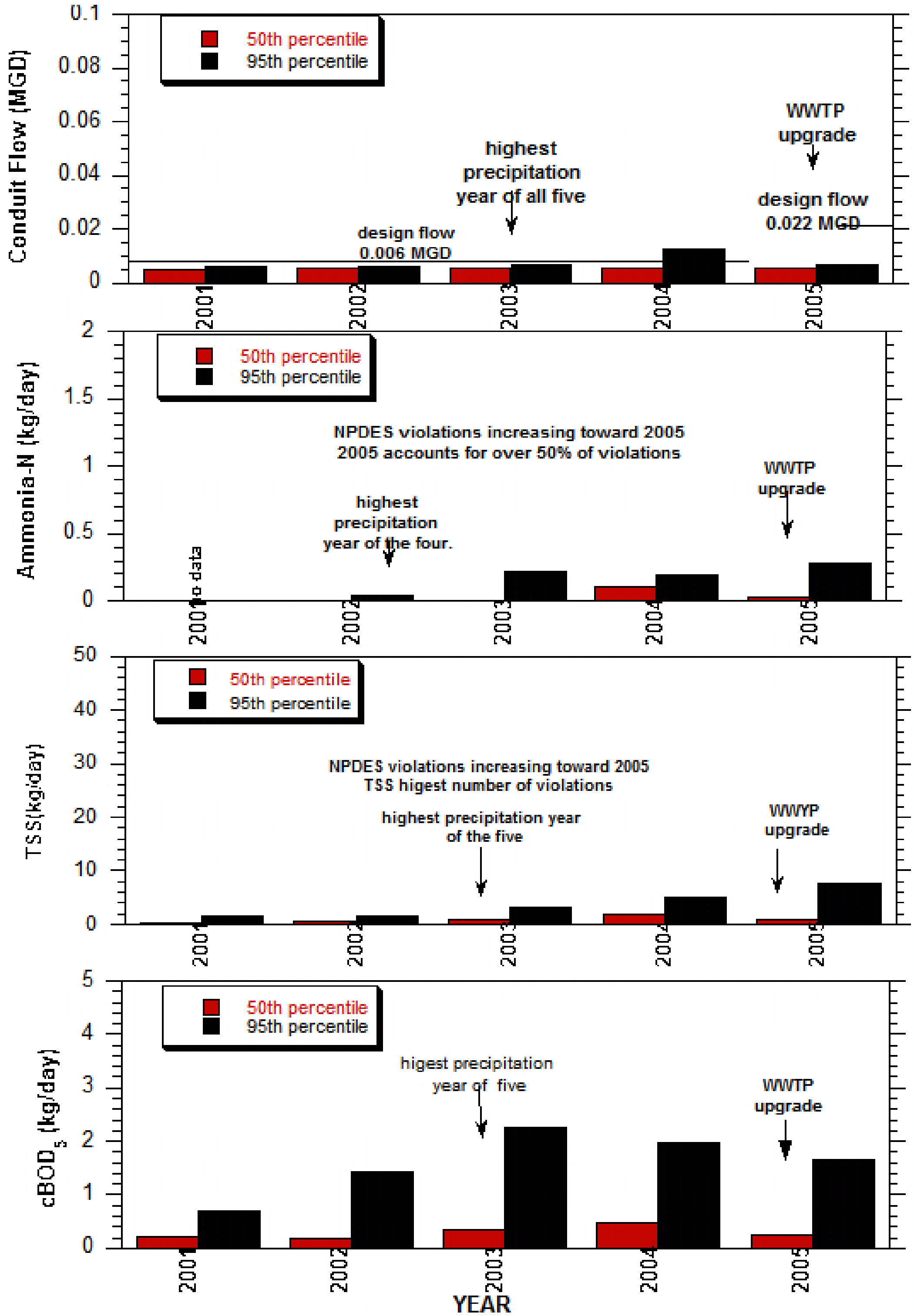


Figure 44. Annual loadings (kg/day) of various parameters and conduit flow at Golden Years Healthcare WWTP in the Indian Creek study area, 2005.

Queen Acres Water Reclamation Facility WWTP--Indian Creek-RM 6.67
Permit #-1PG00043
Lat:39.396667;Long:84.638889

Queen Acres WRF is a community located in Butler County at 2627 Ross-Hanover Rd., in Hamilton, Ohio. The facility was constructed in 1955 and consisted of primary clarifiers, trickling filters, secondary clarifiers, and disinfection facilities with a design flow of 0.115 MGD. A new facility was constructed in 1989 and consists of a flow equalization tank, comminutor, two oxidation ditches, two secondary clarifiers, chlorine contact tank and an aerated sludge holding tank increasing the design capacity to 0.30 MGD (300,000gpd).

In 2001 the average inflow and infiltration (I/I) into the collection system was estimated at 71,000 gpd. Bypassing has occurred historically at the facility and in the collection system and from 2001 to 2004 one overflow was reported at the influent pump station. In 2003, in response to continued hydraulic overloading in part to new development connections, a facility expansion increased the design flow of 0.30 MGD to 0.60 MGD while maintaining existing loads. Upgrades included a third clarifier, an effluent filter, post aeration and ultraviolet light (UV) disinfection. Queen Acres continues to experience high levels of inflow and infiltration (I/I), where in December of 2005 7,000 gallons of raw sewage emanated from a manhole located at 2630 Ross Hanover Road.

Median flows remained below the design flow for the facility for the period of record (Figure 45). Peak flow however exceeded the design flow for the facility until the upgrade of 2003-2004 where the facility flow design doubled in capacity bringing both percentile flows under design. This trend is reflected in reductions of NPDES violations by 2005.

Final outfall (001) bracketing of fixed stations 801 and 901, with few exceptions, demonstrated that both median concentrations of ammonia-N were commensurate with each other shortly after the upgrade to secondary treatment in 1989 (Figure 46). Subsequent years demonstrated oscillation between upstream and downstream values, however, 50% of the values revealed downstream higher than upstream primarily from 1999 to 2004. All other graphical gaps in data are due to the annual median value being below analytical detection. The median value for ammonia-n for the survey year, 2005 was below detection (0.05 mg/l).

Numeric violations of the National Pollutant Discharge Elimination System (NPDES) were evaluated for part of 2000 through 2005. For the nearly five years of data evaluated through SWIMS, an approximate 22 violations were reported. Ohio EPA permit violations were composed wastewater constituents of suspended solids (TSS), chlorine and oil and grease with the greatest frequency respectively.

Over half of the documented violations occurred between 2000 and 2001 and in all seasons of the year. Most Ohio EPA permit violations have reportedly been attributed to excessive precipitation events. Violations decreased over the years evaluated reporting three by 2005.

Ninety-Six (96) Permit Frequency Reporting Violations occurred from 2002 until July of 2005. Metals and chlorine were the most frequent reporting failures.

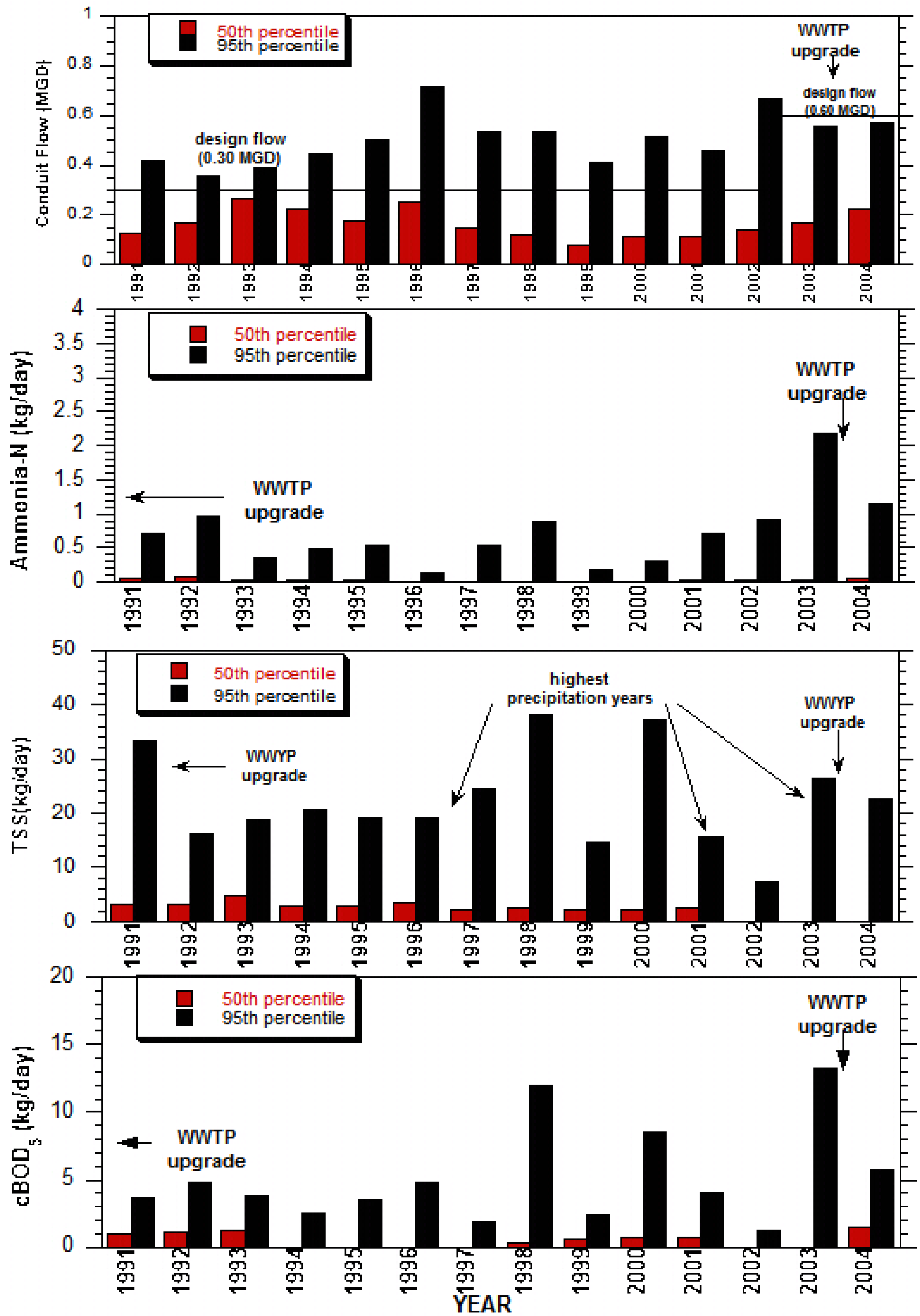


Figure 45. Annual loadings (kg/day) of various parameters and conduit flow at Queen Acres WRF in the Indian Creek study area, 2005.

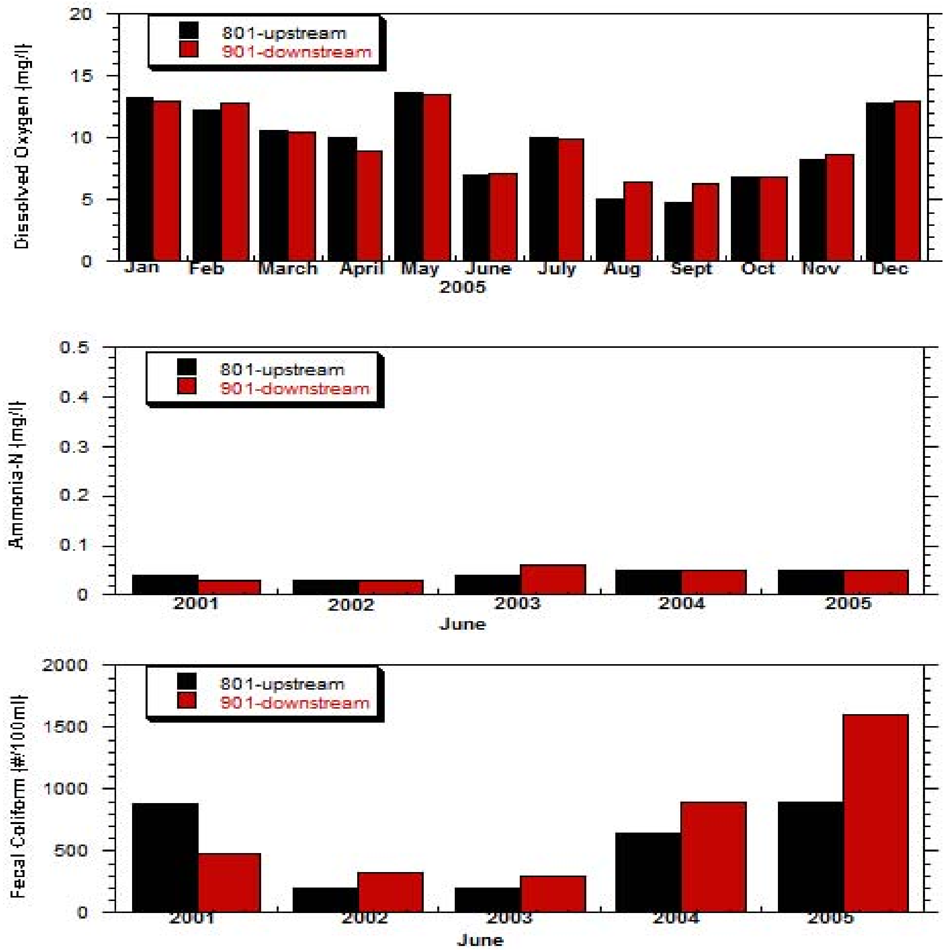


Figure 46. Annual concentrations (mg/day) of various parameters upstream and downstream of Queen Acres WRF in the Indian Creek study area, 2005.

Millville MHP
Permit#-1PV00124
Lat:39.390278;Long:84.652500

The Millville MHP WWTP is located in Butler County at 2840 Ross Hanover Rd., Millville, Ohio. Millville MHP has been discharging before 1974 and brought under an Ohio EPA permit in 2003 with a design flow of 3,000 gpd. Flows reported through Monthly Operating Reports (MORs) were reported daily at 3800-3900 gpd. Millville is an extended aeration facility consisting of a trash trap, aeration tank and clarifier. The current facility is required by their NPDES Permit to upgrade to comply with BADCT. No sanitary sewer overflows were reported for this period.

Numeric Violations of the National Pollutant Discharge Elimination System (NPDES) were evaluated for part of 2003 through February of 2006. For the nearly four years of data evaluated through SWIMS an approximate 22 numeric violations were reported. Ohio EPA permit limit violations were composed of typical wastewater constituents of suspended solids (TSS) and $cBOD_5$ with the greatest frequency respectively. Sixty seven percent (67%) were TSS occurring in all seasons and mostly around the first two weeks of the month. Fecal coliform counts, one year apart from 2005 to 2006, were reported ranged from 20,000 to 2 (#/100ml) respectively. The last quarter of 2006 ammonia-N values were 22 mg/l for both months.

Layhigh Estates MHP WWTP- Unnamed tributary of Lick Run-RM 3.9; 7.9
Permit #-1PZ00002
Lat:39.380278”; Long:84.713611

Layhigh Estates MHP is located in Butler County at 4820 Layhigh Rd., in Morgan Township, Ohio. The 85 mobile home park was permitted in 1982 for an average daily flow of 45,000 gpd. As of 2005, wastewater treatment consisted of Rotating Biological Contactor (RBC), trash trap, flow equalization, primary clarifier, secondary clarifier, dosing tank, four surface sand filters and UV disinfection (added in 2000).

No NPDES Permit violations were reported for March 2001 through February 2006 and unusual occurrence for a wastewater facility. Ammonia-N data reported through MORs, reveal values at or near 0.01mg/l a minimum of 70% of the sampling dates reported since 2001 (Figure 47). Sampling Frequency violations for chlorine were repetitiously reported throughout the period for all years and monthly throughout all seasons. Drastic reductions in these types of reporting violations are seen by 2005. In addition, no sanitary sewer overflows have been reported for this period.

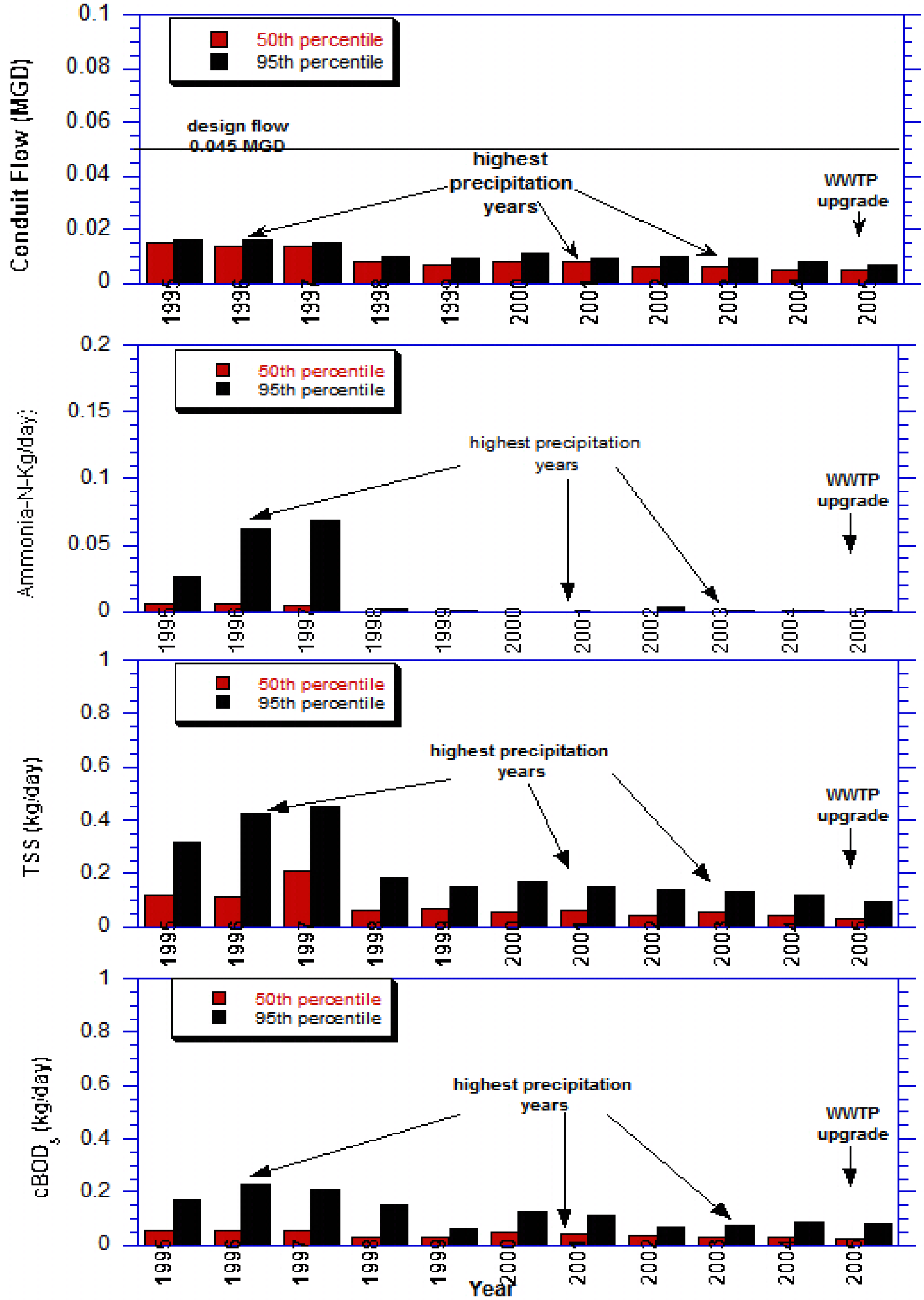


Figure 47. Annual loadings (kg/day) of various parameters and conduit flow at Layhigh WWTP in the Indian Creek study area, 2005.

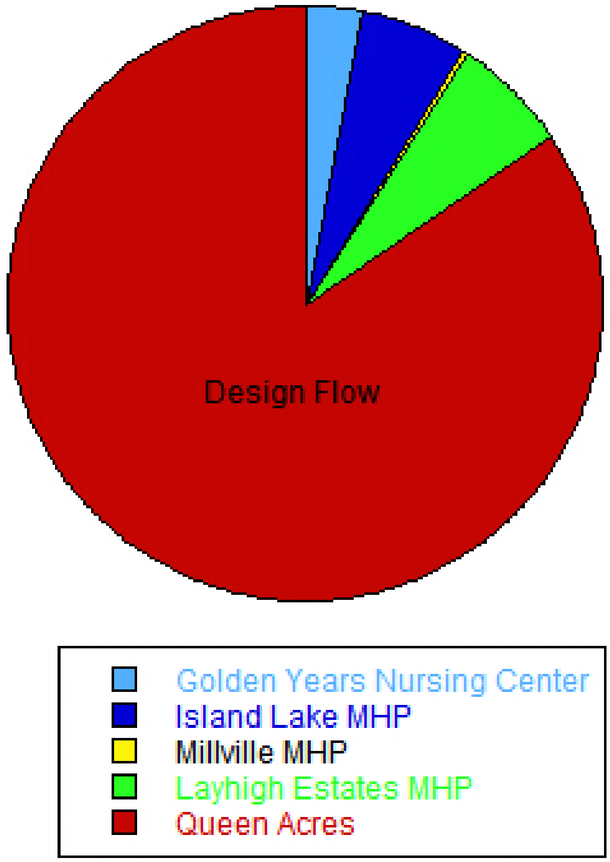


Figure 48. Design Flow (MGD) for permitted dischargers in the Indian Creek study area, 2005.

Spills/Bybasses/Overflows

The Ohio EPA Emergency Response (ER) Section (who responds to any report of a released material into the environment) maintains incident reports from investigations carried out by their division. For the purposes of this section, records were reviewed from 2000 to 2005. Wastewater treatment plant bypasses were the most frequent report to ER for all years (Table 24). The Millville Mobile Home Park (MHP) WWTP clearly populated the database repeatedly from 2001 until 2005 with the greatest number of calls in 2004 and 2005. Most calls were in spring and summer. Golden Years Nursing Center WWTP was second in frequency of calls all made in February and March of 2004.

Indiana spills were dominated by calls to the town of Cottage Grove where seven spills were called in from the 1970's to 2005. Indiana spills were concentrated near the town of Cottage Grove where seven spills were reported from the

1970's to 2005. Many of the spills resulted from the railway system that transverses the upper watershed area. Hazardous materials are shipped on this railroad line that poses a significant threat to the watershed.

Table 24. Spill and releases in the Indian Creek Watershed in Ohio and Indiana from 1992 to 2007 extracted from the Indiana Department of the Environmental Management (IDEM) and Ohio EPA Division of Emergency and Remedial Response (DERR) databases.

Entity	Date	City/Twshp	Material Spilled	Quantity	Waterway
Ohio					
Millville MHP	11/21/2001	Ross	wastewater	unknown	Beals Run
Valley Asphalt	5/27/2003	Ross	diesel fuel	unknown	Indian Ck
Millville MHP	12/8/2003	Millville	wastewater	unknown	Beals Run
Golden Years Nursing Center	2/10/2004	Hanover TWP	wastewater	unknown	Tributary to Beals Run
CHS Oxford	2/27/2004	Millville	wastewater	unknown	Trib to Beals Run
Millville MHP	3/16/2004	Millville	wastewater	unknown	Beals Run
Golden Years Nursing Center	3/16/2004	Hanover TWP	wastewater	unknown	Tributary to Beals Run
Millville MHP	3/26/2004	Millville	wastewater	unknown	Beals Run
Golden Years Nursing Center	3/26/2004	Hanover TWP	wastewater	unknown	Tributary to Beals Run
Butterfield Farm	4/10/2004	Ross TWP	anhydrous ammonia	unknown	Tributary to Indian Ck
Millville MHP	7/9/2004	Millville	wastewater	unknown	Beals Run
Millville MHP	9/10/2004	Millville	wastewater	unknown	Beals Run
Millville MHP	1/05/2005	Millville	wastewater	unknown	Beals Run

Entity	Date	City/Twshp	Material Spilled	Quantity	Waterway
Queen Acres Estates	1/05/2005	Hanover TWP	wastewater	Unknown	Indian Ck
Millville MHP	3/25/2005	Millville	wastewater	unknown	Beals Run
Millville MHP	5/3/2005	Millville	wastewater	unknown	Beals Run
Millville MHP	7/13/2005	Millville	wastewater	unknown	Beals Run
Indiana					
No name	6/26/1992	Cottage Grove	gasoline	15 gal	Cottage Ck
Railtrack station	10/27/1992	Cottage Grove	radioactive waste	unknown	unconfirmed
Trans-RR	11/21/1992	Cottage Grove	phosphoric acid	1600sq ft	unconfirmed
Trans-RR	7/10/1994	Cottage Grove	diesel fuel	1 gal	unconfirmed
Trans-RR	3/21/2005	Cottage Grove	phosphoric acid	unknown	unconfirmed
No name-not confirmed	4/29/2005	Cottage Grove	elemental mercury	unknown	unconfirmed

Chemical Sediment Quality

Sediment is the loose sand, clay, silt and other soil particles that settle at the bottom of water bodies. Sediment can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice help carry these particles to rivers, lakes and streams. Sediment entering stormwater degrades the quality of water for drinking, wildlife and the land surrounding streams. Sediment can clog fish gills, reducing resistance to disease, lowering growth rates, and affecting fish egg and larvae development (Figure 49). Fine grain sediment was collected and evaluated at five sites in the Indian Creek Watershed (Table 25). Four sediment sites were in the Indian Creek mainstem and one in Reserve Run.

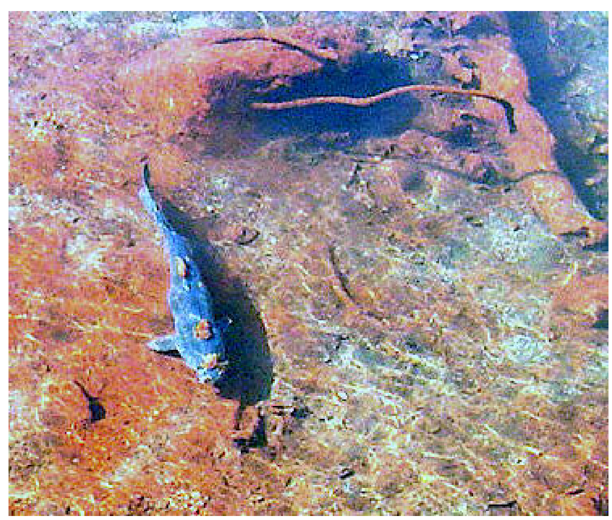


Figure 49. Sediment is a pollutant that can clog fish gills and smother their fish eggs.

Samples reflected contamination from urban influences, wastewater discharges and in-place naturally occurring minerals as every parameter (except lead and sodium) had values above laboratory detection. Many metals are naturally occurring released from metal bearing minerals and dissolving naturally over time from weathering.

Mainstem sediment results were below all Ohio Sediment Reference Value Guidelines used to evaluate sediment metals. Sediment arsenic on the mainstem, near Queen Acres WWTP, was between the MacDonald TEC and PEC (threshold effect concentration and probable effect concentration), but below the Ohio SRV of 18 mg/kg. Sediment values between MacDonald's TEC and PEC indicate that adverse benthic effects should frequently occur (affecting bottom-feeding fish, macroinvertebrate reproduction, growth cycles or longevity). Arsenic values below the OHIO SRV are not considered to adversely affect benthic organisms. Sources of arsenic in this watershed could be related to natural mineral bearing rock, pressure treated lumber and agriculture.

Ammonia-n exceeded the Ontario sediment disposal guideline of 100 mg/kg at two sites above and below Queen Acres WWTP. This is likely connected to fertilizers transported directly off agricultural fields, storm sewers, sewage effluent and manure.

Organics in the higher alkanes group appeared in most samples. The majorities of compounds detected were in the single part per million (mg/kg) range and were not evaluated by any of the guidelines. The most common compounds reported were Tenitively Identified Compounds (TICS) of hydrocarbons appearing at all four sites. The majority of these compounds can be associated with the degradation of organic products such as plant material, sewage sludge and storm water runoff.

Table 25. Concentrations (mg/kg) of metals and nutrients in sediment samples collected in watershed assessment unit **WAU: 05080002-080** in the Indian Creek Watershed during 2005. Parameter concentrations were evaluated based on Ohio EPA sediment metal reference sites (2003), MacDonald (2000) Sediment Quality Guidelines (SQG), and Persuad (1993). Values above guidelines are highlighted.

Analyte	Indian Cr. RM 23.95	Indian Cr. RM 6.80	Indian Cr. RM 6.50	Reserve Run RM 0.25	Indian Cr. adj Reily-Millville Rd	Reference	
						Ohio	MacD
Al-T [O]	9310	16800	25400	28300	24800	39000	*
As-T [OM]	4.97	7.92	10.3	10.4	7.57	18	9.79-33
Ba-T [O]	64.3	112	152	172	138	240	*
Ca-T [O]	70500	90000	68700	62100	95200	120000	*
Cd-T [OM]	0.118	0.170	0.257	0.429	<0.103	0.9	0.99-4.98
Cr-T [OM]	<15	20	29	31	27	40	43.4-111
Cu-T [OM]	5.6	9.9	17.0	15.3	10.6	34	31.6-149
Fe-T [O]	10500	15900	22800	20300	19400	33000	*
Hg-T [OM]	<0.031	<0.027	0.040	<0.056	<0.032	0.12	0.18-1.06
K-T [O]	2750	4910	6560	6300	9620	11000	*
Mg-T [O]	24700	21200	18600	18600	23300	35000	*
Mn-T [O]	264	498	740	383	533	780	*
Na-T *	<2430	<2360	<2590	<3270	<2580	*	*
Ni-T [OM]	<19	<19	21	<26	<21	42	22.7-48.6
Pb-T [OM]	<19	<19	<21	<21	<21	47	35.8-128
Se-T [O]	<0.97	<0.94	1.15	<1.03	<1.03	2.3	*
Sr-T [O]	68	116	92	134	134	390	*
Zn-T [OM]	28.8	50	80.5	44.2	44.2	160	121-459
NH_3-N [P]	52	110	110	44	44	*	100
TOC [P]	4.3	5.2	5.4	4.5	4.5	*	10
pH *						*	*
P-T [P]	481	1330	955	860	860	*	2000
%FGM [O]						30.0%	*
COD*						*	*

□ Below the goal of 30% Fine Grain Material in sample
%FGM Percent Fine Grain Material in sediment sample (<60 micron or >30 seconds settling time)
NA Compound not analyzed.
* Not evaluated
O Evaluated by Ohio EPA (2003)
M Evaluated by MacDonald (2000)
P Evaluated by Persuad (1993)

Ohio SRV Guidelines (2003)
+ above background for this area

Ontario Sediment Guidelines (Persuad (1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to NH3-N only.
• > severe effect level (disturbance in benthic community can be expected)

MacDonald (2000) Sediment Quality Guidelines (SQG)
TEC-PEC Threshold effect concentration (TEC) - Probable effect concentration (PEC) above which adverse effects frequently occur
■ **>PEC** Probable effect concentration (PEC) -Above which adverse effects usually or always occur

Physical Habitat for Aquatic Life

Indian Creek (mainstem)
The assessment of the influence of physical stream features and riparian conditions on ambient biological performance for the Indian Creek basin will proceed in a longitudinal manner (upstream to downstream). The discussion of tributaries will either be treated in the aggregate, or if sufficiently large, tributaries or sub-basins will be broken-out separately for discussion. For the purposes of continuity, this longitudinal reporting structure will also be applied to the assessment of ambient biological performance throughout this document.

As part of the 2005 fish sampling effort, the quality of near and in-steam macrohabitats of the Indian Creek mainstem were evaluated at six sampling locations, assessing approximately 22 miles of the mainstem between RM 23.9 (Fairfield Rd.) and RM 4.3 (Hamilton-New London Rd). QHEI values ranged between 55.5 and 74.5 with a mean score of 64.58 (±6.734 SD). Longitudinal performance of the QHEI and a matrix of macrohabitat features, by stations, are presented in Table 26 and Figure 50. Statistical distributions of QHEI score for the Indian Creek study area are presented in Figure 51.

Mean QHEI values from rivers or river segments equal to or greater than 60.0 generally indicate a level of macrohabitat quality sufficient to support an assemblage of aquatic organisms consistent with the WWH aquatic life use designation. Average reach QHEI values at greater than 75.0 are generally considered adequate to support fully exceptional (EWH) communities (Rankin 1989 and Rankin 1995). Values between 55 and 45 indicate limiting components of physical habitat are present and may exert a negative influence upon ambient biological performance. However, due to the potential for compensatory stream features (e.g., strong ground water influence) or other watershed variables, QHEI scores within this range do not necessarily exclude WWH or even EWH assemblages. Values below 45 indicate a higher probability of habitat derived aquatic life use impairment.

The quality of near and in-stream macrohabitat throughout the entire length of Indian Creek appeared capable of supporting diverse, functionally organized, and well-structured assemblages of aquatic organisms, consistent with its recommended WWH aquatic life use. Most sites contained a compliment of positive channel, substrate, and riparian features, displaying channel form and function typical of till-plains streams of central and west-central Ohio. The channel configuration of the mainstem was generally in a natural or recovered state, displaying a modest degree of sinuosity. Riffle and run complexes were commonly observed throughout. Where evidence of previous channel modification was found, the process of natural restoration or recovery of complex channel features, although incomplete, appeared well underway. Trench and lateral scour pools were regularly observed and often found well-structured with woody debris and fallen timber. Dominant substrates were coarse glacial till. Riparian areas at half of the sites were vegetated, often wooded, attenuating sunlight and providing in-stream structure in the form of woody debris and rootwad formations.

Table 26. A matrix of macrohabitat features and QHEI scores for the Indian Creek study areas, 2005.

Key
QHEI
Components

			WWH Attributes											MWH Attributes																				
														High Influence						Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(14-010) Indian Creek																																		
Year: 2005																																		
23.9	64.0	10.53	■	■				■		■	■		5						0		•			•	•			•			•	5	0.17	1.00
17.7	67.5	10.42	■	■				■		■	■	■	6				♦		1		•			•	•			•		•		5	0.29	1.00
9.4	59.0	16.13		■				■			■		3				♦		1	•	•			•	•			•	•	•		7	0.50	2.25
6.8	74.5	8.33	■	■			■	■		■	■	■	7						0					•				•				2	0.13	0.38
6.5	67.0	8.33	■	■				■			■		4						0		•			•	•			•	•	•		6	0.20	1.40
4.3	55.5	8.47		■				■			■		3				♦		1	•	•			•	•			•	•	•		7	0.50	2.25
(14-011) Salmon Run																																		
Year: 2005																																		
1.9	63.0	62.50	■	■		■				■	■		5			♦	♦		2					•				•			•	3	0.50	1.00
0.1	58.0	71.43	■	■			■	■		■	■		6						0					•				•			•	3	0.14	0.57
(14-195) Lick Run																																		
Year: 2005																																		
0.9	68.0	14.29	■	■			■	■		■	■	■	7			♦	♦		2		•			•				•	•			4	0.38	0.88
(14-198) Little Indian Creek																																		
Year: 2005																																		
0.1	65.0	26.32	■	■				■		■	■		5			♦			1					•				•			•	3	0.33	0.83

Substrate embeddedness and riparian encroachment were the most commonly observed deficient habitat features on Indian Creek. Where these coincided with historical channelization, QHEI scores below 60 where observed. These sites included RMs 9.4 and 4.3, yielding QHEI scores of 59.0 and 55.5, respectively. However, it is important to note that the magnitude and severity of these deficiencies did not appear sufficient to significantly limit biological performance. This due to both the aggregate macrohabitat conditions of Indian Creek, which are well above the WWH threshold, and the fact the local habitat deficits were not profound in nature.

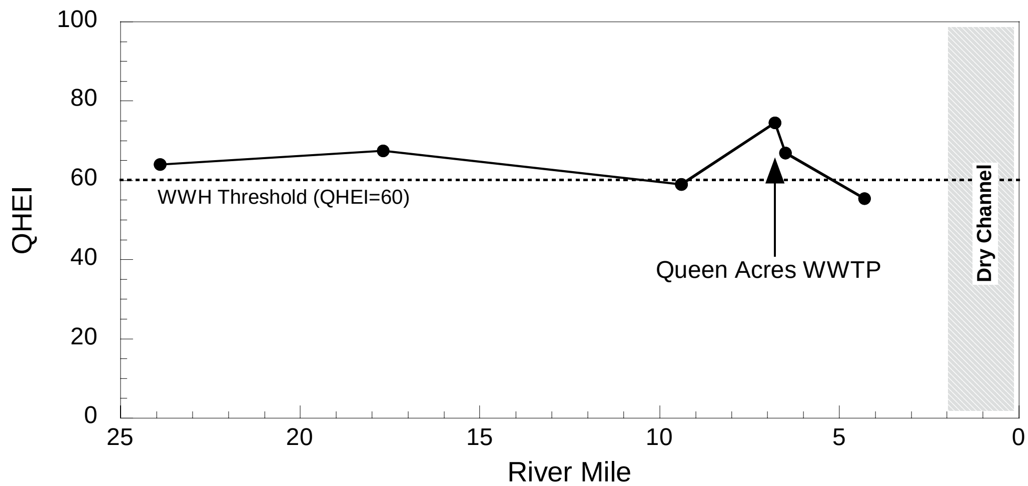


Figure 50. Longitudinal performance of the QHEI for the Indian Creek mainstem, 2005.

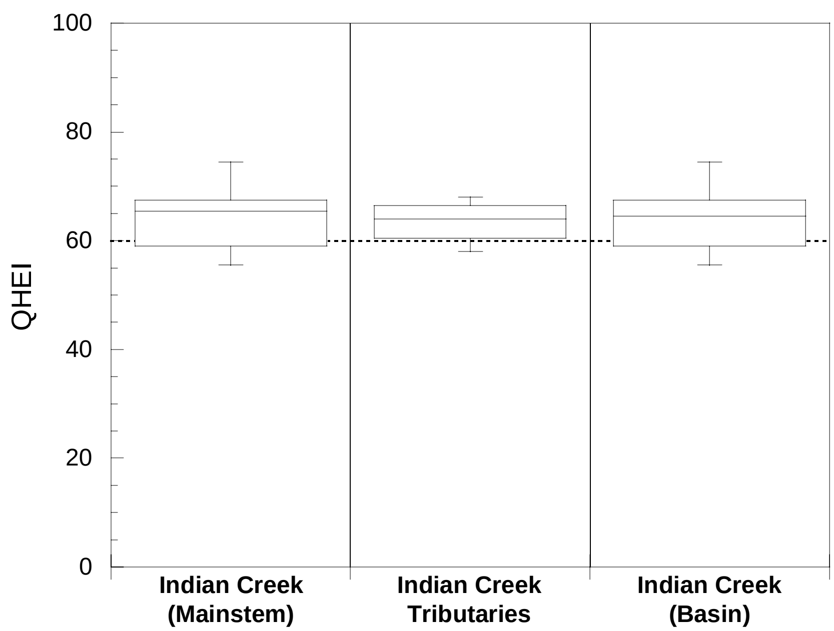


Figure 51. Aggregated and categorized Qualitative Habitat Evaluation Index (QHEI) values from the Indian Creek study area, 2005.

Regarding other aspects of macrohabitat quality and their influence on in-stream biological performance or potential, an important phenomenon was documented that warrants discussion. Namely, sampling efforts scheduled for the lower two miles of Indian Creek were abandoned due to the lack of surface flow. The lower two miles of Indian Creek were dewatered during the late-summer of 2005. Apparently, as Indian Creek entered and coursed through the broader floodplain of the Great Miami River, its surface flow sinks into the streambed becoming hyporheic flow. This is not an uncommon phenomenon, particularly in the Till Plains region of Central Ohio. In fact, the surface flow of most substantial waterbodies is diminished as they join the main river or conveyance of a large catchment. However, complete capture of a major tributary's surface flow is rare. It is not clear whether this is a regular phenomenon for Indian Creek or represents an uncommon event. Previous sampling by Ohio EPA in 1985 included fish and macroinvertebrate collections from the lower two miles, indicating, at least in some years, that the lower channel is wetted. Based upon the Palmer drought severity index, the southwestern quadrant of Ohio never reached severe or extreme drought conditions during the summer of 2005 (Ohio DNR 2005). It is possible that a subsection of southwestern Ohio, including the Indian Creek catchment experienced a localized drought far more severe than the regional index would indicate. Under this scenario, the dewatering of lower Indian Creek was anomalous, and may be related to a period of unseasonably dry weather.

Excluding the lower two miles, which were effectively dewatered, naturally or otherwise, aquatic life use impairment derived solely from deficient, degraded, or otherwise substandard macrohabitat was not anticipated for Indian Creek. Habitat quality appeared adequate to support and maintain WWH communities.

<u>Indian Creek Tributaries</u>

Three direct Indian Creek tributaries were surveyed and assessed as part of the 2005 field sampling effort. Four sampling stations were deployed to these waters, evaluating the habitat quality of four linear stream miles. QHEI values for these tributaries ranged between 68.0 and 58.0, with a mean score of 63.5 (Table 26).

Areas of significant habitat deficit were not observed. A single station on lower Salmon Run (RM 0.1) yielded a QHEI score slightly below the WWH guideline. However, conditions here were by no means degraded, and, as such, impairment derived solely from limited, deficient or otherwise substandard macrohabitat did not appeared likely. Habitat appraisals and resulting QHEI scores from the other Indian Creek tributaries were consistent with the recommended WWH use.

Although aquatic life use impairment resulting from limited macrohabitat was not anticipated for these Indian Creek tributaries, a feature common to two of the three streams warrants a brief discussion. Surface flow of both Salmon Run and Little Indian Creek were found to be ephemeral. When sampled during the summer of 2005, these two streams were reduced to residual pools, separated by substantial lengths of dry stream bed. Emphemerality, in and of itself, does not represent a severe or debilitating habitat deficit. There are many examples, statewide, of ephemeral streams supporting WWH or EWH assemblages.

It is important to note the distinctions between the two classes of ephemeral headwaters: interstitial and intermittent. The first constitutes a category of streams or stream reaches that during the dry summer months regularly lacks visible surface flow, the wetted channel consisting of a series of pools, separated by dry substrates. The pools are kept from becoming stagnant or septic through near constant input of cool subsurface, hyporheic or interstitial flow. Interstitial streams do possess continuous flow, it is just not readily apparent, as water is conveyed below and through the streambed. Healthy and intact headwater faunas are adapted to interstitial conditions, finding the residual pools more than adequate refugia during periods of drought. In contrast, truly intermittent streams, as a class, are completely desiccated during dry periods or are reduced to a few hydrologically isolated pools. These residual wetted areas, where present, stagnate and are rendered inhospitable to all but the most tolerant and facultative organisms. True intermittency significantly affects the biological potential of a water body, precluding the establishment of a resident, diverse and healthy assemblage of aquatic organisms. Even during periods of abundant surface flow (spring or fall), intermittent streams typically support only transient populations of pioneering species.

Both Salmon Run and Little Indian Creek were clearly interstitial rather than intermittent, as the residual pools contained within their otherwise dry streambeds were relatively deep and cool, obviously refreshed by groundwater or hyporheic flow. Therefore, the discontinuous surface flow observed during the 2005 summer sampling effort did not appear to represent a significant impediment to the maintenance of healthy and intact headwater fish assemblages.

Fish Community

<u>Indian Creek</u> (mainstem)
A total of 19,364 fish comprising 39 species and hybrids was collected from Indian Creek between July and September, 2005 (Appendix Table A-7). The fish sampling effort included six stations, evaluating 22 miles of the mainstem between RM 23.9 (Fairfield Rd.) and RM 4.3 (Hamilton-New London Rd.).

Based on aggregated catch statistics, numerically predominant species (No./0.3km) included central stoneroller (31.1%), bluntnose minnow (23.8%), sand shiner (12.2%), striped shiner (6.17%), greenside darter (3.1%), and northern hog sucker (2.3%). In terms of relative biomass (kg/0.3km), dominant species were smallmouth bass (19.4%), black redhorse (15.9%), northern hog sucker (12.0%), golden redhorse (11.5%), central stoneroller (9.6%), and common carp (6.3%). Nearly 20% percent of the numerically dominant species and over 50% of fish biomass were composed of environmentally sensitive species.

No fish species classified as rare, threatened, endangered, or otherwise recognized for special conservation status by the Ohio DNR (2007) were observed. However, highly intolerant, declining or otherwise ecologically significant species included black redhorse, rosyface shiner, silver shiner, banded darter, stonecat, and southern redbelly dace (Ohio EPA 1987 and 1996). Although not presently imperiled, species so defined have experienced a significant reduction in their historical distributions statewide or have been found to be extremely sensitive to a wide range of environmental disturbance, and therefore are considered associates of some of the best riverine habitats in Ohio.

Community indices and accompanying narrative evaluations for Indian Creek ranged between exceptional (IBI=54/MIwb=10.8) and marginally good/exceptional (IBI=38/MIwb=9.7). Overall, the fish assemblage of the Indian Creek was characterized as *very* good/*exceptional*. Longitudinal performance of the IBI, MIwb, and other relevant indicators are presented in Figure 52. Summarized index scores and community statistics by station are presented in Table 27.

As measured by the IBI and MIwb (where applicable), community performance through the entire length of Indian Creek was consistent with the recommended WWH biocriteria. Every sampling station supported an assemblage of fish possessing the expected structure, functional organization, and species richness, comparable to the reference conditions within the ECBP ecoregion. Environmentally sensitive taxa were well-represented and made-up a significant proportion of the catch from each fish sampling station. The incidence of serious disease or other external anomalies was at or below expected levels, never exceeding 0.1%. As measured or by the IBI and MIwb, point and non-point source pollutant loads currently delivered to Indian Creek appeared safely assimilated.

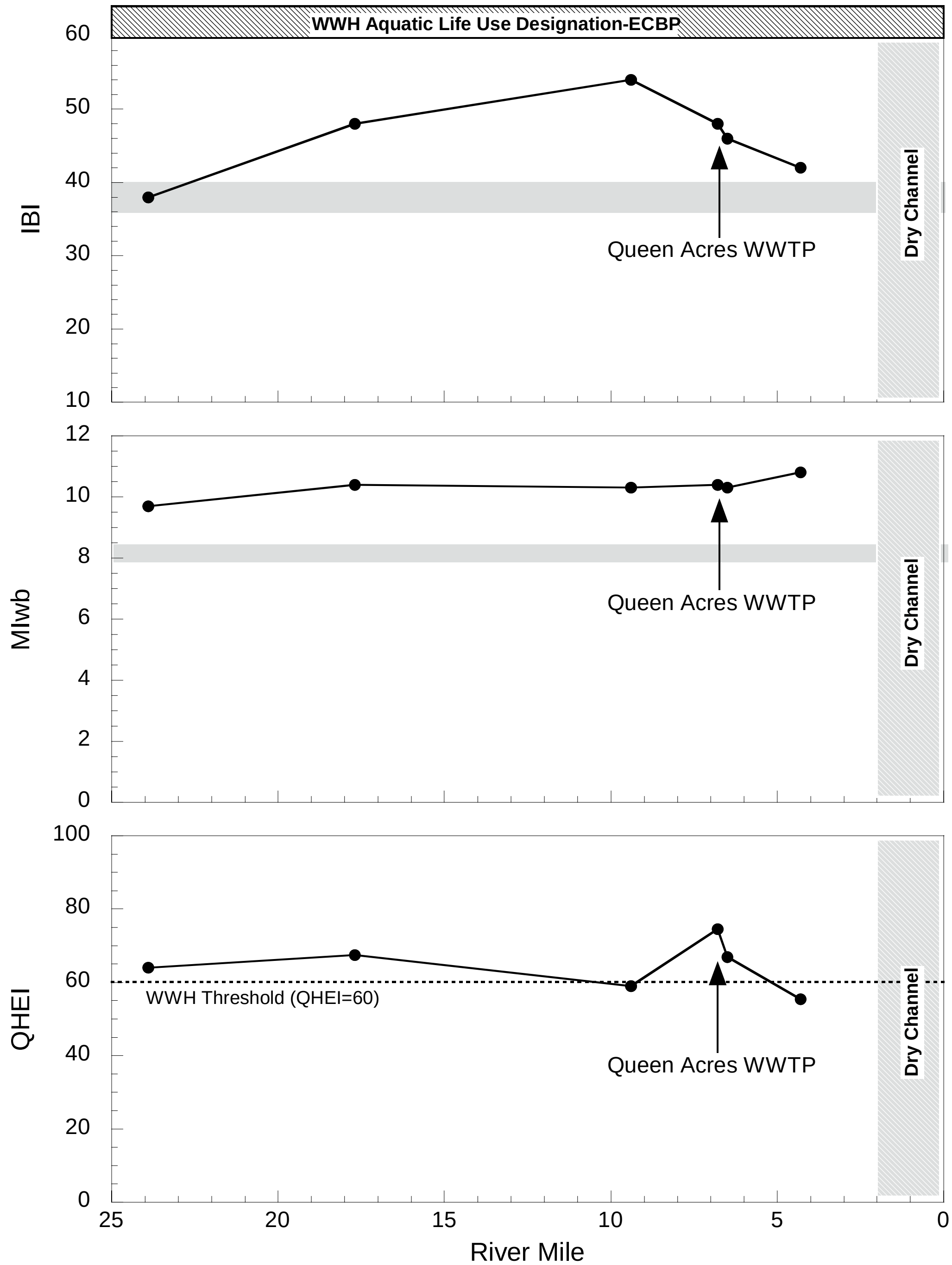


Figure 52. Longitudinal performance of the Index of Biological Integrity (IBI), Modified Index of well-being (MIwb), and Qualitative Habitat Evaluation Index (QHEI) for Indian Creek (mainstem), 2005. Shaded areas represent biocriteria and areas of nonsignificant departure for the EWH aquatic life use. Dashed lines represent QHEI values associated with, WWH and EWH communities. Arrows identify points of discharge for significant NPDES permitted entities.

Table 27. Fish community and descriptive statistics from the Indian Creek study area, 2005.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)[a]	Mean Rel. Wt. (Wt./km)[a]	Mean IBI	Mean MIwb	QHEI	Narrative Evaluation
Indian Creek (2005) [14-010]								
Eastern Corn Belt Plains (ECBP)-EWH/WWH Use Designation (Recommended/Existing)								
23.9 [W]	29.0	29	5667.0	57.6	38[ns]	9.7	64.0	M.Good/Exceptional
17.7 [W]	27.0	27	4018.0	37.3	48	10.4	67.5	V.Good/Exceptional
9.4 [W]	26.0	26	3934.0	42.9	54	10.3	59.0	Exceptional
6.8 [W]	33.0	33	3585.6	123.9	48	10.4	74.5	V.Good/Exceptional
6.5 [W]	24.0	24	3424.5	52.5	46	10.3	67.0	V.Good/Exceptional
4.3 [W]	27.0	27	9055.7	78.5	42	10.8	55.5	Good/Exceptional
Little Indian Creek (2005) [14-198]								
Eastern Corn Belt Plains (ECBP)-WWH Use Designation (Recommended)								
0.1 [W]	17.0	17	2940.0	4.5	52	NA	65.0	Exceptional
Salmon Run (2005) [14-011]								
Eastern Corn Belt Plains (ECBP)-WWH Use Designation (Recommended)								
1.9 [H]	10.0	10	694.0	3.2	44	NA	63.0	Good
0.1 [H]	24.0	24	2156.0	12.6	52	NA	58.0	Exceptional
Lick Run (2005) [14-198]								
Eastern Corn Belt Plains (ECBP)-WWH Use Designation (Recommended)								
0.9 [H]	18.0	18	1432.1	7.8	50	NA	68.0	Exceptional

a - Relative abundance and relative weight estimate normalized to 0.3km.
b - Narrative biological performance.
c - Candidate for Primary Headwater Designation in lieu of WWH
H - Headwaters: sites draining areas ≤ 20 miles^2.
W - Wadable Streams: sites draining areas > 20 miles^2.
ns- Nonsignificant departure from the biocriteria (≤4 IBI units or ≤0.5 MIwb units).
* - Significant departure from the biocriteria (>4 IBI units or >0.5 MIwb units).

Ecoregional Criteria (OQC 3745-1-07, Table 7-14)
Eastern Corn Belt Plains (ECBP)

Index-Site Type	WWH	EWH	MWH[d]
IBI - Headwater/Wading	40	50	24
MIwb – Wading	8.3	9.4	6.2

d - Modified Warmwater Habitat (MWH) for channel modified areas.

Indian Creek Tributaries

The fish assemblages of three direct tributaries that comprise the principal drainage network of Indian Creek were surveyed and assessed in 2005. Four sampling stations were deployed among these tributaries, evaluating four linear stream miles.

Like the mainstem, no fish species classified as rare, threatened, endangered, or otherwise recognized for special conservation status by the Ohio DNR (2007) were observed. However, highly intolerant, declining or otherwise ecologically significant species included southern redbelly dace, stonecat, and banded darter (Ohio EPA 1987 and 1996).

Community indices and accompanying narrative evaluations from these waters ranged between exceptional (IBI=52) and good (IBI=44). Taken together, the fish assemblages of Indian Creek tributaries can be collectively characterized as *exceptional*. Summarized index scores and community statistics by stream and by station are presented in Table 27. All Indian Creek tributaries supported fish assemblages consistent with the recommended WWH biocriterion.

As detailed in the habitat evaluation section of this report, the only perennial Indian Creek tributary was Lick Run. Salmon Run and Little Indian Creek were both ephemeral, more specifically interstitial. Despite the lack of surface flow, these streams supported fish assemblages consistent with the WWH biocriteria; and, as measured by the IBI, were comparable to Lick Run, a perennial stream.

Trend Assessment: Fish Community

Through the biosurvey survey process and reference site re-sampling efforts, the fish fauna of the Indian Creek basin has been surveyed and assessed by Ohio EPA since 1985. Prior field worked included the lower ten miles of the mainstem for the field years 1985 and 1996. For the purposes of trends assessment, these data will be compared against conditions documented in 2005.

In order to succinctly summarize and compare survey results between field years, analysis of trends will examine longitudinal performance of the IBI and MIwb, relative to the principal associated stressors, through time. These data provide an excellent opportunity to evaluate meaningful changes, or lack thereof, in the environmental conditions of Indian Creek over the last 20 years.

Longitudinal fish community performance for Indian Creek indicated relatively stable conditions since 1985 (Figure 53). Community indices from stations common to all field years appeared comparable, with the exception of the IBI for RM 9.4 (Reily-Millville Rd.), where a marked improvement was indicated in 2005. Advanced performance at this site was the result of both minor and significant positive changes in the fish assemblage (Figure 54). These included increases in species richness and number of environmentally intolerant or sensitive taxa. Positive proportional changes were also noted, and included a reduction in the percentage of environmentally tolerant and omnivorous species, and an increase in the proportion of specialist insectivores.

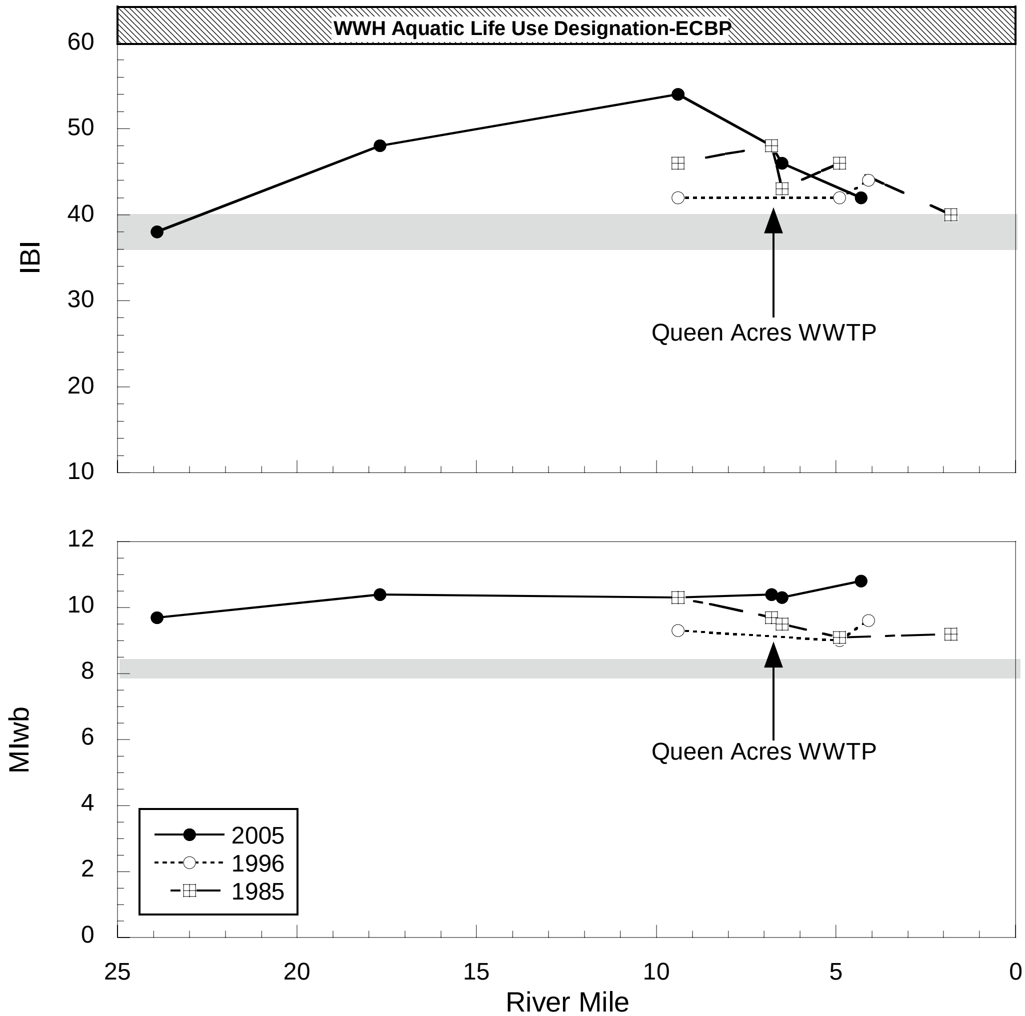


Figure 53. Longitudinal performance of the Index of Biotic Integrity (IBI) and the Modified Index of well-being (MIwb) from Indian Creek (mainstem), 1991, 1996, and 2005. Shaded areas represent the applicable biocriteria in support of the existing EWH Aquatic life use, Eastern Corn Belt Plains (ECBP) ecoregion. Arrows identify points of discharge for significant NPDES permitted entities.

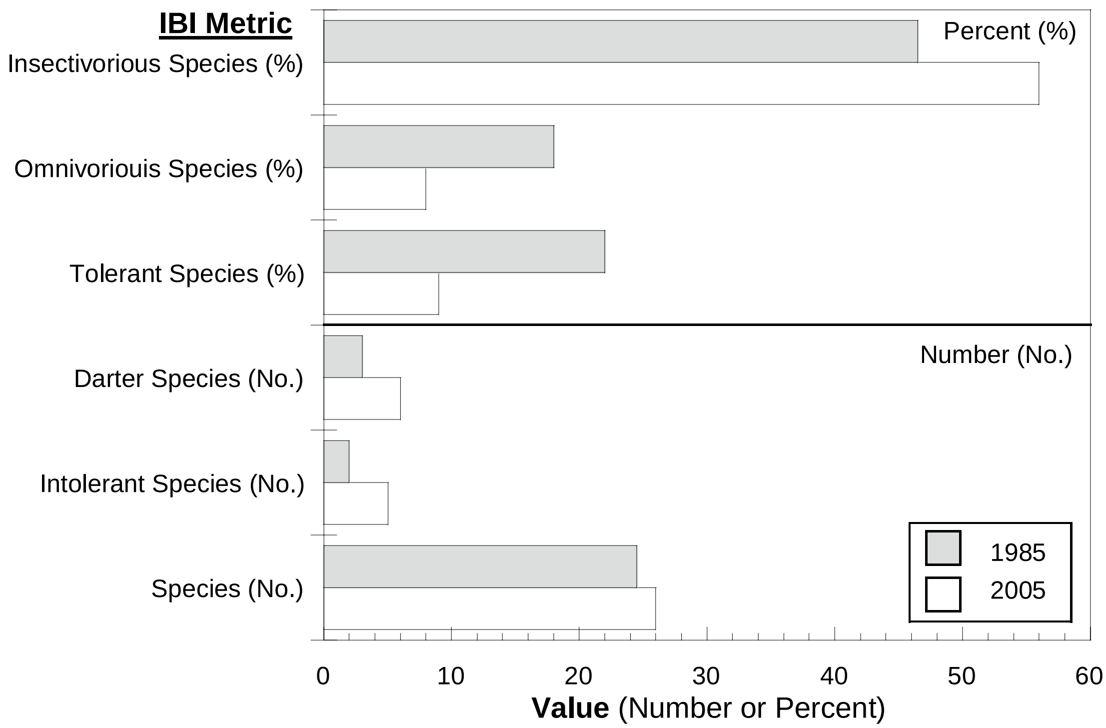


Figure 54. Performance of various IBI metrics from Indian Creek at RM 9.4 (Reily-Millville Rd.), 1985 and 2005.

Macroinvertebrate Community

Macroinvertebrate communities were evaluated at 11 stations in the Indian Creek assessment unit (Table 28, Appendix Table A-8). The community performance was evaluated as exceptional at two stations, very good at two, good at three, fair at three, and poor at one station. The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT) was on Indian Creek at Indian Creek Road (RM 17.8) with 25 taxa. The same station had the highest number of total sensitive taxa with 32. Sensitive taxa found in this assessment unit which are noteworthy because they are not commonly collected were the mayflies *Acentrella turbida* in Indian Creek (RM 17.8), *Paracloeodes sp. 3* in Indian Creek (RM 9.7), and *Maccaffertium mediopunctatum* in Indian Creek (RMs 23.9, 17.8, 9.7, 6.9, 6.4) and the midge *Sublettea coffmani* in Indian Creek (RM 17.8). The state threatened crayfish *Orconectes sloanii* was collected from Little Indian Creek (RM 0.1), Reserve Run (RM 0.3), and Salmon Run (RMs 1.9, 0.1).

Indian Creek

Macroinvertebrate community performance in Indian Creek was generally good to exceptional (Table 28, Fig. 55). The station with the highest EPT and sensitive taxa diversity collected from the natural substrates was at Indian Creek Road (RM 17.8) with 22 and 25 taxa, respectively. EPT and sensitive taxa diversity declined downstream with a low recorded downstream from the community of Millville at RM 6.9. The percent other dipteran and non-insect ICI metric score increased at this station to 51.9%, from 28.7% at the upstream station (RM 9.7), which may indicate a mild impact from the Millville area. The community sampled downstream from the Queen Acres WWTP at RM 6.4 was exhibiting increased density (1103 orgs./ft^2 compared to 199 at RM 6.9) with increased abundances of mostly facultative taxa. The Queen Acres WWTP discharge was having a mild enrichment effect on the macroinvertebrate community.

Indian Creek Tributaries

The Indian Creek tributaries Little Indian Creek (RM 0.1), Reserve Run (RM 0.3), Salmon Run (RM 1.9), and Lick Run (RM 0.9) had interstitial flow at the time of the macroinvertebrate collections. The communities at all of these stations were limited by the lack of surface flow. The downstream station on Salmon Run (RM 0.1) had sufficient flow to maintain surface water through the riffles, and was supporting a community consistent with WWH expectations.

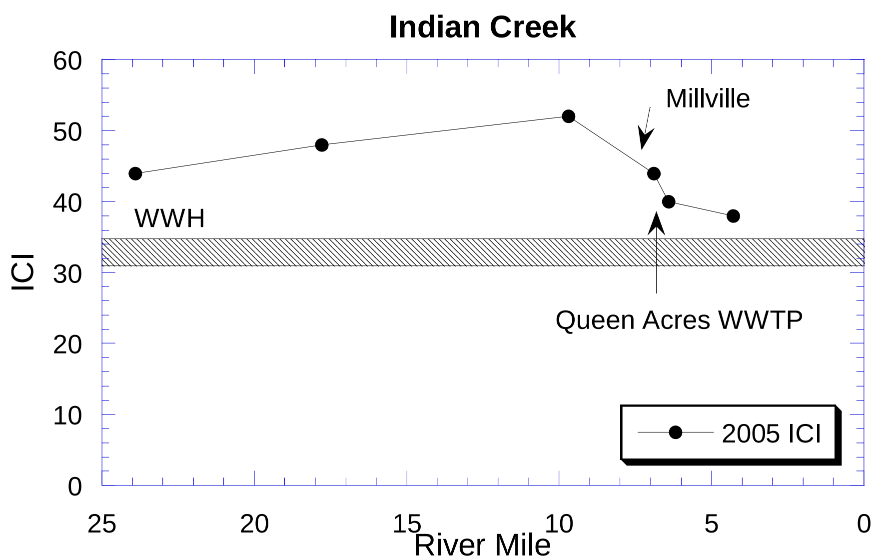
Trend Assessment: Macroinvertebrate Community

The 2005 macroinvertebrate survey was the first time that this basin was sampled in a comprehensive method. Previous sampling efforts were restricted to a few stations in the lower 10 miles of the Indian Creek mainstem, primarily to evaluate regional reference sites. Community performance in this area since 1985 has been in the good to exceptional range without a clear trend (Fig. 56).

Table 28. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Indian Creek study area, July to October, 2005.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Indian Creek (14-010)										
23.9	39.0	-	54	18	22	M	0	Caddisflies (MI,F), midges (MI,F)	-	Very Good
17.8	53	15	69	22 / 25	25 / 32	M / 462	0	*Rheotanytarsus* midges, *Helicopsyche* caddisflies (MI)	48	
9.7	82	5,15	43	15 / 19	19 / 27	M / 422	0	Hydropsychid caddisflies (F,MI), *Rheotanytarsus* midges (MI)	52	
6.9	95	15	38	13 / 17	14 / 23	H / 199	0	Caddisflies (MI,F), *Isonychia* mayflies (MI)	44	
6.4	98	15	48	15 / 16	16 / 22	H / 1103	0	Caddisflies (MI,F), mayflies (MI,F), *Petrophila* moth larvae (MI)	40	
4.3	102	-	48	18	18	M-H	0	Hydropsychid caddisflies (MI,F)	-	Good
Little Indian Creek (14-198)										
0.1	5.6	9	25	5	7	-	0	Heptageniid mayflies (F)	-	Fair
Reserve Run (14-197)										
0.3	4.5	9	22	3	2	L-M	0	Beetles (F), heptageniid mayflies (F)	-	Low Fair
Salmon Run (14-011)										
1.9	1.4	9	14	2	5	L	1	Midges (F,MI)	-	Poor
0.1	4.8	-	40	14	14	M	0	Caddisflies (MI,F)	-	Good
Lick Run (14-195)										
0.9	4.7	9	25	7	6	L-M	0	Heptageniid mayflies (F), aquatic sow bugs (F)	-	Fair

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 5=3 HD Only, 9=Intermittent or Near-Intermittent Conditions, 15=Current >0.0 fps but <0.3 fps.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
CW: Coolwater/Coldwater.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant
[a] ICI values in parentheses are invalidated due to insufficient current speed over the artificial substrates. The station evaluation is based on the qualitative sample narrative evaluation.



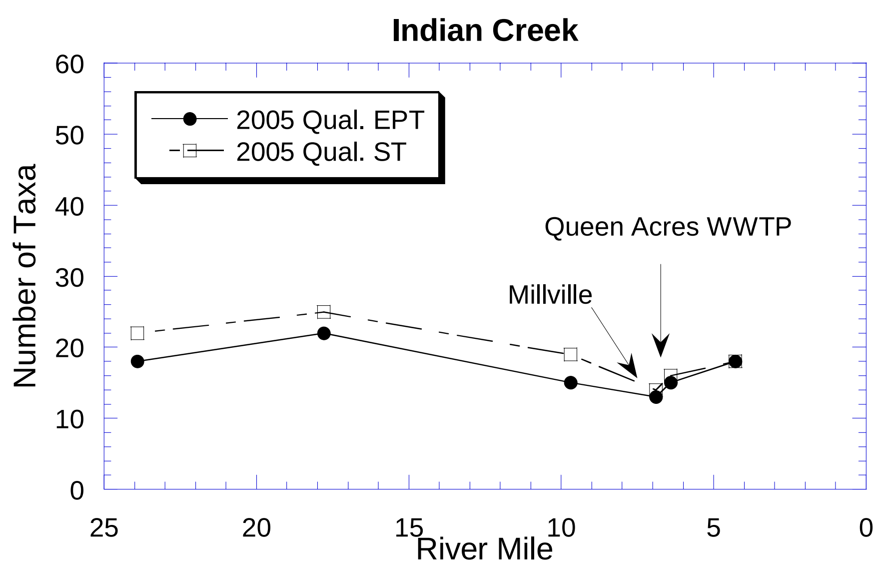


Figure 55. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in Indian Creek, 2005. ICI equivalent values were used for RMs 23.9 and 4.3 based on the qualitative narrative evaluation.

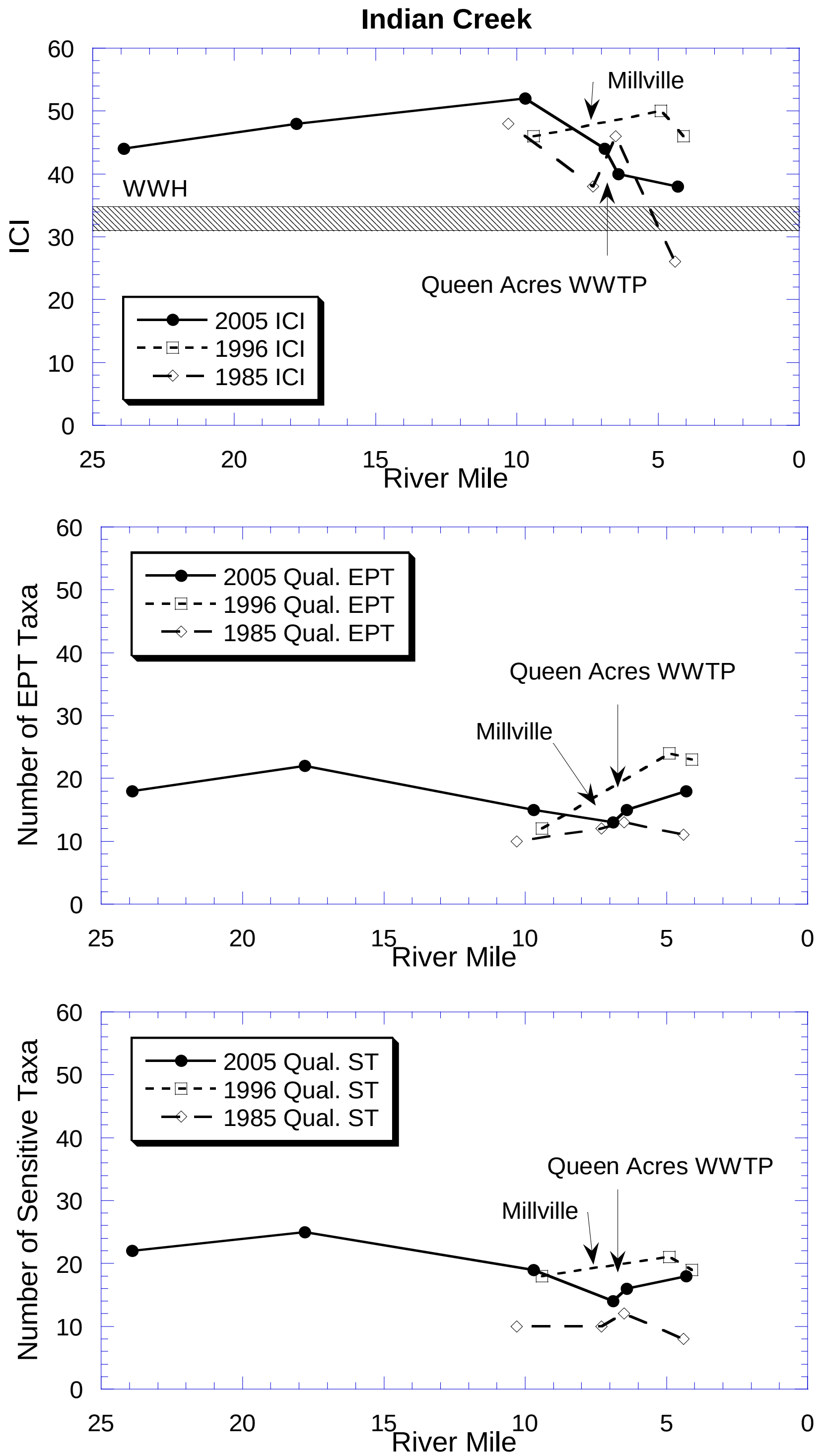


Figure 56. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in Indian Creek, 1985-2005. ICI equivalent values were used for RMs 23.9 and 4.3 in 2005 and RM 7.3 in 1985 based on the qualitative narrative evaluation.

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