Ohio EPA

State of Ohio Environmental Protection Agency

Biological and Water Quality Study of Twin Creek and Selected Tributaries, 2005

Darke, Preble, Montgomery and Warren Counties

October 22, 2007

Ted Strickland, Governor
Chris Korleski, Director

Hester-Dendy Macroinvertebrate Sampler

Smallmouth Bass

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OHIO EPA Technical Report EAS/2007-10-03

Prepared by:

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
50 W. Town Street, Suite 700
Columbus, Ohio 43215
Mail to:
P.O. Box 1049, Columbus, Ohio 43216-1049

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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:

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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

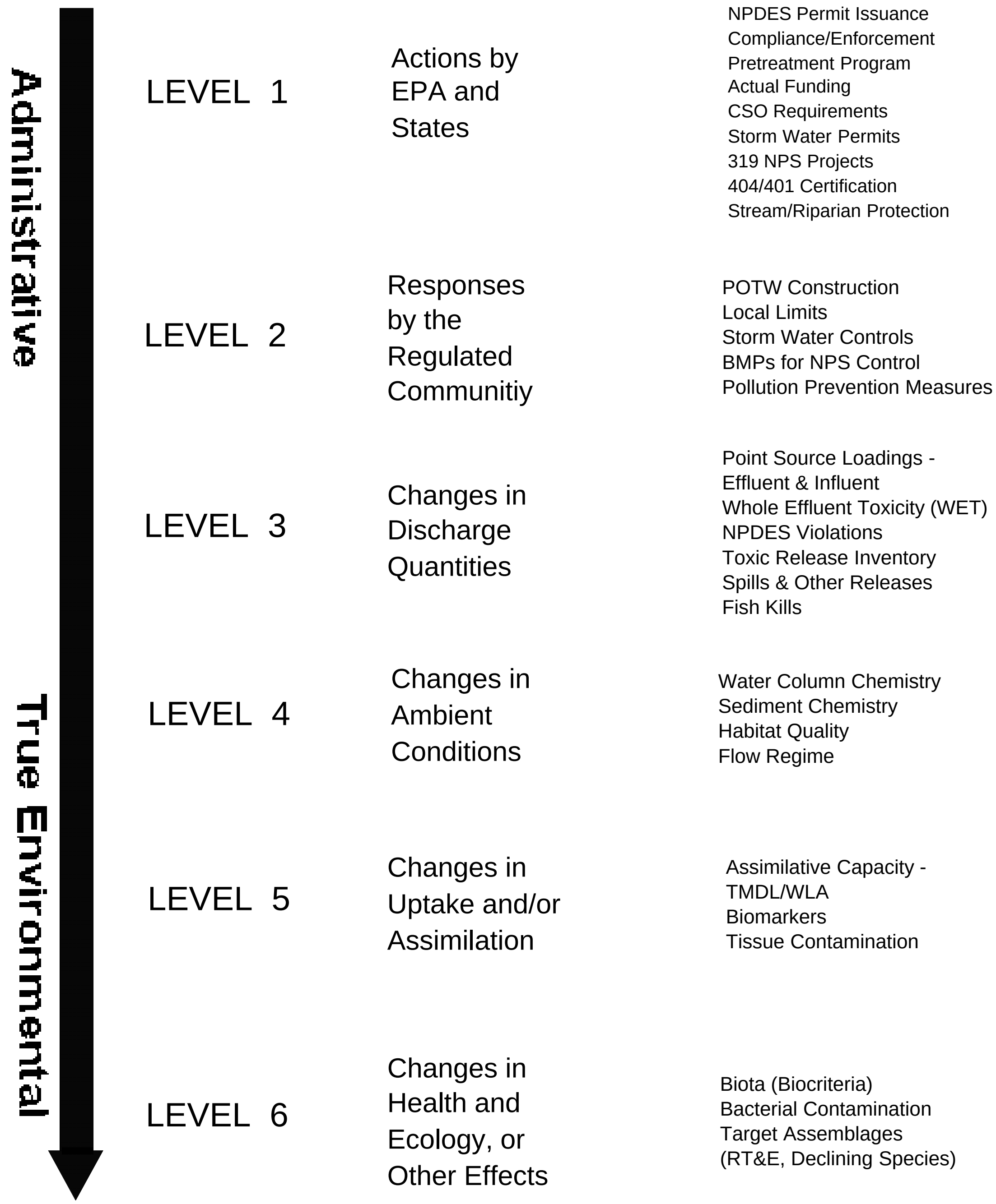


Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

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) *Cold-water 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 phosphorus and percent total organic carbon are evaluated using the Provincial Sediment Quality Guidelines Severe Effect Level (SEL) (Persuad et al. 1993). Sediments over the SEL guidelines are considered grossly polluted and will significantly affect use of sediments by benthic organisms. Sediment ammonia is evaluated using the Ontario Open Water Disposal Guidelines (Persuad and Wilkins 1976). Sediments over the Open Water Disposal Guidelines are considered to be marginally to significantly polluted, affecting sediment use by some benthic organisms.

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).

Biological and Water Quality Study of Twin Creek and Select Tributaries, 2005

Darke, Preble, Montgomery, and Warren Counties

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
50 W. Town Street, Suite 700
Columbus, Ohio 43215

INTRODUCTION

Ambient biological, water column chemical, and sediment sampling occurred in the Twin Creek study area from June through September, 2005. The Twin Creek watershed is located in southwestern Ohio (Figure 2), where its waters originate in Darke County, meander south into Preble County, and pass through the towns of Lewisburg, West Alexandria, and Gratis. Southeast of Gratis, the watershed continues into Montgomery County, with the mainstem finally joining the Great Miami River in Warren County in the town of Carlisle. A list of the mainstem and tributary sites evaluated in this study is included in Table 1.

Figure 2. Twin Creek study area location.

Objectives of the study were to:

1) Monitor and assess the chemical, physical and biological integrity of the water bodies within the Twin Creek study area;

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, and urban and suburban community development;

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

5) Determine any aquatic impacts from known point sources including the Lewisburg, P&G Pet Care (formerly Iams), North American Nutrition (formerly Carl Akey Co.), West Alexandria, Gratis, Eldorado, and Farmersville wastewater treatment plants (WWTPs) and from unsewered communities; and

6) Conduct a water resource trend assessment where historical data exists.

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).

Table 1. Sampling locations and coordinates assessed during the Twin Creek study, 2005.

River Mile	Drainage (mi^2)	Location	Longitude	Latitude
TWIN CREEK				
46.5	19.7	State Route 722	-84.6228	39.9313
42.1	28.0	Euphemia-Castine Rd.	-84.5953	39.8962
38.0^	38.0	East Lock Road	-84.5684	39.8660
35.5^	90.0	NW Knapke Road	-84.5325	39.8518
34.9^	91.0	Salem Road	-84.5328	39.8442
33.6^	94.0	Adj.SR 503, opposite Eaton-Lewisburg Rd.	-84.5372	39.8285
31.7^	99.0	Pyrmont Road	-84.5303	39.8030
27.5^	142.0	Adj. Stotler Road	-84.5275	39.7515
26.7^	143.0	End of Myers Lane	-84.5217	39.7413
23.9^	197.0	Halderman Road	-84.5246	39.7088
19.2^	226.0	Enterprise Road	-84.5123	39.6567
19.0	226.0	Adj. Enterprise Rd., Dst. Gratis WWTP	-84.5081	39.6552
18.29**	228.0	Dst. Gratis WWTP	-84.4984	39.6482
13.4	271.0	Adj. Anthony Road, Dst. Tom's Run	-84.4422	39.6640
9.8^	275.0	Germantown Metro Park @ gage	-84.3987	39.6367
3.4	312.0	Chamberlain Road	-84.3446	39.5851
0.9	315.0	Franklin-Trenton Road	-84.3496	39.5560
0.1	316.0	New channel mouth	-84.3509	39.5463
MAPLE SWAMP DITCH – Trib. to Twin Creek @ RM 47.03				
2.4	5.5	Grubbs-Rex Road	-84.6416	39.9603
1.4	10.2	Otterbine-Ithaca Road	-84.6399	39.9458
DRY FORK – Trib. to Twin Creek @ RM 39.35				
0.8	5.4	Locke road	-84.5956	39.86.69
MILLER'S FORK – Trib. to Twin Creek @ RM 35.71				
10.8	5.7	Grubbs-Rex Road	-84.5682	39.9607

Table 1 continued				
8.0	10.1	Clark Road	-84.5559	39.9362
3.9^	19.7	Georgetown-Verona Road	-84.5232	39.9029
SWAMP CREEK – Trib. To Twin Creek @ RM 35.59				
6.3	8.7	County Line Road, Ust. Verona	-84.4855	39.9090
0.2^	18.0	US 40	-84.5303	39.8550
TRIB. to SWAMP CREEK @ RM 6.45				
0.3	4.7	Baltimore-Phillipsburg Road	-84.4796	39.9034
PRICE CREEK – Trib. to Twin Creek @ RM 29.74				
13.7	5.2	Pence-Shewman Road	-84.6809	39.9019
10.9	11.4	Shurley Road	-84.6527	39.8726
3.8	20.1	Jim's Run Road	-84.5669	39.8131
0.6**	29.0	Upstream SR 503	-84.5354	39.7802
LESLEY RUN – Trib. to Twin Creek @ RM 24.6				
6.0	5.5	Snyder Road	-84.4904	39.7739
3.6*	6.0	US 35	-84.4830	39.7446
1.2	7.5	East Factory Road	-84.5054	39.7220
BANTAS FORK – Trib. to Twin Creek @ RM 24.32				
13.7	6.6	Orphans Road	-84.6780	39.8283
9.4	11.8	US 127	-84.6332	39.7886
7.1	24.4	Bantas Creek Road	-84.5990	39.7734
1.3^	34.0	State Route 503	-84.5354	39.7255
GOOSE RUN – Trib. to Bantas Fork @ RM 7.55				
4.4^	3.3	Scheyhing Road	-84.6107	39.8302
0.3	11.2	Eaton-Lewisburg Road	-84.6057	39.7822
AUKERMAN CREEK – Trib to Twin Creek @ RM 19.29				
3.3	5.2	Ketterman Road	-84.5625	39.6637
1.8	13.7	Adj. Swartzel Road, Ust. Sandy Run	-84.5410	39.6544
0.5	20.7	Fudge Road	-84.5205	39.6602
TRIB. to AUKERMAN CREEK @ RM 2.88				
0.5	4.5	Aukerman Creek Road	-84.5651	39.6554
TRIB. to TWIN CREEK @ RM 18.29				
0.7	3.3	State Route 725	-84.4242	39.6818
TOM'S RUN – Trib. to Twin Creek @ RM 13.52				
12.0	6.0	Amity Road	-84.4454	39.7886
8.5	9.5	Bull Road	-84.4526	39.7418
0.4	24.3	Adj. Anthony Road	-84.4493	39.6658
0.1**	25.7	Adj. Anthony Road	-84.4449	39.6638
LITTLE TWIN CREEK – Trib. to Twin Creek @ RM 6.69				
6.2	4.9	Hemple Road	-84.4119	39.6851
4.7	12.4	Farmersville-W. Carrollton Road	-84.3946	39.6724
2.0^	19.8	Little Twin Road	-84.3721	39.6469

Table 1 continued				
REIGLE DITCH – Trib. to Little Twin Creek @ RM 5.43				
1.2*	3.1	Ust. Pump station – wet weather bypass	-84.4242	39.6818
0.5*	3.3	Ust. Farmersville WWTP	-84.4168	39.6760
0.3*	3.4	Dst. Farmersville WWTP	-84.4120	39.6771

All locations include biological (fish and macroinvertebrate) and conventional water chemistry sampling except: (*) -conventional water chemistry sampling only; (**) -conventional water chemistry, organics, sediment, and Datasonde© sampling only; (^) -biological, conventional chemistry, organics, sediment, and Datasonde© sampling. Twin Creek RM 33.6 did not include sediment sampling. Goose Run RM 4.4 did not include Datasonde© sampling.

STUDY AREA DESCRIPTION

The Twin Creek watershed drains an area of 316 mi^2 in southwestern Ohio (Figure 3). Twin Creek, 47.03 miles long, originates in Darke Co., Butler Twp., flows southeast into Preble Co. and generally south through the eastern portion of the county, then southeast through the southwest corner of Montgomery Co., and then into Warren Co., Franklin Twp. where it meets the Great Miami River. The average gradient is 9.1 feet per mile (from an elevation of 1067 to 645 feet above mean sea level, Ohio DNR 1960). Principal tributaries to Twin Creek include Maple Swamp Ditch (essentially the mainstem above RM 47.0), Millers Fork, Swamp Creek, Price Creek, Lesley Run, Bantas Fork, Aukerman Creek, Tom's Run and Little Twin Creek.

Located in the Eastern Corn Belt Plains ecoregion, the Twin Creek watershed is typified by gently rolling glacial till plains including moraines, kames and outwash features (Omernick and Gallant 1988). Original vegetation was mostly beech forest with areas of elm-ash swamp forests. Near the Great Miami River confluence, an area of oak-sugar maple and bottomland hardwood forest existed in pre-settlement times. Remnants of these forest types still exist in isolated locations (Gordon 1966). Silurian and Ordovician era bedrock is exposed principally as limestone with some shale outcrops. Soils are considered nearly level to gently sloping and tend to be neutral to slightly alkaline. Drainage varies from well to very poorly drained.

Land use is predominantly row crop agriculture for corn, soybeans, and winter wheat with some livestock production (Figure 4). There is some variation between the upper and lower assessment units of Twin Creek. The upper watershed (Hydrologic Assessment Unit (HUC) 05080002-030 – Twin Creek headwaters to upstream Bantas Fork) is 75% row crop while the lower catchment (HUC 05080002-040 – Twin Creek and tributaries downstream and including Bantas Fork) is 62.3% row crop. This difference is accounted for with the upper basin having only 9.7% of its area in forest while the lower has 21.6% forest. The 5 Rivers MetroParks owns or holds conservation easements on 4332 acres within lower Twin Creek. Much of this land was purchased with the intent of protecting

Figure 3. The Twin Creek watershed, showing major roads, cities, and county boundaries.

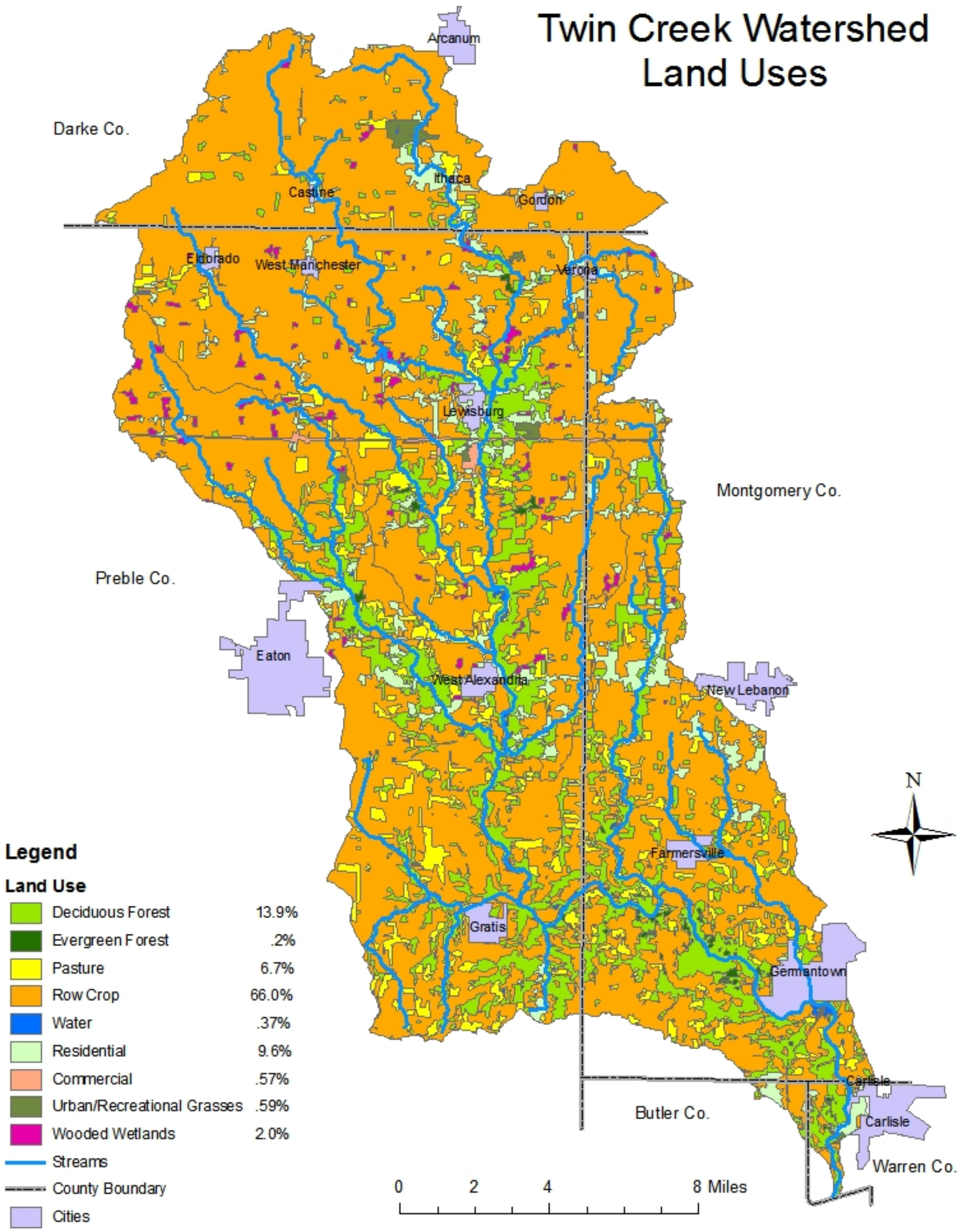


Figure 4. Land uses in the Twin Creek watershed.

the water quality of Twin Creek. Another 1200 acres are pending protection at this time (Dave Nolin, personal communication). Another difference between the upper and lower watersheds is the level of urban/recreational grasses. Upper Twin Creek has 0.6% in this category while lower Twin Creek has 8.2%, which reflects the presence of the village of Germantown, the largest community in the watershed.

Upland soils in the watershed vary from the well-drained Miamian-Celina association to the very poorly-drained Brookston-Crosby association. Even the well-drained soils have significant inclusions of poorly-drained soils, so drainage is needed to support agricultural crop production. An extensive tile drainage system has been installed and the extreme headwaters of many small streams have been straightened and deepened to accelerate water movement away from fields. Each county has programs that maintain the artificial structure of these streams. Maintained streams are located in the upper parts of the watershed where landforms are level to gently sloping. Along larger streams, soils tend to be either Ross-Medway or Fox Ockley-Thackery associations, which are very well-drained, having formed in the floodplains over sand and gravel aquifers with deposited materials from the upland.

Much of the Twin Creek watershed overlies the Great Miami River Buried Valley Aquifer System. This ancient river valley filled with glacially deposited sand, gravel and clay till to depths of 200 feet is the principal water source for the area. Designated as a Sole Source Aquifer by the U.S. EPA in 1988, all federally funded projects within the aquifer must be reviewed for their potential water quality impact. Additionally, many communities have enacted or are considering wellhead protection legislation.

SUMMARY

While the primary focus of this report is to uncover and address impairments within the Twin Creek watershed, the positive aggregate performance of the basin should not be understated. The 2005 survey found **no** sites or reaches to be in non-attainment of applicable biocriteria basin-wide, with **all** fish communities meeting or exceeding their assigned aquatic life use. Overall, the basin achieved full attainment at 32 of 48 stations (67%). Most impairment, found only within the macroinvertebrate communities, was either attributed to or exacerbated by naturally occurring low flows. Of the impaired sites, 14 of 15 were located on tributaries and not on Twin Creek itself.

The Twin Creek mainstem reaffirmed itself as worthy of its EWH status in 2005. While Twin Creek does not stand out in terms of species diversity when compared to other similarly-sized, high quality Ohio streams, when biological performance is considered in terms of mean index scores, Twin Creek is among the best. The mean Index of Biotic Integrity (IBI - a fish index) of Twin Creek in 2005 (53.3) is the highest in Ohio when compared to similar-sized streams sampled in the last 10 years. The 2005 Invertebrate

Community Index (ICI) mean (48.9), which included one score below the EWH criterion, still was high enough to rank third-highest in the state among comparable streams in the last 10 years. This kind of performance is attributed not only to Twin Creek's assimilative nature, but also to the good stewardship demonstrated by the landowners along this water body. Natural riparian corridors, important for bank stabilization, contaminant filtering, and stream shading, were left intact throughout most of Twin Creek's length. Given the abundance of agricultural land use throughout the watershed, such protection of this important habitat feature is commendable.

Aquatic Life Use Attainment Status

The Twin Creek watershed is comprised of two Watershed Assessment Units (WAUs). The upper watershed, corresponding to Hydrologic Unit Code (HUC) 05080002-030, includes Twin Creek from its headwaters to upstream of Bantas Fork. Associated tributaries studied in this sub-basin included Maple Swamp Ditch, Dry Fork, Miller's Fork, Swamp Creek, Unnamed Tributary to Swamp Creek at River Mile (RM) 6.45, Price Creek, and Lesley Run. The lower watershed, corresponding to HUC 05080002-040, includes Twin Creek from Bantas Fork to the confluence with the Great Miami River. Associated tributaries studied in this sub-basin included Bantas Fork, Goose Run, Aukerman Creek, Unnamed Tributary to Aukerman Creek at RM 2.88, Unnamed Tributary to Twin Creek at RM 18.29, Tom's Run, and Little Twin Creek. In all, 48 stations with drainage areas ranging from 3.3 to 316 mi^2 were sampled to determine attainment of aquatic life uses. Of these, 15 (31%) were in partial attainment of their existing or recommended use. No stations were in non-attainment, and 1 station was left unassessed due to lack of a fish sample. Figure 5 shows aquatic life use attainment by stream segment. In all cases where aquatic life use goals were not fully met, macroinvertebrate performance was the limiting factor. Detailed discussions of biological findings within each HUC begin on page 43. The Aquatic Life Use Attainment Table (Table 2) provides biological index scores along with causes and sources of impairment at each impaired site. The most prominent causes of impairment in the Twin Creek watershed are described below.

Biological performance is often a byproduct of surrounding land use, a notion that is active in Twin Creek, particularly in the headwaters. There, as mentioned in the Study Area Description, agriculture dominates a landscape that is comprised of hydric soils that, left unaltered, drain poorly and can lead to saturated conditions not conducive to crop production. Therefore, an extensive network of field tiling exists in order to render the soils suitable for planting. To facilitate drainage via this network, many of the streams in the upper portion of the watershed have been ditched, straightened, stripped of riparian buffer, or otherwise altered in order to act as receiving waters that quickly and effectively move excess water away from planting fields. The 'artificial' stream segments that result from these alterations are left with substandard habitat features that more readily allow for impairments attributable to siltation and nutrient enrichment from unfiltered runoff. That said, the upper portion of Maple Swamp Ditch, upper Miller's Fork, upper Swamp Creek, upper Lesley Run, and upper Tom's Run were found to have been adversely influenced by such modifications. None of the macroinvertebrate communities found in these stream segments were in attainment of their current or recommended aquatic life use.

Most of the streams cited above were additionally impaired by naturally-occurring low flows. August 2005 in particular was extraordinarily dry, with significant precipitation not occurring until August 30, when remnants of hurricane Katrina saturated the area. However, base flows in the beginning of September, when macroinvertebrate sampling began, still remained low. Figure 6 shows both flow and precipitation values, July-October, 2005. In addition to hydromodification, upper Miller's Fork, upper Swamp Creek, upper Lesley Run, and upper Tom's Run were also affected by low flow conditions. Upper Price Creek, lower Lesley Run, the upper and lower reaches of Bantas Fork, upper Goose Run, and upper Little Twin Creek experienced flow-related impairments as well. Where the fish communities sampled were found to be intact and apparently adapted to the changes in flow regime, the benthic communities were exhibiting distress. In these cases, most sensitive taxa that would normally be present in a flowing stream with riffle/run complexes were not found.

Only two stations were acknowledged as being potentially influenced by point source wastewater discharge, in spite of numerous system bypasses reported at many of the facilities (see Spills and Kills, page 31). Goose Run at RM 4.4, while experiencing notably low flows at the time of sampling, also had large growths of filamentous algae, indicative of nutrient enrichment attributable to several upstream package wastewater facilities. The fair benthic community collected here subsequently fell short of the applicable WWH biocriterion. On Twin Creek itself, downstream from the Lewisburg WWTP, while a good narrative ICI score was garnered, the EWH criterion for that reach was not achieved. Nutrient enrichment from either the Lewisburg WWTP, runoff from an upstream municipal park, or contaminated stormwater via a culvert at the Salem Road bridge could be responsible for the impairment.

Figure 5. Attainment status by stream segment in the Twin Creek watershed, 2005. Note that most cases of partial attainment occur in the headwater tributaries of upper Twin Creek.

Table 2. Aquatic life use attainment status for stations sampled in the Twin Creek basin based on data collected July-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. In cases where a new aquatic life use is recommended, attainment status is based on that recommendation.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Twin Creek (14-500)	*ECBP Ecoregion – EWH Existing*						
Upper Twin Creek Assessment Unit – HUC 05080002-030							
46.5[H] /46.6	48 [ns]	N/A	VG[ns]	43.0	FULL		
42.1[W]/42.0	48[ns]	9.1[ns]	46	75.5	FULL		
38.0[W]/38.1	46[ns]	9.0[ns]	50	61.0	FULL		
35.5[W] /35.4	58	10.2	50	67.0	FULL		
34.9[W] /34.9	58	10.2	38*	71.0	PARTIAL	Nutrient enrichment: phosphorus	Municipal point source discharges-Lewisburg WWTP/ Runoff from municipal park
33.6[W] /33.5	58	10.3	52	77.0	FULL		
31.7[W] /31.7	55	9.6	54	72.5	FULL		
27.5[W] /27.6	55	10.4	52	80.0	FULL		
26.7[W] /26.6	56	11.1	44[ns]	88.5	FULL		
Lower Twin Creek Assessment Unit – HUC 05080002-040							
23.9[W] /23.7	54	10.0	50	79.0	FULL		
19.2[W] /19.2	51	9.8	52	76.5	FULL		
19.0[W]/19.0	48[ns]	10.0	E	72.0	FULL		

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
13.4[W] /13.4	53	10.3	50	88.0	FULL		
9.8[W] /9.7	56	10.4	52	74.0	FULL		
3.4[W] /3.4	51	10.2	E	86.5	FULL		
0.9[W] /0.9	54	9.8	48	82.0	FULL		
0.1[W] /0.1	54	10.6	46	71.5	FULL		
Upper Twin Creek Assessment Unit (Tributaries) – HUC 05080002-030							
Maple Swamp Ditch -Trib to Twin Creek @ RM 47.03 (14-519) *ECBP Ecoregion – Undesignated – MWH Recommended*							
2.4[H] /2.4	38	N/A	P*	21.0	PARTIAL	Sedimentation/Siltation Excess Algal Growth	Channelization; Loss of Riparian Habitat; Crop Production with Subsurface Drainage. (Darke County ditch maintenance)
ECBP Ecoregion – Undesignated – WWH Recommended							
1.4[H] /1.4	44	N/A	G	38.5	FULL		(Darke County ditch maintenance)
Dry Fork -Trib to Twin Creek @ RM 39.35 (14-515)					*ECBP Ecoregion – WWH Existing*		
0.8[H] /0.8	40	N/A	G	50.0	FULL		
Millers Fork -Trib to Twin Creek @ RM 35.71 (14-513)					*ECBP Ecoregion – EWH Existing – WWH Recommended*		
10.8[H] /10.8	40	N/A	Low F*	33.0	PARTIAL	Low Flow (Interstitial) Sedimentation/Siltation; Low Dissolved Oxygen (DO) Nutrients: ammonia	Natural Channelization; Loss of Riparian Habitat; Crop Production with Subsurface Drainage; Sewage Discharge from Unsewered Area
ECBP Ecoregion – EWH Existing							
8.0[H] /8.0	48[ns]	N/A	G*	66.5	PARTIAL	Natural Habitat (Shallow Bedrock)	Natural

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
3.9[H] /3.9	48[ns]	N/A	MG[*]	58.0	PARTIAL	Sedimentation/Siltation; Low DO; Nutrients: ammonia	Loss of Riparian Habitat Animal Feeding Operations
Swamp Creek -Trib to Twin Creek @ RM 35.59 (14-512) *ECBP Ecoregion – WWH Existing*							
6.3[H] /6.4	44	N/A	F*	34.0	PARTIAL	Low Flow Nutrients: ammonia, phosphorus; Sedimentation/Siltation	Natural Channelization; Loss of Riparian Habitat; Crop Production w/ Subsurface Drainage
ECBP Ecoregion – EWH Existing							
--- /0.2	---	---	MG*	---	Unknown		
Trib to Swamp Creek @ RM 6.45 (14-521)					*ECBP Ecoregion - Undesignated – WWH Recommended*		
0.3[H] / ---	38[ns]	N/A	---	37.5	(FULL)		
Price Creek -Trib to Twin Creek @ RM 29.74 (14-510)					*ECBP Ecoregion – WWH Existing*		
13.7[H] /13.6	38[ns]	N/A	Low F*	47.0	PARTIAL	Low Flow Low DO; Nutrients: ammonia, phosphorus	Natural Agriculture; Failing On-Site Septic Systems
10.9[H]/10.9	42	N/A	G	62.5	FULL		
ECBP Ecoregion – EWH Existing – WWH Recommended							
3.8[W] /3.9	36 [ns]	8.4	50	65.5	FULL		
Lesley Run -Trib to Twin Creek @ RM 24.60 (14-508)					*ECBP Ecoregion - WWH Existing*		
6.0[H] / 4.9	48	N/A	Low F*	35.0	PARTIAL	Low Flow (Interstitial) Sedimentation/Siltation; Low DO	Natural Channelization; Loss of Riparian Habitat; Crop Production w/ Subsurface Drainage
1.2[H] /1.3	38[ns]	N/A	Low F*	60.0	PARTIAL	Low Flow (Interstitial)	Natural

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Lower Twin Creek Assessment Unit (Tributaries) – HUC 05080002-040							
Bantas Fork -Trib to Twin Creek at RM 24.32 (14-505) *ECBP Ecoregion - EWH Existing*							
13.7[H] /13.7	46[ns]	N/A	G*	69.0	PARTIAL	Low Flow	Natural
9.4[H] /9.5	56	N/A	54	67.0	FULL		
7.1[W]/7.0	56	8.7 [na*]	50	72.5	FULL		
1.3[W] /1.2	53	9.8	G*	80.5	PARTIAL	Low Flow	Natural
Goose Run -Trib to Bantas Fork @ RM 7.55 (14-506) *ECBP Ecoregion - WWH Existing*							
4.4[H] /4.2	44	N/A	F*	55.0	PARTIAL	Low Flow Nutrient Enrichment: phosphorus, ammonia, COD, low DO	Natural Upstream Package Plants
ECBP Ecoregion – EWH Existing							
0.3[H] /0.3	56	N/A	VG[ns]	73.0	FULL		
Aukerman Creek -Trib to Twin Creek @ RM 19.29 (14-504) *ECBP Ecoregion - WWH Existing*							
3.3[H]/3.3	50	N/A	VG	82.0	FULL		
1.8[H] /1.8	54	N/A	G	75.5	FULL		
0.5[W] /0.4	46	8.0[ns]	52	70.5	FULL		
Trib to Aukerman Creek @ RM 2.88 (14-520) *ECBP Ecoregion - Undesignated / WWH Recommended*							
0.5[H]/0.5	48	N/A	VG	73.0	FULL		
Trib to Twin Creek @ RM 18.29 (14-518) *ECBP Ecoregion – Undesignated – WWH Recommended*							
0.6[H] / 0.7	48	N/A	E	70.5	FULL		

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Tom's Run -Trib to Twin Creek @ RM 13.52 (14-502) *ECBP Ecoregion - WWH Existing*							
12.0[H]/12.0	52	N/A	Low F*	40.5	PARTIAL	Low Flow (Interstitial) Low DO; Sedimentation/Siltation	Natural Channelization; Crop Production w/ Subsurface Drainage
8.5[H] /8.5	40	N/A	Low F*	58.5	PARTIAL	Low Flow (Interstitial)	Natural
0.4[W]/0.4	48	8.7	34[ns]	82.0	FULL		
Little Twin Creek -Trib to Twin Creek @ RM 6.69 (14-501) *ECBP Ecoregion - EWH Existing*							
6.2[H]/6.3	46[ns]	N/A	36*	65.5	PARTIAL	Low Flow	Natural
4.7[H] /4.6	52	N/A	50	59.5	FULL		
2.0[H]/2.0	54	N/A	VG [ns]	77.0	FULL		

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 is given for the proposed status when a change is recommended.

ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

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

d - Limited Warmwater Habitat is an archaic use designation.

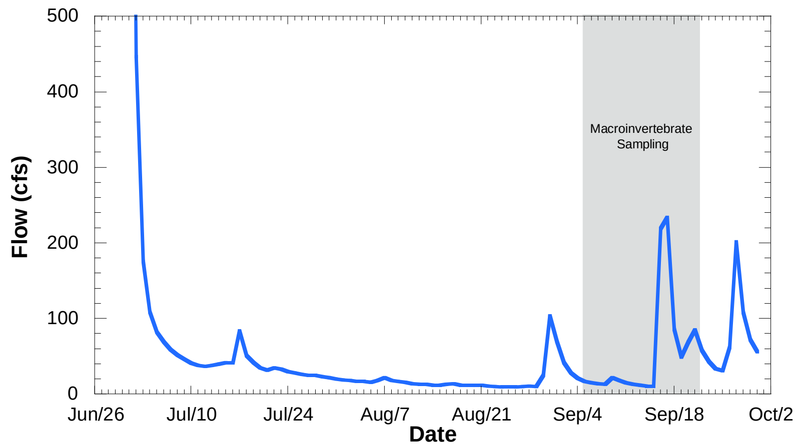
e - Low flow precluded use of boat method on the second pass.

f - Modified Warmwater Habitat criteria for channel modified habitats.

na* - The MIwb for RM 7.1, Bantas Fork, was invalidated to due to a sampling error associated with significant bridge effect.

Ecoregion Biocriteria: Eastern Corn Belt Plain

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



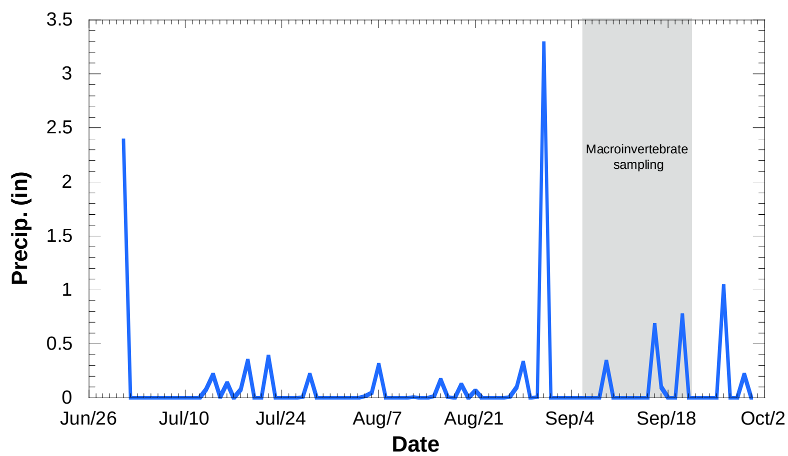


Figure 6. Stream flow (top) and precipitation (bottom), July-October 2005, as measured at the Germantown gage station on Twin Creek. Macroinvertebrate sampling period is shaded in gray. Flow data from USGS,http://waterdata.usgs.gov . Precipitation data courtesy of www.miamiconservancy.org/water/data.asp.

Recreational Use Attainment Status

Five sampling events for bacteria were collected within thirty days during the month of September, 2005. A total of twenty sites, designated Primary Contact Recreation (PCR), were sampled on five separate occasions, with 12 sites in the upper Twin assessment unit and 8 sites in the lower Twin assessment unit. In all, 99 of the 100 samples were included in the calculations (one was invalidated due to a lab transport accident). Each Watershed Assessment Unit was evaluated for bacteria compliance using Water Quality Standards (WQS) in OAC 3745-1-07, Table 7-13.

According to WQS, the geometric mean density for each PCR watershed after 5 samples are taken within a 30 day period shall not exceed 1000 colonies/100ml for fecal coliform, and shall not exceed 126 colonies/100ml for *Escherichia coli.* The geometric mean density value of 126 colonies/100 ml for *E. coli* relates to 8 gastrointestinal illnesses per 1000 persons per month having contact with PCR waters. The standards for PCR waters have a single maximum allowable density for fecal coliform of 2000 colonies/100 ml and 298 colonies/100 ml for *E coli.* A water quality violation is declared when more than 10% of samples taken within 30 days exceed the maximum allowable density. Both fecal coliform and *E. coli* densities must exceed WQS for the stream to be considered out of attainment of the recreational criteria.

Table 3 indicates that the upper Twin Creek assessment unit has exceeded the PCR Water Quality Standards for both *Escherichia coli* and fecal coliform. The lower Twin Creek assessment unit exceeded WQS for *Escherichia coli*, but met the criteria for fecal coliform. This would indicate that a bacteriological TMDL would be required for the upper Twin Creek subwatershed. Individual *sites* that are in non-attainment of PCR standards are indicated in Table 4.

Twin Creek remained below the mean flow for most of the sampling season. Three rainfall events were captured during the bacteriological sampling: September 9 (0.4 inches in W. Manchester, 0.35 inches in Germantown), September 16 (1.35 inches in W. Manchester, 0.68 inches in Germantown), and September 20 (1.35 inches in W. Manchester, 0.77 inches in Germantown).

The five bacteria sampling events were conducted on September 8, 9, 12, 21, and 22. The September 9 and 21 bacteria sampling events were influenced by rainfall (Figure 9). Rainfall influenced maximum concentrations for 78% of all *E. coli* exceedences and 88% of fecal coliform exceedences in the upper Twin watershed. Rainfall influenced maximums for 75% of all *E. coli* exceedences and 100% of the fecal coliform exceedences in the lower Twin watershed.

Sites with geometric mean bacteria contamination are depicted in Figures 7 and 8. The upper Twin Creek assessment unit downstream from the Lewisburg WWTP (RM 34.9), significant levels of *E. coli* (601.8 colonies / 100 ml) and fecal coliform (1360 colonies /100 ml) were measured. The sanitary sewer collection system of Lewisburg is influenced by inflow and infiltration problems. The bacteria levels were still elevated at the site downstream from the Iams outfall (RM 33.6). Further upstream, Swamp Creek (RM 0.2) had significant levels of *E. coli* (416 colonies/100 ml) and fecal coliform (864 colonies/100 ml). Animal waste is land-applied in the Swamp Creek watershed, and it has been documented that the village of Verona has failed septic systems. Both issues could contribute to bacterial impacts. A sewage treatment plant for Verona is under construction during 2007.

The overall *E. coli* levels in the upper Twin Creek watershed are above the geometric mean density standard even on non-rainfall sampling events. The influence of the September 9 and 20 rainfall events are dramatically shown in Figure 9.

All four tributaries sampled in the upper Twin Creek watershed documented impacts from bacteria (Figures 8 and 10). All tributaries documented impacts during rainfall events and 3 of 4 sampling events during dry weather. A selected set of tributaries was sampled, but almost any small tributary in the watershed could show bacteria contamination if sampled during a wet weather event. Influences from either land application or mismanagement of animal wastes was likely responsible for wet weather exceedence events. Exceedences on non-rainfall influenced sampling events may reflect failed septic system discharges.

Table 3. Results of Ohio EPA bacteriological sampling collected from September 8-22 in the Twin Creek study area during 2005. For Primary Contact Recreational streams, at least one of two bacteriological standards (fecal coliform or *E. coli*) must be met. Values above criteria are highlighted in red.

	Watershed Assessment unit (5080002)	
	030 (59 sites)	**040** (40 sites)
Recreational use attained?	No	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 colonies per 100 ml and fecal coliform content shall not exceed 2000 colonies per 100 ml in more than ten percent of the samples taken during any thirty day period.		
Geometric mean (#colonies/100 ml)	581.5	300.3
%>2000 colonies / 100 ml	(8/59) 13.5 %	(2/40) 5.0%
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 colonies per 100 ml., and E. coli content shall not exceed 298 colonies per 100 ml. in more than ten percent of the samples taken during any thirty-day period.		
Geometric mean (#colonies/100 ml)	285.2	144.1
% > 298 colonies/ 100 ml	(23/59) 39%	(8/40) 20%

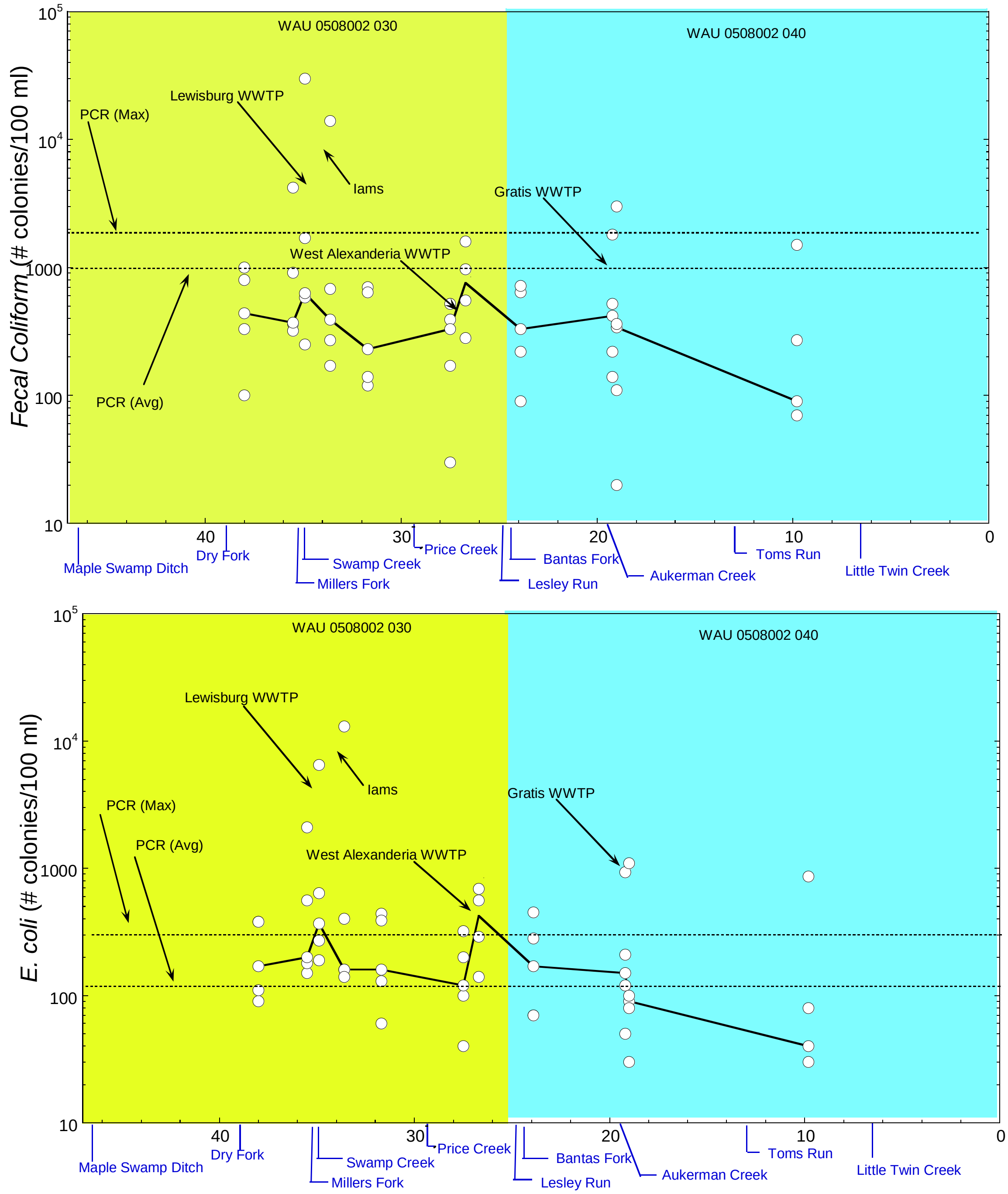


Figure 7. Longitudinal plots of E. coli (top) and fecal coliform (bottom) bacteria results from Twin Creek during the 2005 survey. The dotted line represents water quality standards. The solid line represents the median value at each river mile. Watershed Assessment Units (WAUs) are shown for each plot.

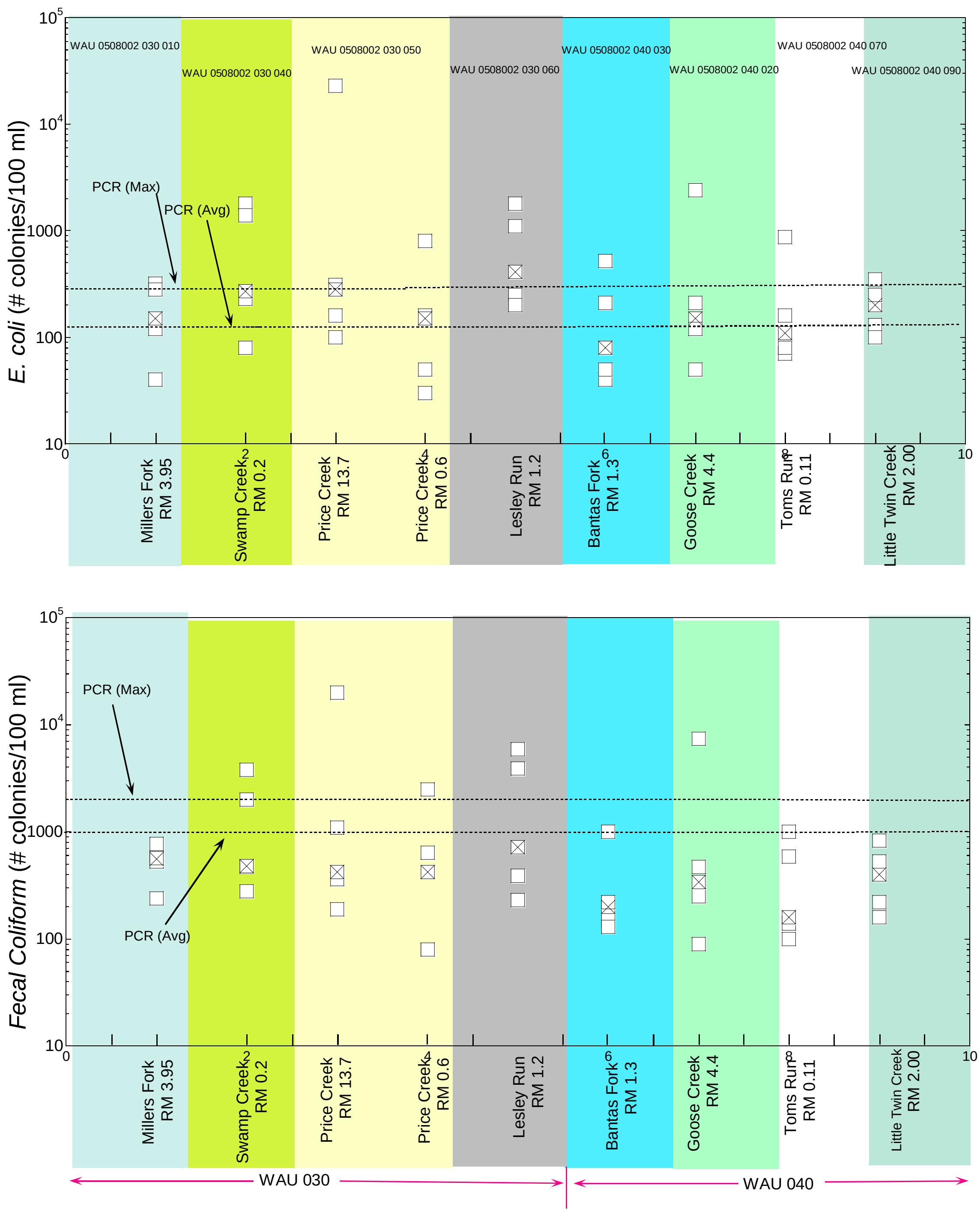
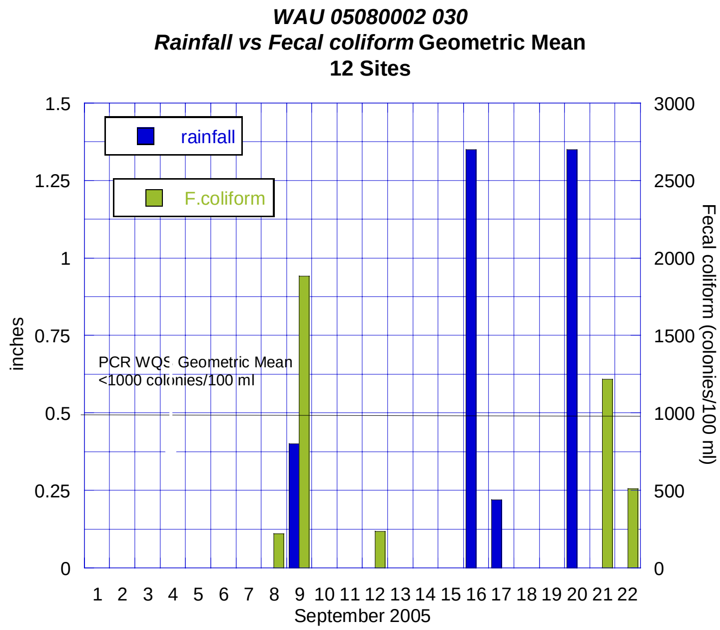


Figure 8. Longitudinal plots of E. coli (top) and fecal coliform (bottom) bacteria results from Twin Creek tributaries during the 2005 survey. The dotted line represents WQS.



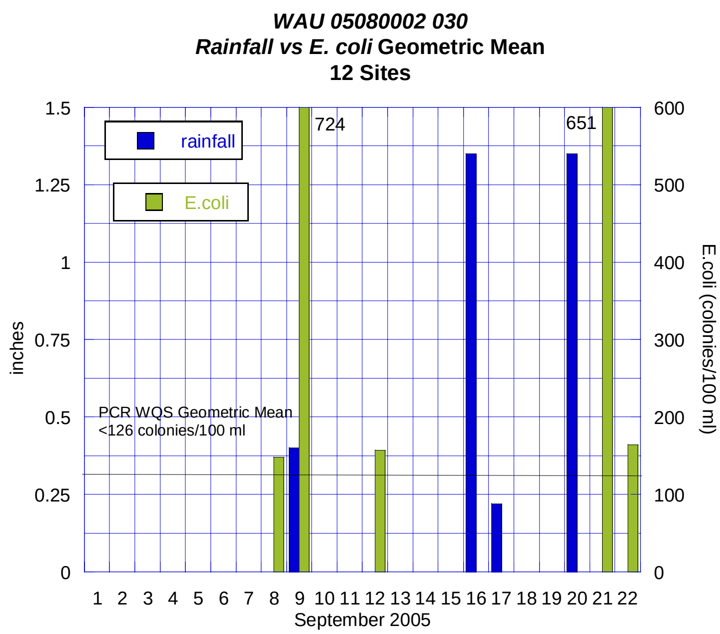
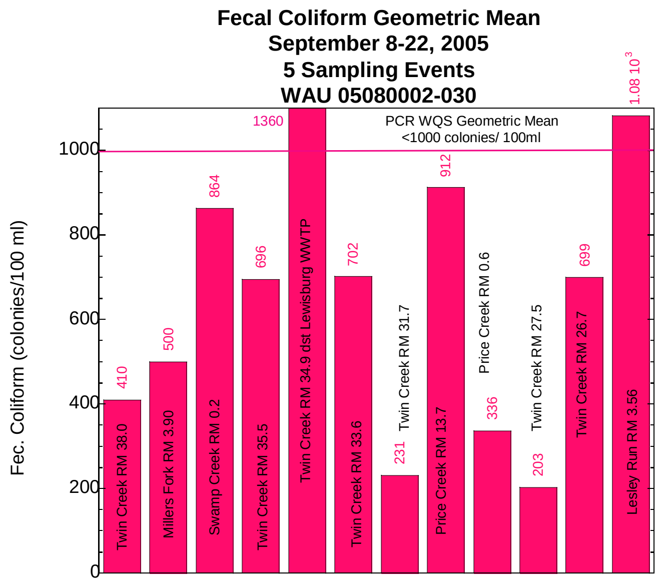


Figure 9. The effect of rainfall (as measured at West Manchester) upon the daily geometric mean of 12 bacteriological samples in the upper Twin Creek watershed.



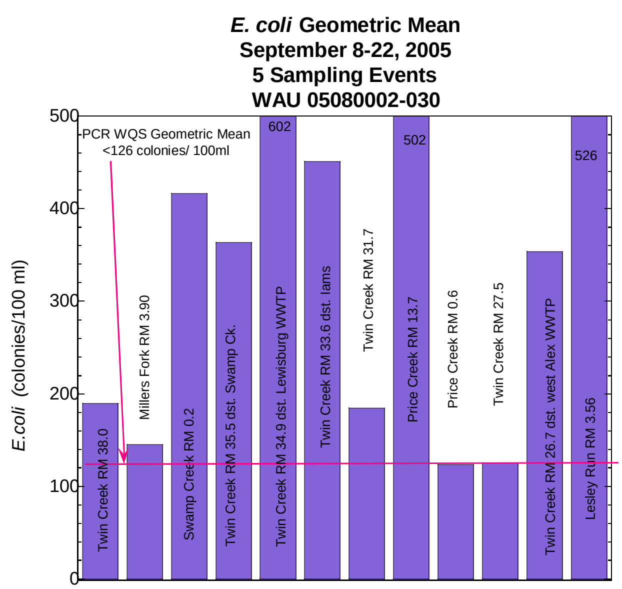


Figure 10. Geometric mean values for each biological sampling site in upper Twin Creek after five sampling events in September 2005.

Table 4. Individual sites with PCR criteria violations. Sites shaded in yellow are located in the upper Twin Creek assessment unit; those in blue are located in the lower assessment unit.

Stream	River Mile	Location
Twin Creek	35.5	Dst. Swamp Creek, NW of Knapke Road
Twin Creek	34.9	Dst. Lewisburg WWTP
Twin Creek	33.6	Dst. P&G Pet / North American Nutrition
Swamp Creek	0.2	US 40
Price Creek	13.7	Pence-Shewman Road, Eldorado
Price Creek	0.6	Ust. SR 503
Twin Creek	26.7	Dst. West Alexandria WWTP
Lesley Run	3.56	US 35
Goose Run	4.4	Scheyhing Road
Twin Creek	19.2	Enterprise Road, Gratis
Twin Creek	19.0	Dst. Gratis WWTP
Twin Creek	9.8	Germantown Gage station

Chemical Water Quality Status

Physical and chemical assessments were completed at 52 sites (25 in the upper and 27 in the lower Twin Creek watersheds). Each site had five sets of grab samples collected from July to September. Water quality exceedences of Ohio EPA WQS criteria (OAC 3745-1) for the watershed are listed in Table 5.

U.S. EPA mandated that States adopt nutrient criteria, as nutrients are consistently identified as a cause of impairment. This document uses the Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999) as benchmarks to evaluate nutrient concentrations in surface water. Ohio streams are categorized by ecoregions and subdivided by stream size. Size categories are divided by drainage area (mi^2) and waters are defined as headwater (≤20 mi^2), wadeable (20-200 mi^2), small river (200-1000 mi^2), or large river (>1000 mi^2). The 90th percentile statistics, found in the appendix of the Associations document, are used as the benchmark to evaluate whether a site has elevated nutrients. Twin Creek is in the Eastern Corn Belt Plains ecoregion and is considered a small river, being 316 mi^2 at its mouth. Most sites on the mainstem were evaluated as wadeable sites and tributaries mostly were evaluated as headwater sites.

The mainstem of Twin Creek exhibited good assimilative capacity. Nutrients discharged from four point sources between RM 34.9 and RM 26.7 accounted for elevated values of phosphorus, nitrate, and ammonia in the upper mainstem during the survey season (Table 6). Downstream from these point sources, only one benchmark elevation of ammonia occurred in the lower mainstem during the survey season. Conservation easements along Twin Creek in the lower catchment help to insure that Twin Creek remains an Exceptional Warmwater Habitat (EWH) stream far into the future.

In general, headwater sites in upper Twin Creek exhibited impairment from hydromodification, drainage of hydric soils, destruction of riparian vegetation, and nonpoint nutrient enrichment in streams less than 10 mi^2 (Price Creek RM 13.7, Swamp Creek RM 6.3, Lesley Run RMs 3.6 and 1.2, and Millers Fork RM 10.8). Miller's Fork had water column ammonia in exceedence of the 90^{th} percentile benchmark value, as referenced in the Associations Document, in 11 of 14 samples taken at three sites. Ammonia values this high could potentially jeopardize the EWH designation of Miller's Fork.

In the lower Twin Creek watershed, Bantas Fork RM 13.7, and Tom's Run RMs 12.0 and 8.5 were impacted by hydromodification, destruction of riparian vegetation and nonpoint nutrient enrichment. Point source nutrient enrichment, hydromodification, and destruction of riparian vegetation were noted above Goose Run RM 4.4. During rain events, elevated water column nitrates were commonly observed throughout both the upper and lower Twin Creek watersheds.

Water Quality Standards dissolved oxygen minimum and/or average criteria were exceeded numerous times in several of the tributaries and occasionally in the mainstem of Twin Creek. Low stream flows, habitat modification, riparian removal, and algal growth resulted in lower dissolved oxygen concentrations. Elevated nutrient levels stimulated algal growth in several locations which resulted in wide diel swings in the dissolved oxygen concentrations. Dissolved oxygen criteria exceedences were more prevalent in the upper watershed due to higher nutrient concentrations, lower flows, and more habitat modifications. The lower watershed experienced fewer dissolved oxygen exceedences due to better habitat and riparian conditions which result in greater stream assimilative capacity.

Table 5. Exceedences of Ohio EPA Water Quality Standards (WQS) (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 Twin 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 (*use designation* [a]) River Mile	Parameter [c] (value)
<u>WAU: 05080002 030 010</u>	
Twin Creek *(EWH, PCR, AWS, IWS)*	
45.56	Dissolved oxygen (4.40[‡‡])
42.1	Dissolved oxygen (3.93[‡‡], 4.67[‡‡], 4.85[‡‡], 5.46[‡])
38.0	Dieldrin (0.0028[#] , 0.0034[#])
	E. coli (170 [JL], 380, 380 [J])
	Heptachlor epoxide (0.0043[#],0.0057[#])
<u>WAU: 05080002 030 020</u>	
Millers Fork *(EWH, PCR, AWS, IWS)*	
10.78	Dissolved oxygen (3.38[‡‡], 3.62[‡‡], 4.5[‡‡], 4.57[‡‡])
7.96	Dissolved oxygen (5.82[‡])
3.95	*E. coli* (150 [JL], 280[J], 320)
	Dissolved oxygen (2.72[‡‡], 3.40[‡‡], 3.95[‡‡], 4.70[‡‡])
	Dieldrin (0.0028#, 0.0058#)
	Heptachlor epoxide (0.0031[#],0.0049[#])
<u>WAU: 05080002 030 030</u>	
Twin Creek *(EWH, PCR, AWS, IWS)*	
35.5	Fecal coliform (4200)
	E. coli (150 [JL], 180 [JL], 200, 560, 2100)
	Dieldrin (0.0027#, 0.0031#)
	Heptachlor epoxide (0.0033[#],0.0055[#])
34.9	Fecal coliform (30000, 1700 [JL])
	E. coli (190 [JL], 270, 370, 640, 6500)
	Dieldrin (0.0039# , 0.0057#)
	Dissolved oxygen (4.94[‡‡])
	Heptachlor epoxide (0.0046[#],0.0055[#])
33.6	*E. coli* (160 [JL], 160 [JL], 140 [JL], 400, 13000 [JL])
	Dissolved oxygen (5.60[‡‡])
	Fecal coliform (14000 [JL])
	Dissolved oxygen (4.76[‡‡])
	Heptachlor epoxide (0.0025[#],0.0062[#])
31.7	*E. coli* (130 [JL], 160 [JL] 390, 440)
	Dissolved oxygen (5.00[‡], 5.54[‡], 5.7[‡])
	Dieldrin (0.0028#)
	Heptachlor epoxide (0.0032[#],0.0046[#])

Table 5 Continued

Stream (*use designation* [a]) River Mile	Parameter [c] (value)
<u>WAU: 05080002 030 040</u>	
Swamp Creek *(EWH, PCR, AWS, IWS)*	
0.2	Fecal coliform (2000,3800) *E. coli* (1800[JL], 230, 1400[JL], 270) Dissolved oxygen (5.09[‡]) Dieldrin (0.0034[#]) Heptachlor epoxide (0.0032[#],0.0032[#],0.0038[#])
<u>WAU: 05080002 030 050</u>	
Price Creek *(WWH, PCR, AWS, IWS)*	
13.7	*E. coli* (310, 160 [JL], 23000, 280) Fecal coliform (1100 [JL], 20000) Dissolved oxygen (3.87[‡‡], 4.00[‡], 4.80[‡]) Dieldrin (0.0033#) Heptachlor epoxide (0.0022[#])
10.88	Dissolved oxygen (4.19[‡], 4.71[‡])
<u>WAU: 05080002 030 050</u>	
Price Creek *(EWH, PCR, AWS, IWS)*	
0.6	*E. coli* (160 [JL], 800, 150 [JL,P]) Dissolved oxygen (5.77[‡], 5.80[‡]) Fecal coliform (2500) Dieldrin (0.0023#, 0.0024#) Heptachlor epoxide (0.0034[#],0.0036[#])
<u>WAU: 05080002 030 060</u>	
Twin Creek *(EWH, PCR, AWS, IWS)*	
27.5	*E. coli* (200, 320) Dissolved oxygen (5.80[‡]) Dieldrin (0.0025#, 0.0029#) Heptachlor epoxide (0.0031[#],0.0036[#]) Aldrin (0.0025[#])
26.7	*E. coli* (140 [JL], 290, 560, 690) Fecal coliform (1600 [JL]) Dieldrin (0.0034#) Heptachlor epoxide (0.0032[#],0.0027[#])
<u>WAU: 05080002 030 060</u>	
Lesley Run *(WWH, PCR, AWS, IWS)*	
6.0	Dissolved oxygen (2.50[‡‡], 2.50[‡‡], 3.27[‡‡])
3.56	*E. coli* (1800 [JL], 250, 200, 410, 1100 [JL]) Fecal coliform (5900, 3900) Dissolved oxygen (1.50[‡‡], 2.70[‡‡], 3.10[‡‡] ,2.71[‡‡],2.90[‡‡])
1.20	Dissolved oxygen (1.95[‡‡], 2.48[‡‡], 4.89[‡])

Table 5 continued

Stream (*use designation* [a]) River Mile	Parameter [c] (value)
WAU: 05080002 040 010	
Bantas Fork *(EWH, PCR, AWS, IWS)*	
13.68	Dissolved oxygen (4.13[‡‡], 4.00[‡‡], 4.72[‡‡], 4.79[‡‡])
WAU: 05080002 040 020	
Goose Creek *(WWH, PCR, AWS, IWS)*	
4.4	Fecal coliform (7400 [JL])
	E. coli (2400, 210, 150 [JL])
	Dissolved oxygen (2.1[‡‡], 4.12[‡], 4.40[‡], 4.50[‡])
	Heptachlor epoxide (0.0021[#)]
WAU: 05080002 040 030	
Bantas Fork *(EWH, PCR, AWS, IWS)*	
7.1	Dissolved oxygen (5.68[‡‡])
1.3	*E. coli* (210, 520,)
	Dieldrin (0.0037[#], 0.0026[#])
	Heptachlor epoxide (0.0027[#],0.0025[#])
WAU: 05080002 040 040	
Twin Creek *(EWH, PCR, AWS, IWS)*	
23.9	*E. coli* (280, 450,170 [JL])
	Dieldrin (0.0023[#], 0.0024[#])
	Heptachlor epoxide (0.0028[#])
WAU: 05080002 040 060	
Twin Creek *(EWH, PCR, AWS, IWS)*	
19.2	*E. coli* (210, 150 [JL], 930 [JL])
	Fecal coliform (1800 [JL])
	Dieldrin (0.0024[#])
	Heptachlor epoxide (0.0030[#],0.0021[#])
19.0 *E. coli* (1100)	
	Fecal coliform (3000)
	Dieldrin (0.0023[#])
	Heptachlor epoxide (0.0040[#])
WAU: 05080002 040 070	
Toms Run *(WWH, PCR, AWS, IWS)*	
12.0	Dissolved oxygen (1.82[‡‡], 2.00[‡‡], 2.50[‡‡])
8.5	Dissolved oxygen (4.15[‡], 4.8[‡])
0.11	*E. coli* (160 [JL], 870 [JL])
	Dieldrin (0.0028[#])
	Heptachlor epoxide (0.0025[#])

Table 5 continued

Stream (*use designation* [a]) River Mile	Parameter [c] (value)
<u>WAU: 05080002 040 080</u>	
Twin Creek *(EWH, PCR, AWS, IWS, SRW)*	
9.8	*E. coli* (860 [JL])
	Fecal coliform (1500 [JL])
	Dieldrin (0.0024[#])
	Heptachlor epoxide (0.0032[#],0.0024[#])
<u>WAU: 05080002 040 090</u>	
Little Twin Creek *(EWH, PCR, AWS, IWS)*	
6.2	Dissolved oxygen (4.2[‡‡], 5.63[‡])
4.7	Dissolved oxygen (5.66[‡], 5.60[‡])
2.0	*E. coli* (200, 350, 130 [JL], 250)
	Dieldrin (0.0021[#], 0.0025[#])

a Use designations:
SRW - State Resource Water

Aquatic Life Habitat
EWH – Exceptional Warmwater Habitat
WWH – Warmwater Habitat
CWH – Coldwater Habitat
MWH – Modified Warmwater Habitat
Undesignated – WWH criteria applies

Water Supply
IWS – Industrial Water Supply
AWS – Agricultural Water Supply

Recreation
PCR – Primary Contact
SCR – Secondary Contact

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

* exceedence of numerical criteria for prevention of chronic toxicity (CAC).
** exceedence of numerical criteria for prevention of acute toxicity (AAC).
*** exceedence of numerical criteria for prevention of lethality (FAV).
. exceedence of the pH criteria (6.5-9.0).
exceedence of numerical criteria for the protection of human health (non-drinking—protective of people against adverse exposure to chemicals via eating fish).
exceedence of agricultural water supply criterion.
‡ value is below the CWH minimum 24-hour average D.O criterion (7.0 mg/l) or 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) or value is below the MWH minimum 24-hour average D.O criterion (4.0 mg/l) as applicable.

‡‡ value is below the CWH 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.

. 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.]

P The reported result is estimated because the sample was not analyzed within the required holding time.

JL The reported result is estimated because it has been computed using a colony count that is not within the standard counting range.

Table 6. Elevated nutrients in the Twin Creek mainstem, using guidelines from Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999).

Stream (RM)	Area mi^2	Frequency of elevated Phosphorus	Phosphorus Median (mg/l)	Frequency of elevated NH_3	NH_3 Median (mg/l)	Frequency of elevated NO_3	NO_3 Median (mg/l)
Twin Creek (42.1)	28.0	0/5	0.075	3/5	0.121	0/5	0.24
Twin Creek (34.9)	91.0	3/5	0.239	1/5	0.082	0/5	2.93
Twin Creek (33.6)	94.0	5/5	0.894	3/5	0.135	2/5	4.73
Twin Creek (31.7)	99.0	2/5	0.208	0/5	0.074	0/5	1.22
Twin Creek (26.7)	143	3/5	0.272	1/5	0.076	0/5	3.19
Twin Creek (13.40)	271	0/5	0.029	1/5	0.057	0/5	1.32

Yellow = upper Twin Creek WAU 030
Blue = lower Twin Creek WAU 040

Fish Tissue

Throughout the state of Ohio there is a fish consumption advisory of no more than one meal per week of any sport fish due to mercury contamination. For the Twin Creek basin, there is an additional advisory of one meal per month for smallmouth bass ≥13 inches. This advisory is specific for Twin Creek from US 40 in Lewisburg to its confluence with the Great Miami River. This advisory covers Twin Creek through Montgomery, Preble, and Warren Counties. For additional information related to the Fish Consumption Advisory, please see the 2007 Ohio Sport Fish Consumption Advisory homepage at: http://www.epa.state.oh.us/dsw/fishadvisory/waters/Twin.html .

Spills and Kills

A total of 55 spills potentially affecting the Twin Creek watershed were reported to Ohio EPA Division of Emergency and Remedial Response from 2001-2006 (Table 7). No animal manure spills were reported in this database; however, other spill information documented these incidences. The majority of the spills reported (32) involved wastewater treatment plant upsets discharging undertreated sewage into Twin Creek from RMs 35.2 to 26.97. The Iams Company (RM 33.7) had 20 reported spills, West Alexandria WWTP (RM 26.97) reported 5 spills, Lewisburg WWTP (RM 35.2) reported 4 spills and Gratis WWTP (RM 19.0) reported 3 spills.

Agricultural chemicals accounted for 6 spills and 2 fish kills from 2001-2006. On April 16, 2006, a farm application truck containing liquid ammonia (28%) overturned near West Manchester on Georgetown-Verona Road. Much of the liquid was captured, but some did reach Twin Creek (RM 42.06). A small fish kill was reported (42 minnows). Two large animal manure spills were also reported from this area during 2005.

On May 6, 2004, a farm application truck containing liquid ammonia and atrazine overturned on SR 503 and Georgetown-Verona Road near West Manchester. Six hundred gallons were spilled and the majority was captured. Some liquid entered Millers Fork (RM 4.7) via an unnamed tributary. A small fish kill was reported.

Table 7. Spill reports in the Twin Creek watershed 2001-2006.

Date	Entity	City	Location	Product
12/01/2006	Gratis WWTP	Gratis	Twin Creek	Bypass
11/01/2006	Lowman logging	Twin Twp.	503/New Market	Diesel fuel
10/17/2006	Gratis WWTP	Gratis	Twin Creek	Bypass
10/06/2006	Gratis WWTP	Gratis	Twin Creek	Bypass
9/27/2006	FedEx	Monroe Twp Truck Stop America	Trib to Goose Ck	Diesel fuel
9/19/2006	Unknown	Unknown	11559 Preble Co. Line	Diesel fuel

Date	Entity	City	Location	Product
6/23/2006	Unknown	Monroe Twp	SR503/G'town-Verona	Diesel
4/16/2006	Unknown	W. Manchester	Twin Creek	Fertilizer **Fish kill (42)**
3/12/2006	Lewisburg WWTP	Lewisburg	Twin Creek	Bypass
10/26/2005	DP&L	West Alex	127 Stover Rd	Transformer oil
9/16/2005	Iams	Lewisburg	Twin Creek	Waste water
9/01/2005	Iams	Lewisburg	Twin Creek	Waste water
8/01/2005	Unknown	Twin Twp	Twin Creek	Fish Kill
7/14/2005	Iams	Lewisburg	Twin Creek	Waste water
6/17/2005	Agrotend Farms	Eldorado	Price Creek	Liquid Nitrogen
1/07/2005	W. Alex WWTP	West Alex	Twin Creek	SewageBypass
1/04/2005	Iams	Lewisburg	Twin Creek	Waste water
1/03/05	Lewisburg WWTP	Lewisburg	Twin Creek	Sewage Bypass
11/04/2004	Unknown	Lewisburg	SR40/Twin Creek	30-1qt cont.
11/01/2004	Unknown	Verona	Swamp Creek	Diesel fuel
5/6/04	Royster-Clark	W. Manchester	Millers Fork @ SR503	Atrazine + fertilizer **Fish Kill**
6/27/2004	Unknown	Gratis	6158 Pleasant Valley Dr	Red substance
6/16/2004	W. Alex WWTP	West Alex	Twin Creek	Sewage Bypass
6/11/2004	Unknown	Lanier Twp	SR 503/Lexington	antifreeze
4/14/2004	Harvest Land Coop	Lewisburg	Twin Creek	fertilizer
2/25/2004	Unknown	Gratis Twp	Twin Creek	oil
1/05/2004	Lewisburg WWTP	Lewisburg	Twin Creek	Sewage Bypass
2/11/2003	New Paris Oil	Lewisburg	10333 SR 503	Fuel oil
10/01/2003	DP&L	West Alex	35 E. Third St.	Transformer oil
9/11/2003	W. Alex WWTP	West Alex	Twin Creek	Sewage Bypass
9/11/2003	unknown	Monroe Twp	SR40/SR726	Diesel fuel
9/05/2003	W. Alex WWTP	West Alex	Twin Creek	Sewage Bypass
7/15/2003	W. Alex WWTP	West Alex	Twin Creek	Sewage Bypass
7/07/2003	Lewisburg WWTP	Lewisburg	Twin Creek	Sewage Bypass
5/29/2003	Iams	Lewisburg	Twin Creek	Waste water
4/28/2003	Haunted Cave	Lewisburg	Twin Creek	Drums
4/24/2003	unknown	Washington Twp	Bantas Creek	sewage
4/18/2003	Harvest Land Coop	West Alex	Bantas Creek	fertilizer

Date	Entity	City	Location	Product
3/29/2003	Harvest Land Coop	Eldorado	150 E Ohio St	fertilizer
1/31/2003	Iams	Lewisburg	Twin Creek	Waste water
1/03/2003	Iams	Lewisburg	Twin Creek	Waste water
12/20/2002	Iams	Lewisburg	Twin Creek	Waste water
11/19/2002	Iams	Lewisburg	Twin Creek	Waste water
8/19/2002	Iams	Lewisburg	Twin Creek	Waste water
1/22/2002	Iams	Lewisburg	Twin Creek	Waste water
9/24/2001	Iams	Lewisburg	Twin Creek	Waste water
9/04/2001	Iams	Lewisburg	Twin Creek	Waste water
7/17/2001	Iams	Lewisburg	Twin Creek	Waste water
5/31/2001	Iams	Lewisburg	Twin Creek	Waste water
5/01/2001	Iams	Lewisburg	Twin Creek	Waste water
4/02/2001	Iams	Lewisburg	Twin Creek	Waste water
2/15/2001	Iams	Lewisburg	Twin Creek	Waste water
1/19/2001	Iams	Lewisburg	Twin Creek	Waste water
1/08/2001	Iams	Lewisburg	Twin Creek	Waste water
1/04/2001	DP&L	West Elkton	SR122/Greenbush	Transformer oil

Nonpoint Source Impacts

Historically, nonpoint sources of pollution in the Twin Creek watershed are almost exclusively the result of runoff from agricultural fields. Soil erosion, a primary nonpoint source pollution type of impact in the study area, causes sedimentation in streams that clog the spaces that would normally be used by macroinvertebrates. Conservation tillage systems help to prevent soil erosion by leaving more than 30% of the surface covered with residue from the previous crop. This residue protects the soil from erosion by rainfall and slows the movement of water across the fields. Tillage surveys by the Preble Soil and Water Conservation District estimate about half (49.3%) of the land used for corn production is cultivated using conservation tillage techniques. The same surveys show that a greater percentage (93.6%) of land planted into soybeans use conservation tillage.

Recent survey data are not available for livestock in the watershed but an inventory by the Miami Valley Regional Planning Commission provided some historical indication of animal populations. Seventy-six animal feedlot operations, including 10,026 animal units, existed in the Darke, Preble, and Montgomery County portions of the study area (MVRPC 1991, 1992). These operations produced approximately 9,614 tons of animal waste annually. Animal agricultural facilities are most dense in the Darke Co. upper watershed area. The 2002 USDA Census of Agriculture indicated county level data on farms with animal populations. This census noted a decline in the number of swine in all three counties, an increase in the number of poultry, and cattle numbers remained consistent. The majority of poultry operations in Darke County, which has one of the highest concentrations of operations in the state, are not in the Twin Creek watershed.

Germantown, the largest community in the watershed (pop. 5,157) is served by the

Franklin WWTP which discharges to the Great Miami River (estimated 2005 population sizes from U.S. Census Bureau, http://factfinder.census.gov/). Six smaller communities in the watershed are served by wastewater treatment plants (WWTPs) which discharge in the basin including Lewisburg (pop. 1784), Eldorado (pop. 518), West Alexandria (pop. 1343), Gratis (pop. 905), West Manchester (pop. 412) and Farmersville (pop. 964). A small part of Eaton lies within the basin but is served by city sanitary sewers flowing to a WWTP on Seven Mile Creek. A WWTP is under construction in 2007 for Verona (pop. 456). The rest of the watershed is served by on-site septic systems.

Almost all of the soils in the watershed have severe limitations for household septic tank leach fields. Many have slow permeability and high seasonal water tables that prevent adequate soil treatment of wastes. To allow development of housing on these soils, county health departments have previously permitted the installation of "curtain drains" (subsurface tile drains near the perimeter of leach fields) to provide for residential development. In theory, curtain drains can lower the water table enough to dewater the leach field and allow treatment of wastes. In practice, homeowners often neglect to maintain their systems and failure results. Failure means that the soils in the leach field and around the tank become saturated with untreated waste water. This untreated water can surface, becoming an immediate health threat, or find its way to field drains and enter waterways. This can cause streams to fail to meet recreational use standards.

The Miami Valley Conservancy District (MCD) maintains Germantown Dam, a flow-through structure at RM 10.08. Constructed after the 1913 flood, the dam reduces flood flows downstream at Middletown and Hamilton. There is no permanent pool of water above this dam. It functions as a dry basin which impounds water only during flood conditions. Fixed conduits through the base of the dam allow normal flows to pass through unimpeded. With an 815 foot elevation at the spillway, the dam is capable of impounding 3520 acres which would require eight days to drain. At maximum storage, this dam would impound 14 miles of Twin Creek to Halderman Road (www.miamiconservancy.org/flood/dams_germantown.asp). The Conservancy District and Five Rivers MetroParks manage much of the potentially flooded property. Other mainstem hydromodifications include a breached low head dam at RM 26.6 and an area of historical gravel mining at RM 19.0. Instream gravel mining disrupts the substrate of the stream, deepening previously shallow areas and reducing substrate diversity. It also can remove bottom-dwelling organisms which is especially harmful to non-motile species such as freshwater mussels.

Since the previous study on Twin Creek, Warren County established the Franklin-Clear Creek wellfield adjacent to the stream on MCD property near the mouth. In 1997, in violation of Clean Water Act requirements, the county filled the lower stream channel, straightened, and redirected Twin Creek away from a new pipeline that carries water from the wellfield under the Great Miami River. The county was ordered to restore the

Figure 11. Twin Creek at the mouth in 1994 (left) and in 2005 (right), showing the original and relocated channels. United States Department of Agriculture, Natural Resources Conservation Service, Geospatial Data Gateway: http://datagateway.nrcs.usda.gov/

water quality in this portion of Twin Creek. Figure 11 shows Twin Creek's original mouth location in 1994 and the relocated channel in 2005. This project affected the aquatic life in Twin Creek by covering any organisms in the old channel and creating adverse conditions in the new channel. The straightened channel has an unstable sand and gravel substrate that moves about with each high water event, making it potentially difficult for organisms to thrive. This is especially true for freshwater mussels. Because of the shifting substrate and a widened riparian area, the natural stream will likely not be stable again for some time.

Restoration and Protection Actions

In 1987 the federal Clean Water Act amendments created a national program to control nonpoint source pollution, established under Section 319 of the Clean Water Act. Section 319(h) implementation grant funding is targeted to Ohio waters where nonpoint source pollution is a significant cause of aquatic life use impairments. The cornerstone of Ohio's 319 program is working with watershed groups and others who are implementing locally developed watershed management plans and restoring surface waters impaired by nonpoint source pollution (http://www.epa.state.oh.us/dsw/nps/319Program).

Three Valley Conservation Trust (3VCT), a local non-profit group, was awarded an Ohio Department of Natural Resources Watershed Coordinator grant in 2004. This grant, which is partially funded with Clean Water Act Section 319 money, allowed the organization to hire a watershed coordinator. A major requirement of the grant is development of a Watershed Action Plan (WAP) for Twin Creek. Several meetings were held within the watershed to solicit input from the public and to inform them of the project and this survey. The watershed coordinator position was vacated, but 3VCT is committed to the completion of the WAP for Twin Creek. Three VCT will no longer participate in the watershed coordinator grant; however, Miami University has assumed the grant for implementation and integration with any Total Maximum Daily Load (TMDL) project that may be developed. Three VCT has also been approved to receive a 319 project grant to purchase easements and repair stream bank erosion along the stream.

RECOMMENDATIONS

Changes in Aquatic Life Uses

Current and recommended aquatic life, water supply and recreation uses are presented in Table 8. 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.

Five small tributary streams were sampled by Ohio EPA for the first time during this study. Dry Fork, Unnamed Tributary to Swamp Creek at RM 6.45, Unnamed Tributary to Aukerman Creek at RM 2.88, and Unnamed Tributary to Twin Creek at RM 18.29 all were identified as having potential to support WWH communities, and are all therefore recommended for the WWH aquatic life use. Although the length of Maple Swamp Ditch is petitioned and maintained by Darke County for agricultural drainage purposes, only the upper segment is recommended for the sub-goal MWH aquatic life use. The lower portion, in spite of a QHEI score associated with habitat-derived impairment, appears to be experiencing the compensatory effect of ground water augmentation. Both IBI and ICI scores indicate strong WWH communities, thus justifying a WWH designation in this reach.

Two previously verified aquatic life uses are being recommended for downgrade as a result of the findings of this report. Both represent past erroneous EWH recommendations, and are therefore recommended to be re-designated as WWH. The first stream is the upper segment of Miller’s Fork, from the headwaters downstream to Otterbine-Ithaca Road (RM 9.6). Both 1995 and 2005 QHEI scores at RM 10.8 are well below that which is considered capable of supporting EWH communities (28.5 in 1995 and 33.0 in 2005). Consequently, EWH criteria were not met in either survey. When more realistic WWH criteria are invoked, attainment status for both surveys shifts to full (1995) and partial (2005), rather than the partial and non-attainment that were achieved in lieu of EWH criteria. Clearly, the WWH use is therefore more appropriate for this reach.

The other use in question occurs on Price Creek, on the reach that includes the station at RM 3.9 (Jim's Run Road). In both 1995 and 2005, the MIwb, a structural fish index, failed to meet EWH criteria, rendering that sampling reach in partial attainment in both surveys. The relative low productivity and monotonous nature of bedrock substrates, abundant in this segment of Price Creek, bears a heavy influence upon MIwb scoring. It is considered unlikely that the MIwb will ever score high enough to meet EWH criteria at this station. As a result, this reach, at best, could only consistently achieve partial attainment of the EWH aquatic life use. Therefore, WWH is recommended for Price Creek from the headwaters to Brennersville-Pyrmont Road (RM 2.9). A detailed trend assessment of the Price Creek fish community, which includes additional support of this recommendation, begins on page 124.

Table 8. Waterbody use designations for the Twin Creek basin. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). Designations based on Ohio EPA biological field assessments appear as a plus sign (+). 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. A delta (Δ) indicates a new recommendation based on the findings of this report.

Water Body Segment	Use Designations												
	Aquatic Life Habitat							Water Supply			Recreation		
	OSW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Twin Creek	+		+						+	+		+	
Little Twin Creek			+						+	+		+	
Reigle Ditch		+							+	+		+	
Tom's Run		+							+	+		+	
Unnamed Tributary (RM 5.34)		+							+	+		+	
Wysong Run		*							*	*		*	
Unnamed Trib. to Twin Creek (RM 18.29)		Δ							Δ	Δ		Δ	
Aukerman Creek		+							+	+		+	
Unnamed Tributary (RM 2.88)		Δ							Δ	Δ		Δ	
Bantas Fork	+		+						+	+		+	
Goose Run													
-Downstream Winnerline Road (RM 3.0) to mouth			+						+	+		+	
-all other segments		+							+	+		+	
Lowry Run		*							*	*		*	
Lesley Run		+							+	+		+	

Water Body Segment	Use Designations												
	Aquatic Life Habitat							Water Supply			Recreation		
	OSW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Coffman Run		*							*	*		*	
Price Creek													
-Downstream Brennersville-Pyrmont Road (RM 2.9) to mouth			+						+	+		+	
-Downstream Yohe Road (RM 6.5) to Brennersville-Pyrmont Road (RM 2.9)		Δ	+						+	+		+	
-all other segments		+							+	+		+	
Jim's Run		*							*	*		*	
Swamp Creek													
-Downstream Sonora Road (RM 4.0) to mouth			+						+	+		+	
-all other segments		+							+	+		+	
Unnamed Trib. to Swamp Cr.		Δ							Δ	Δ		Δ	
Miller's Fork													
-Headwaters to Otterbine-Ithaca Road (RM 9.6)		Δ	+						+	+		+	
-all other segments			+						+	+		+	
Lick Run		*							*	*		*	
Dry Fork		*+							*+	*+		*+	
Maple Swamp Ditch													
-Downstream confluence of unnamed tributary at RM 1.7 to mouth		Δ							Δ	Δ		Δ	
-all other segments				Δ					Δ	Δ		Δ	

Improvements to Water Quality

Improvements to water quality can be made by addressing the causes and sources outlined in Table 2. While it is obvious that there is not much recourse regarding impairment caused by naturally-occurring low flows, it is possible to address some of the agriculturally-related habitat concerns. As mentioned previously, the extreme headwaters of many streams in the Twin Creek watershed have been physically altered in order to facilitate agricultural drainage. Some of these streams are legally petitioned and maintained by either their respective county engineers or their local Soil and Water Conservation District (SWCD). Recognizing the indispensable nature of agriculture and the underlying importance for soil drainage, funding should be sought to improve these water courses as such to balance the need for agriculture with the attainment of water quality standards. Restoration to more natural, self-maintaining channel design could prove to achieve this dual goal. Research exploring the incorporation of alternative drainage channel technologies, such as two-stage channel forms, is being conducted via the Ohio Natural Channel Design Project (http://www.ag.ohio-state.edu/~ncd/index.html).

Additional recommendations include improvements at WWTPs in order to reduce or eliminate system bypasses and to remedy inflow and infiltration problems. These should be initiated not only to address biological impairment, but recreational impairment as well. The management of failing septic systems and the proper land application of animal wastes, in concert with improved riparian buffers where needed to filter runoff, are also encouraged to improve biological, chemical, and recreational water quality.

Future Considerations

As mentioned throughout this document, water quality is a reflection of the surrounding land use. Agriculture, the predominating land use in the Twin Creek watershed, has contributed minimally overall to water quality impairment basin-wide. With proper management, it is conceivable that both agriculture and water quality can continue to coexist in years to come. However, given Twin Creek's proximity to the greater Dayton metropolitan area, possible future impacts resulting from urbanization should be considered. Population stability in the past 10 years has resulted in little change to the urbanized areas of Twin Creek, and thus is considered to be a contributing factor to the watershed's overall stability. However, the effects of urbanization have been documented as impacting water quality in some of Ohio's higher quality streams; some of which were once dominated by agriculture as well. Increased development in the outlying suburbs of Columbus, Ohio has had negative impacts on EWH portions of the Olentangy River (Ohio EPA 2005). West of Columbus, the status of Big Darby Creek, a State and National Scenic River, is considered threatened due to similar development patterns (Ohio EPA 2004). In order to avoid a similar scenario in Twin Creek, development should be carefully monitored. The continued purchase of conservation easements, when feasible, should be sought as a proactive and protective measure, should the notion of increased urbanization become realized.

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), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) 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). 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 $4^{o}C$) in a cooler, and shipped to Ohio EPA Division of Environmental Services. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to 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). 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).

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).

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.

RESULTS

Upper Twin Creek: Hydrologic Unit Code 05080002-030: Twin Creek headwaters to upstream of Bantas Fork

Includes associated tributaries: Maple Swamp Ditch, Dry Fork, Miller's Fork, Swamp Creek, Price Creek, and Lesley Run.

SUMMARY

Twenty-three biological, 25 chemical, and 12 recreational (bacteria) stations representing 85.6 cumulative stream miles were assessed in the upper Twin Creek watershed in 2005 to determine possible impacts to water quality. In addition, sediment quality was also measured at 10 stations for chemical parameters. Biological performance was limited in only 9 stations, 8 of which were attributed primarily to direct habitat alterations, low flow conditions, or a combination of both. One site on the Twin Creek mainstem was in partial attainment of EWH criteria. In these cases, deficiencies contributing to partial attainment were only noted in the macroinvertebrate communities. Figure 12 depicts the upper Twin Creek watershed, aquatic life use designations, and use attainment. Detailed discussions and assessments are outlined in the sections that follow.

Point Sources

A schematic representation of the upper Twin Creek watershed, including point sources (orange ovals), is depicted in Figure 13.

Lewisburg WWTP (Twin Creek RM 35.2)

The Lewisburg WWTP was built in 1938 and modified in 1985 and 2004. Design capacity is 0.261 MGD (million gallons per day) with a service population of 3190. Flow from industrial users is 0.011 MGD. Treatment consists of bar screen, gravity channel, in-line comminutor, extended aeration, circular clarifiers, UV disinfection, and post aeration. There are no combined sewers in the service area.

The outfall discharges to Twin Creek at RM 35.2. The upstream sampling location is located at the bridge on US Rt. 40. The downstream sampling location is located at the bridge on Salem Road (CR 15).

During operation under the previous permit, design flow (0.174 MGD) was exceeded in the monthly operational report 54.9% of the time from January 1, 2000-March 31, 2005. The new permit increased design flow to 0.261 MGD and this number was exceeded 19.7% of the time from April 1, 2005 to November 30, 2006. The median flow since the last upgrade was 0.217 MGD. The sanitary sewer collection system for Lewisburg has an inflow and infiltration problem that overloads the system during rain events.

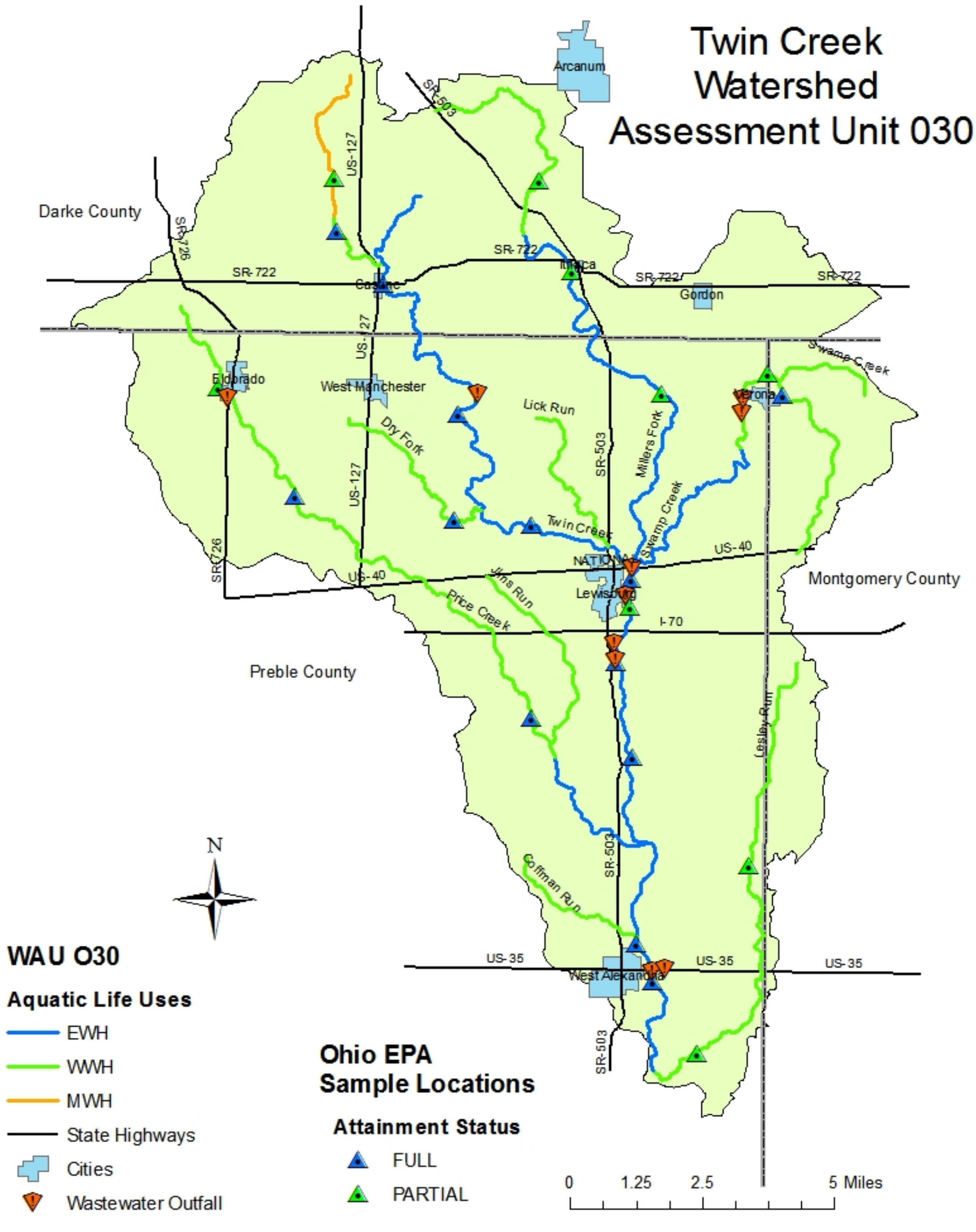


Figure 12. Use designations and attainment status of upper Twin Creek basin, Hydrologic Assessment Unit 05080002-030.

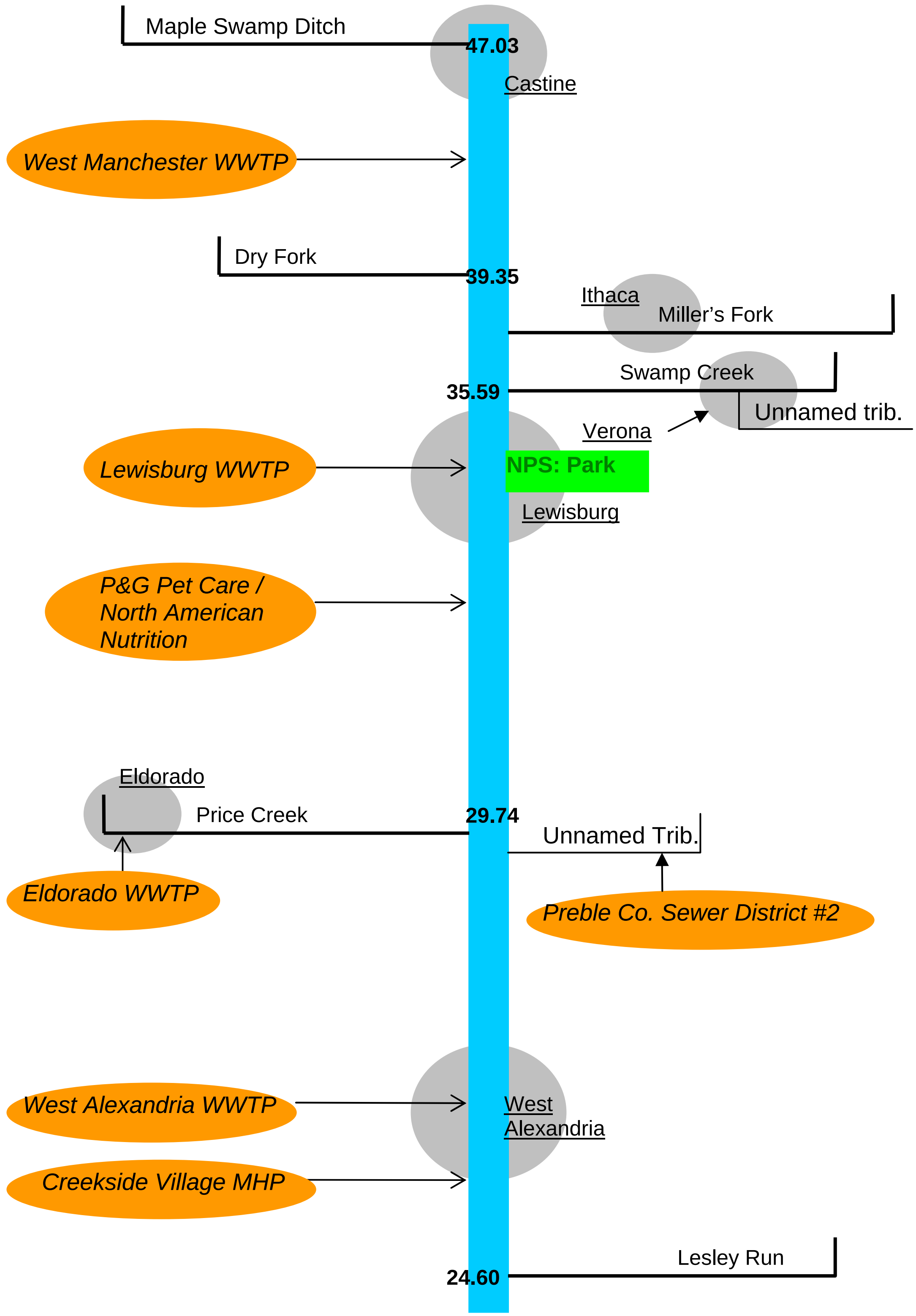


Figure 13. Schematic representation of the upper Twin Creek watershed.

In 5 years (2001-2006), the Lewisburg WWTP reported 29 NPDES permit violations. Parameters violated included 18 total suspended solids (TSS), 5 dissolved oxygen (DO), 3 fecal coliform, 2 pH, and 1 oil and grease.

Lewisburg's summertime permit ammonia discharge limit is 5.01 mg/l (weekly average) and 3.34 mg/l (monthly average). These NPDES permit numbers are high for an EWH stream but the MOR (Monthly Operating Report) data indicate that Lewisburg is easily meeting discharge limits much below 1 mg/l. The median ammonia value from 2001-2006 is 0.1 mg/l. Only 16 of 299 sampling events documented in the MORs for Lewisburg exceeded 1.0 mg/l and these were during the winter. There are no limits in the Lewisburg NPDES permit for winter ammonia discharge.

Nutrients appear to be causing a sag in the ICI values downstream of Lewisburg. There are no permit limits for phosphorus, nitrates or nitrites in the Lewisburg National Pollutant Discharge Elimination System (NPDES) permit. Nitrate-nitrite discharges have been monitored monthly since 2005. The median Nitrate-nitrite value was 14.1 mg/l. Phosphorus has been monitored monthly since 2000. The median phosphorus value was 1.8 mg/l.

Spill reports documented 4 bypasses from Lewisburg from 2001-2006. This number is believed to be larger due to the inflow and infiltration problems in the collection system. The September 9, 2005 bacteria sampling at RM 34.9 downstream of the Lewisburg WWTP documented fecal coliform at 30,000 colonies/100 ml and *E.coli at* 6500 colonies/100 ml. The site immediately upstream of RM 35.5 documented fecal coliform at 4,200 colonies/100 ml. No bypass was mentioned in the spill report for this wet weather event. No exceedence of the fecal coliform permit limit (2000 colonies/100 ml) was listed for all of September 2005.

P & G Pet Care (Iams WWTP; Twin Creek RM 33.7)
The Iams Company, doing business as Proctor and Gamble Pet Care, is a subsidiary of Procter and Gamble. The facility is located at 6571 SR 503 in Lewisburg, Ohio. The Lewisburg site has two operations: manufacturing and research and development (Lewisburg Innovation Center). The manufacturing operation of the plant converts raw materials into a dry pet food supplement for dogs and cats. The Innovation Center has a pilot plant, laboratory, and animal care center. Process wastewater (83%) and sanitary sewage (17%) make up the total discharge for the site. The original WWTP, designed to treat 75,000 gallons per day, was constructed in 1982 and upgraded in 1988 and 1992. In 2000 a new wastewater treatment facility was constructed across SR 503 next to Twin Creek. This new facility was upgraded in 2001.

Treatment consists of a bar screen, rotary screener, 24 hour aerated flow equalization basin, dissolved air flotation cell, 7-day aerated flow equalization basin, activated sludge aeration basin, clarifiers, tertiary sand filters, chlorination, and de-chlorination. The outfall to Twin Creek is at RM 33.7.

Design flow (0.075 MGD) was exceeded in the monthly operational report 1.1% of the time during the 2000-2006 time period. The mean flow was 0.0345 MGD from 2001-2006. The majority of design flow exceedences occurred during 2006 (24 of 26 events). This corresponds with six new animal care facilities being brought online in 2006.

Iams Lewisburg reported 99 NPDES permit violations between 2001 and 2006. Violated parameters included 20 TSS, 39 ammonia-N, 32 $CBOD_5$ (Carbonaceous Biochemical Oxygen Demand), 4 fecal coliform, 1 pH, and 3 oil and grease. The majority of violations occurred in 2005 (22) and 2006 (48) for 71% of total violations. Inadequate preventative maintenance leading to the breakdown of equipment and lack of backup equipment caused problems in the past. Analytical lag time caused treatment problems and exceedences to continue for days until the lab results were received.

On July 13, 2005, Ohio EPA sampled Twin Creek RM 33.7 during a plant upset. A blue/black discharge and solids from the outfall were observed in a side channel entering Twin Creek upstream from the sampling location. Water column phosphorus (0.893 mg/l) and ammonia (0.135 mg/l) were above the nutrient guidelines (90^{th} percentile wadeable values; 0.220 mg/l and 0.096 mg/l respectively) and nitrates-nitrites (4.73 mg/l) were just below the nutrient guideline (4.84 mg/l). Iams reported this spill on July 14. This was one of 20 plant upsets reported in Ohio EPA spill reports from 2001-2006.

The results from the survey indicated the sampling location downstream of Iams, Twin Creek RM 33.7, was over the nutrient guidelines for all sampling events for phosphorus (median 0.89 mg/l), 4 of 5 times for ammonia (median 0.14 mg/l), and 2 of 5 times for nitrate (median 4.73). Despite all these problems, Twin Creek RM 33.7 is in full attainment of EWH criteria. This indicates that Twin Creek exhibits good assimilative capacity.

Iams has responded to these problems by investing $200,000 in repairs and operational changes to implement a preventative maintenance program, in-line sample testing and additional checks to reduce the amount of time between lab test results and equipment break down. Further WWTP improvements are under investigation and study.

North American Nutrition (Formerly Carl Akey Co.: Twin Creek RM 33.9)
The North American Nutrition Company is located at 6531 SR 503 in Lewisburg, Ohio. The facility packages dry vitamin, minerals and second generation antibiotics for feed additives used in the livestock feed industry. Complete feeds are pelleted.

A WWTP was built in 1993 with a design capacity of 5894 gallons per day. Median flow since 2001 has been 980 gallons per day discharging to Twin Creek at RM 33.9. Conduit flow has exceeded the design flow 9.1% times from 2001 to 2006. The majority of events (77.8%) exceeding design capacity have occurred in 2005 (80) and 2006 (71).

Wastewater is primarily from sanitary service and truck washing operations. Pretreatment of truck wash wastewater is carried out in a 4800 gallon aerated holding tank with a 1000 gallon trash trap. Sanitary sewage and pretreatment wash water is collected in a 3300 gallon aerated equalizer tank and then fed into an extended aeration tank with a 29 hour detention time. Sludge is conveyed to a sludge holding tank and sent to a sludge drying bed prior to land application. Effluent is treated in a single hopper clarifier, sent to a fixed media clarifier and then sand-filtered prior to chlorination and dechlorination.

In 5 years (2001-2006), the North American Nutrition Company has had 31 NPDES permit violations. Parameters violated include 2 TSS, 8 ammonia-N, 12 $CBOD_5$, 8 fecal coliform, and 1 chlorine. Forty-five percent of the violations happened in 2001.

West Alexandria WWTP (Twin Creek RM 26.97)
The West Alexandria WWTP is located at 33 DeSoto Drive in West Alexandria, Ohio. The plant was built in 1939 and upgraded in 1972 and in 1990. Repairs to broken treatment equipment at the plant were conducted in 2003. Population in the service area is 1500 persons. The design flow is 0.3 MGD with the median flow of 0.165 MGD since 2001. Conduit flow has exceeded the design flow 4.5% of the time from 2001 to 2006. Discharge to Twin Creek is at the US 35 bridge at RM 26.97.

Influent passes through a comminutor (grinder) and is pumped to a sequencing batch reactor. Following the aeration phase, the wastewater is settled, allowing the solids to fall out of solution. After settling, the wastewater is sent to the chlorine contact basin. Chlorinated effluent is dechlorinated, sent to a post aeration chamber and discharged. Untreated sewage is bypassed when either one of the four lift stations fails or the plant is overwhelmed by incoming sewage mixed with stormwater. West Alexandria has an inflow and infiltration problem due to the aging collection system.

In 5 years (2001-2006), the West Alexandria WWTP has had 265 NPDES permit violations. Parameters violated include 45 $CBOD_5$, 30 TSS, 115 dissolved oxygen, 57 pH, 17 fecal coliform, and 1 oil and grease. Sixty percent of the violations occurred in 2003. Violated parameters included 91 dissolved oxygen, 40 pH and 13 total suspended solids. West Alexandria has been issued numerous Notice of Violation letters since 2001.

West Manchester WWTP (Twin Creek RM 42.68)
The West Manchester WWTP is located at 212 Maple Street in the village of West Manchester. The plant was built in 2002 in response to failing septic systems in the village. Population in the service area is 486 persons. The design flow is 0.065 MGD with the median flow of 0.023 MGD since 2005. Conduit flow has exceeded the design flow 0.4% of the time from 2005 to 2006. Both flow exceedences were in the Fall of 2006.

Treatment consists of a trash trap, equalization tank, extended aeration, secondary settling, sand filter, and chlorination followed by dechlorination. There are no CSOs

(Combined Sewer Overflows) in the service area and there is one lift station. Discharge to Twin Creek is at the railroad bridge at RM 42.68.

No NPDES permit violations have been documented.

Preble County Sewer District #2 (Unnamed Trib. to Twin Creek, RM 29.61)
Preble County Sewer District #2 is located on Pinewood Drive in Twin Township, Preble County. It was built to service 32 homes in the Northwood Estates near Westbrook road just inside the Preble County line. The plant was built in 1975 and upgrades are planned for 2007-8. The design flow is 0.015 MGD with the median flow of 0.0224 MGD since 2001. The facility operates over design capacity 80% of the time.

Treatment consists of a trash trap, extended aeration tanks, clarifier, sand filter, chlorination and dechlorination. There are no CSOs in the service area and there is one lift station. Effluent is piped 3335 feet and is discharged at RM 4.68 to an unnamed tributary near Utz Road. The tributary enters Twin Creek at RM 29.61 just south of the mouth of Price Creek.

In 5 years (2001-2006), the Preble County Sewer District #2 has had 25 NPDES permit violations. Violated parameters include 16 total suspended solids, 5 ammonia-N, and 4 $CBOD_5$. Forty percent of violations have occurred in 2006, indicating the need for a plant upgrade.

Creekside Village Mobile Home Park, formerly Twin Valley Mobile Home Park (Twin Creek RM 26.9)
Twin Valley Mobile Home Park was a major problem identified in the 1995 Twin Creek report. Raw sewage was entering Twin Creek at RM 26.9 downstream from the West Alexandria discharge at US 35 (RM 26.97) Impacts to the benthic community were observed.

Creekside Village Mobile Home Park is located at 6405 US 35 in West Alexandria. The plant was built in the 1950s and upgraded in 2005. The design flow is 0.0045 MGD with the median flow of 0.0027 MGD since 2005. There have been no permit violations since 2005.

Treatment consists of an aeration tank, settling basin and return sludge handling, sand filter, chlorination and dechlorination. Currently there are 3 trailers in service with expected growth to 15 units. There are plans to connect to the West Alexandria sewer system in the future.

Verona WTP (Swamp Creek RM 5.45)
The Verona Waterworks treats approximately 42,000 gallons of drinking water each day. Every two weeks the iron and manganese filters use up to 2000 gallons each to backwash. The median discharge per month is 2460 gallons. Discharge is to Swamp Creek (RM 5.45), 150 yards downstream of the Verona-Georgetown bridge.

In 5 years (2001-2006), the Verona WTP has had 30 NPDES permit violations. There have been a total of 24 Total Suspended Solid violations, 2 pH, and 4 iron violations.

Verona WWTP
Verona WWTP is under construction in 2007.

Eldorado WWTP (Price Creek RM 13.28)
Eldorado WWTP is located at State Route 726 in the village of Eldorado and discharges to Price Creek at the SR 726 bridge (RM 13.28). The plant was built in 1980 and was upgraded in 1996. Population in the service area is 543 persons in 212 households.

The design flow is 0.1 MGD with the median flow of 0.0412 MGD since 2001. Conduit flow has exceeded the design flow 3.5% times since 2001. Conduit flow has exceeded the design flow most noticeably in 2003 (22 events) and 2006 (19 events).

Treatment consists of a bar screen, equalization tank, extended aeration, rapid sand filter, aerobic sludge digester, sludge drying bed and disinfection with sodium hypochlorite followed by dechlorination with sodium bisulfite. There are no CSOs in the service area and there is one lift station.

In 5 years (2001-2006), the Eldorado WWTP has had 84 NPDES permit violations. Parameters in violation included 79 chlorine, 1 total suspended solid, 2 pH, 1 ammonia, and 1 fecal coliform. The majority of the violations happened in 2002 (21) and in 2003 (57).

Chemical Water and Sediment Quality

Upper Twin Creek
The headwaters of the mainstem start in the vicinity of Maple Swamp Ditch, in the hydric soils of Darke County. Sites at RM 46.56 and 42.1 are sediment-laden and channelized. The flow gradients are low and the water stagnates during the summer. Downstream at RM 38.0, north of Lewisburg, the geology changes and the stream flows over bedrock. South of U.S 40 in Lewisburg, the substrate becomes dominated by sand, gravel and cobbles and gradient increases.

Water column cadmium, chromium, copper, mercury, nickel and selenium were found to be at or below the detection limit at all mainstem sites on upper Twin Creek. Water column calcium, iron, manganese, magnesium, zinc, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

Naturally-occurring arsenic is found in the Silurian carbonate deposits around Lewisburg. The upper parts of Swamp Creek, Tributary to Swamp Creek, Maple Swamp Ditch, Dry Fork, Millers Fork, and upper Price Creek are in this elevated arsenic area. Arsenic levels are above background levels, but are below the water quality standard of 150 µg/l OMZA. In 1997, USEPA initiated a 1.5 million dollar excavation and removal of printing waste disposed on a farm at 2518 Swishers Mill Road north of Lewisburg. Twin Creek (RM 39.37) and Dry Fork (RM 0.15) cross the property. As a result of the drum removal, drinking water wells were sampled in the vicinity of the property. Elevated levels of arsenic were detected in the wells and it was believed an arsenic plume was emanating from the site. Residential wells near the site were found to have arsenic present as high 494 µg/l. Drinking water wells within a 4 mile radius (655 wells) were sampled and 28 residential wells were above the Removal Action Level for metals. Point of entry water treatment systems were installed in 27 residences. The results of the Lewisburg drum removal study found that no significant contamination was leaving the site. The groundwater arsenic contamination was found to be from natural sources.

During the 2005 study, no significant concentrations of volatile or semivolatile organic compounds were detected in the sediment samples taken in Twin Creek or Dry Fork. No metals above the Ohio Sediment Reference Values were detected in Dry Fork or Twin Creek.

Exceedences of water quality criteria were documented for dieldrin and heptachlor epoxide at RMs 38.0, 35.5, 34.9, 27.5, and 26.9. A heptachlor epoxide exceedence was detected at RM 33.6. One aldrin exceedence was documented at RM 27.5. Aldrin and dieldrin are similar in chemical structure. Aldrin is not toxic to insects, but upon oxidization inside the insect, it becomes toxic forming dieldrin. Most dieldrin detected in the environment is from oxidation of aldrin. Heptachlor epoxide is the metabolic byproduct of heptachlor. Heptachlor, aldrin and dieldrin are insecticides that were banned from use by EPA in 1987. These legacy compounds are still found in our environment in decreasing numbers.

Water chemistry organic analysis detected other agricultural chemicals in low levels. A common chemical was the class of hexachlorocyclohexanes, also called BHC (benzene hexachloride). The most common isomer, γ-BHC, or lindane, is used as an insecticide in agriculture and to treat head lice and scabies. There are eight isomers of BHC found in lindane. Lindane (γ-BHC) and its isomer (α-BHC) were found at RMs 38.0, 35.5, 34.9, 33.6, 31.7, and 27.5. The other isomer of lindane (δ-BHC) was found at RM 33.6. All were below water quality standards.

During the survey, atrazine and metolachlor were found across the watershed at all six organic sites at levels below any advisories. Atrazine and metolachlor are usually applied in spring and sometimes in fall to corn crops as a pre-emergent herbicide. They are mobile in water and are found in higher concentrations at high stream flows during the growing season. Atrazine is a suspected endocrine disrupter. Atrazine is usually the dominant agricultural chemical found in the watershed. Low levels of atrazine during the survey are attributed to the lack of rainfall events during the survey. Higher levels of Atrazine and metolachlor were documented during higher stream flows at the sentinel sites.

The headwater site at RM 42.1 fell below the dissolved oxygen 24 hour average of 6.0 mg/l on four of five sampling events. Three of the events were below the EWH dissolved oxygen minimum of 4.0 mg/l. On July 27, five of the seven mainstem sites were below the WWH 24 hour average (Figure 14).

Phosphorus concentrations were above the 90th percentile wadeable value (0.22mg/l) downstream of the Lewisburg WWTP (RM 34.9) 3 of the 5 sampling events (median 0.24 mg/l), and noticeably above the 90th percentile wadeable value downstream of the Iams discharge (RM 33.6) during all sampling events (median 0.89 mg/l). Maximum concentration was 3.15 mg/l (Figure 14) at this site. Dissolved phosphorus was sampled three times (July 27, August 10, and September 7) in Twin Creek (RM 35.5) downstream of Swamp Creek. Dissolved phosphorus was only detected on the September 7 sampling event. In that sampling event, dissolved phosphorus (0.056 mg/l) made up 38.4% of total phosphorus (0.146 mg/l).

A sample was taken on September 15, 2005 to document an obviously contaminated drainage tile near the town of Castine on SR 722. This tile drained into Twin Creek at RM 46.55. Analytical results documented ammonia at 10 mg/l, fecal coliform at 60,000 colonies/100ml and E. coli at 67,000 colonies/100ml. Both bacteria samples were submitted past holding time, but are a good screening tool to document failing septic systems in the watershed near Castine.

Six sites on the mainstem were sampled for sediment contamination. Sediments in Twin Creek mainstem were free of organic contamination with the exception of the occasional acetone detection. This was most likely a lab contamination. None of the 18 metals evaluated exceeded the Ohio Sediment Reference Values (SRV). Sediment arsenic at RM 38.0 (11.1 mg/kg) and 27.5 (10.0 mg/kg) was between the MacDonald Sediment Quality Guideline Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC). Adverse effects frequently occur in this range, but in the case for arsenic, the OHIO SRV indicates the level was within the expected range for Ohio. Sediment ammonia was above the Ontario Disposal Guideline (100 mg/Kg) (Persuad and Wilkins, 1976) at Twin Creek RM 27.5 (130 mg/kg) and RM 26.7 (170 mg/kg). The site at RM 27.5 is beautiful with good riparian and substrate, but it is surrounded by farmland. Runoff from land-applied animal wastes is the suspected source of contamination. The site at RM 26.7 is downstream from the West Alexandria WWTP. During the survey, sediment embeddedness was observed at RM 26.7. Solids are frequently discharged from the West Alexandria WWTP as the plant has been out of compliance for years.

Datasonde© continuous recorders were placed in six locations on the mainstem to determine the diel swings in pH, temperature, conductivity and dissolved oxygen (Figure 15). The first sonde placement (July 12-14) corresponded with a minor rainfall event (0.2 in) and the second placement was during low flow conditions (August 9-11). Wide swings in dissolved oxygen occurred during both sonde placements. The swings were more pronounced downstream of the Lewisburg WWTP outfall (RM 34.9). Dissolved oxygen swings from below the EWH minimum (5.0 mg/l) to supersaturation (150%) are indicative of algae blooms. The most noticeable dissolved oxygen swing was downstream of the West Alexandria WWTP (RM 26.7). The widest diel swing for pH occurred at this site also. There is a correlation between pH and dissolved oxygen from algae blooms. Mainstem conductivity was in a narrow band (600-700µmhos/cm) for all sites with the exception of downstream of Iams on the August 9-11 run. Wide swings in conductivity at RM 33.6 were related to a plant upset sampled on August 10 documenting elevated levels of undertreated wastewater including nitrate (14.6 mg/l) and phosphorus (3.15 mg/l).

Maple Swamp Ditch

The main channel of Maple Swamp Ditch flows through hydric soils (Brookstone) of low gradient. It enters Twin Creek at RM 47.03. Hydromodification from county ditch maintenance prevents riparian cover and any natural sinuosity to occur. Algal mats and sedimentation resulting from the habitat modification impacted the stream. Water column ammonia levels were over the 90^{th} percentile headwater value (0.1 mg/l) 1 of 5 sampling events at RM 2.4 and 1 of 5 times at RM 1.4 (Table 11). Nitrate and phosphorus samples were below their respective 90^{th} percentile headwater value. Dissolved oxygen at the headwater site had median percent oxygen of 203.5% (supersaturation). Water temperature was measured at a high 30^0 C on August 10. Filamentous green algae were in abundance due to no riparian cover and potential nutrients stored in the heavy sediment load.

Dry Fork

Dry Fork is 1.4 miles long and drains 5.76 mi^2 of Preble County farmland into Twin Creek (RM 39.37) north of Lewisburg. The stream tends to go interstitial during the summer months and has heavy algal growth. Dissolved oxygen ranged from 4.57 mg/l (below the WWH 24 hour average) on July 27 to supersaturation during the next two sampling events. Water column ammonia levels were over the 90^{th} percentile headwater value (0.1 mg/l) 2 of 5 times at RM 0.80 (median 0.087 mg/l). Water column phosphorus levels were over the 90^{th} percentile headwater value (0.206 mg/l) 3 of 5 times at RM 0.80 (median 0.210 mg/l). Nitrate samples were below the 90^{th} percentile headwater value.

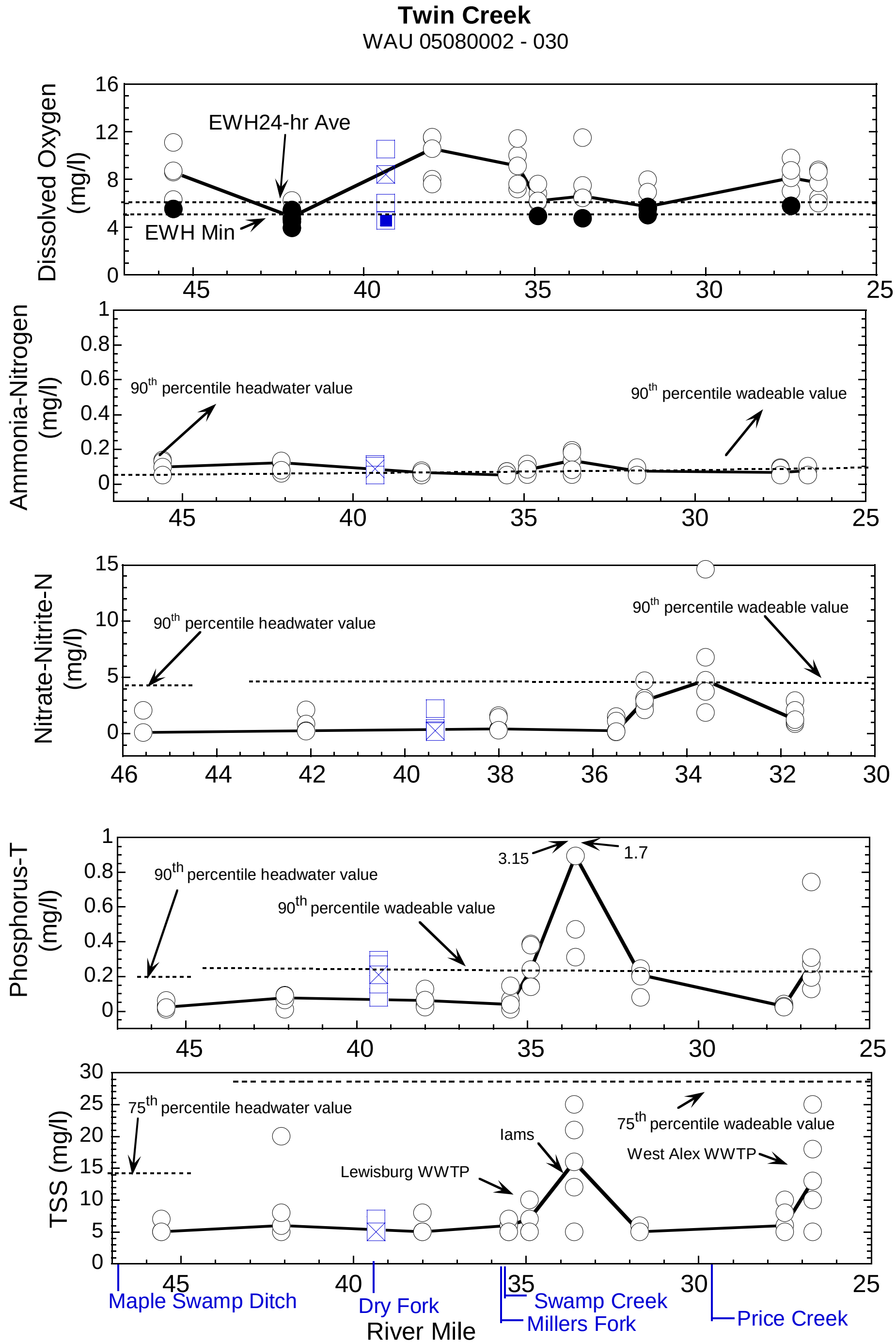


Figure 14. Longitudinal plots of water chemistry daytime grabs in Twin Creek during the 2005 survey. Top to bottom: dissolved oxygen, ammonia-N, nitrate-nitrite-N, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile. WQS criteria are shown in 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.

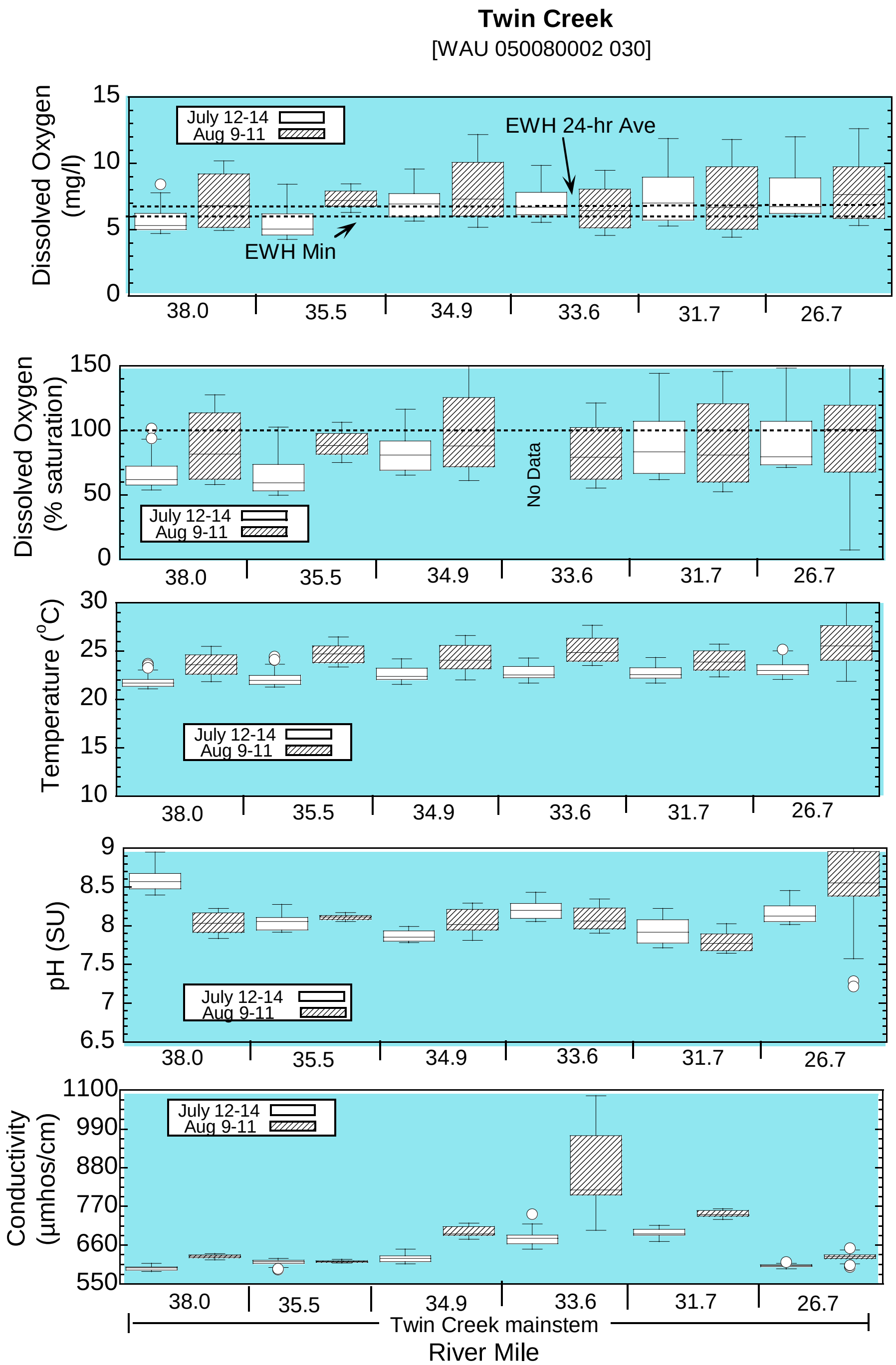


Figure 15. Distributions of dissolved oxygen, temperature, pH, and conductivity recorded hourly with Datasonde© monitors in Upper Twin Creek 2005. Each box encloses 50% of the data with the median value displayed as a line. The top and bottom of the box mark the 75^{th} and 25^{th} percentile. The lines extending from the top and bottom of the 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.

Millers Fork

Millers Fork is 10.6 miles in length, draining 24.2 square miles of farmland in lower Darke and upper Preble Counties. The headwaters are characterized by rolling farmland with defined drainage patterns having hydric soils in much of the stream bottom. Millers Fork is under the county ditch maintenance program in the headwaters, therefore the streambed is channeled and riparian growth is removed. In addition, there are several large livestock operations in the watershed and failing septic systems are suspected in the watershed as well.

Water column cadmium, chromium, copper, mercury, nickel, and selenium were found to be at or below the detection limit at all sites on Millers Fork. Water column calcium, iron, manganese, magnesium, zinc, hardness, BOD_5, chloride, and sulfate were within acceptable ranges. Ammonia was over the 90^{th} percentile headwater value (0.1) on 11 of 14 sampling events.

The headwater site at RM 10.78 went dry during the August sampling event. Dissolved oxygen was below EWH minimum of 5.0 mg/l on all sampling events (Figure 16). Ammonia exceeded the 90^{th} percentile headwater value (0.1 mg/l) on 3 of 4 events, with a median value of 0.35 mg/l. Median phosphorus at this site was 0.364 mg/l, above 90^{th} percentile headwater value (0.206 mg/l).

Millers Fork RM 7.96 at Clark Road improved slightly in water quality. Riparian corridors were wider. There was one water column dissolved oxygen exceedence of the 24-hour average. Water column phosphorus and nitrate were below the 90^{th} percentile headwater value. Ammonia still exceeded the 90^{th} percentile headwater value on 4 of the 5 sampling events (Table 11).

A microbial film covered the surface of Millers Fork RM 3.8 throughout most of the summer. Riparian corridors shade the stream at this site. Water column ammonia exceeded the 90^{th} percentile headwater value on 4 of the 5 sampling events (median 0.160 mg/l). Water column phosphorus (median 0.12 mg/l) and Nitrates (median 0.10 mg/l) were below the 90^{th} percentile headwater value on all sampling events. A major log jam downstream of RM 3.8 caused stagnant flow. Dissolved oxygen was below the EWH minimum 4/5 times. This site was degraded with major embeddedness and TSS levels exceeded the 75^{th} percentile headwater values on 4 of the 5 sampling events.

Datasonde© continuous recorders were placed at RM 3.95 during July and August. The results documented continuous dissolved oxygen levels below the EWH minimum for both sonde placement dates for all hours monitored. Algal mats were present at the site, however the Datasonde© results did not follow conventional dissolved oxygen swings associated with photosynthesis of algae. In addition, pH, conductivity, and temperature did not fluctuate as would be expected for an algae-influenced water column. The combination of algae with shade may be a factor in these abnormal Datasonde© results.

The geometric mean of Millers Fork RM 3.95 was calculated based on five sampling events for bacteria in September 2005. *E.coli* was documented at 150 colonies/100 ml; an exceedence of the Primary Contact Recreational Water Quality Standard (PCR WQS) of 126 colonies/100 ml. Fecal coliform (500 colonies/100ml) was below the PCR WQS of 1000 colonies/100 ml. *E.coli* was over the PCR WQS maximum (298 colonies/100 ml) on the dry weather day of September 12.

A tile to Millers Fork (RM 10.78) at Grubbs-Rex Road was sampled on July 27, 2005 due to a suspicious discharge observed entering Millers Fork. Analytical results documented ammonia at 27 mg/l, fecal coliform at 60,000 colonies/ 100ml and E. coli at 80,000 colonies/100ml. Both bacteria samples were submitted past holding time, but are a good screening tool to document failing septic systems in the area.

A tributary to Millers Fork (RM 8.0) draining the unsewered community of Ithaca, was sampled on September 7, 2005. The tributary had indications of sewage discharge. Analytical results documented ammonia at 7.43 mg/l, Fecal coliform at 6100 colonies/100ml and E. coli at 3200 colonies/100ml. Both bacteria samples were submitted past holding time, but are a good screening tool to document failing septic systems in the community of Ithaca.

Sediment samples were collected at Millers Fork RM 3.9. The organochloride chemicals DDD (**D**ichloro**d**iphenyl**d**ichloroethane) and DDE (**D**ichloro**d**iphenyl dichloro**e**thylene were detected in sediment above the MacDonald Threshold Effect Concentration (TEC), in which adverse effects frequently occur in benthic organisms. Both DDE and DDD are breakdown products of the legacy pesticide DDT (**D**ichloro**d**iphenyl**t**richloroethane). DDT use was banned in the United States in 1972, but it and its breakdown products strongly bind to sediment particles.

Swamp Creek

Swamp Creek watershed comprises 5.7% (11520 acres or 18 mi^2) of the Twin Creek watershed. It is 7.3 miles long and drains the flat farmland soils of western Montgomery and Eastern Preble County. The main channel and tributaries are made up of hydric Brookstone soils in Montgomery County and hydric Kokomo and Sloan soils in Preble County. As Swamp Creek enters Preble County near Sonora Road north of Lewisburg, the soils become rockier and better-drained. The use designation changes to Exceptional Warm Water Habitat with wider riparian corridors and less siltation of the substrate.

The upper site at RM 6.3 is low gradient, draining farmland in hydric Brookstone soils, with channelization and narrow riparian cover. Siltation and nutrient enrichment are impacting water quality. Exceedences of water quality criteria for dissolved oxygen were recorded on three of five sampling events. Ammonia–N exceeded the benchmark 90^{th} percentile headwater value (0.096 mg/l) on all five sampling events (median 0.197 mg/l). Water column phosphorus was elevated above the benchmark 90^{th} percentile headwater value (0.206 mg/l) on 3 of the 5 sampling events (median 0.211 mg/l).

Exceedences of water quality criteria at Swamp Creek RM 0.2 were documented for *E. coli*, fecal coliform, dissolved oxygen, dieldrin and heptachlor epoxide. The bacterial geometric mean documented *E. coli* at 416 colonies/100ml, an exceedence of the Primary Contact Recreational Water Quality Standard of 126 colonies/100 ml. *E. coli* was over the PCR WQS maximum (298 colonies/100 ml) on both wet weather events (September 9 and 21). No exceedence of the geometric mean for fecal coliform was documented. One exceedence of the fecal coliform PCR WQS maximum (2000 colonies/100 ml) was documented on September 9.

Failed septic systems in the village of Verona contributed to biological and organic enrichment to Swamp Creek in 1995. This problem was not resolved as of the 2005 survey but a new wastewater treatment plant designed to treat 85,000 gallons per day is under construction in 2007. The discharge from the plant will be to Swamp Creek near RM 5.5. In addition to septic problems from the village of Verona, the surrounding farmland drains farm tiles to the tributaries and mainstem. Farming practices include the land application of manure from local farms and one hog CAFO in the watershed. Aging septic systems (30+ years old) in the farming community also can contribute bacterial and organic enrichment to Swamp Creek.

One sediment sample was obtained from Swamp Creek at RM 0.2 (Tables 12 and 13). No organic compounds were detected in the sediment and all other parameters were found to be within the Ohio, MacDonald, and Persuad guidelines.

Swamp Creek at RM 0.2 was a sentinel site; chemical samples and stream flow data were collected throughout the year. Inorganic and nutrient chemical analyses were conducted on 10 events and organic analyses were conducted on 4 events outside the survey. One sampling event was not conducted due to Swamp Creek becoming interstitial during August. Table 9 demonstrates seasonal agricultural impacts to Swamp Creek.

Nitrate-nitrite-N levels were documented over the 90^{th} percentile background level on 7 of 10 events. Ammonia-N levels were documented over the 90^{th} percentile background headwater level (0.096 mg/l) on one event. One CAFO is in the Swamp Creek watershed, where many millions of gallons of liquid manure is land-applied. Hog manure is applied to wheat fields after harvest in early July. Manure is also applied to farm fields after corn and beans are harvested in fall. What is more notable is that 6 of 10 events recorded ammonia below the detection limit (0.05 mg/l). Liquid manure, when correctly applied to the soil, should oxidize ammonia to nitrate. Total phosphorus was only detected over the 90^{th} percentile background wadeable level (0.220 mg/l) on October 25, 2005. Phosphorus levels were generally low despite high flow events.

Table 9. Sentinel site sampling at Swamp Creek RM 0.2 demonstrating the relationship between higher flows and elevated water column nutrients.

Date	Discharge ft^3/sec	Velocity ft/sec	Discharge ft^3/sec Twin Creek RM 9.8	NO_3-NO_2-N mg/l	P total mg/l	NH_3-N mg/l	Atrazine(µg/l)
4/14/2005	4.28	0.154	119	5.00	<0.01	<0.05	>0.51
5/17/2005	11.1	0.363	274	9.66	0.235	0.096	1.66
6/30/2005	1.82	0.118	68	4.58	0.105	0.051	ND
7/21/2005	0.5	0.222	32	1.16	0.115	0.128	ND
8/23/2005	**Dry**	**Dry**	10	ND	ND	ND	ND
9/22/2005	1.94	0.114	58	3.65	0.106	<0.05	ND
10/25/2005	59.0	1.05	831	13.3	0.098	<0.05	ND
11/21/2005	11.1	0.385	200	8.13	0.052	0.104	ND
1/12/2006	22.1	0.66	654	9.36	0.048	<0.05	0.24
2/02/2006	ND	ND	95	8.75	0.024	<0.05	ND
4/26/2006	13.6	0.411	349	7.29	0.018	<0.05	3.36

ND- not done
red= above the 90^{th} percentile for nutrients in headwater (<$20mi^2$) streams found in Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999)

Tributary to Swamp Creek

This stream is on the eastern edge of Verona and has been channelized for farm field drainage. The majority of the creek is characterized with little to no riparian cover. The sampling site had narrow riparian cover with little or no flow. The channel was covered in duckweed. Dissolved oxygen was below the WWH minimum criteria of 4.0 mg/l on all sampling events, with a minimum value of 1.6 mg/l. Ammonia exceeded the 90^{th} percentile headwater value on all five sample events with the maximum value of 0.988 mg/l. Phosphorus concentrations were elevated above the 90^{th} percentile headwater value on 4 of the 5 sampling events with the maximum value of 0.548 mg/l. No bacteria were sampled at this site. Failing septic systems are suspected in the watershed and documented in the village of Verona.

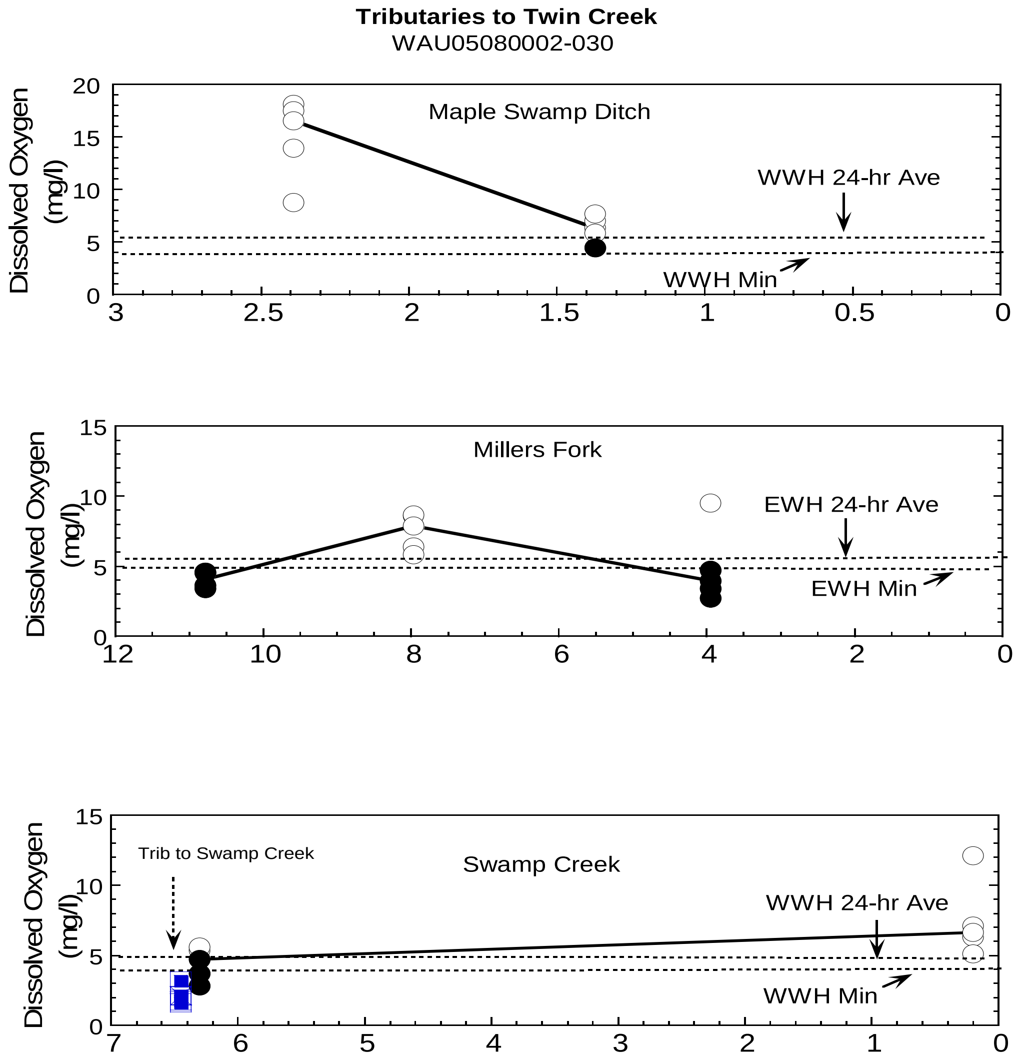


Figure 16. Longitudinal plots of water chemistry daytime dissolved oxygen grabs in Twin Creek tributaries during the 2005 survey. Tributary mainstem is indicated by circles and tributaries of tributaries are indicated by squares. The solid line indicates median value of each river mile sampled while an 'X' depicts the median for the tributary of tributaries.

Price Creek

Price Creek is 14.6 miles in length, draining 18,854 acres (29.46 mi^2) of farmland in lower Darke and Preble Counties. North of Lewisburg, the headwaters are characterized by flat to rolling topography with defined drainage patterns having hydric soils in the much of the stream bottom. Use designations change from WarmWater to Exceptional WarmWater habitat at RM 6.5 near the Geeting Covered Bridge west of Lewisburg. Price Creek enters Twin Creek at RM 29.74 upstream of West Alexandria and contributes to 9.3% of the Twin Creek drainage area.

Water column cadmium, chromium, copper, mercury, nickel, and selenium were found to be below the detection limit at all sites. Water column calcium, iron, manganese, magnesium, zinc, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

Elevated nutrients at the headwater site (RM 13.7) are most likely from agricultural influences and a failing septic system in the immediate area. Dissolved oxygen was below the WWH average of 5.0 mg/l on 3 of 4 sampling events. Ammonia exceeded the 90^{th} percentile headwater value (0.10 mg/l) on 3 of 4 events (Median 0.158). Phosphorus was elevated above the 90^{th} percentile headwater value (0.206 mg/l) on 1 of 4 events (Median 0.196). Dissolved phosphorus was sampled two times (July 27 and September 7) on Price Creek (RM 13.7) upstream of the Eldorado WWTP. The July 27 sampling event documented dissolved phosphorus (0.134 mg/l) making up 69.4% of total phosphorus (0.193). The September 7 sampling event had dissolved phosphorus (0.142 mg/l) making up 45.2% of total phosphorus (0.314mg/l).

Price Creek RM 10.9 is downstream of the Eldorado WWTP. Ammonia exceeded the 90^{th} percentile headwater value (0.10 mg/l) on 4 of 5 events (Median 0.124). Phosphorus was elevated above the 90^{th} percentile headwater value (0.206 mg/l) on 2 of 4 events (Median 0.203).

Sediment samples were obtained from Price Creek near the mouth (RM 0.6) and at the headwater site at RM 13.6 (Tables 12 and 13). No parameters of concern were detected at the RM 13.6 site. Dieldrin was found at RM 0.60 between the MacDonald TEC and PEC, meaning adverse effects are likely to occur. Arsenic was found to be over the MacDonald TEC, but below the Ohio SRV indicating that it falls within the acceptable ranges for Ohio. Sediment ammonia was 1000 mg/l, over the Ontario Open Water Disposal Guidelines (100 mg/l) (Persuad and Wilkins, 1976). This site, RM 0.60, had the highest sediment ammonia found in the Twin Creek basin. Land application of animal manure is a suspected source.

Water column bacteria (Fecal coliform, *E. coli*) were monitored five times during September 2005, at the sentinel site at RM 0.6 and at the headwater site at RM 13.7. Two sampling days were considered dry weather events (September 8 and 12) and for three days, wet weather influenced events (September 9, 21 and 22). Samples taken on September 9 and 21 were close to sampling the first flush of runoff. September 22 caught the dilution effect. The headwater site (RM 13.7) had an *E. coli* geometric mean for 5 sampling events of 502 colonies/100ml, an exceedence of the PCR WQS geometric mean standard of 126 colonies/100ml. Failing septic systems were indicated due to dry weather exceedences of the PCR WQS maximum of *E. coli* (298 colonies/100 ml). Results from September 8 had 310 colonies/100 ml and September 12 had 370 colonies/100 ml. The September 21 wet weather event (1.3 inches on September 19-20) had an *E. coli* PCR WQS maximum exceedence of 23,000 colonies/100ml and a fecal coliform exceedence of 20,000 colonies/100 ml. The sentinel site at RM 0.6 did not document PCR WQS geometric mean exceedences for *E. coli* or for fecal coliform. PCR WQS maximums were exceeded at RM 0.6 during the wet weather event of September 21 for total fecal coliform (2500 colonies/100 ml) and for *E.coli* (800 colonies/ 100 ml).

Price Creek at RM 0.6, a sentinel site, has a drainage area of 29 mi^2. During the 2005 survey, no nutrients were detected over the 90^{th} percentile background level. Inorganic and nutrient chemical analyses were conducted on 11 events and organic analyses were conducted on 5 events outside the survey. Table 10 demonstrates seasonal agricultural impacts to Price Creek. Nitrate-nitrite-N levels were documented over the 90^{th} percentile background level on 4 of 11 events. Non-growing season nitrate discharges are documented in Table 10. These are most likely from farm field drainage tiles draining nitrate-rich soils in contact with ground water. Ammonia-N levels were documented over the 90^{th} percentile background wadeable level (0.096 mg/l) on 3 events. What is more notable is that 6 of 11 events recorded ammonia below the detection limit (0.05 mg/l). Total phosphorus was only detected over the 90^{th} percentile background wadeable level (0.220 mg/l) on October 25, 2005. Phosphorus levels were generally low despite high flow events.

Table 10. Sentinel site sampling at Price Creek RM 0.60 demonstrates the relationship between higher flows and elevated water column nutrients.

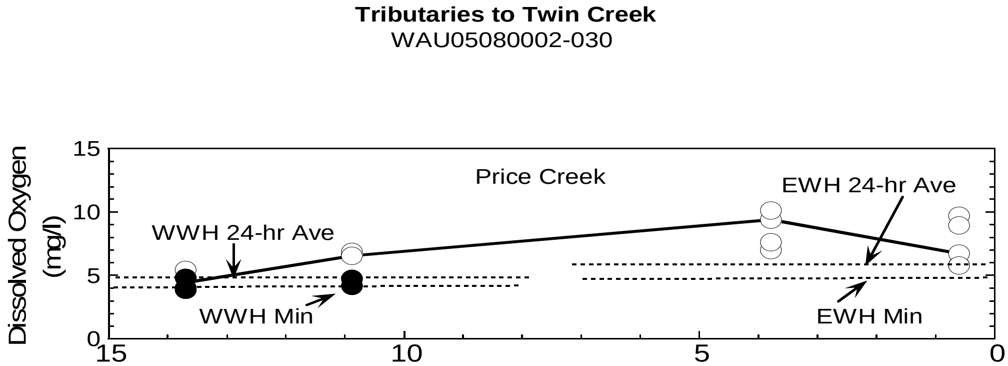
Date	Discharge ft^3/sec	Velocity ft/sec	Discharge ft^3/sec Twin Creek RM 9.8	NO_3-NO_2-N mg/l	P total mg/l	NH_3-N mg/l	Atrazine µg/l
4/14/2005	9.1	0.187	119	2.46	0.015	<0.05	<0.20
5/17/2005	24.2	0.361	274	8.16	0.055	0.103	8.08
6/29/2005	3.84	0.209	55	2.15	0.037	<0.05	1.45
7/21/2005	2.67	0.105	32	1.14	0.011	0.112	ND
8/23/2005	0.896	0.037	10	0.66	0.065	0.069	ND
9/22/2005	4.67	0.11	58	3.75	0.043	.0.58	ND
10/25/2005	80.5	1.32	831	8.16	0.324	<0.05	ND
11/21/2005	8.98	0.185	200	4.75	0.033	0.142	ND
1/12/2006	35.0	0.8	197	5.59	0.077	<0.05	0.27
2/02/2006	ND	ND	95	5.34	0.031	<0.05	ND
4/26/2005	15	0.342	358	3.12	0.011	<0.05	0.24

ND- not done
red= above the 90^{th} percentile for nutrients in wadeable (20-200 mi^2) streams found in Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999)

Lesley Run
Lesley Run is 8.5 miles in length, draining 5325 acres (8.32 mi^2) of farmland in Eastern Preble and Western Montgomery Counties. The stream begins at Westbrook Road west of Brookville and flows south, parallel and close to the County Line Road. At US 35, Lesley Run begins to head southeast entering Twin Creek at RM 24.60 south of West Alexandria.

The headwaters are slow-flowing and silt-laden, with little or no riparian cover. Downstream from US 35, the substrate becomes represented by more cobble and rock, has better riparian cover, and has much greater soil permeability. The headwater site at RM 6.0 was observed to be very turbid, even when no rainfall has occurred, indicating cattle in the stream. A definite impact was documented at the US 35 bridge (RM 3.56). Ammonia levels exceeded the 90^{th} percentile headwater value (0.1 mg/l) during all sampling events, with a median of 0.3 mg/l. Dissolved oxygen below the WWH minimum of 4.0 mg/l was also documented during all sampling events.

The site at RM 3.56 was sampled for bacteria five times in September 2005. Geometric median values for fecal coliform (1080 colonies/100 ml) and *E. coli* (526 colonies/100 ml) were in exceedence of the Primary Contact Recreational Water Quality Standards. *E. coli* levels were high during wet and dry sampling events. The dry sampling events of September 8 and 12 documented 1100 and 690 colonies/100 ml. The wet sampling events of September 8 and 21 documented 1800 and 410 colonies/ 100 ml.



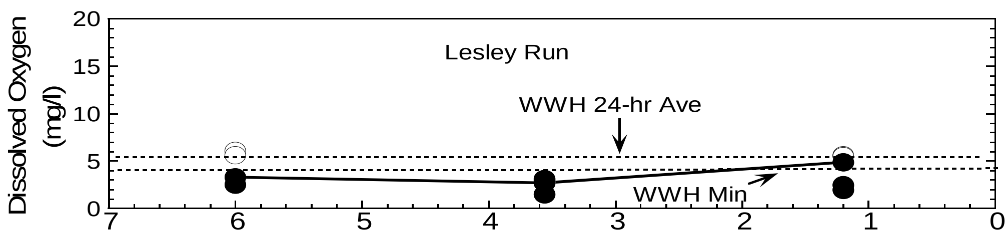


Figure 17. Longitudinal plots of water chemistry daytime dissolved oxygen grabs in Twin Creek tributaries during the 2005 survey. Tributary mainstem is indicated by circles and tributaries of tributaries are indicated by squares. The solid line indicates median value of each river mile sampled while an ‘X’ depicts the median for the tributary of tributaries.

Table 11. Nutrient evaluation of Twin Creek tributaries in WAU 05080002-030 during the 2005 survey using Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999).

Stream (RM)	**area mi^2**	**Frequency of Phosphorus >90th Percentile**	**Phosphorus Median(mg/)**	**Frequency of NH_3 >90th Percentile**	**NH_3 Median (mg/l)**	**Frequency of NO_3 >90th Percentile**	**NO_3 Median (mg/l)**
Price Creek (13.7)	5.2	1/ 4	0.1955	3 / 4	0.1575	0 /5	0.1
Price Creek (10.9)	11.4	2/ 5	0.203	4/5	0.124	0 / 5	0.55
Price Creek (3.8)	20.1	0 /5	0.030	1/5	0.065	0 / 5	2.46
Price Creek (0.6)	29.0	0 / 5	0.012	0/5	0.06	0 /5	0.84
Lesley Run (6.00)	5.0	0/5	0.131	0/5	0.05	0/5	0.1
Lesley Run (3.60)		3/5	0.221	5/5	0.297	0/5	0.41
Lesley Run (1.20)	7.7	2/4	0.189	1/4	0.0855	0/4	0.27
Swamp Creek (6.3)	8.7	3/5	0.211	1/5	0.197	0/5	0.16
Swamp Creek (0.2)	18.0	0/5	0.091	0/5	0.062	0/5	0.16
Trib to Swmp (0.3)	4.7	4/5	0.366	5/5	0.625	0/5	0.13
Millers Fork (10.8)	5.7	3 / 4	0.364	3/4	0.35	0/4	.010
Millers Fork (8.00)	10.1	0/5	0.142	4/5	0.146	0/5	0.47
Millers Fork (3.95)	19.7	0/5	0.12	4/5	0.160	0/5	0.10
Dry Fork (0.80)	5.4	3/5	0.210	2/5	0.087	0/5	0.27
Maple Swamp Ditch (2.40)	5.5	0/5	0.037	1/5	0.059	0/5	0.1
Maple Swamp Ditch (1.4)	10.2	0/5	0.028	1/5	0.060	0/5	0.1

Table 12. Sediment concentrations of organic compounds (priority pollutant scan) detected in the Twin Creek watershed assessment unit (WAU 05080002 030) during 2005. Individual compounds were evaluated by the MacDonald Sediment Quality Guidelines (2000).

River / Landmark	Analysis Performed	Compound Detected	Result mg/kg unless noted
Twin Creek RM 38.0 E .Lock Rd TOC= 4.5% Fine Grain Material = 39.9 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Twin Creek RM 35.5 Dst Swamp Creek TOC= 6.1 % Fine Grain Material = 14.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Twin Creek RM 34.9 Dst Lewisburg WWTP TOC= 5.6 % Fine Grain Material = 18.6 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Twin Creek RM 31.7 Pyrmont Rd WAU 05080002 - TOC= 6.2 % Fine Grain Material = 34.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	Acetone	0.094 * BDL BDL BDL
Twin Creek RM 27.5 Stoller Rd. TOC= 6.6 % Fine Grain Material = 38.6 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Twin Creek RM 26.7 Dst. W. Alex WWTP TOC= 6.8 % Fine Grain Material = 28.7 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Millers Fork RM 3.90 Georgetown-Verona Rd. TOC= 4.0 % Fine Grain Material = 35.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	 4,4'-DDD# 4,4'-DDE#	BDL BDL 7.7 µg/kg 28.5 µg/kg BDL
Swamp Creek RM 0.2 U.S.40 TOC= 7.6 % Fine Grain Material = 43.2 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Price Creek RM 13.70 Pence- Shewman Rd TOC= 3.7% Fine Grain Material = 51.7 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Price Creek RM 0.60 Ust. SR 503 TOC= 5.3 % Fine Grain Material = 49.4 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	Acetone Dieldrin#	0.138* BDL 14.9 µg/kg BDL

* Not evaluated
NA -Compound not analyzed
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-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

Table 13. Concentrations (mg/kg) of metals and nutrients in sediment samples collected in the Twin Creek watershed assessment unit (WAU 05080002 030) 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	Site Location (RM)											
	Twin Creek RM 38.0	**Twin Creek** RM 35.5	**Twin Creek** RM 34.9	**Twin Creek** RM 31.7	**Twin Creek** RM 27.5	**Twin Creek** RM 26.7	**Millers Fork** RM 3.90	**Swamp Creek** RM 0.2	**Price Creek** RM 13.70	**Price Creek** RM 0.60	**Reference**	
											Ohio	**MacD**
Al-T O	20300	7630	11300	18400	17600	13200	16900	19800	28600	28100	39000	*
As-T OM	11.1 #	5.37	5.65	7.08	10.0 #	6.65	7.72	7.98	8.30	10.8 #	18	9.79-33
Ba-T O	188	57.4	91.0	146	114	99.5	133	130	156	180	240	*
Ca-T O	77200	61800	60100	45000	68300	55800	36300	75000	31400	63700	120000	*
Cd-T OM	0.422	0.255	0.416	0.440	0.306	0.337	0.306	0.357	0.476	0.442	0.9	0.99-4.98
Cr-T OM	<25	<14	<21	<23	20	17	23	26	30	32	40	43.4-111
Cu-T OM	10.9	6.0	14.9	14.8	10.6	14.3	11.9	13.1	11.4	16.4	34	31.6-149
Fe-T O	17000	8890	11000	14800	15900	12300	15100	16500	17900	21400	33000	*
Hg-T OM	<0.040	0.034	0.048	<0.034	0.042	0.039	0.038	0.039	0.004	0.037	0.12	0.18-1.06
K-T O	4250	2000	2820	4200	3710	3210	3830	4870	6470	6560	11000	*
Mg-T O	20800	21700	20600	12200	26000	17600	15300	25300	12700	19700	35000	*
Mn-T O	520	233	225	371	317	262	327	341	351	402	780	*
Na-T *	<4090	<2360	<3510	<3760	<3140	<2280	<2940	<3570	<3680	<3840	*	*
Ni-T OM	<33	<19	<28	<30	<25	<18	<24	<29	<29	<31	42	22.7-48.6
Pb-T OM	<33	<19	<28	<30	<25	<18	<24	<29	<29	<31	47	35.8-128
Se-T O	1.75	<0.95	<1.40	<1.50	1.41	1.08	<1.17	1.61	<1.47	1.96	2.3	*
Sr-T O	251	82	118	149	121	148	110	199	56	139	390	*
Zn-T OM	79.4	36.4	106	84.6	52.8	59.2	60.4	78.9	86.6	93.9	160	121-459
NH_3-N P	69	11	32	20	130 L	170 L	46	41	58	1000 L	*	100
TOC P	4.5 %	6.1%	5.6%	6.2 %	6.6 %	6.8 %	4.0 %	7.6 %	3.7 %	5.3 %	*	10.0%
pH *	7.6	7.8	7.7	7.6	7.5	7.7	7.5	7.7	7.4	7.3	*	*
P-T P	817	468	739	556	698	670	592	864	855	808	*	2000
%FGM O	39.9 %	14.3 % ↘	18.6 %↘	34.3	38.6%	28.7%↘	35.3 %	43.2 %	51.7%	49.4%	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 (1976, 1993)

Ohio SRV Guidelines (2003)

+ above background for this area

Ontario Sediment Guidelines (Persuad,1993, and Persuad and Wilkins, 1976)

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-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

Twin Creek (mainstem)

The assessment of the influence of physical stream features and riparian conditions on ambient biological performance for the Twin 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. This section applies to ***both*** of Twin Creek's assessment units, not just HUC 030. Detailed discussions about particular stations or reaches were limited only to the upper watershed, and therefore are included in this corresponding unit report. For the purposes of continuity, this reporting structure will also be applied to the assessment of ambient fish community performance throughout this document.

As part of the 2005 fish sampling effort, the quality of near and instream macrohabitats of the Twin Creek mainstem were evaluated at 17 sampling locations, assessing approximately 47 miles of the mainstem, between RM 46.5 (SR 722) and RM 0.1 (at mouth). QHEI values ranged between 88.5 and 43.0, with a mean score of 74.4 (±10.9 SD). Longitudinal performance of the QHEI and a matrix of macrohabitat features, by stations, are presented in Table 14 and Figure 18.

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 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.

By and large, the quality of near and instream macrohabitat throughout the entire length of Twin Creek appeared fully capable of supporting diverse, functionally organized, and well-structured assemblages of aquatic organisms, consistent with its existing EWH aquatic life use. Most sites contained a full complement 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. 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 and generally unencumbered with extensive deposits of clayey silts. Riparian areas at most sites were vegetated, more often wooded, attenuating sunlight and providing instream structure in the form of woody debris and rootwad formations.

Table 14. A matrix of macrohabitat features and QHEI scores for the Twin Creek study area, 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
(14-500) Twin Creek																																		
Year: 2005																																		
46.5	43.0	3.11									■		1	♦		♦	♦		3		●			●				●	●	●		5	2.00	4.50
42.1	75.5	5.81	■	■		■	■	■		■	■	■	8				♦		1		●			●	●			●	●			5	0.22	0.78
38.0	61.0	21.28	■							■	■	■	4				♦		1					●	●			●				3	0.40	1.00
35.5	67.0	9.43		■						■	■	■	4				♦		1	●	●		●	●	●			●	●			7	0.40	1.80
34.9	71.0	9.43		■		■		■			■	■	5						0	●	●			●	●			●	●			6	0.17	1.17
33.6	77.0	5.18	■	■		■	■	■		■	■	■	8						0		●				●			●	●			4	0.11	0.56
31.7	72.5	5.68	■	■		■	■	■		■	■		7						0				●	●				●	●	●		5	0.13	0.75
27.5	80.0	9.62	■	■		■	■	■	■		■	■	8						0	●	●			●	●				●	●		6	0.11	0.78
26.7	88.5	8.13	■	■		■	■	■	■	■	■	■	9						0		●								●			2	0.10	0.30
23.9	79.0	13.70	■	■		■	■				■	■	6				♦		1		●			●	●			●	●	●		6	0.29	1.14
19.2	76.5	8.00	■	■		■	■	■	■	■	■	■	9				♦		1						●				●			2	0.20	0.40
19.0	72.0	8.00	■	■		■				■	■	■	6				♦		1						●			●	●			3	0.29	0.71
13.4	88.0	6.54	■	■	■	■	■	■	■	■	■	■	10						0													0	0.09	0.09
9.8	74.0	5.95		■	■	■				■	■	■	6				♦		1	●				●	●			●				4	0.29	0.86
3.4	86.5	8.00	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
0.9	82.0	12.29	■	■		■	■	■	■	■	■	■	9				♦		1						●							1	0.20	0.30
0.1	71.5	12.29		■		■			■	■	■	■	6				♦		1	●				●	●							3	0.29	0.71
(14-501) Little Twin Creek																																		
Year: 2005																																		
6.2	65.5	18.87		■		■		■		■	■	■	6			♦	♦		2	●			●	●				●				4	0.43	1.00
4.7	59.5	17.24		■	■	■				■	■	■	6			♦	♦		2	●				●				●				3	0.43	0.86
2.0	77.0	17.54	■	■	■	■	■	■		■	■	■	9			♦	♦		2					●				●				2	0.30	0.50
(14-502) Toms Run																																		
Year: 2005																																		
12.0	40.5	10.00		■									1	♦		♦	♦	♦	4	●	●		●	●				●	●		●	7	2.50	6.00
8.5	58.5	12.50	■	■				■			■		4			♦	♦		2		●		●	●				●	●		●	6	0.60	1.80
0.4	82.0	15.87	■	■	■	■	■	■		■	■	■	9						0									●				1	0.10	0.20

Table 14 continued.

Key QHEI Components

WWH Attributes

Stream / 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
(14-504) Aukerman Creek, Year: 2005													
3.3	82.0	29.41	■	■	■	■	■	■		■	■	■	9
1.8	75.5	23.26	■	■		■	■	■			■	■	7
0.5	70.5	15.63	■	■						■	■	■	5
(14-505) Bantas Fork, Year: 2005													
13.7	69.0	9.71		■		■	■	■			■	■	6
9.4	67.0	29.41	■	■		■	■				■		5
7.1	72.5	21.28		■						■	■	■	4
1.3	80.5	16.39	■	■		■	■	■		■	■	■	8
(14-506) Goose Run, Year: 2005													
4.4	55.0	20.41	■	■		■	■			■	■		6
0.3	73.0	20.00	■	■		■	■	■		■	■	■	8
(14-508) Lesley Run, Year: 2005													
6.0	35.0	11.24		■									1
1.2	60.0	27.03	■	■			■			■	■		5
(14-510) Price Creek, Year: 2005													
13.7	47.0	12.35		■									1
10.9	62.5	6.80	■	■		■	■			■	■		6
3.8	65.5	13.51	■	■						■		■	4
(14-512) Swamp Creek, Year: 2005													
6.3	34.0	5.38		■									1

MWH Attributes — High Influence

Stream / 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
(14-504) Aukerman Creek						
3.3						0
1.8			♦	♦		2
0.5				♦		1
(14-505) Bantas Fork						
13.7	♦					1
9.4				♦		1
7.1				♦		1
1.3						0
(14-506) Goose Run						
4.4			♦	♦		2
0.3				♦		1
(14-508) Lesley Run						
6.0	♦		♦	♦	♦	4
1.2				♦		1
(14-510) Price Creek						
13.7			♦	♦	♦	3
10.9			♦	♦		2
3.8				♦	♦	2
(14-512) Swamp Creek						
6.3	♦	♦	♦	♦	♦	5

MWH Attributes — Moderate Influence

Stream / 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
(14-504) Aukerman Creek															
3.3				•					•		•		3	0.10	0.40
1.8		•			•				•	•	•		5	0.38	1.00
0.5					•	•			•	•	•		5	0.33	1.17
(14-505) Bantas Fork															
13.7	•	•		•	•				•	•	•		7	0.29	1.29
9.4		•			•				•	•	•		5	0.33	1.17
7.1	•				•	•			•		•		5	0.40	1.40
1.3									•				1	0.11	0.22
(14-506) Goose Run															
4.4					•				•			•	3	0.43	0.86
0.3					•				•		•		3	0.22	0.56
(14-508) Lesley Run															
6.0		•			•			•	•	•		•	6	2.50	5.50
1.2		•			•				•			•	4	0.33	1.00
(14-510) Price Creek															
13.7	•	•			•			•	•	•		•	7	2.00	5.50
10.9	•				•				•			•	4	0.43	1.00
3.8					•	•			•				3	0.60	1.20
(14-512) Swamp Creek															
6.3	•	•			•			•	•	•		•	7	3.00	6.50

Table 14 continued.

Key QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: 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
(14-513) Millers Fork																																		
Year: 2005																																		
10.8	33.0	3.78											0	♦	♦	♦	♦	♦	5	●	●			●			●	●	●		●	7	6.00	*.**
8.0	66.5	6.76	■	■		■	■	■		■	■		7				♦		1					●				●			●	3	0.25	0.63
3.9	58.0	7.14	■	■			■	■			■		5		♦		♦		2	●	●		●	●				●	●		●	7	0.50	1.67
(14-515) Dry Fork																																		
Year: 2005																																		
0.8	50.0	23.26								■			1			♦	♦	♦	3	●				●				●			●	4	2.00	4.00
(14-518) Trib. to Twin Creek (RM 18.29)																																		
Year: 2005																																		
0.6	70.5	22.22	■	■	■	■	■			■	■	■	8				♦		1				●					●				2	0.22	0.44
(14-519) Maple Swamp Ditch																																		
Year: 2005																																		
2.4	21.0	3.41									■		1	♦	♦	♦	♦		4		●			●		●		●	●		●	6	2.50	5.50
1.4	38.5	3.11									■	■	2	♦	♦	♦	♦		4		●			●				●	●			4	1.67	3.00
(14-520) Trib. to Aukerman Creek (RM 2.88)																																		
Year: 2005																																		
0.5	73.0	22.22	■	■		■	■	■		■	■	■	8				♦		1					●				●				2	0.22	0.44
(14-521) Trib. to Swamp Creek (RM 6.45)																																		
Year: 2005																																		
0.3	37.5	6.76		■									1	♦	♦	♦	♦	♦	5	●	●			●			●	●	●		●	7	3.00	6.50

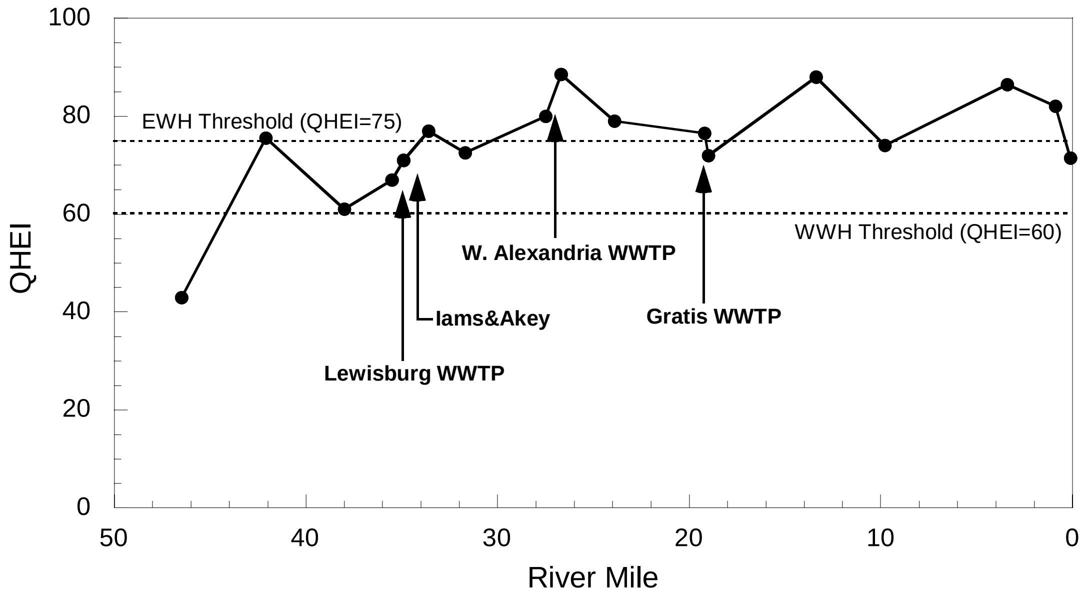


Figure 18. Longitudinal performance of the QHEI for the Twin Creek mainstem, 2005.

Degraded, diminished or otherwise substandard habitat on the mainstem was documented at the uppermost site only (RM 46.5, SR 722 – Figure 19). Due to low relief and generally poor natural drainage, the upper portion of the Twin Creek basin (Northern Preble, Southern Darke, and Northwest Montgomery Counties), the upper mainstem, and nearby tributaries have been channelized, with selected waters obviously maintained in an artificial state so as to serve as efficient drainage outlets. At RM 46.5, diminished or simplified macrohabitat features included, a deeply incised channel, limited riparian vegetation, highly simple or monotonous channel development, and high to moderate level of substrate embeddedness. High and moderate influence modified habitat attributes were overwhelmingly dominant at this site (Table 14). The combined influence of these features yielded a *poor* habitat score (QHEI=43.0).

Figure 19. Twin Creek at RM 46.5**.**

However, multiple factors can diminish the anticipated negative effects of the locally degraded conditions documented at RM 46.5. The first includes ground water. Surface flow of upper Twin Creek, and nearby tributaries, are clearly augmented by ground water. Typically, sustained inputs from the water table to surface waters results in greater sustained surface flow, cooler instream temperatures, and improved chemical water quality. It has been regularly observed, statewide, that the deleterious effects of degraded macrohabitat 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 Twin Creek.

It is also important to consider the aggregate macrohabitat condition of Twin Creek. Poor conditions documented at the uppermost site are truly anomalous, in comparison with all remaining downstream stations (Figures 18 and 20). 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).

Ultimately, in light of the abundance of macrohabitat at or greater than the WWH or EWH thresholds, the small segments of sub-par habitat found in the uppermost reaches of Twin Creek would potentially have a limited effect on the performance of the local aquatic fauna. Furthermore, the positive and often mitigating effects of ground water, 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 regionally calibrated EWH 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 instream physical features of Twin Creek appeared capable of supporting aquatic communities consistent with the EWH biological criteria.

Twin Creek Tributaries

Fourteen direct and indirect Twin Creek tributaries were surveyed and assessed as part of the 2005 field sampling effort. Thirty sampling stations were deployed to these waters, evaluating the macrohabitat quality of 86.0 cumulative liner stream miles. QHEI values for these tributaries ranged between 82.0 and 21.0, with a mean score of 59.3 ($\pm$16.67 SD).

Areas of obviously deficient habitat were limited to six streams, and included seven (23.3%) of the 30 tributary monitoring sites. QHEI scores from these sites ranged between 21.0 and 47.0 (Table 14 and Figure 20). Specifically these physically degraded or otherwise simplified streams were, Maple Swamp Ditch, upper Millers Fork, Swamp Creek, UN Swamp Creek Tributary, upper Price Creek, upper Lesley Run, and upper Toms Run. As observed for the upper Twin Creek mainstem, these waters drain the same low relief and historically wet areas in Northern Preble, Southern Darke, and Northwest Montgomery Counties, and are ether adjacent to the upper Twin Creek mainstem or actually serve as the source tributaries that coalesce to form the headwaters of Twin Creek proper. Like the uppermost Twin Creek station, QHEI scores for these waters were distinct from the distribution of scores from the majority of study area. Taken together, the full distribution of scores for the basin appeared bimodal.

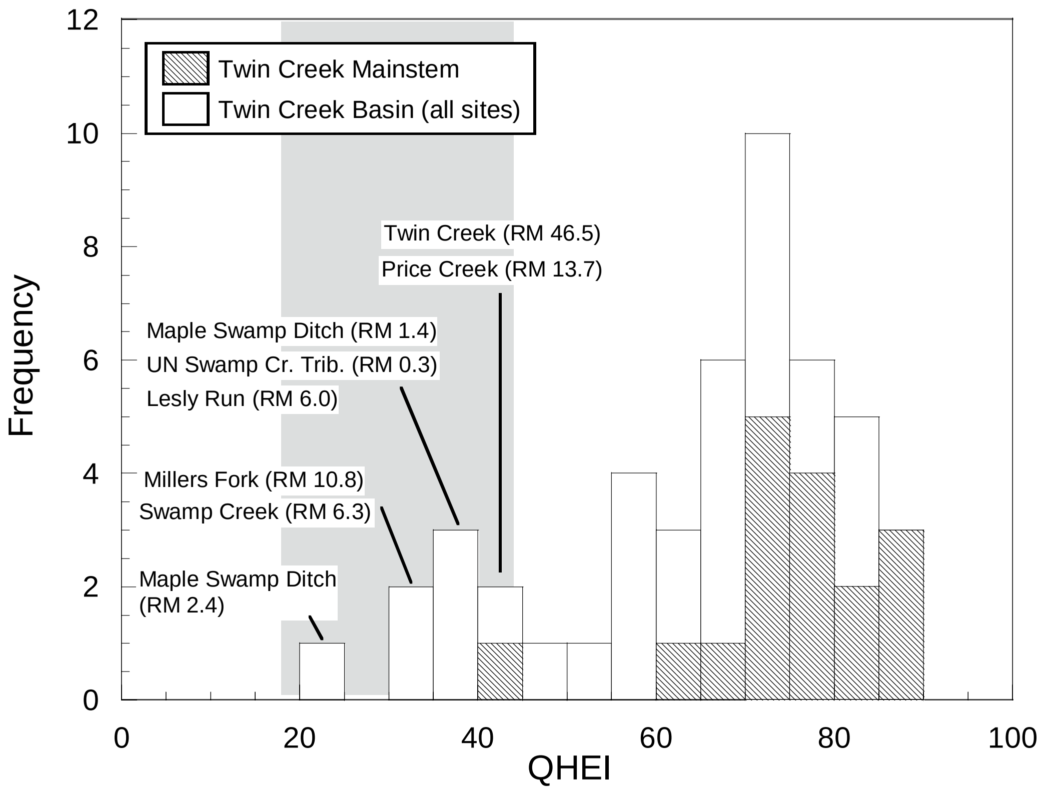


Figure 20. Distribution of QHEI scores for all monitoring stations within the Twin Creek study area, 2005. Shaded area includes seven streams (eight stations), all draining low relief areas within the upper portion of the basin. Historically, this area supported wet prairie, ash/elm forest, or other plant associations indicative of poorly drained or wet conditions (Gordon 1966). Presently, all are channelized and appeared maintained, to varying degrees, so as to meet local drainage needs.

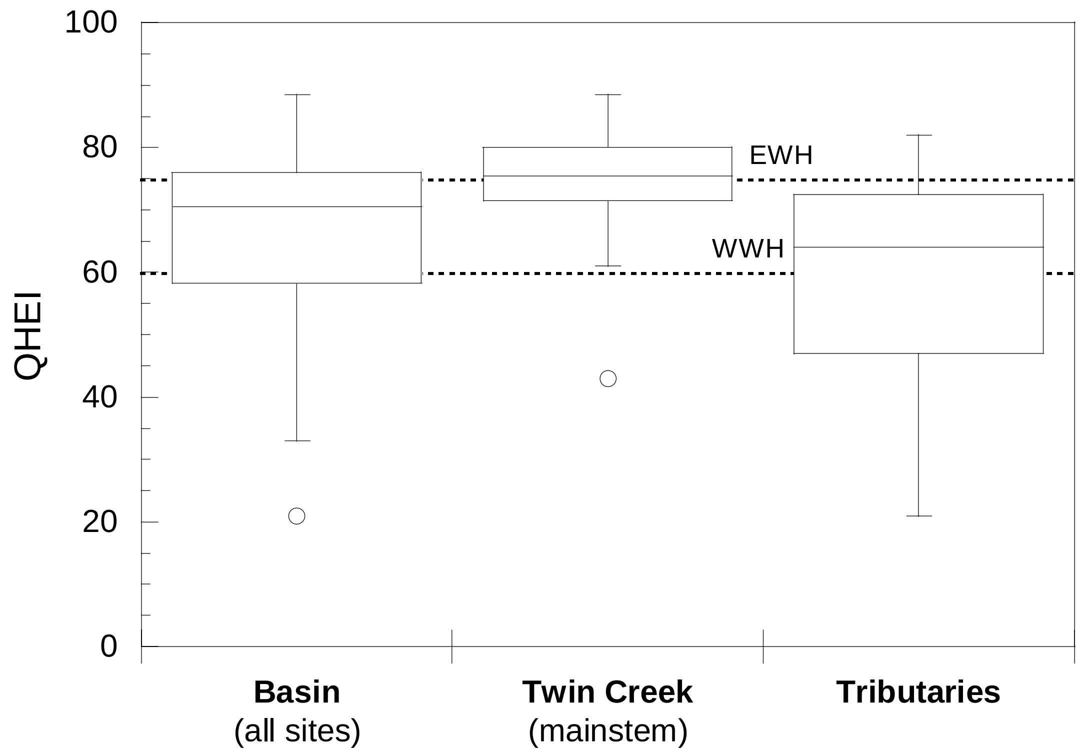


Figure 21. Aggregated and categorized Qualitative Habitat Evaluation Index (QHEI) values from the Twin Creek study area, 2005.

The negative and controlling channel feature common to theses sites/streams was principally direct channelization. Nearly all of the other negative attributes are attendant to or stem from the original channel incision and subsequent maintenance activity—limited or monotonous channel development, siltation, sparse instream cover, and, at times, ephemeral stream flow. These streams were originally dug, trenched, or otherwise channelized to lower the local water table and to serve as a reliable outlet for field tile.

In additional to the deficiencies identified above, most of these waterbodies were found to be ephemeral, either intermittent or interstitial. Ephemerality, in and of itself, does not represent a severe or debilitating habitat deficit. On the contrary, there are many examples, statewide, of ephemeral streams supporting WWH or EWH assemblages. However, as a category, intermittent or interstitial waters tend to yield low QHEI scores given absence of flow dependent channel features (e.g., riffles and runs). It is also important to note the distinctions between interstitial flow and true intermittence. 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 flow. Interstitial streams do possess continuous flow, it is just not readily apparent, as water is conveyed below and through 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, quickly 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, virtually precluding the permanent establishment of a diverse and healthy assemblage of aquatic organisms. Even during periods of abundant surface flow (spring or fall), intermittent stream typically support only transient populations of pioneering species. Based upon limited field observations, it is difficult to discern the true nature of these ephemeral waters (intermittent or interstitial), but most appeared interstitial.

In the absence of mitigating or compensatory features (e.g., ground water), diminished ambient biological performance derived from poor instream habitat appeared possible or likely for the above mentioned waterbodies. All remaining waters were found to contain a suite of near and instream habitat features, that at a minimum appeared capable of supporting WWH communities, and in selected instances suggested exceptional potential.

Biological Assessment: Fish Community

Twin Creek (mainstem)

A total of 28,037 fish comprising 53 species and four hybrids were collected from Twin Creek between July and September 2005. The fish sampling effort included 23 sampling events, at 12 stations, evaluating 47 miles of the mainstem, between RM 46.5 (SR 722) and RM 0.1 (at mouth).

Based on aggregated catch statistics, numerically predominant species (No./0.3km) included, Central stoneroller (24.4%), rosyface shiner (9.0%), bluntnose minnow (7.8%), rainbow darter (6.8%), greenside darter/sand shiner (5.9%), and Northern hog sucker (4.9%). In terms of relative biomass (kg/0.3km), dominant species were, black redhorse (29.4%), Northern hog sucker (13.4%), Central stoneroller (8.5%), rockbass (5.8%), and smallmouth bass (6.9%). Thirty-three percent of the numerically dominant species and fully 50% of fish biomass were composed of environmentally sensitive species. Remarkably, nearly 50% of all fish captured from the 47 miles of the mainstem were environmentally sensitive taxa.

Fish species classified as rare, threatened, endangered, or otherwise recognized for special conservation status by the Ohio DNR (2003), included the least darter. This species was limited to the headwaters of the mainstem. Historically, this portion of the watershed supported wet prairie, Ash/Elm forests, or other plant associations indicative of poorly drained or wet conditions (Gordon 1966). The least darter is functionally a wet prairie relic within the Twin Creek basin. Other highly intolerant, declining or otherwise ecologically significant species included bigeye chub, river chub, rosyface shiner, silver shiner, banded 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 Twin Creek ranged between exceptional (IBI=58/MIwb=11.1) and very good (IBI=46/MIwb=9.0). Overall, the fish assemblage of Twin Creek was characterized as *exceptional*. Longitudinal performance of the IBI, MIwb, and other relevant indicators are presented in Figure 22. Summarized index scores and community statistics by station are presented in Table 15.

Presently, the entire length of Twin Creek is designated EWH. As measured by the IBI and MIwb (where applicable), community performance through its entire length was found fully consistent with the EWH biocriteria. Every station was found to support an assemblage of fish possessing the expected structure, functional organization, and species richness, comparable to the best reference conditions within the Eastern Corn Belt Plains (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 typically at or below expected levels, and was no where found greater than 0.5%.

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

The need to discuss community performance at a reach or station scale is limited to the uppermost site (RM 46.5), where, despite poor quality macrohabitat, the reach was found to support a community consistent with minimum EWH criterion. As articulated in the Physical Habitat section of this report, there are many possible explanations for community performance exceeding that predicted by the QHEI alone. The principal mitigating factor here appeared the positive influence of ground water. Typically, sustained inputs from the water table to surface waters result in greater sustained surface flow, cooler instream temperatures, and improved chemical water quality. It has been regularly observed, state-wide, that the deleterious effects of degraded macrohabitat on ambient biological performance in small headwater streams can be largely mitigated by the influence of ground water.

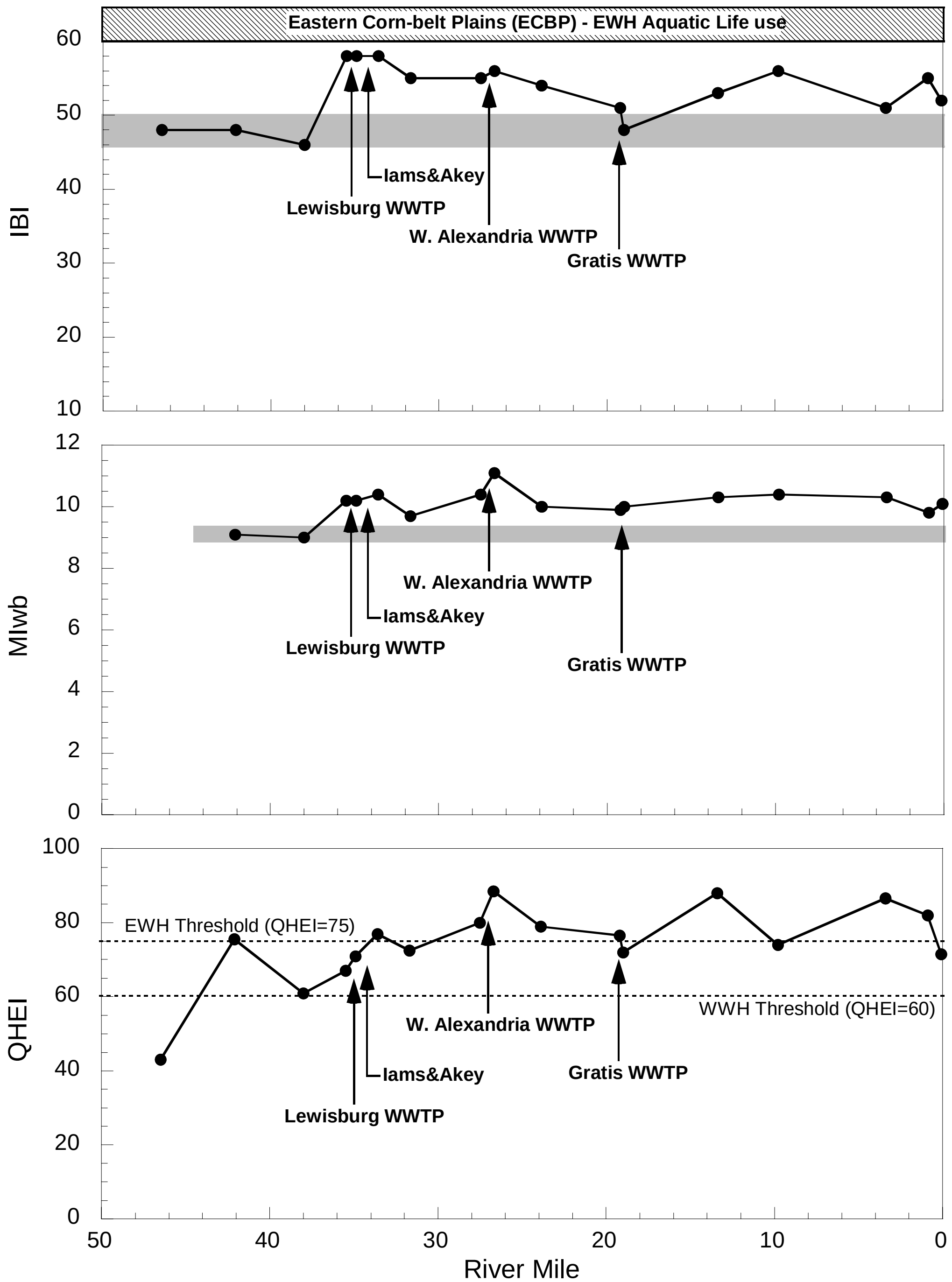


Figure 22. Longitudinal performance of the Index of Biological Integrity (IBI), Modified Index of well-being (MIwb), and Qualitative Habitat Evaluation Index (QHEI) for Twin Creek (mainstem), 2005. Shaded areas represent biocriteria and areas of nonsignificant departure for the EWH aquatic life use. Dashed lines represent QHEI values associated with, WWH and EWH communities. Arrows identify points of discharge for significant NPDES permitted entities.

Table 15. Fish community and descriptive statistics from the Twin Creek study area, 2005.

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
Upper Twin Creek WAU: 05080002-030								
Twin Creek (2005) [14-500]								
Eastern Corn-belt Plain (ECBP)-EWH Use Designation (Existing)								
46.5[H]	18.0	18	1406.00	10.63	48[ns]	NA	43.0	Very Good
42.1 [W]	23.0	23	1524.00	32.16	48[ns]	9.1[ns]	75.5	Very Good
38.0 [W]	20.0	20	2569.50	27.31	46[ns]	9.0[ns]	61.0	Very Good
35.5 [W]	26.0	26	1057.50	44.60	58	10.2	67.0	Exceptional
34.9 [W]	30.5	34	1107.75	40.98	58	10.2	71.0	Exceptional
33.6 [W]	27.0	27	1603.50	46.84	58	10.4	77.0	Exceptional
31.7 [W]	28.0	31	705.75	21.84	55	9.7	72.5	Exceptional
27.5 [W]	27.0	29	1354.50	57.18	55	10.4	80.0	Exceptional
26.7 [W]	32.5	34	2970.00	64.71	56	11.1	88.5	Exceptional
Lower Twin Creek WAU: 05080002-040								
23.9 [W]	28.0	31	1735.50	50.79	54	10.0	79.0	Exceptional
19.2 [W]	26.0	29	2066.25	62.05	51	9.9	76.5	Exceptional
19.0 [W]	25.5	28	2298.00	49.25	48[ns]	10.0	72.0	V.Good-Except.
13.4 [W]	28.0	33	2786.25	57.07	53	10.3	88.0	Exceptional
9.8 [W]	30.5	38	1753.50	41.13	56	10.4	74.0	Exceptional
3.4 [W]	28.0	34	1648.50	63.47	51	10.3	86.5	Exceptional
0.9 [W]	28.0	31	1019.25	52.03	55	9.8	82.0	Exceptional
0.1 [W]	31.5	40	3238.50	39.49	52	10.1	71.5	Exceptional
Upper Twin Creek WAU: 05080002-030								
Maple Swamp Ditch (2005) [14-519]								
Eastern Corn-belt Plain (ECBP)-MWH Use Designation (Recommended)								
2.4[H]	10.0	10	140.00	0.37	38	NA	21.0	M. Good
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Recommended)								
1.4 [H]	23.0	23	1234.00	10.63	44	NA	38.5	Good
Dry Fork (2005) [14-515]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
0.8[H]	13.0	13	1382.00	4.34	40	NA	50.0	Good
Millers Fork (2005) [14-513]								
Eastern Corn-belt Plain (ECBP)-EWH/WWH Use Designation (Existing/Recommended)								
10.8[H]	21.0	21	1672.00	6.76	40	NA	33.0	Good

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]
Eastern Corn-belt Plain (ECBP)-EWH Use Designation (Existing)								
8.0[H]	22.0	22	1324.50	6.19	48[ns]	NA	66.5	Very Good
3.9[H]	19.0	19	405.00	11.11	48[ns]	NA	58.0	Very Good
Swamp Creek (2005) [14-512]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
6.3[H]	19.0	19	1880.00	4.20	44	NA	34.0	Good
Swamp Creek Tributary at RM 6.45 (2005) [14-521]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.3[H]	17.0	17	1770.00	3.43	38[ns]	NA	37.5	Marginally Good
Price Creek (2005) [14-510]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
13.7[H]	14.0	14	1582.00	2.37	38[ns]	NA	47.0	Marginally Good
10.9[H]	17.0	17	2103.00	10.90	42	NA	62.5	Good
Eastern Corn-belt Plain (ECBP)-EWH/WWH Use Designation (Existing/Recommended)								
3.8[W]	15.0	15	4342.50	18.22	36[ns]	8.4	65.5	M.Good/Good
Lesley Run (2005) [14-508]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
6.0[H]	15.0	15	382.00	1.26	48	NA	35.0	Very Good
1.2[H]	13.0	13	520.50	2.58	38[ns]	NA	60.0	Marginally Good
Upper Twin Creek WAU: 05080002-030								
Bantas Fork (2005) [14-505]								
Eastern Corn-belt Plain (ECBP)-EWH Use Designation (Existing)								
13.7[H]	19.0	19	1179.00	11.47	46[ns]	NA	69.0	Very Good
9.4[H]	18.0	18	1774.50	9.40	56	NA	67.0	Exceptional
7.1[W]	24.0	24	1215.00	12.89	56	NA[c]	72.5	Exceptional
1.3[W]	27.0	31	2336.25	14.87	53	9.8	80.5	Exceptional
Goose Run (2005) [14-506]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
4.4[H]	13.0	13	1866.00	11.30	44	NA	55.0	Good
Eastern Corn-belt Plain (ECBP)-EWH Use Designation (Existing)								
0.3[H]	18.0	18	1353.00	10.09	56	NA	73.0	Exceptional
Aukerman Creek (2005) [14-504]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
3.3[H]	16.0	16	1160.00	12.66	50	NA	82.0	Exceptional

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[b]
1.8 [H]	16.0	16	3954.00	24.85	54	NA	75.5	Exceptional
0.5 [W]	20.0	20	2398.50	9.35	46	8.0[ns]	70.5	Very Good/M.Good
Aukerman Creek Tributary at RM 2.88 (2005) [14-520]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.5 [H]	12.0	12	3204.00	11.56	48	NA	73.0	Very Good
Twin Creek Tributary at RM 18.29 (2005) [14-518]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Recommended)								
0.6 [H]	15.0	15	1442.00	4.28	48	NA	70.5	Very Good
Toms Run (2005) [14-502]								
Eastern Corn-belt Plain (ECBP)-WWH Use Designation (Existing)								
12.0 [H]	15.0	15	4730.00	37.33	52	NA	40.5	Exceptional
8.5 [H]	16.0	16	775.50	8.19	40	NA	58.5	Good
0.4 [W]	23.0	23	1615.50	13.93	48	8.9	82.0	Very Good/Good
Little Twin Creek (2005) [14-501]								
Eastern Corn-belt Plain (ECBP)-EWH Use Designation (Existing)								
6.2 [H]	14.0	14	1798.50	20.79	46[ns]	NA	65.5	Very Good
4.7 [H]	20.0	20	2989.50	14.43	52	NA	59.5	Very Good
2.0 [H]	22.0	22	4140.00	30.95	54	NA	77.0	Exceptional

a - Relative abundance and relative weight estimate normalized to 0.3km.
b - Narrative biological performance.
c - Due to a sampling error, the MIwb was invalidated for Banats Fork, RM 7.1.
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).
WAU – Watershed Assessment Unit, corresponds to USGS 11 digit HUC

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.

Twin Creek Tributaries

The fish assemblages of 14 direct and indirect tributaries that comprise the principal drainage network of Twin Creek were surveyed and assessed in 2005. Thirty sampling stations were deployed among these tributaries. A total of 35,596 fish comprising 42 species and six hybrids was collected from all Twin Creek tributaries, between July and September 2005.

Based on aggregated catch statistics from all tributaries, numerically predominant species (No./0.3km) included Central stoneroller (30.0%), Northern creek chub (16.1%), white sucker (7.2%), rainbow darter (6.1%), mottled sculpin (5.1%), and striped shiner (3.6%). In terms of relative biomass (kg/0.3km), dominant species were, Central stoneroller (30.2%), Northern creek chub (23.6%), white sucker (14.1%), striped shiner (6.4%), rockbass (3.6%), and mottled sculpin (3.2%). In terms of ranked abundance and biomass measures, these dominant species are typical associates of headwater or brook environments.

Like the mainstem, fish species classified as rare, threatened, endangered, or otherwise recognized for special conservation status by the Ohio DNR (1997), included only the least darter. Eighty-eight individuals were collected from five direct and indirect Twin Creek tributaries: upper Lesley Run, Swamp Creek, unnamed Swamp Creek Tributary, upper Millers Fork, and Dry Run. Distribution of this species was limited to these northern headwater tributaries that historically drained wet prairie, Ash/Elm forests, or other poorly drained landscapes (Gordon 1966). Other highly intolerant, declining or otherwise ecologically significant species included, bigeye chub, river chub, southern red-bellied dace, rosyface shiner, silver shiner, and banded darter (Ohio EPA 1987 and 1996).

Community indices and accompanying narrative evaluations from these waters ranged between exceptional (IBI=56/MIwb=9.8) and marginally good (IBI=36/MIwb=8.0). Taken together, the fish assemblages of the Twin Creek tributaries can be collectively characterized narratively as *very good*. Summarized index scores and community statistics by stream and by station are presented in Table 15.

Biological performance narratives for eight of the 14 tributaries ranged between *very* good and exceptional. These waters included, Millers Fork, Bantas Fork, Goose Run, Aukerman Creek, Aukerman Tributary, Little Twin Creek, Toms Run, and an unnamed direct Twin Creek tributary. Good to marginally good communities were indicated for the remaining six waterbodies: Maple Swamp Ditch, Dry Fork, Swamp Creek, Swamp Creek tributaries, Price Creek, and Lesley Run.

Existing and recommended Aquatic Life Uses for Twin Creek tributaries included MWH, WWH, and EWH. Application or recommendation of the sub-goal MWH use was limited to upper reach of Maple Swamp Ditch, due to extensive hydromodification. Habitat conditions here were by far the worst documented throughout the study area (QHEI=21.0). The existing EWH designation on lower Miller's Fork, Bantas Fork, lower Goose Run, and Little Twin Creek were affirmed based upon the 2005 survey results. All remaining tributaries are recommended to retain the WWH use where existing, or are recommended to this use if previously unassessed or erroneously designated a higher aquatic life use in the past. The latter re-designations were made in light of additional data and field observation gathered in 2005.

All tributaries where found to support fish assemblages fully consistent with the biocriteria applicable to existing and recommended Aquatic Life Uses. Community performance below the minimum WWH, ECBP, and biocriteria was nowhere observed. As full attainment was universal, further discussions of the 2005 results will be limited to lower Price Creek, where the existing EWH aquatic life use is recommended to be replaced by the more appropriate WWH designation.

The lower reach of Price Creek was designated EWH based upon the recommendations of the 1995 Twin Creek survey (Ohio EPA 1997). This, despite the lack of clear and compelling evidence of strong existing EWH performance or similar evidence indicating reasonable potential to support EWH at some point in the future. In 1995, only one of the five stations allocated to Price Creek was found to support a fish assemblage consistent with both the recommended WWH and EWH biocriteria. Restated another way, only 0.6 miles (4.3%) of the 14 mile segment of Price Creek evaluated at that time met the applicable biocriteria. Full agreement with the biocriteria was limited to the lowest site (RM 0.6), and in all probability community performance here was buoyed or otherwise enhanced by its close proximity to Twin Creek, a large and fully exceptional water body. Results from the 2005, survey found similar conditions to those observed in 2005, confirming the absence of reasonable EWH potential. In light of these observations it is abundantly clear that the Price Creek was a poor candidate for the EWH use, and therefore is recommended to WWH.

Biological Assessment: Macroinvertebrate Community

Upper Twin Creek

Nine stations were assessed on the upper segment of Twin Creek; beginning with the headwaters in Castine, to downstream south of West Alexandria. In 1995, Twin Creek was noted as “home to the most exceptional macroinvertebrate community in the state. No other stream in Ohio maintains macroinvertebrate populations which meet the EWH aquatic life use designation without exception over as long a sampling reach (>40 mi^2) as Twin Creek did in 1995” (Ohio EPA 1997). This status was interrupted in 2005, as one of the stations assessed did not meet EWH expectations. That site, at RM 34.9, garnered an Invertebrate Community Index score (ICI) of 38; a narratively good score, but below the exceptional criterion. Here, relative density nearly doubled from the preceding upstream site at RM 35.4 and populations of the cnidarian *Hydra sp.* were also nearly doubled. The facultative midge*, Dicrotendipes neomodestus,* increased tenfold over the upstream site as well, which contributed to a dipteran/noninsect metric percentage of 67.7%. This was, by far, the highest percentage of all Twin Creek sites. Decreases in qualitative EPT[1] (24 to 18) and sensitive taxa (31 to 22) were recorded, along with an increase in qualitative tolerant taxa (4 to 10). Excessive phosphorus from the Lewisburg WWTP, herbicide runoff from an upstream municipal park, or contaminated stormwater are considered potential contributors to this impairment.

[1] EPT stands for Ephemeroptera, Plecoptera, and Trichoptera – mayflies, stoneflies, and caddisflies. Their increased presence as a group is generally considered to be indicative of higher water quality.

Figure 23 shows longitudinal performances of the ICI, sensitive and EPT taxa, and relative density in upper Twin Creek.

In spite of the one non-attaining ICI documented in 2005, the overall performance of the upper segment of Twin Creek remains outstanding. ICI scores averaged an exceptional score of 48, which also included the highest ICI recorded in the survey (54 at RM 31.7). Table 16 includes a summary of macroinvertebrate data collected in the upper Twin Creek watershed. Out of 162 total taxa collected in this reach, 70 were sensitive. The stream also hosted a number of rare, intolerant, or infrequently-collected taxa; including the mayflies *Acentrella turbida* and *Pseudocloeon frondale*, the caddisfly *Psychomyia flavida,* and the midges *Ablabesmyia simpsoni*, *Paracladopelma undine*, *Sublettea coffmani*, and *Cladotanytarsus vanderwulpi group Type I*. The persistent presence of the aquatic moth genus *Petrophila* and the dobsonfly *Corydalus cornutus* throughout the mainstem is further evidence of high water quality, as both thrive in fast, flowing waters rich in oxygen. High gradient, continuous ground water augmentation and a mostly intact riparian corridor are large contributors to the overall quality of the stream, especially during a sampling season that experienced widespread low flow conditions. That the stream meanders through an area predominated by agriculture and hosts numerous NPDES dischargers, yet still maintains its overall high biotic integrity, is a statement of Twin Creek's extraordinary assimilative capacity.

A study of mussel populations in Twin Creek, conducted by Wright State University graduate student Kara Wendeln in 2004, also gives insight to the condition of the upper portion of the Twin Creek mainstem. Twelve species (live and fresh-dead) were found throughout the length of Twin Creek, with nine of those being found in the upper portion. Four species were found live exclusively at upper Twin Creek sites. All three sites where Ohio EPA encountered mussels were also in upper Twin Creek only (RMs 46.6, 42.1, and 31.7). The study found that in Twin Creek, mussel species richness was positively correlated to high percent canopy cover, which functions to create instream habitat conducive to mussel proliferation. In spite of heavy agricultural land use, the maintenance of wooded riparian buffer along Twin Creek has contributed to these findings, and thus should be maintained.

Table 16. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the upperTwin Creek study area, July to September, 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) in Parentheses	ICI[a]	Narrative Evaluation
Twin Creek (14-500)										
46.6	19.7	-	53	20	19	H-M	0	Flatworms (F), riffle beetles (F,MI), *Elimia* snails (MI)	-	Very Good
42.0	28.0	15	72	22/22	32/38	M/116	1	Baetid mayflies (F,I), hydropsychid, caddisflies (F,MI)	46	Exceptional
38.1	38.0	-	49	19/20	22/25	M/139	0	Net-spinning caddisflies (F,MI), *Petrophila* moths (MI), mayflies (F,MI)	50	Exceptional
35.4	90.0	-	61	24/27	31/38	M-L/338	0	*Rheotanytarsus* midges (MI), net-spinning caddisflies (F,MI)	50	Exceptional
34.9	91.0	-	59	18/19	22/25	M/596	0	Net-spinning caddisflies (F,MI)), waterpennies (MI), mayflies (F,MI)	38	Good
33.5	94.0	-	56	18/20	22/30	M/399	0	Net-spinning caddisflies (F,MI), baetid mayflies (F,I)	52	Exceptional
31.7	99.0	-	55	24/27	31/38	L/448	0	Case-making caddisflies (MI), net-spinning caddisflies (F,MI), riffle beetles (F,MI)	54	Exceptional
27.6	142.0	-	51	21/23	20/33	M/620	0	Net-spinning caddisflies (F,MI), mayflies (F,MI)	52	Exceptional
26.6	143.0	-	60	20/21	25/30	M/659	0	Net-spinning caddisflies (F, MI), *Rheotanytarsus* midges (MI)	44	Very Good
Maple Swamp Ditch -Trib to Twin Creek @ RM 47.03 (14-519)										
2.4	5.5	-	21	2	2	M-L	0	Midges (MT, MI), Aquatic worms (T), Fingernail clams (F)	-	Poor
1.4	10.2	-	49	13	13	M	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F,I), midges (T,F,MI), *Helicopsyche* mayflies (MI)	-	Good
Dry Fork -Trib to Twin Creek @ RM 39.35 (14-515)										
0.8	5.4	-	49	10	16	M	0	Net-spinning caddisflies (F,MI), *Helicopsyche* caddisflies (MI), *Elimia* snails (MI)	-	Good
Millers Fork -Trib to Twin Creek @ RM 35.71 (14-513)										
10.8	5.7	-	38	5	5	L	0	Sow bugs (F), snails (MT,F,MI), fingernail clams (F)	-	Low fair

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) in Parentheses	ICI[a]	Narrative Evaluation
8.0	10.1	-	46	13	16	M	0	Net-spinning caddisflies (F,MI), case-building caddisflies (MI), riffle beetles (F,MI), *Elimia* snails (MI)	-	Good
3.9	19.7	-	47	10	14	M	0	Riffle beetles (F,MI), *Elimia* snails (MI), *Caenis* mayflies (F), waterpenny beetles (MI)	-	Marg. Good
Swamp Creek -Trib to Twin Creek @ RM 35.59 (14-512)										
6.4	8.7	-	36	4	6	M-L	0	*Helicopsyche* caddisflies (MI), *Elimia* snails (MI), *Caenis* mayflies (F), Beetles (MT,F,MI)	-	Fair
0.2	18.0	-	34	9	12	M-L	0	Riffle beetles (MT,F,MI), Sow bugs (F), waterpenny beetles (MI)	-	Marg. Good
Price Creek -Trib to Twin Creek @ RM 29.74 (14-510)										
13.6	5.2	-	33	3	5	L	0	Sow bugs (F), Beetles (MT, F, MI), midges (T,F,MI), pouch snails (F)	-	Low Fair
10.9	11.4	-	55	12	21	M	1	Net-spinning caddisflies (F,MI), *Helicopsyche* caddisflies (MI), waterpenny beetles (MI), *Caenis* mayflies (F), midges (T,MT,F,MI,I)	-	Good
3.9	20.1	-	42	16/20	20/32	M-L	2	Caddisflies (F,MI), mayflies (F, MI,I), *Elimia* snails (MI), *Petrophila* moths (I), waterpenny beetles (MI)	50	Exceptional
Lesley Run -Trib to Twin Creek @ RM 24.60 (14-508)										
4.9	5.0	9	20	4	5	L	0	*Elimia* snails (MI), heptageniid mayflies (F)	-	Low Fair
1.3	7.5	9	18	3	4	L	1	*Elimia* snails (MI), waterpenny beetles (MI), heptageniid mayflies (F)	-	Low fair

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 8=Non-Detectable Current, 9=Intermittent or Near-Intermittent Conditions, 12=Suspected High Water Influence/Disturbance, 13=Suspected Disturbance by Vandalism, 15=Current >0.0 fps but <0.3 fps, 29=Primary Headwater Habitat Stream.
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

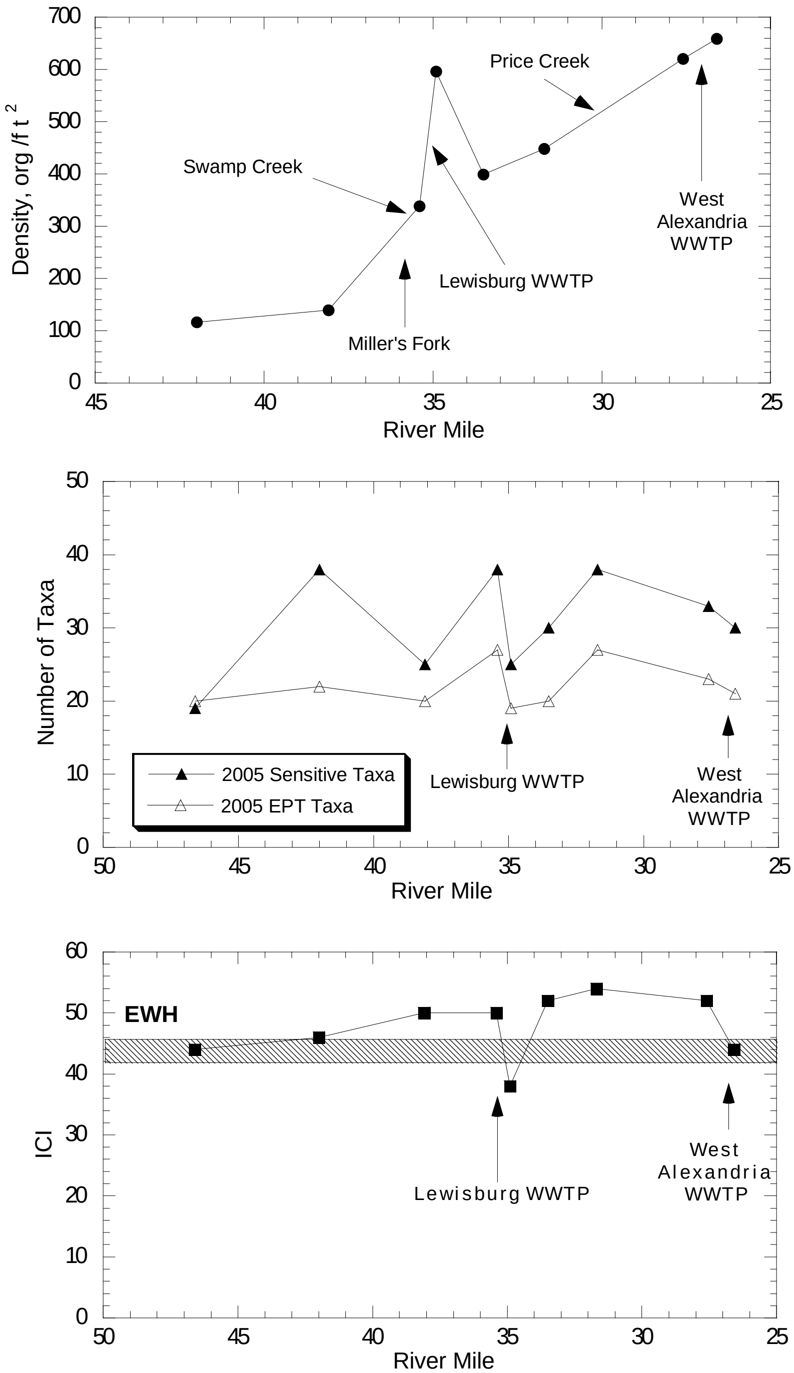


Figure 23. Longitudinal plots showing, from top to bottom: density of organisms found on artificial substrates, number of EPT and sensitive taxa, and ICI scores at each station sampled on upper Twin Creek, 2005. ICI is estimated for RM 46.6

Maple Swamp Ditch

Maple Swamp Ditch is a petitioned agricultural stream maintained by Darke County Ditch Maintenance, from its headwaters at Arcanum Road through its length to the confluence with Twin Creek. As such, adequate habitat to support a diverse macroinvertebrate community is exceedingly limited due to the hydromodification and loss of riparian vegetation resulting from these maintenance activities. Two stations were evaluated qualitatively on this stream; one at RM 2.4 and another at RM 1.4. At RM 2.4, the stream was open and channelized, with primarily muck substrates and grassy margins as available habitats. Consequently, tolerant midges, oligochaetes, and fingernail clams predominated within the collected fauna, with tolerant organisms outweighing sensitive ones 11:2. Thus, this site received an evaluation of poor, below even the recommended MWH use. Nutrient enrichment is also suspected as a plausible source of impairment, as evidenced by the presence of filamentous algae.

Conversely, a marked improvement was noted at the downstream site at RM 1.4. Although the channel persisted with regard to being open, channelized, and silt-laden, the addition of some cobble and boulder substrates created a small riffle habitat. Here, 13 sensitive and 13 EPT taxa were collected, as opposed to 2 of each in the upstream site. Included in these numbers are moderate populations of hydropsychid caddisflies and baetid mayflies, as well as several intolerant taxa, all of which prefer the flowing habitat that riffle/run complexes provide. In addition, an apparent groundwater influence appears to compensate for the otherwise poor habitat features, further aiding the support of a typical WWH benthic assemblage by keeping water temperatures cooler in spite of the absence of riparian canopy.

Dry Fork

The community sampled at Dry Fork (RM 0.8) was evaluated as good, which was meeting current WWH expectations. The stream seems to be recovering from prior channel modification, with young trees populating the riparian corridor on both banks. Instream, the presence of cobble and gravel substrates, and significant gradient, allowed for a reasonably healthy and diverse community consisting of 16 sensitive and 10 EPT taxa.

Miller's Fork

Three stations were qualitatively sampled on Miller's Fork, with evaluations spanning from low-fair to good. The uppermost station at RM 10.8 scored below the recommended WWH use designation, with the sampled community performing in the low-fair range. Sparse riparian buffer, along with channelization and pervasive siltation instream allowed for a dominance of facultative and tolerant organisms such as leeches and planorbid snails. Out of 38 taxa collected, only 5 were sensitive, and 12 were tolerant. In addition, a drainage tile just upstream of the Grubbs-Rex Road bridge was observed to be dumping raw sewage into the stream, which also may have had a toxic effect on the biota.

Moving downstream from RM 10.8, Miller's Fork resembles less a ditch, and starts to take on the appearance of a more natural stream, with denser riparian canopies, greater sinuosity, and better instream habitat. However, the improved stream conditions also warrant the EWH use designation, of which both communities failed to meet at the subsequent downstream stations. RM 8.0 received a narrative evaluation of good, with 13 EPT and 16 sensitive taxa collected. Although the site is adjacent to the unsewered community of Ithaca, there was no significant impact to the macroinvertebrate community attributable to the village. Instead, community performance may have been depressed due to the natural limitations imposed by the predominance of bedrock substrates found in the shallow runs and pools.

While bedrock was an issue at RM 8.0, silt seemed to pose a problem at RM 3.9. Riffle development was sparse and substrates were embedded, along with silty, slow-moving waters. As a result, community performance was limited to only 10 EPT and 14 sensitive taxa, a marginally good performance, and well below EWH expectations. Moderate bank erosion related to an absence of stabilizing riparian along the left bank was also observed. Agriculture, including a few hog farms, dominates the surrounding land use, and associated runoff may be a possible source of impairment in this area.

Swamp Creek

Both stations sampled in Swamp Creek performed below their aquatic life use designation, though only one of the communities is likely demonstrative of impairment related to nonpoint sources. That site, located north of the town of Verona at RM 6.4, directly abuts a cornfield on the right bank, and contained little direct canopy cover in spite of the presence of larger trees on the left bank. It seems to be recovering from prior channelization. Regardless, the community performance here was sub par with regard to its WWH designation. Algal blooms (nutrient enrichment) were observed, along with silty waters and embedded substrates, which served to depress the benthic community. The sensitive to tolerant taxa ratio at this site (6/14; 0.43) was among the lowest in the entire watershed for a WWH stream.

Downstream near the confluence with Twin Creek (RM 0.2), Swamp Creek performs slightly better, yet still below ecoregional expectations. However, an entirely different phenomenon seemed to drive community performance at this location. Flow conditions were found to be normal on the day of sampling (September 19, 2005); with a number of riffles comprised mostly of coarse and fine gravel substrates. In spite of these conditions, organisms were scarce in this habitat. Most of the collected fauna were found primarily in the margins and pools. The channel was observed to be dry on August 30 and September 7, and was interstitial on September 15, per chemistry field crew observations. A rainfall event occurred on September 16. The re-wetting of the channel only three days prior to sampling clearly was not enough time for many of the benthos to re-establish riffle communities, and performance was adversely affected by this phenomenon.

Price Creek

The macroinvertebrate community in Price Creek was evaluated at three locations. Two of the three sites (RM 10.9 and RM 3.9) met the current or recommended WWH aquatic life use. The non-attaining upstream site at RM 13.6 received a qualitative evaluation of low fair (in lieu of Hester-Dendys, which were dry upon retrieval). Tolerant taxa comprised nearly a third of the community at this site (10/33), with sow bugs, beetles, midges, and snails comprising the majority of the organisms. These findings indicate that there may be some degradation at this site beyond merely that of the low to near interstitial flow conditions encountered at the time of sampling. High bacteria concentrations, low dissolved oxygen, and elevated ammonia levels were noted in chemistry sampling, indicative of possible failing septic tanks in the area. The performance of the benthos here, in spite of sub-prime flow conditions, supports the notion of a nonpoint source impact.

Lesley Run

Interstitial to intermittent flow conditions affected the macroinvertebrate community performance at both sites sampled on Lesley Run. Riffle/run complexes were absent, therefore rendering the study area a series of non-flowing pools. The organisms found at both sites were reflective of these flow conditions, as the majority of both communities were comprised of facultative species that were in low to moderate abundance. The upstream community at RM 4.9 may have been additionally influenced by the effects of channelization and riparian removal related to agricultural activities.

RESULTS

Lower Twin Creek: Hydrologic Unit Code 05080002-040: Twin Creek upstream of Bantas Fork to the confluence with the Great Miami River

Includes the associated tributaries: Bantas Fork, Goose Run, Aukerman Creek, Tom's Run, and Little Twin Creek

SUMMARY

In this catchment, 25 biological, 29 chemical, and 8 recreational (bacteria) stations representing 91.1 cumulative stream miles were assessed to determine water quality. In addition to water quality sampling, sediments were also analyzed at 9 stations for chemical parameters. Only 6 tributary stations were biologically impaired as noted in the benthic communities. No impairments were located on the Twin Creek mainstem. Impairment was limited primarily to low flow conditions. Figure 24 depicts the lower Twin Creek watershed, aquatic life use designations, and use attainment. Detailed discussions and assessments are outlined in the sections that follow.

Point Sources

A schematic representation of the lower Twin Creek watershed, including point sources (orange ovals), is depicted in Figure 25.

Gratis WWTP (Twin Creek RM 19.05)

The Gratis WWTP was built in 1981 and modified in 1997. Design capacity is 0.119 million gallons per day (MGD) with a service population of 900. The average daily flow from 2001-2006 was 0.1162 MGD with 22% (467) of the daily averages within the past 5 years exceeding the design limit. This corresponds to significant rainfall events; Gratis has severe inflow and infiltration problems in the sanitary sewer conveyance system.

Treatment plant consists of influent pumped through a comminutor to a continuous flow four-cell aerated lagoon system. Effluent leaving the lagoon system passes through a slow sand filter; is chlorinated, dechlorinated and then travels down a cascade aerator before being discharged into Twin Creek at RM 19.05. The lagoon system relies upon biological denitrification. During the winter months, ammonia removal efficiency decreases with decreased biological activity.

In 5 years (2001-2006), Gratis WWTP had 105 NPDES permit violations. Parameters violated include 40 residual chlorine, 36 $CBOD_5$, 13 NH_3-N, 9 dissolved oxygen, 6 total suspended solids, and 1 oil and grease. There are no combined storm and sanitary sewers in the service area, but untreated sewage is bypassed at two lift stations when malfunctions occur.

Dayton Travel Center (Goose Run RM 4.75)

Dayton Travel Center is located at 6762 US Route 127, near the intersection of I-70 and US 127. It employs 95 persons servicing the trucking industry. There are 8 truck diesel fueling lanes (8 pumps and 8 satellites), 4 auto gasoline fueling lanes, a repair shop, 8 showers, a

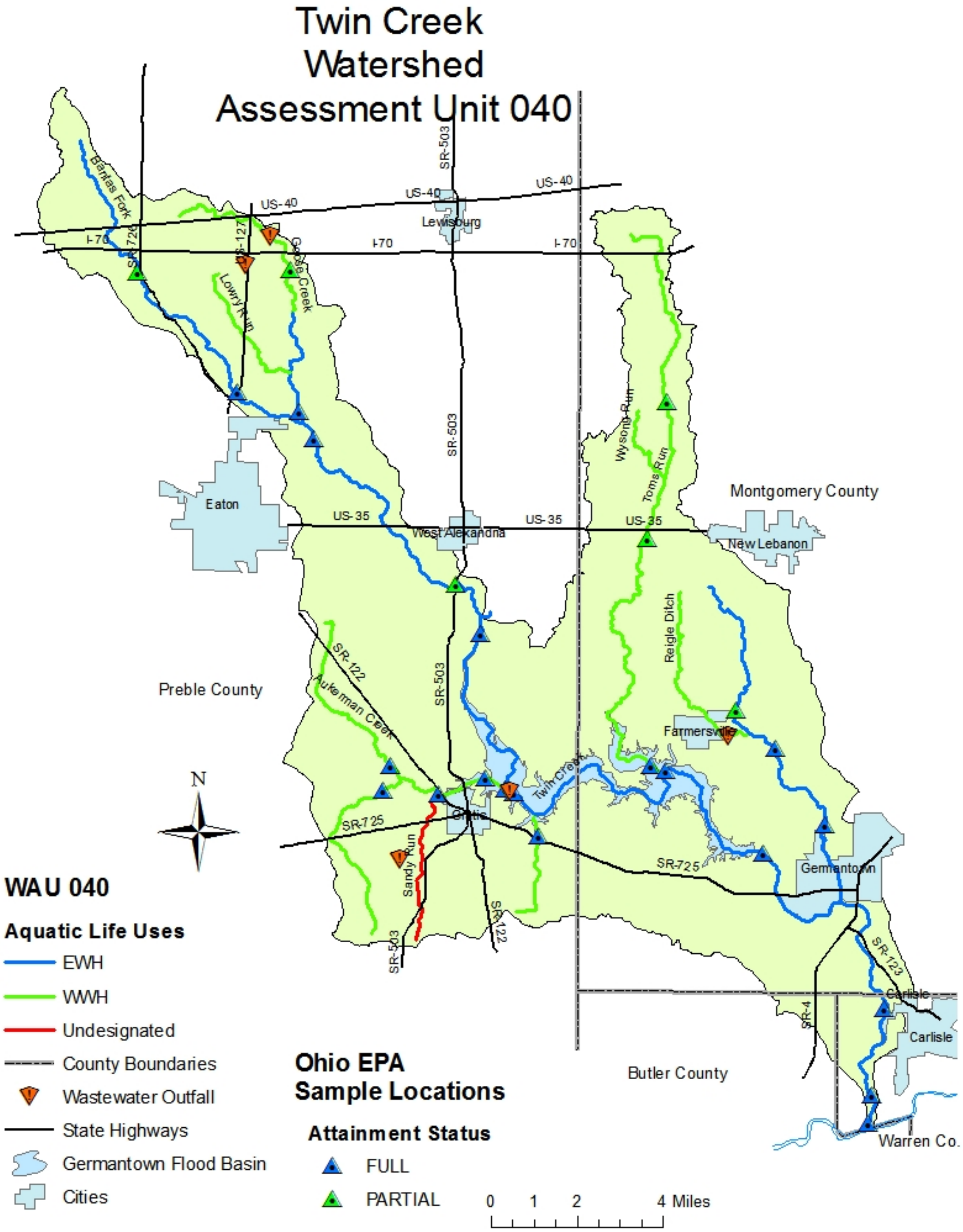


Figure 24. Use designations and attainment status of lower Twin Creek, Hydrologic Assessment Unit 05080002-040.

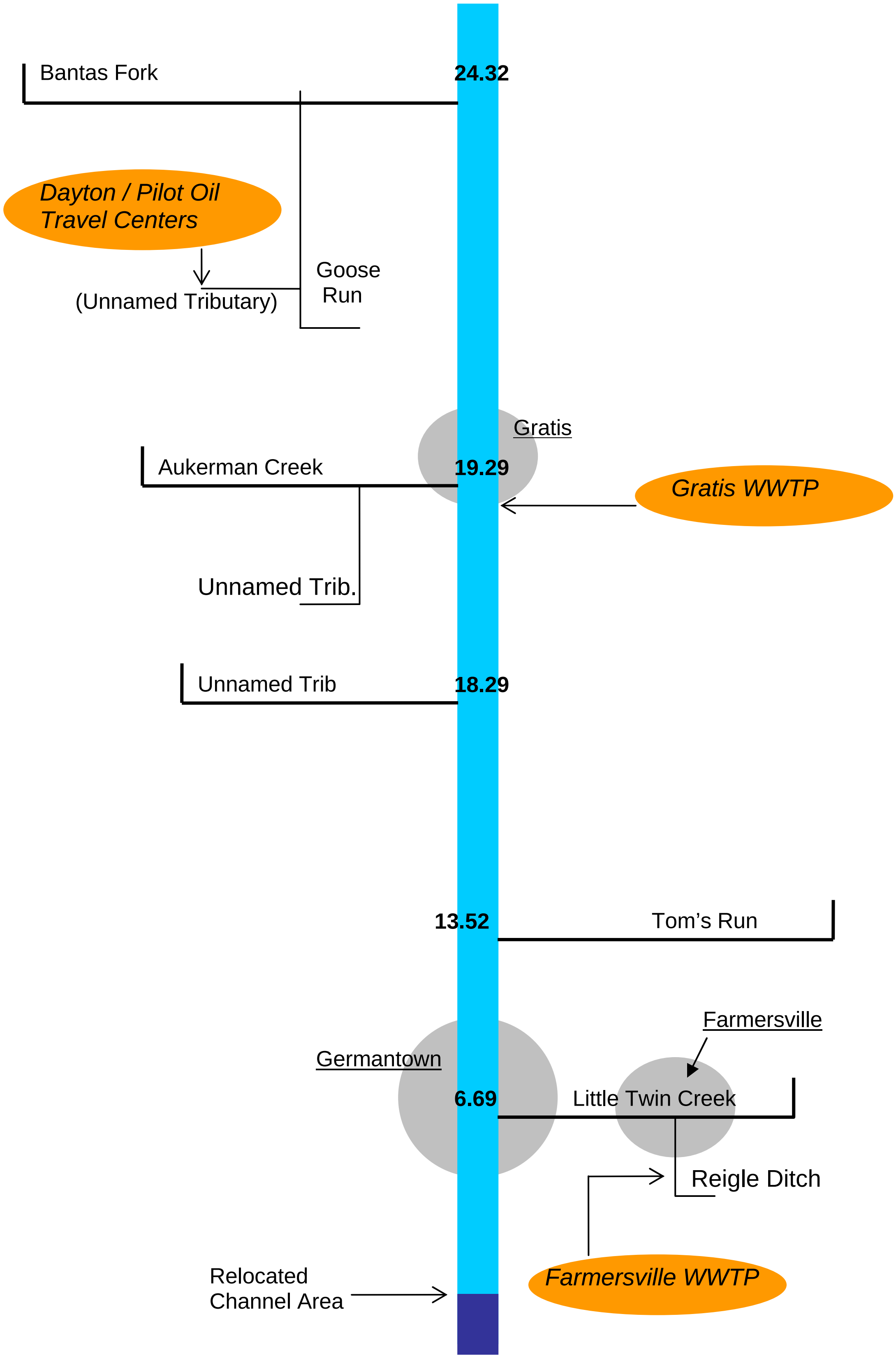


Figure 25. Schematic representation of the lower Twin Creek watershed.

small self serve laundry and a 100 person restaurant. In addition there is also a Subway and a Burger King in the center.

Sanitary wastewater from restrooms, kitchens, showers, and the laundry area is discharged to an onsite wastewater treatment plant. The WWTP is a typical package plant system. Unit processes are: scum separation, activated sludge (extended air), secondary settling, surface sand filters, chlorination, post aeration and dechlorination. Flow design is 20,000 gallons per day with daily average flow of 14,882 gallons (2001-2006). Stormwater and spills under the diesel fueling canopies are captured by a series of catch basins and then processed through a 10,000 gallon oil and water separator near the wastewater plant. The outfall for the WWTP, oil and water separator, and stormwater retention basin is to an unnamed tributary of Goose Run that discharges to Goose Run at RM 4.75.

In 5 years (2001-2006), Dayton Travel Center has been issued 22 Notice of Violations (NOV) by the Ohio EPA Division of Surface Water. Violated parameters included 6 total suspended solid, 2 oil and grease, 6 ammonia-N, 4 fecal coliform, and 4 residual chlorine.

Pilot Oil Travel Center (Goose Run RM 4.54)
Pilot Oil Travel Plaza is located at 6141 US Route 127, near the intersection of I-70 and US 127. It services the trucking industry by providing retail sales, gasoline and diesel fuel with a convenience store and a Dairy Queen.

Sanitary wastewater is discharged to an onsite wastewater treatment plant. The WWTP is a typical package plant system. Unit processes are: scum separation, activated sludge (extended air), secondary settling, surface sand filters, chlorination, post aeration and dechlorination. Flow design is 20,000 gallons per day with daily average flow of 8241 gallons per day (2001-2006). Stormwater and spills under the diesel fueling canopies are captured by a series of catch basins and then processed through an oil and water separator. The outfall for the WWTP, oil and water separator, and stormwater retention basin is to an unnamed tributary of Goose Run that discharges to Goose Run at RM 4.54

In 5 years (2001-2006), Pilot Oil Travel Center was issued 19 Notice of Violations (NOV) by the Ohio EPA Division of Surface Water. All were residual chlorine violations occurring during 2004 -2005.

Farmersville WWTP (Reigle Ditch RM 0.45)
Farmersville WWTP was built in 1961. It was modified in 1969, 1992 and 1994. Design capacity is 0.22 MGD and the average discharge since 2001 has been 0.209 MGD. Treatment includes screening, extended aeration, secondary clarification, chlorination, dechlorination and post cascade aeration. The collection system consists of 100% separate sewers. Approximately 40% of the town relies upon private septic systems. Effluent is discharged to Reigle Ditch at RM 0.45. Reigle Ditch flows into Little Twin Creek at RM 5.43, which joins Twin Creek at RM 6.61.

In 5 years (2001-2006), the Farmersville WWTP was issued 27 Notice of Violations (NOV) by the Ohio EPA Division of Surface Water. There have been 8 total suspended solids, 8 $CBOD_5$, 4 ammonia-N, 3 fecal coliform, 2 residual chlorine, 1 dissolved oxygen and 1 pH. Sewage bypasses are not part of this calculation.

Stormwater infiltration into the sanitary collection system was overloading the plant for years. During major rain events, raw sewage entered the plant through a bar screen and then to the extended aeration tank. An undersized pipe from the aeration tank to the secondary clarifier caused partially treated sewage to bypass the aeration tank and flow down the driveway into Reigle Ditch.

In addition, wet weather sanitary sewer bypasses also occured at the Hemple Road and Elm Street lift stations upstream of the WWTP and discharge to Reigle Ditch. The Village of Farmersville did not consistently report the frequency or amount of bypasses, but it was estimated that each bypass potentially exceeded 20,000 gallons of untreated sewage.

The Ohio Attorney Generals Office issued orders to Farmersville seeking compliance with ORC 6111 by correcting infiltration and bypass problems. Farmersville signed a Consent Order with the Ohio Attorney General in 1995 to resolve this problem. In 1997, Director's Findings and Orders were issued to Farmersville to build an additional clarifier. As of the survey in 2005, bypasses continued. Farmersville signed another Consent Order with the Ohio Attorney General for the same reason in 2006. The Village of Farmersville worked to comply with the conditions of the 2006 Consent Order, and the bypass issue was corrected.

Chemical and Sediment Water Quality

Lower Twin Creek

Lower Twin Creek begins at the mouth of Bantas Fork, south of West Alexandria. This assessment unit of Twin Creek is 24.32 miles in length, draining 101,788.9 acres (159.05 mi^2) of farmland in western Montgomery County. Much of the riparian around Twin Creek is wooded and protected by either the Miami Conservancy District or is within the Five Rivers Metro Park district. This part of Twin Creek has steeper gradient and stream banks than the upper portion. Twin Creek at RM 24.32 near Halderman Road cuts through the Farmersville Moraine boulder belt. The stream flows through alluvium of sand, gravel and boulders. The abundant sand and gravel deposits in Lower Twin Creek have resulted in instream mining. This problem is very noticeable at the broad alluvium terrace near Gratis at RM 19.0. Gravel mining accelerates sediment movement and stream bed instability prohibits the development of mussel beds. Mussel populations were noticeably absent in this stretch of the river.

Results from the survey indicated conventional water chemistry was good. Almost all samples taken for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium or zinc were below the detection limit (BDL) in water column samples.

Water column calcium, iron, manganese, magnesium, hardness, BOD_5, chloride, and sulfate were within acceptable ranges. All water column samples were below the 90^{th} percentile background level for total phosphorus and NO_3-N. One NH_3-N sample was detected above the 90^{th} percentile background level at Twin Creek RM 13.4, downstream from Tom's Run (Figure 26).

Four sites on the mainstem (RMs 23.9, 19.2, 19.0, and 9.8) were also sampled hourly for 48 hours on July 12-14 and August 9-11 using Datasonde© continuous recorders. Results indicated that dissolved oxygen (D.O.) swings were more noticeable during the lowest flow conditions on August 9-11(Figure 27). Wide D.O. swings ranging from 150% saturation to below the EWH minimum were recorded at RM 19.0, caused by algal growth. In general, D.O. swings improved further downstream of RM 19.0. All four mainstem Datasonde© continuous recorders sites fell below the EWH 24-hour average for dissolved oxygen during the night for both sampling events. Temperature maximums during the August sampling event were between 26-29^{0}C during the daytime.

Organic compound exceedences of water quality criteria were documented for dieldrin and heptachlor epoxide at RMs 23.9, 19.2, 19.0, and 9.8. Heptachlor epoxide is the metabolic byproduct of heptachlor. Heptachlor and dieldrin are insecticides that were banned from use in the late 1980s. These legacy compounds are still found in our environment in decreasing numbers.

Water chemistry organic analysis also detected agricultural chemicals in low levels. A common chemical was the class of hexachlorocyclohexanes, also called BHC (benzene hexachloride). The most common isomer, γ-BHC, or lindane, is used as an insecticide in agriculture and to treat head lice and scabies. There are eight isomers of BHC found in lindane. Lindane (γ-BHC) and its isomer (α-BHC) were found at RM 23.90 and RM 9.8. Isomers of lindane were found at RMs 19.20 and 19.00. All levels were below water quality standards.

During the survey, the herbicide atrazine was found across the watershed at all four organic sites in levels below any advisories. Atrazine is usually applied in spring and sometimes in fall to corn crops as a pre-emergent herbicide. It is mobile in water and is found in higher concentrations at high stream flows during the growing season. Atrazine is a suspected endocrine disrupter. Atrazine is usually the dominant agricultural chemical found in the watershed. Low levels of atrazine detected during the survey are attributed to the lack of rainfall events during the survey. Higher levels of atrazine were documented during higher stream flows at the sentinel site at RM 9.8.

Chemical samples and stream flow were collected throughout the year at sentinel sites. Typically survey sampling reflects low flow conditions; sentinel sampling events are used to look at other flow events throughout the year. Inorganic and nutrient chemical analyses were conducted on 9 events and organic analyses were conducted on 5 events in addition to the survey samples. Table 17 demonstrates seasonal agricultural impacts to the sentinel site at RM 9.8. Nitrate-nitrite-N levels were documented over the 90th percentile background level on 7 of 9 events. Non-growing season nitrate discharges are documented in Table 17. These are most likely from farm field drainage tiles. Ammonia-N levels were documented over the 90th percentile background level (0.096 mg/l) at 2 of 9 events.

Table 17. Sentinel site sampling at Twin Creek RM 9.8 demonstrates the relationship between higher flows and elevated water column nutrients.

Date	Discharge ft^3/sec Twin Creek RM 9.8	NO_3-NO_2-N mg/l	P total mg/l	NH_3-N mg/l	Atrazine µg/l
4/27/2005	1460	7.66	0.258	0.345	23.2
5/24/2005	180	6.62	0.028	<0.05	2.11
6/30/2005	52	5.73	0.061	<0.05	2.20
9/22/2005	58	3.87	<0.05	<0.05	ND
10/25/2005	831	7.32	0.296	<0.05	ND
11/28/2005	132	4.92	0.036	0.228	ND
1/12/2006	335	5.38	0.045	<0.05	<0.21
2/02/2006	95	5.81	0.019	<0.05	ND
4/26/2006	349	3.68	0.017	<0.05	0.36

red - above the 90^{th} percentile for nutrients in small rivers 200-1000 mi^2 found in Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999)
Green - above the 2001 USEPA draft aquatic criteria for atrazine 12 µg/l (chronic criteria)
ND - not done

Agricultural chemicals were detected at higher levels during the sentinel sampling events than during the survey. Atrazine was listed in Table 17 as the indicator chemical for agricultural chemicals, although others are found at lower levels. The April 27, 2005 sampling event documented a high flow event with agricultural runoff from the spring chemical application. In addition to atrazine at 23.2 µg/l, metolachlor (7.21 µg/l), simizine (2.25 µg/l), and acetochlor (5.06 µg/l) were also found in the water column. Nutrient analysis detected ammonia (0.345 mg/l), phosphorus (0.258 mg/l) and nitrate-nitrite (7.66 mg/l) over the 90^{th} percentile values for small streams (200-1000 mi^2). This would correspond to a daily load of 60,168 pounds of nitrate-nitrite-N, 2710 pounds of ammonia-N, 382 pounds of phosphorus and 182 pounds of atrazine in 944 million gallons of water flowing past RM 9.8 in 24 hours. These values are not unusual for spring time agricultural runoff, but are presented in a way to see how many pounds are lost from soil after spring application.

Sediment samples in the lower watershed were collected at four sites: RMs 23.9, 19.2, 19.0 and 9.8 (Tables 20 and 21). Sediment ammonia levels over the Ontario Open Water Disposal Guidelines (100 mg/kg) (Persuad and Wilkins, 1976) were detected at RM 23.9 (110mg/kg) and 19.0 (120 mg/kg). Land application of manure and failing septic systems are suspected at both sites. The RM 19.0 site may also have some solids discharge from the Gratis WWTP that may contribute some ammonia to the sediments.

The sediment sampling site at RM 19.0 documented arsenic at 9.9 mg/kg. This level of sediment arsenic is above the MacDonald Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC), but below the Ohio Sediment Reference Values (SRV) of 18 mg/kg. Normally sediments between the MacDonald TEC and PEC indicate that adverse benthic effects frequently occur, but Ohio's SRV value is geologically naturally higher than the MacDonald guidelines for arsenic and not considered to adversely affect benthic organisms.

No PCBs were detected in water column samples or in sediment samples. Mercury was found below detection limit in 4 of 5 sediment samples. The one detection of sediment mercury was

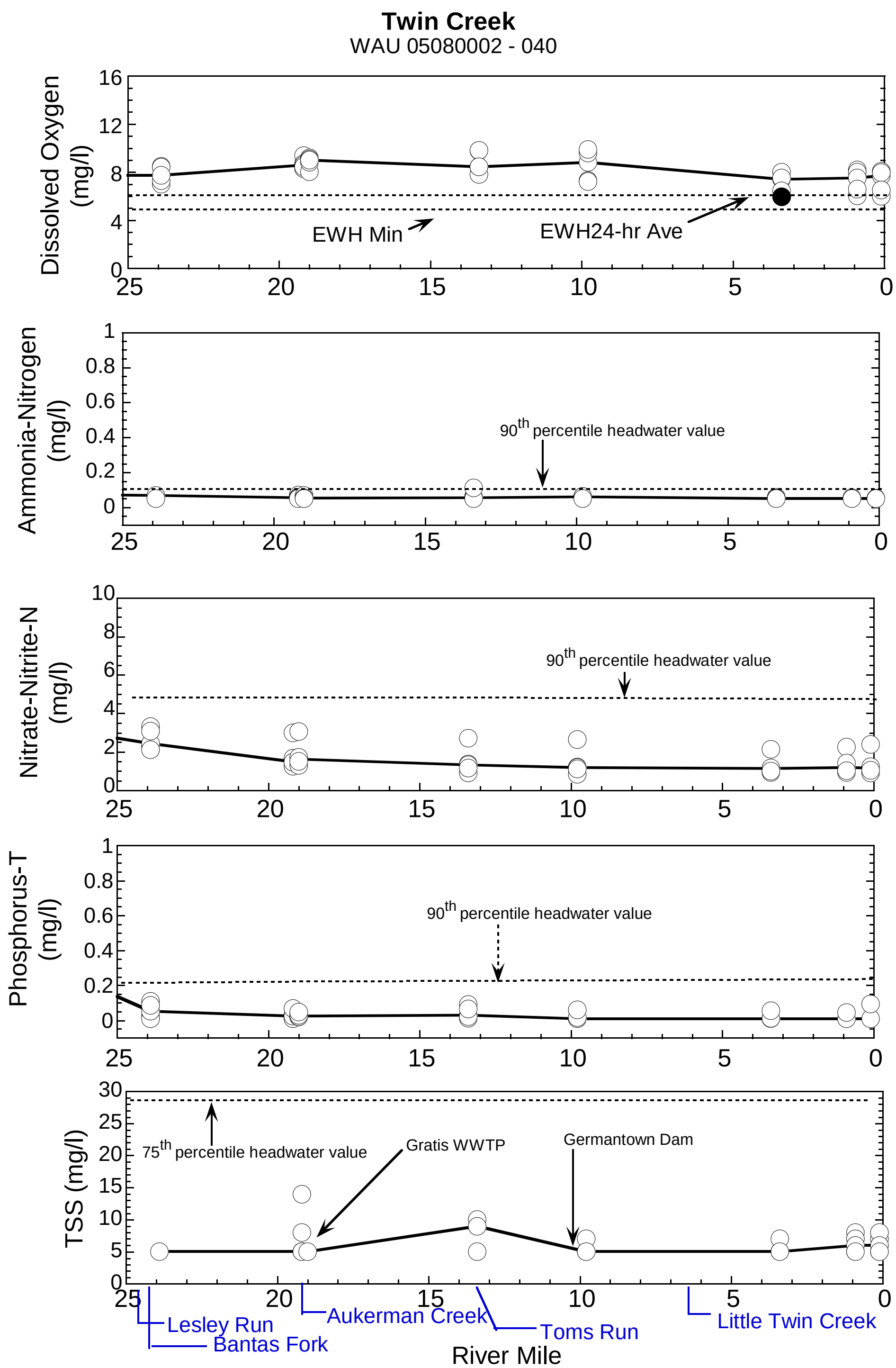


Figure 26. Longitudinal plots of water chemistry daytime grabs in Twin Creek during the 2005 survey. Top to bottom: dissolved oxygen, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile. WQS criteria 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.

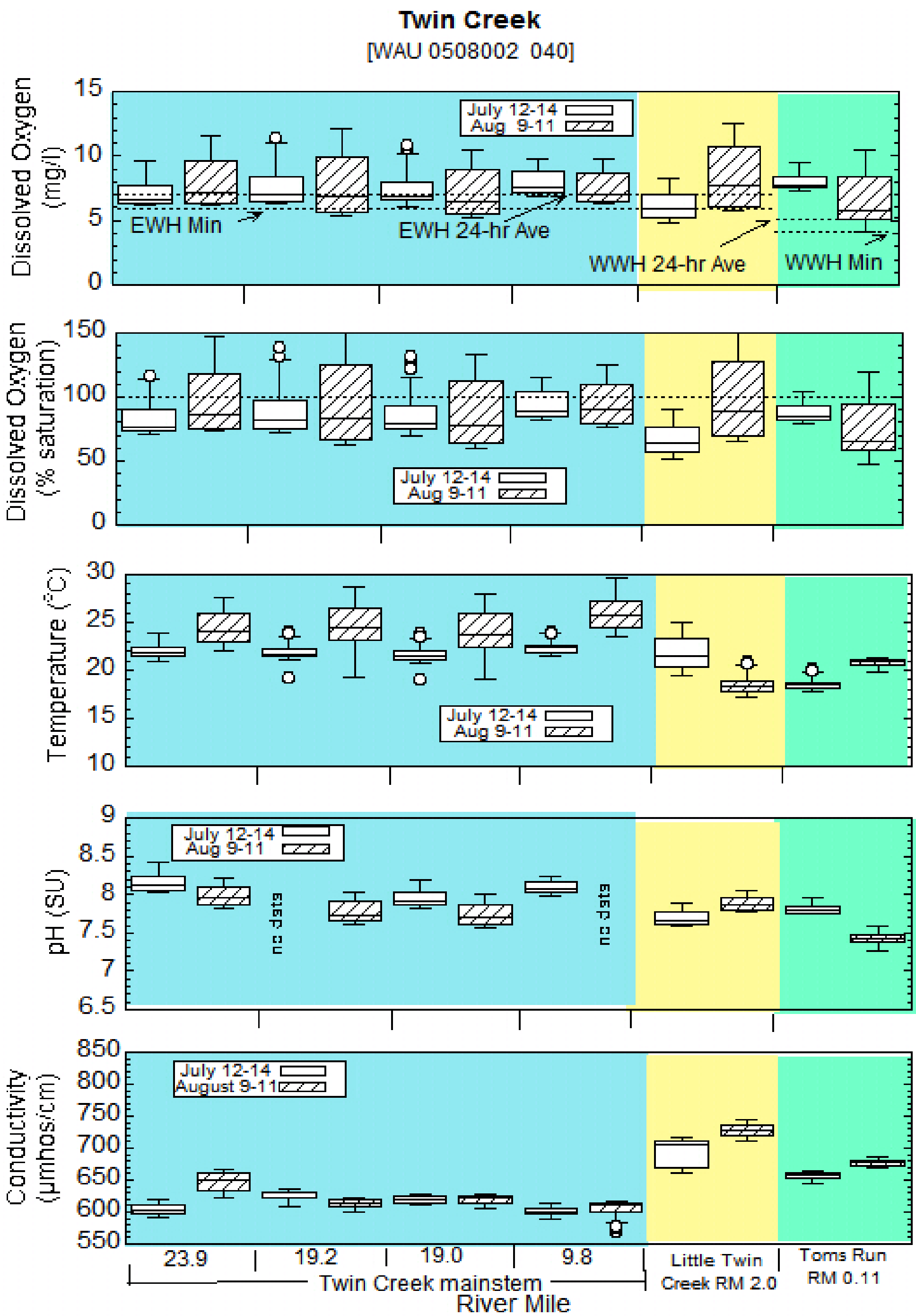


Figure 27. Distributions of DO, temperature, pH, and conductivity recorded hourly with Datasondes© in Lower Twin Creek 2005. Each box encloses 50% of the data with the median value displayed as a line. The top and bottom of the box mark the 75th and 25th percentile. The lines from top to bottom of the box mark the min. and max. values within the data set that fall within an acceptable range. Any value outside of this range is displayed as an individual point.

below the Ohio Sediment Reference Value. Water column mercury was not detected in any of the samples taken in the lower mainstem. Low human population density, broad protected riparian corridors, and only one point source help make this an exceptional stream.

Bantas Fork

Bantas Fork is 16.8 miles in length, draining 22,464 acres (35.1 mi^2) of farmland in central Preble County. The headwaters begin north of US 40 near Gettysburg and flow 2.0 miles through hydric Kokomo soils with flat topography and no riparian cover. At Orange Road (RM 13.7), the stream flows through very flat Eel silt loam soils and is much embedded with silt (5 inches thick). Only narrow bands of riparian border the stream. As Bantas Fork travels south, the soils become better-drained, and the gradient begins to increase. At RM 9.4, the soils become Rossburg silt loam with sand and gravel substrate. The stream at RM 7.1 flows through Stonelick loam with some silt-embedded gravel substrate. As the stream travels southeast to the mouth, good riparian cover with sand and gravel substrate is evident, but siltation is present. Bantas Fork enters Twin Creek at RM 24.32 south of West Alexandria and contributes to 11.1% of the Twin Creek drainage area.

No arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, or zinc measured above the detection limit in water column samples. Water column calcium, iron, manganese, magnesium, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

Habitat destruction, sedimentation, and nutrient enrichment were evident at RM 13.7. Water column ammonia levels were over the 90^{th} percentile headwater value (0.1 mg/l) 4 of 5 times (median 0.13 mg/l) samples were collected. Water column phosphorus and nitrate levels were below the 90^{th} percentile headwater value. Impacts from farming practices and failed septic systems are suspected. None of the nutrient samples collected from RM 9.40 was over the 90^{th} percentile headwater value. Stream substrate was characterized by sand, gravel, and cobble. Riparian cover increased at RM 9.40. Samples from RM 7.10 documented one water column phosphorus result over the 90^{th} percentile headwater value of 0.206mg/l. Algal mats and substrate embeddedness from siltation were noted at this site. Results from RM 1.30 had no nutrient samples over the 90^{th} percentile headwater value. Stream substrate was sand, gravel, and cobble with a partial riparian cover.

Two sites on Bantas Fork (RMs 1.3 and 7.1) were sampled hourly for 48 hours on July 12-14 and August 9-11 using Datasonde© continuous recorders. Results indicated that dissolved oxygen (D.O.) fell below the EWH minimum at both stations due to algal growth from nutrient enrichment and lack of shading due to riparian removal.

The sediment was sampled at RM 1.30. No organic compounds were detected in the sample. Both nutrients and metals were found to be within guidelines (Tables 19-21).

Goose Run (also known as Goose Creek)

Goose Run is 5.1 miles in length, draining 7232 acres (11.3 mi^2) of farmland in central Preble County. The headwaters begin near US 40 and Monroe Central Road in north central Preble County and are designated as WWH. The designation of the creek changes to EWH at Winnerline Road (RM 3.0). Goose Run enters Bantas Fork at RM 7.55 north of Eaton and contributes 32% to the drainage area of Bantas Fork and 3.58% of the Twin Creek drainage area.

Nutrient enrichment was noted in the headwater site at RM 4.4. Dissolved oxygen was below the WWH 24-hour minimum (5.0 mg/l) on 4 of 5 sampling events. One sampling event (8/9/05) was below the WWH minimum (4.0 mg/l). All ammonia–N samples were above the 90th percentile background value (0.10 mg/l) with the median value being 0.151 mg/l and the maximum value being 0.2 mg/l. All phosphorus values sampled were above the 90th percentile background headwater value (0.206 mg/l), with the median value being 0.595 mg/l and the maximum value detected being 0.974 mg/l. On July 12, the chemical oxygen demand (COD) was 106 mg/l which was above the 90th percentile headwater value (33.2 mg/l), the median COD value was 22 mg/l. This site is downstream of the Dayton Travel Center, Pilot Oil Travel Center, EconoLodge, and the Sandman efficiency apartment complex. The EconoLodge had no NPDES permit and the package plant discharged into an unnamed tributary of Goose Run. The Sandman efficiency apartment complex was a motel that has been converted to rental units with a questionable leach field and no NPDES permit.

A proposed industrial park and wastewater treatment plant discharging 5 million gallons per day into Goose Run was being considered for the I-70 and US 127 interchange. If this was to occur, the flow in this small tributary would dramatically increase from treatment plant discharge and from impervious surface runoff. An effluent-dominated stream with high flows can destabilize the downstream corridor. Discharge-driven physical disturbances of fish and benthic populations may alter the stability of species assemblage and ultimately lower the use designation. If this proposal is pursued, innovative technology for wastewater treatment and stormwater management should be evaluated to minimize the impact to Goose Run.

Water column organic chemicals were sampled two times during the survey. Heptachlor epoxide was detected once at 0.0021 µg/l, which is an exceedence of the numerical criteria for human health. The agricultural chemicals acetochlor, atrazine, endrin, metolachlor, simazine and hexachlorocyclohexanes (a, d, y –BHC) were detected at levels below criteria or proposed criteria.

Water column bacteria (fecal coliform, *E. coli*) were monitored five times during September 2005, at the headwater site at RM 4.4. Exceedences of Primary Contact Recreation (PCR) Water Quality Standards (WQS) for *E. coli* geometric mean and maximum concentrations occurred on September 9. Geometric mean and maximum concentrations were 214 colonies/100 ml and 2400 colonies/100 ml respectively. The PCR WQS maximum for fecal coliform (2000 colonies/100 ml) was exceeded on September 9, with a result of 7400 colonies/100 ml. September 9, 2005 was a wet-weather event.

Goose Run was sampled for sediment at RM 4.4. No organic compounds were detected in the sample. Arsenic was detected in sediment at 10.8 mg/kg, which is between the MacDonald TEC and PEC, a level at which adverse effects frequently occur. This level was below the Ohio SRV guideline for arsenic, meaning this amount of arsenic is normal for this area. Sediment calcium was 160,000 mg/kg, which is above background for this area.

Aukerman Creek

Aukerman Creek is 6.5 miles in length, draining 13,347.6 acres (20.86 mi^2) of farmland in central Preble County. The headwaters begin near the intersection of SR 122 and Quaker Trace near Wheatville, southeast of Eaton. Aukerman Creek enters Twin Creek at RM 19.29 near Gratis and contributes 6.58% of the Twin Creek drainage area.

Aukerman Creek has good riparian cover, clear water and the substrate is sand and gravel. Water chemistry was good on all parameters tested except for strontium. Strontium was above the Tier II Water Quality Standard (5300 ug/l) at RM 1.8 (median 5480 ug/l; maximum 7620 ug/l) and at RM 0.55 (median 3290 ug/l; maximum 4030 ug/l). Some filamentous algae were found at RM 0.55, but overall a very nice stream. No organic compounds or bacteria were tested. Strontium is a naturally occurring metal found in celestite ($SrSO_4$) and strontinite ($SrCO_3$) deposited in valley fill from Silurian aged carbonates.

Tributary to Aukerman Creek at RM 2.88

This tributary enters Aukerman Creek at RM 2.88 and drains 4.5 mi^2 of farmland. The stream had good sand and gravel substrate, and the water is clear. The water chemistry was good on all parameters tested, with the exception of strontium, which was above the Tier II Water Quality Standard (5300 µg/l). This little stream had the highest strontium levels (maximum 9610 µg/l; median 8140µg/l) documented on the entire survey. The median value of strontium in the entire watershed was 1160 µg/l.

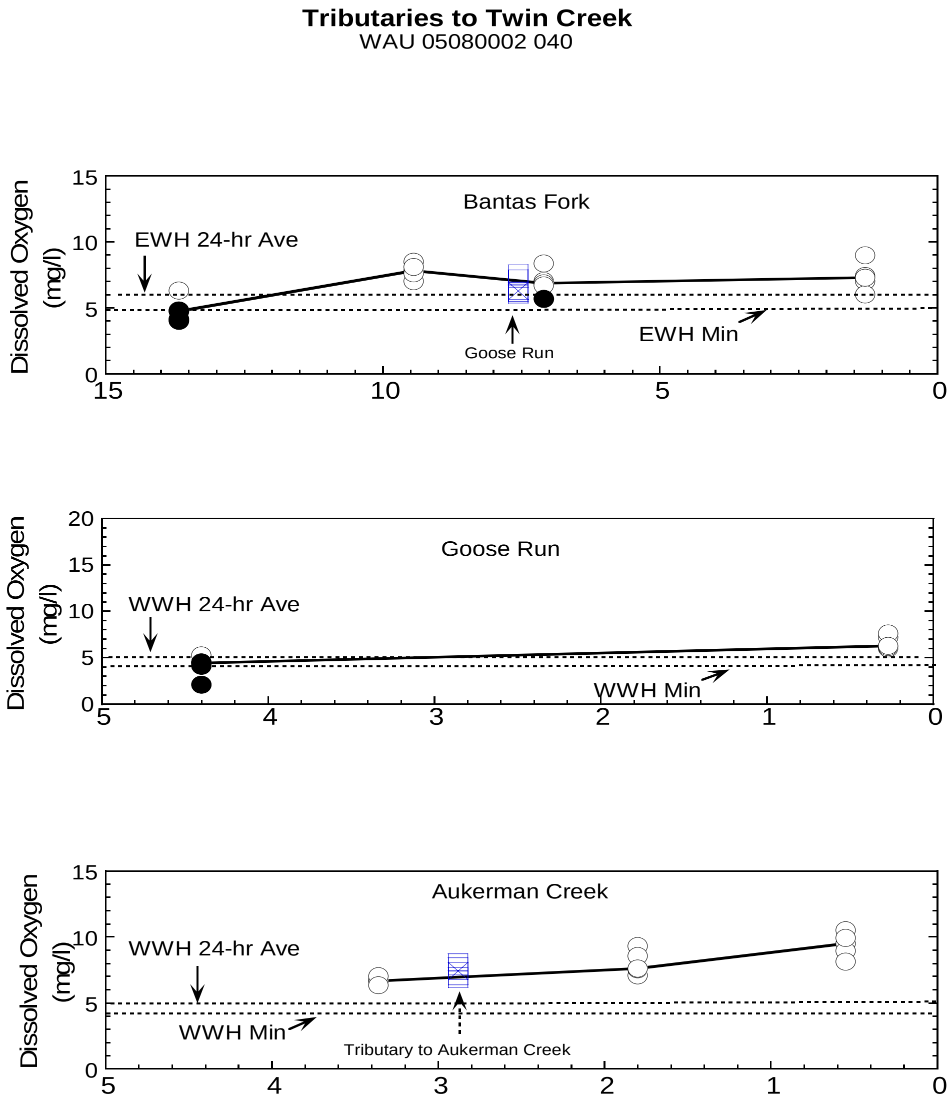


Figure 28. Longitudinal plots of water chemistry daytime dissolved oxygen grabs in Twin Creek tributaries during the 2005 survey. Tributary mainstem is indicated by circles and tributaries of tributaries are indicated by squares. The solid line indicates median value of each river mile sampled while an 'X' depicts the median for the tributary of tributaries.

Tom's Run

Tom's Run is 17.1 miles in length, draining 16,503.2 acres (25.79 mi^2) of farmland in western Montgomery County. The headwaters begin north of I-70 near Brookville and flow 2.4 miles through hydric Brookston soils, with flat to rolling topography having no riparian cover. South of Brookville-Pyrmont Road (RM 14.6), the stream becomes more incised and drainage gradient increases with better-drained Medway silt loan and Ross silt loam making up the stream bed. Tom's Run enters Twin Creek at RM 13.52 near Farmersville and contributes to 8.1% of the Twin Creek drainage area.

During the survey, stream flow continually decreased throughout July and August until Tom's Run became interstitial at the two headwater sites (RM 12.0 at Amity Road and RM 8.5 at Bull Rd). Remnants of Hurricane Katrina released 3.15 inches of rain at the West Manchester precipitation station on August 30 and 31, which increased flow in the Twin Creek watershed. After Katrina, stream flow rapidly dropped, continuing low flow conditions during the two sampling events in September.

No arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium or zinc was above the detection limit in water column samples. Water column calcium, iron, manganese, magnesium, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

The Amity Road site (RM 12.0) had ammonia-N levels over the 90^{th} percentile headwater value (0.1 mg/l) during 4 of 5 sampling events (max 0.402 mg/l), indicating that animal feedlot or failed septic systems could be a factor. Also, D.O levels fell below 4.0 mg/l (WWH minimum) on the first three sampling events at RM 12.0.

Stream habitat improved at RM 8.5 (Bull Road) with better riparian corridors, but nutrient contamination was still present. Dissolved oxygen levels fell to below the WWH 24-hour average (5.0 mg/l) on two sampling events prior to the rain event from Katrina. Ammonia–N levels in the stream exceeded the 90^{th} percentile background levels on all three sampling events prior to the rain remnants of Katrina (max 0.172 mg/l) and fell to near the detection limit (0.05 mg/l) in September.

During the survey, none of the nutrient and D.O. impacts were documented near the mouth (RM 0.11). Exceedences of water quality criteria were documented for dieldrin and heptachlor epoxide. Atrazine (0.61 µg/l), simizine (0.20 µg/l), and metolachlor (0.27 µg/l) were found at low levels during non-rainfall events.

Five bacteria sampling events at RM 0.11 (September 8-22) documented the *Escherichia coli* geometric mean value (154 colonies/100 ml) exceeded the PCR WQS geometric mean value of 126 colonies/100 ml. Two rainfall events during the bacteria sampling influenced the geometric mean. The September 21st sampling event documented *E. coli* at 1000 colonies/100ml, which exceeded the maximum allowable density of 298 colonies/100 ml.

The sediment sampling site at RM 0.11 documented that only 11.5% fine grained material was collected in the sample. This indicated that the site had good substrate and did not have much sediment embeddedness. No organic compounds were detected in the sample. Both nutrients and metals were found to be within the guidelines (Tables 19 and 20).

RM 0.11 was also sampled hourly for 48 hours on July 12-14 and August 9-11 using Datasonde© continuous recorders. Results indicated that dissolved oxygen (D.O.) swings were more noticeable during the lowest flow conditions on August 9-11, but were not as wide a swing as other sites in the watershed. All other parameters were in a narrow band, not indicating anything unusual.

Tom's Run at RM 0.11 was a sentinel site. Chemical samples and stream flow were collected throughout the year. Inorganic and nutrient chemical analyses were conducted on 10 events and organic analyses were conducted on 5 events outside the survey. Table 18 demonstrates seasonal agricultural impacts to Tom's Run. Nitrate-nitrite-N levels were documented over the 90^{th} percentile background level on 5 of 10 sentinel events. These are most likely from farm field drainage tiles draining ground water. Ammonia-N levels were documented over the 90^{th} percentile background level (0.096 mg/l) during 2 of 10 events. Both events could be related to the application of hog manure on farm fields. There is one CAFO in the watershed with 4800 hogs. Hog manure is applied to wheat fields after harvest in early July, and also to farm fields after corn and beans are harvested in fall. What was more notable was that 6 of 10 events recorded ammonia below the detection limit (0.05 mg/l). Liquid manure, when correctly land-applied, should convert ammonia to nitrate by oxidation of NH_3 to NO_3 through biological activity in the soil.

Agricultural chemicals were detected at higher levels during the sentinel sampling events than during the survey. Atrazine was listed in Table 18 as the indicator chemical for agricultural chemicals, although others are found at lower levels. The April 27, 2005 sampling event documented a high flow event with agricultural runoff from the spring chemical application. In addition to atrazine at 27.6 µg/l, metolachlor (8.4 µg/l), simizine (6.86 µg/l), and acetochlor (1.1 µg/l) were also found in the water column. Unfortunately the cubitainer containing the nutrient samples for 4/27/2005 was unable to be analyzed. Atrazine (27.6 µg/l) was found to be over the USEPA draft aquatic criteria for atrazine (12 µg/l; chronic criteria).

Little Twin Creek

Little Twin Creek is 7.8 miles in length, draining 14,528 acres (22.7 mi^2) of rolling farmland in western Montgomery County. The headwaters begin south of US 35 near Johnsville and flow through well-drained Ross silt loam soils with an average fall of 25 ft/ mile. The stream was bordered by various widths of riparian cover. Little Twin Creek enters Twin Creek at RM 6.69 in Germantown and contributes to 7.2 % of the Twin Creek drainage area.

No arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium or zinc was above the detection limit in water column samples. Water column calcium, iron, manganese, magnesium, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

Two exceedences of water quality criteria were documented for dieldrin at RM 2.0. The headwater site at RM 6.2 documented dissolved oxygen below the EWH minimum (5.0 mg/l)

Table 18. Sentinel site sampling at Toms Run RM 0.2 demonstrates the relationship between higher flows and elevated water column nutrients.

Date	Discharge ft^3/sec	Velocity ft/sec	Discharge ft^3/sec Twin Creek RM 9.8	NO_3-NO_2-N mg/l	P total mg/l	NH_3-N mg/l	Atrazine µg/l
4/27/2005	77.3	2.84	1460	ND	ND	ND	27.6
5/24/2005	16.8	1.43	180	6.31	0.047	0.058	1.66
6/29/2005	1.97	0.377	51	1.64	0.019	<0.05	0.32
7/21/2005	1.17	0.17	32	1.56	<0.10	0.091	ND
8/23/2005	0.068	0.018	10	1.61	0.10	0.099	ND
9/22/2005	5.15	0.482	58	7.38	0.094	<0.05	ND
10/25/2005	62.1	2.24	1130	9.43	0.283	<0.05	ND
11/28/2005	5.95	0.961	87	4.65	0.017	0.270	ND
1/12/2006	31.5	2.07	654	5.40	0.045	<0.05	<0.21
2/02/2006	ND	ND	95	5.11	0.014	<0.05	ND
4/26/2006	21.1	1.85	349	3.07	0.015	<0.05	0.28

Red - above the 90th percentile for nutrients in wadeable streams (<20-200mi^2) found in Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999)
Green - above the 2001 USEPA draft aquatic criteria for Atrazine 12 µg/l (chronic criteria)
ND- not done

on September 14 and below the EWH average (6.0 mg/l) on September 6. Dissolved oxygen fell below the EWH average at RM 4.7 on July 26 and September 14 due to algal growth.

Water column bacteria (*E. coli* and fecal coliform) were monitored five times during September 2005, at RM 2.0 on Little Twin Road. Neither *E. coli* nor fecal coliform were above median PCR WQS standards. The PCR WQS maximum for *E.coli* (298 colonies/100 ml) was exceeded on July 26, having 350 colonies/100 ml.

Sediment analysis of Little Twin Creek at RM 2.0 did not detect any metals above the MacDonald or Ohio SRV guidelines. Nutrients were below the Ontario guidelines, and organic chemicals were not detected.

Reigle Ditch

Reigle Ditch is 4.7 miles in length, draining 2176 acres (3.4 mi^2) of farmland in southwestern Montgomery County. Reigle Ditch contributes 15.0% to the drainage area of Little Twin Creek and 1.1% of the Twin Creek drainage area.

The upstream site on Reigle Ditch (RM 1.2) documented one ammonia exceedence of 90th percentile background headwater value. The results from the site, immediately upstream of the WWTP outfall, did not document any exceedences or elevations of nutrient criteria or guidelines.

The Farmersville WWTP dominates flow in Reigle Ditch. Filamentous algae was found downstream of the outfall. Water column phosphorus was above the 90th percentile background headwater value during all sampling events (median 0.659 mg/l). Water column ammonia was above the 90th percentile background headwater value during one sampling event. Water column Nitrate was above the 90th percentile background headwater value twice during the survey (median 4.38).

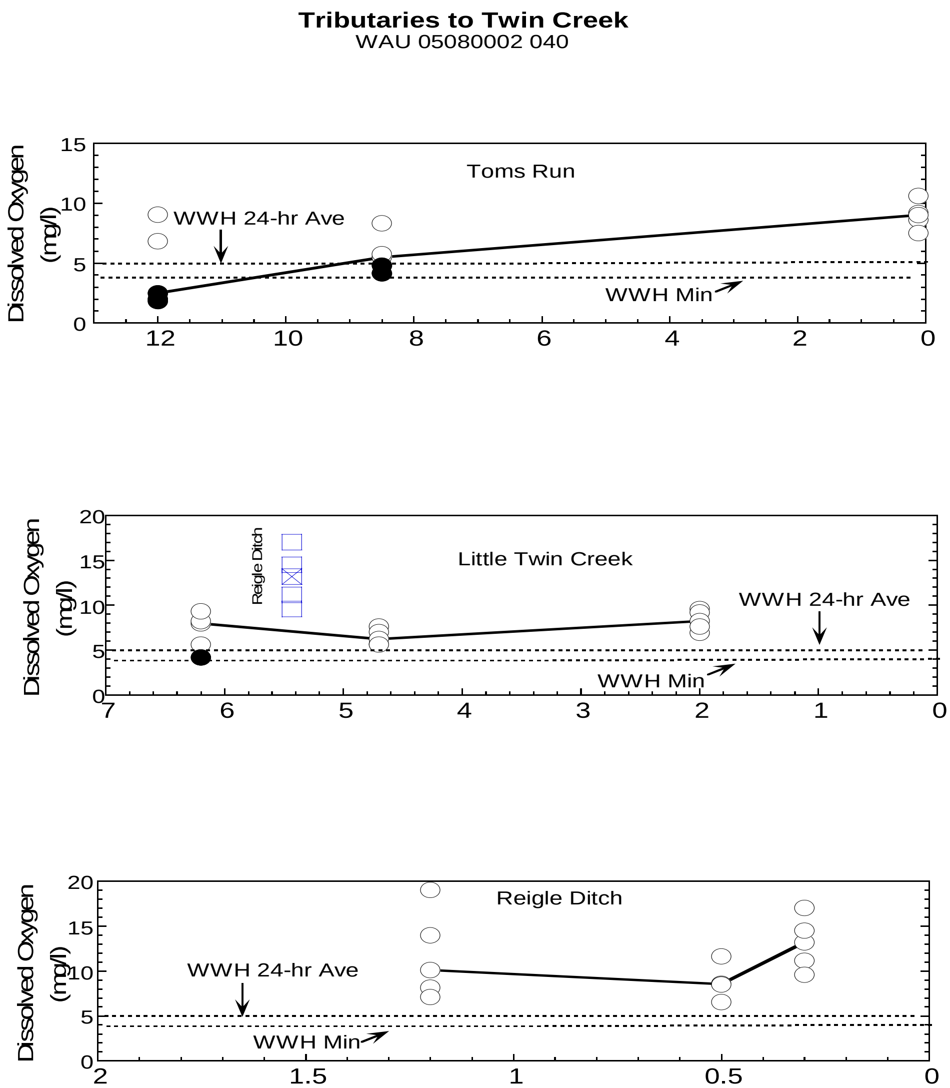


Figure 29. Longitudinal plots of water chemistry daytime dissolved oxygen grabs in Twin Creek tributaries during the 2005 survey. Tributary mainstem is indicated by circles and tributaries of tributaries are indicated by squares. The solid line indicates median value of each river mile sampled while an 'X' depicts the median for the tributary of tributaries.

Table 19. Twin Creek tributaries in WAU 05080002-040 showing nutrient elevation during 2005 survey using Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999).

Stream (RM)	area mi^2	Frequency of Phosphorus >90th Percentile	Phosphorus Median (mg/l)	Frequency of NH_3 >90th Percentile	NH_3 Median (mg/l)	Frequency of NO_3 >90th Percentile	NO_3 Median (mg/l)
Bantas Fork (13.70)	6.6	0/5	0.022	4/5	0.13	0/5	.25
Bantas Fork (9.40)	11.8	1/5	0.024	0/5	0.066	0/5	1.15
Bantas Fork (7.10)	24.4	0/5	0.01	1/5	0.066	0/5	0.61
Bantas Fork (1.30)	34	0/5	0.01	0/5	0.057	0/5	0.63
Goose Creek (4.40)	3.3	5/5	0.595	5/5	0.151	0/5	0.52
Goose Creek (0.30)	11.25	0/5	0.016	0/5	0.075	0/5	0.68
Aukerman Creek (3.30)	5.2	0/5	0.119	0/5	0.057	0/5	0.052
Aukerman Creek (1.80)	13.7	0/5	0.025	0/5	0.063	0/5	.0.65
Aukerman Creek (0.50)	20.7	0/5	0.016	0/5	0.05	0/5	1.34
Trib Aukerman Creek (0.50)	4.5	0/5	0.022	0/5	0.069	0/5	0.37
Toms Run (12.00)	6.0	0/5	0.145	4/5	0.174	2/5	1.7
Toms Run (8.50)	10.6	0/5	0.088	3/5	0.123	0/5	0.19
Toms Run (0.11)	24.3	0/5	0.011	0/5	0.051	0/5	1.48
Little Twin Creek (6.20)	4.9	0/5	0.025	0/5	0.054	0/5	1.6
Little Twin Creek (4.70)	11.5	1/5	0.15	0/5	.077	0/5	1.55
Little Twin Creek (2.00)	19.8	0/5	0.01	0/5	0.05	0/5	0.79
Reigle Ditch (1.20)		0/5	0.082	1/5	0.072	0/5	0.01
Reigle Ditch (0.50)	3.4	0/5	0.054	0/5	0.05	0/5	0.42
Reigle Ditch (0.30)		5/5	0.659	1/5	0.074	2/5	4.38

Table 20. Concentrations (mg/kg) of metals and nutrients in sediment samples collected in the Twin Creek watershed assessment unit (WAU 05080002 040) 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	Site Location (RM)								Reference	
	Twin Creek RM 23.9	**Twin Creek** RM 19.20	**Twin Creek** RM 19.0	**Twin Creek** RM 9.8	**Goose Creek** RM 4.40	**Bantas Fk** RM 1.3	**Toms Run** RM 0.11	**Little Twin Creek** RM 2.0		
									Ohio	**MacD**
Al-T O	14200	15600	24300	15200	23600	26900	6890	7690	39000	*
As-T OM	6.22	6.69	9.99#	7.90	10.2#	8.33	5.14	5.43	18	9.79-33
Ba-T O	112	117	188	94.2	216	194	56.4	61.0	240	*
Ca-T O	57600	68700	75600	46100	160,000 +	49700	74200	76100	120000	*
Cd-T OM	0.268	0.215	0.412	0.345	0.281	0.687	0.139	0.146	0.9	0.99-4.98
Cr-T OM	17	19	<31	18	27	36	12	<16	40	43.4-111
Cu-T OM	11.4	8.5	15.4	13.2	12.0	20.4	4.7	5.4	34	31.6-149
Fe-T O	12800	13200	18900	14200	17100	22800	9010	8730	33000	*
Hg-T OM	0.026	<0.031	<0.066	<0.021	<0.043	<0.047	<0.025	<0.023	0.12	0.18-1.06
K-T O	3190	4070	5980	3180	6000	6590	2240	2170	11000	*
Mg-T O	15700	21500	19100	16100	29800	19500	26400	27100	35000	*
Mn-T O	295	309	409	267	428	517	249	240	780	*
Na-T *	<2550	<3040	<5180	<2270	<4150	<4380	<1880	<2650	*	*
Ni-T OM	<20	<24	<41	<18	<33	<35	<15	<21	42	22.7-48.6
Pb-T OM	<20	<24	<41	<18	<33	<35	<15	<21	47	35.8-128
Se-T O	1.20	1.38	2.32	<0.91	<1.66	<1.75	<0.75	<1.06	2.3	*
Sr-T O	134	202	283	113	479	162	84	105	390	*
Zn-T OM	53.1	42.0	79.9	47.2	68.2	132	24.8	25.7	160	121-459
									Ohio	**Pers.**
NH_3-N P	110	78	120	36	50	52	<9	<10	*	100
TOC P	6.8 %	5.2 %	6.8%	4.8%	6.6%	4.4%	5.0%	5.3%	*	10.0%
pH *	7.6	7.5	7.5	7.6	7.9	7.5	7.9	7.9	*	*
P-T P	469	330	1620	339	699	1030	350	374	*	2000
%FGM O	25.3%↘	40.8 %	59.7 %	35.3%	41.8%	51.6%	11.5% ↘	18.9%↘	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 Evaluatedby Persuad (1976, 1993)

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

Ontario Sediment Guidelines (Persuad, 1993 and Persuad and Wilkins, 1976)
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-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

Table 21. Sediment concentrations of organic compounds (priority pollutant scan) detected in the Twin Creek watershed assessment unit (WAU 05080002 040) during 2005. Individual compounds were evaluated by the MacDonald Sediment Quality Guidelines (2000).

River / Landmark	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
Twin Creek RM 23.9 Haldeman Rd. TOC= 6.8 % Fine Grain Material = 25.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Twin Creek RM 19.20 Enterprise Rd TOC= 5.2 % Fine Grain Material = 40.8 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Twin Creek RM 19.0 Dst. Gratis WWTP TOC= 6.8 % Fine Grain Material = 59.7 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	Acetone	0.132 * BDL BDL BDL
Twin Creek RM 9.8 Old Gage at Dam TOC= 4.8 % Fine Grain Material = 35.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Goose Creek RM 4.40 Scheyhing Rd TOC= 6.6 % Fine Grain Material = 41.8 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Bantas Fk RM 1.3 SR 503 TOC= 4.4 % Fine Grain Material = 51.6 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Toms Run RM 0.11 Anthony Rd. TOC= 5.0 % Fine Grain Material = 11.5 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Little Twin Creek RM 2.0 Little Twin Rd. TOC= 5.3 % Fine Grain Material = 18.9 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL

* Not evaluated NA Compound not analyzed 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

Physical Habitat and Fish Assessment

Assessment of both the physical habitat and the fish community of Twin Creek were conducted using a whole basin approach, rather than an assessment unit approach. Discussions on a reach scale were limited to areas within the upper Twin Creek watershed (HUC 030) only, and therefore the assessment is located in the corresponding section, beginning on page 70.

Biological Assessment: Macroinvertebrate Community

Lower Twin Creek

All 8 sites in the lower segment of Twin Creek received exceptional scores, thus meeting the EWH aquatic life use (Table 22). ICIs in this reach were consistent (Figure 30), with a mean near 50. Two artificial substrate samplers were not retrieved (RMs 19.0 and 3.4), and received narrative evaluations based on qualitative analysis, in lieu of an ICI. Both of those sites scored exceptionally as well. Total EPT and pollution-sensitive taxa averaged 23 and 34, respectively, with the station at RM 13.4 (downstream from Tom's Run) yielding the largest number of sensitive taxa in the entire survey at 43 total (Table 22). Overall, 146 total taxa were collected from the lower mainstem, of which 68 that are considered pollution-sensitive. Rare, intolerant, or infrequently-collected taxa that were encountered in this catchment included the mayflies *Acentrella turbida*, *Plauditus cestus*, and *Paracloeodes* sp. 3; and the midges *Thienemanniella similis*, *Cladotanytarsus vanderwulpi group Type 1*, *Sublettea coffmani*, and *Tanytarsus glabrescens group sp 4*. As with the upper segment, the lower Twin Creek found healthy populations of organisms which thrive in fast, flowing waters replete with oxygen, such as the dobsonfly *Corydalus cornutus* and the aquatic moth *Petrophila*.

All of these aforementioned positive findings underscore Twin Creek's assimilative capacity in the face of potential threats to the stream in this reach. The Gratis WWTP had no discernable impact to the community at RM 19.0. Evidence of instream gravel mining was apparent at several locations, yet to no apparent detriment to the biota in this survey. The ever-present predominance of agriculture in the study area also left no discernable impacts.

Perhaps the most remarkable demonstration of Twin Creek's assimilative character in 2005 occurred at the mouth (RM 0.1). Since the last survey in 1995, Warren County had relocated the lower stream channel, in violation of Clean Water Act requirements, to accommodate a new wellfield in the area. In spite of this considerable alteration, the macroinvertebrate community scored an exceptional ICI of 46. Included in this score are an impressively high diversity and abundance of mayfly taxa that consisted of 21 total taxa and a 76.1% relative abundance, including several rare or intolerant species. However, as mayflies increased, the overall density of organisms on the artificial substrates also increased. Here, relative density was the highest of any other station on Twin Creek (1333 org/ft^2 - Figure 30). A marked increase in density is often associated with nutrient enrichment. At the time of the survey, direct canopy cover was sparse, and eroding banks were reminiscent of prior excavation. In order to assure the continued endurance of this exceptional benthic assemblage, efforts should be initiated to address these habitat concerns.

Table 22. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Lower Twin Creek assessment unit, July to September, 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) in Parentheses	ICI[a]	Narrative Evaluation
Twin Creek (14-500)										
23.7	197.0	-	53	22/24	29/40	H-M/784	0	Net-spinning caddisflies (F,MI), *Helicopsyche* caddisflies (MI), *Rheotanytarsus* midges (MI)	50	Exceptional
19.2	226.0	-	53	18/21	21/33	M-L/496	0	Net-spinning caddisflies (F,MI), *Rheotanytarsus* midges (MI)	52	Exceptional
19.0	226.0	-	56	21	31	M	0	*Chimarra* caddisflies (MI), baetid mayflies (F), *Rheotanytarsus* midges	-	Exceptional
13.4	271.0	-	64	26/27	30/43	M/894	0	Net-spinning caddisflies (F,MI), mayflies (F,MI)	50	Exceptional
9.7	275.0	-	47	16/19	23/35	M-L/814	0	Net-spinning caddisflies (F,MI), mayflies (F,MI)	52	Exceptional
3.4	312.0	-	55	22	29	M	0	Net-spinning caddisflies (F,MI), *Isonychia* mayflies (MI), baetid mayflies (F,I)	-	Exceptional
0.9	315.0	-	53	22/25	21/32	M/894	0	Net-spinning caddisflies (F,MI), mayflies (F,MI)	48	Exceptional
0.1	316.0	-	56	20/26	19/27	M/1333	0	Mayflies (F,MI,I), Net-spinning caddisflies (F,MI)	46	Exceptional
Bantas Fork -Trib to Twin Creek at RM 24.32 (14-505)										
13.7	6.6	-	45	9	16	M-L	1	Hydropsychid caddisflies ((F), snails (F, MI), midges (MT, F, MI, I)	-	Good
9.5	11.8	-	54	20/21	22/36	M	1	Net-spinning caddisflies (F,MI), baetid mayflies (F, MI, I), heptageniid mayflies (F,MI)	54	Exceptional
7.0	24.4	-	46	20/21	23/33	M	1	Net-spinning caddisflies (F,MI), *Helicopsyche* caddisflies (MI), heptageniid mayflies (F, MI), *Caenis* mayflies (F)	50	Exceptional
1.2	34.0	15	38	14/14	17/26	L	1	*Helicopsyche* caddisflies (MI), *Caenis* mayflies (F), midges (MT, F, MI)	(32)	Good
Goose Run -Trib to Bantas Fork @ RM 7.55 (14-506)										
4.2	3.3	-	41	8	11	L	1	*Elimia* snails (MI), sow bugs (F), midges (MT,F,MI), case-building caddisflies (MI)	-	Fair
0.3	11.2	-	50	17	23	M	1	Net-spinning caddisflies (F,MI), case-building caddisflies (MI), mayflies (F,MI)	-	Very Good
Aukerman Creek -Trib to Twin Creek @ RM 19.29 (14-504)										
3.3	5.2	-	50	17	23	M-L	2	Net-spinning caddisflies (F,MI), mayflies (F,MI,I), waterpenny beetles (MI), midges (T,MT,F,MI)	-	Very 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) in Parentheses	ICI[a]	Narrative Evaluation
1.8	13.7	-	47	13	21	M-L	0	Net-spinning caddisflies (F,MI), mayflies (F,MI), midges (T,MT,F,MI)	-	Good
0.4	20.7	15	63	20/24	30/41	M	3	Net-spinning caddisflies (F,MI), *Rheotanytarsus* midges (MI), mayflies (F,MI,I), midges (MT,F,MI,I)	52	Exceptional
Trib to Aukerman Creek @ RM 2.88 (14-520)										
0.7	4.5	-	38	19	21	L	0	Net-spinning caddisflies (F,MI), *Helicopsyche* caddisflies (MI), *Elimia* snails (MI), mayflies (F,MI,I)	-	Very Good
Trib to Twin Creek @ RM 18.29 (14-518)										
0.7	3.3	-	57	23	30	M	3	Net-spinning caddisflies (F,MI), *Helicopsyche* caddisflies (MI), mayflies (F,MI,I)	-	Exceptional
Tom's Run -Trib to Twin Creek @ RM 13.52 (14-502)										
12.0	6.0	9	23	4	6	L	0	*Stenelmis* beetles (F), sow bugs (F), mayflies (F)	-	Low Fair
8.5	9.5	9	24	3	6	L	0	Flatworms (F), *Stenelmis* beetles (F), sow bugs (F), midges (T,F,MI), heptageniid mayflies (F)	-	Low fair
0.4	24.3	15	57	19/19	29/39	L	3	Net-spinning caddisflies (F,MI), midges (F,MI,I)	34	Marg. Good
Little Twin Creek -Trib to Twin Creek @ RM 6.69 (14-501)										
6.3	4.9	15	42	9/9	14/21	M-L	3	Sow bugs (F), riffle beetles (F,MI), *Helicopsyche* caddisflies (MI), waterpenny beetles (MI)	36	Good
4.6	12.4	-	46	14/15	17/22	M	1	Net-spinning caddisflies (F,MI), mayflies (F,I), waterpenny beetles (MI)	50	Exceptional
2.0	19.8	-	55	18	24	M	1	Net-spinning caddisflies (F,MI), mayflies (F), midges (F,MI)	-	Very Good

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 8=Non-Detectable Current, 9=Intermittent or Near-Intermittent Conditions, 12=Suspected High Water Influence/Disturbance, 13=Suspected Disturbance by Vandalism, 15=Current >0.0 fps but <0.3 fps, 29=Primary Headwater Habitat Stream.
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 due to insufficient current speed over the artificial substrates. The station evaluation is based on the qualitative sample narrative evaluation.

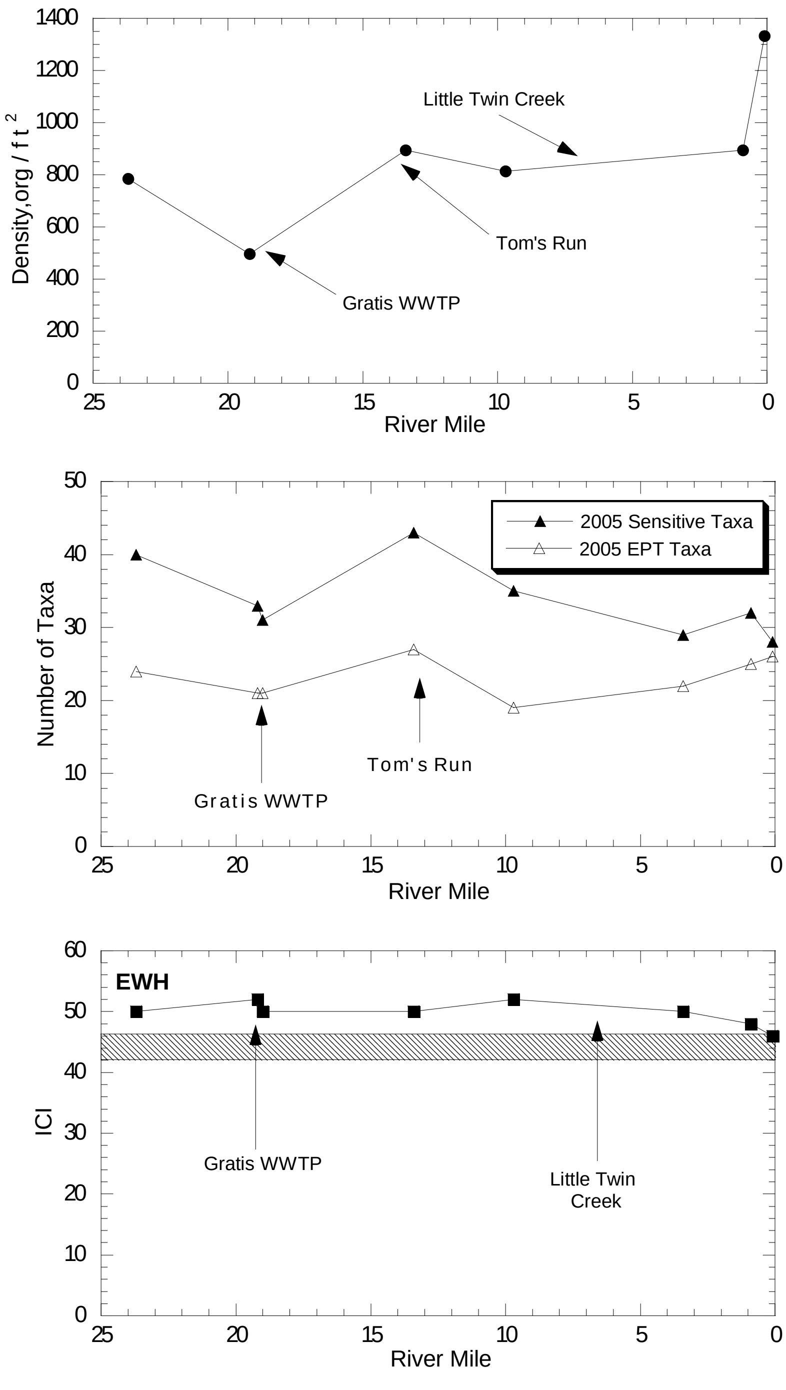


Figure 30. Longitudinal plots showing, from top to bottom: density of organisms found on artificial substrates, number of EPT and sensitive taxa, and ICI scores encountered at each sampling station on lower Twin Creek, 2005. ICI scores for RMs 19.0 and 3.4 are estimated.

A study of mussel populations in Twin Creek, conducted by Wright State University graduate student Kara Wendeln in 2004, also gives insight to the condition of the lower portion of the Twin Creek mainstem. Twelve species (live and fresh-dead) were found throughout the length of Twin Creek, with five of those being found in the lower portion. No species were found live exclusively at any lower Twin Creek site. No mussels were encountered by Ohio EPA staff in lower Twin Creek during the 2005 survey. Mussel species found by Wendeln were encountered almost entirely at sites within the Germantown MetroPark, where near and instream habitat, including and especially riparian corridors, remained undisturbed. The near absence of mussels from other reaches in lower Twin Creek was attributed to instream gravel mining and dredging in the lower stream mile. Generally, mussels are more sensitive to these activities, which can result in increased sedimentation and shifts in flow regime, than the benthos in general.

Bantas Fork

Bantas Fork is considered to be perhaps the most exceptional tributary to Twin Creek and is, in part, essential to the maintenance of the high quality fauna in Twin Creek. Historically, the stream has produced ICI scores that are impressively high (54-56), especially when the relatively small drainage area of the stream ($<35mi^2$) is considered. However, even a stream as high quality as Bantas Fork can find itself vulnerable to natural phenomena, as in 2005 when the stream had experienced very low flows. While it is obvious that complete desiccation of a stream would be detrimental to the benthos, a marked decrease in flow can lead to a variety of potential stressors that can depress an otherwise healthy community. Low flows can lead to slower current, higher temperatures, and lower dissolved oxygen – all of which can negatively impact many of the organisms which are not as tolerant of such changes in flow regime.

That said, the most upstream community at RM 13.7 and the lowermost community at RM 1.2 both received evaluations of good, which did not meet the EWH use designation. EPT and sensitive taxa numbers appeared depressed when compared to what was found at the middle two sites that did meet EWH criteria (Table 22). The mitigating factor was flow condition. Both RM 13.7 and RM 1.2 were met with very low flows when sampled, as opposed to the middle two sites that were experiencing more moderate flows. As a result, riffle development and quality in the non-attaining sites was inferior, and the communities performed accordingly.

With respect to the otherwise high quality of Bantas Fork, it should be noted that the community at US Route 127 (RM 9.5) shares the distinction of having the highest ICI in the entire survey, along with that of Twin Creek RM 31.7. An ICI of 54 in an area that drains 11.8 square miles is a commendable performance, especially in light of the lower flows encountered at similarly-sized sites.

Goose Run

Two stations were assessed on Goose Run, one downstream (RM 4.2) from the Dayton Travel Center and the Pilot Oil Travel Center package plants, and one near the confluence with Bantas Fork (RM 0.3). The upstream station at RM 4.2 hosted a fair community that was comprised mostly of snails, sowbugs, and midges. This performance did not meet the current WWH criteria for that segment of the stream. The presence of filamentous algae at the site, along with substrate embeddedness, makes a case for some type of impact; perhaps from the travel center effluents upstream. Chemical analyses determined excesses of ammonia and phosphorus, as well as dissolved oxygen violations. In addition, the stream was also sampled during low flow conditions. Many empty cases of the caddisfly *Neophylax* were collected above water level (no live specimens were identified), suggesting that flow condition may have also compromised the community assemblage.

The downstream station at RM 0.3 performed adequately to meet its EWH designation. The improvement here over the upstream station is highlighted by a doubling of both EPT and sensitive taxa groups (17 and 23, respectively), along with the presence of a few intolerant species. These include the mayflies *Diphetor hageni* and *MacCaffertium mediopunctatum*, and the cased caddisfly *Neophylax sp*.

Aukerman Creek

All three communities sampled at Aukerman Creek in 2005 met or exceeded WWH biocriteria. All included healthy, abundant populations of pollution-sensitive taxa on the natural substrates and showed good diversity of qualitative EPT, ranging from 13-20 taxa. The community sampled at RM 0.4, downstream of Fudge Road, scored an exceptional ICI of 52. Its 63 qualitative taxa were the highest collected in all of Twin Creek's tributaries. The mayfly *Baetis tricaudatus*, a coldwater species, was identified only at this location in the entire survey.

Tributary to Aukerman Creek at RM 2.88

This small tributary was qualitatively sampled at RM 0.7. The community was found to be very good, comprised of 19 EPT and 21 sensitive taxa, which meets the recommended WWH aquatic life use. Noteworthy of the collected fauna were three different case-building caddisfly species from the family Leptoceridae, all of which are pollution-sensitive organisms; and the intolerant mayflies *Acerpenna macdunnoughi* and *Diphetor hageni*.

Tributary to Twin Creek at RM 18.29

The community collected at RM 0.7 was found to be exceptional. This stream's performance seemed to indicate an immunity to the low flow phenomenon found at other tributaries of similar size (<10mi^2). The 23 EPT and 30 sensitive taxa, which included the coldwater caddisfly *Ceratopsyche slossonae*, suggest that this stream experiences ground water influx. The site was also densely canopied. Such attributes would enable a small stream such as this tributary to support a healthy and diverse benthic community capable of surviving dry conditions.

Tom's Run

Three sites were assessed on Tom's Run in 2005, with evaluations ranging from low fair to marginally good. The two low fair sites were concentrated in the upper portion of the stream, where flows seemed to have the greatest influence on community performance. Both sites were characterized by stagnant, turbid water with no current due to interstitial or intermittent conditions. The lower site near the confluence with Twin Creek netted an ICI of 34, a marginally good performance, which meets the WWH use designation. It is significant to note that the community performance relative to the ICI may have been undermined by slow current over the artificial substrates (i.e. no caddisflies collected). The qualitative sample revealed a more solid performance with 19 EPT (9 of which were caddisflies) and 29 sensitive taxa.

Little Twin Creek

Low flows resulting in a sparse array of weak riffles influenced sampling at the uppermost Little Twin site. RM 6.3 was sampled during these low flows, and the depressed benthic community collected was reflective of such conditions. Moving downstream, the benthos recovered at both stations sampled. The community at RM 4.6 scored an exceptional ICI of 50, which met the EWH aquatic life use designation and showed no negative effect from the Farmersville WWTP via Reigle Ditch. A qualitative evaluation of RM 2.0 found a very good community, a non-significant departure from EWH criteria.

TRENDS: 1995-2005

Chemical Quality

The Twin Creek watershed has not changed significantly in the ten years since the previous biological and water quality survey. Agriculture remains the predominant industry and population growth in the six Twin Creek watershed townships of Preble County had increased by 359 persons from 1990-2000. Population density of these 6 townships is 67.75 persons/ mi^2 (excluding cities and villages).

No metals were detected in concentrations of concern water column or sediment in either of the years the watershed was surveyed. Organic chemicals related to agriculture were present in water and sediment for both years. The mainstem in 2005 tended to be higher in water column phosphorus, ammonia and bacteria from point sources and headwater nonpoint sources. Water column nitrates were higher in 1995.

Tributaries indicated nutrient increases in 2005 of phosphorus and ammonia for Millers Fork, Swamp Creek, and Price Creek in the upper Twin Creek assessment unit, and Goose Run and Tom's Run in the lower unit (Figure 32). Goose Run was influenced by point and nonpoint sources in both years.

Nutrients and bacteria from failed home septic systems, farming operations, and wastewater treatment were present in both years. Wastewater treatment plants violated NPDES permit conditions in both years (West Alexandria and Farmersville). Point source nutrients were more noticeable in 2005 (Figure 31). New wastewater treatment plants discharging to Twin Creek have been constructed in West Manchester and at the Twin Valley Mobile Home Park. A new wastewater treatment plant is being built in 2007 in Verona on Swamp Creek.

Precipitation was greater prior to and during the 1995 survey season (May set rainfall records with 9.05 inches) than in 2005. Flows at Germantown were higher during the 1995 sampling season than during 2005. Nutrients were highest during the first sampling event in 1995.

The year 2005 was generally wet except during the survey season (July-September). By August, headwater streams were interstitial. Hurricane Katrina brought over 3 inches of rain on August 30, but by the sampling on September 7, Twin Creek was back to near base flow conditions. September 2005 set a rainfall record (7.37 inches), but did not influence the conventional chemistry collection.

More intense bacteria assessment occurred in 2005 than in 1995. In 1995, bacteria sampling was done for screening purposes due to not meeting sampling frequency and holding time restrictions. Only fecal coliform was sampled in 1995 and those levels were lower than 2005 across the watershed. Plant upsets at West Alexandria and failed septic systems in Verona (Swamp Creek) were documented in 1995. In 2005, bacteria sampling was conducted to meet Ohio Water Quality Standards. Five samples were taken from each site over a 30 day period. In 2005, Ohio EPA was able to document Primary Contact Recreational (PCR) water quality standard exceedences in the entire upper watershed.

The 2005 water column sampling included additional analytical parameters to detect agricultural chemicals such as atrazine, metolachlor, simizine, glyphosate (Roundup), and carbamates. In both years, Ohio EPA evaluated legacy compounds that were banned by USEPA before 1987 (DDT, Endosulfan, DDE, BHC, aldrin, endrin, heptachlor, and heptachlor epoxide). Many of these legacy compounds are still bound to soil particles that are released during rain events either adsorbed to colloidal particles and sediments or in the dissolved phase.

Dieldrin and aldrin were found at levels in the water column to trigger water quality exceedences for Human Health, Drinking, and Dermal Exposure in both years. Heptachlor and was detected in the water column in 1995, and heptachlor epoxide was detected in the water column in 2005. However, the criteria for exposure are all below the reporting limit (0.022 ug/l) for all detected compounds. Endosulfan was found in 1995, but was not detected in 2005.

A sentinel site sampling program was initiated in 2005 to assess Twin Creek and its tributaries during the entire year. A selected set of sites (Twin Creek RM 9.8 at the Germantown Dam, Price Creek RM 0.6, Swamp Creek RM 0.2 and Toms Run RM 0.1) were sampled in addition to the regular survey. Steam flows were also taken during each sampling event.

Atrazine, triazine, metolachlor, and nitrates were found during higher flow events in 2005. The highest levels were found during spring high water events. April 2005 sampling of Twin Creek RM 9.8 and Tom’s Run RM 0.11 detected atrazine at 23.2 µg/l and 27.6 µg/l, over the draft USEPA chronic atrazine level (12 µg/l).

Atrazine use in the watershed has decreased from 1995 to 2005. Farmers in the watershed are planting Roundup-ready soybeans and corn for grass and weed control. This has increased the usage of glyphosate (Roundup) and decreased the usage of atrazine. No glyphosate or carbamates were detected in water column samples in Twin Creek or its tributaries in 2005.

Nutrients were evaluated in 2005 using the Ohio EPA nutrient guidelines found in the Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999). Phosphorus and nitrate water column levels were higher in the 1995 due to the capture of more storm water events during that survey. Sentinel site data taken during 2005 under high flow events gives comparable nutrient data to the 1995 survey.

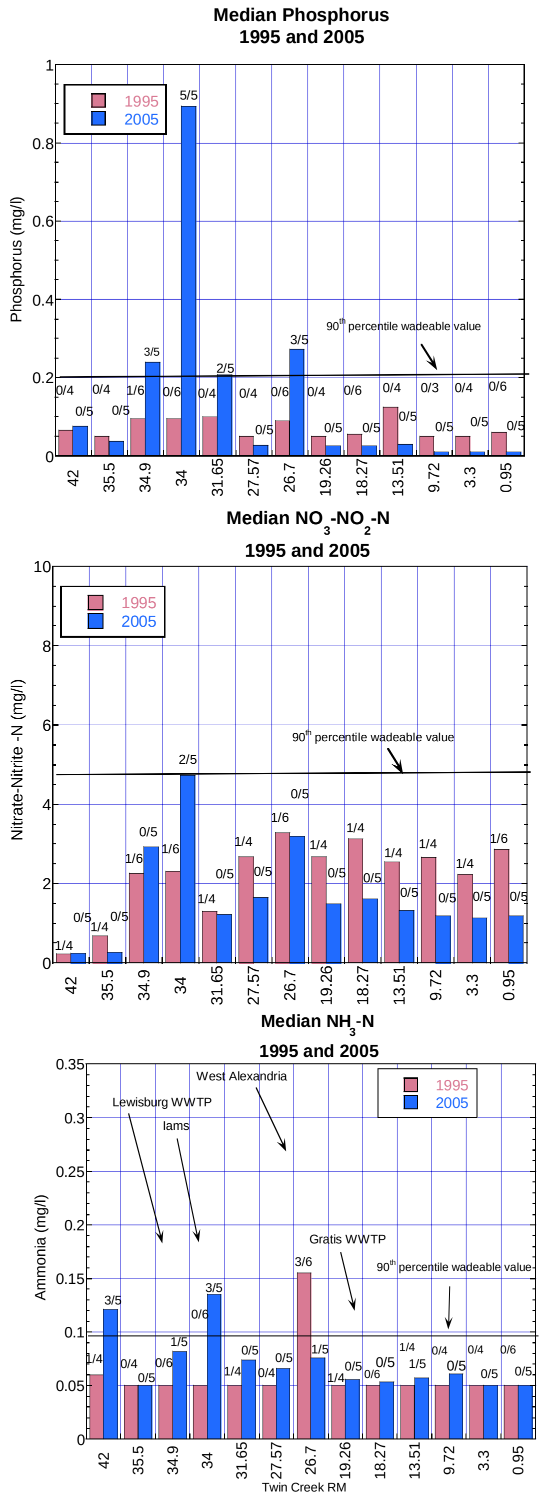


Figure 31. Median nutrient values for comparable sites on Twin Creek mainstem for the years 1995 and 2005. Nutrient 90th percentile values are from Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999). 2/4 indicates # elevated values/ # samples.

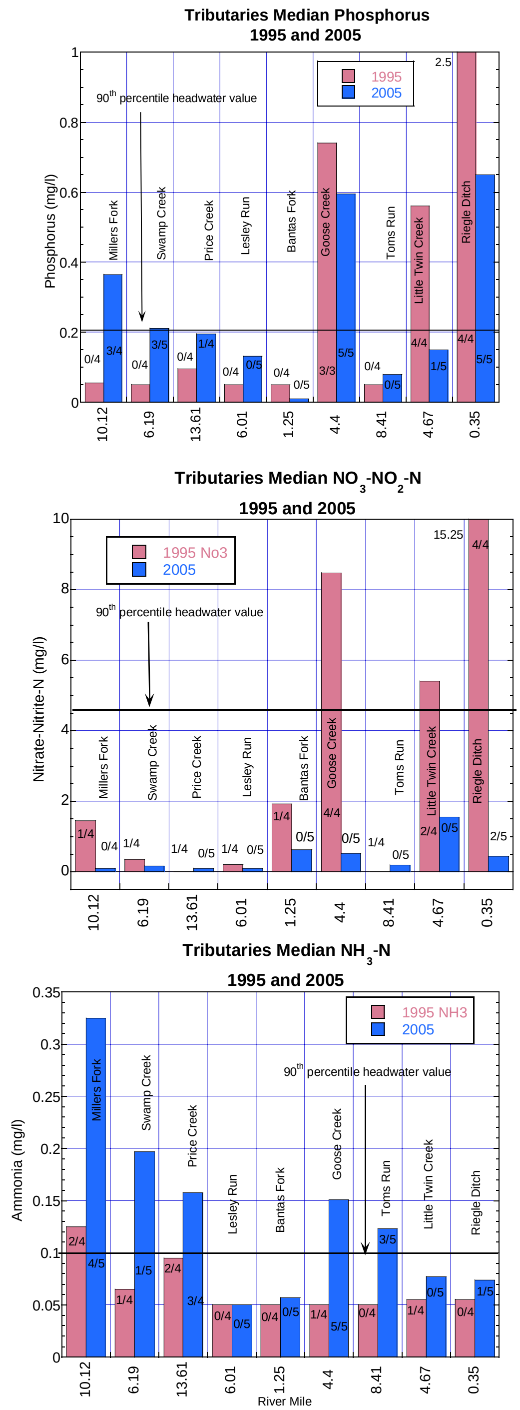


Figure 32. Median nutrient values for comparable sites on Twin Creek tributaries for the years 1995 and 2005. Nutrient 90th percentile values are from Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999). 2/4 indicates # elevated values/ # samples.

Fish Community

Through the biosurvey survey process, the fish fauna of the Twin Creek basin has been regularly surveyed and assessed by Ohio EPA since the mid-1980s. The most thorough of these historical surveys was done in 1995, where the entire basin (mainstem and tributaries) was symmetrically sampled. Prior field work included all or portions of the mainstem and selected tributaries. For the purposes of trends assessment, the 1995 results will be compared against conditions documented in 2005. For an assessment of conditions prior to 1995, the reader is directed to Ohio EPA (1997), where these findings are discussed.

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, through time. The only significant structural difference between the two survey years (1995 and 2005) was a slightly greater station density in 1995. Given this, these data provided an excellent opportunity to evaluate meaningful changes, or lack thereof, in the environmental conditions of Twin Creek watershed over the last 10 years. This approach will be applied to both the mainstem of Twin Creek and its tributaries.

Aggregate Community Performance: 1995-2005

Annual cumulative community performance summarized by box and whisker plots of the IBI for the Twin Creek mainstem and principal tributaries are presented in Figures 33 and 34. Taken together, median, 75th percentile, 25th percentile, maximum, and minimum values for the IBI appeared comparable between field years. Outside of expected natural variation, conditions within the watershed appeared stable through time, with median performance remaining clearly in the exceptional range over the past ten years.

Longitudinal Trends: 1995-2005

As observed for the aggregated analysis, longitudinal trends for named streams within the basin indicated remarkable correspondence through time (Figures 35 and 36). By and large, condition appeared stable, if not modestly improved. However, there are areas, reaches, streams or stations that do warrant additional discussion regarding trends.

Two areas on the mainstem of Twin Creek are of particular interest: 1) RM 0.1, at the mouth, and 2) the approximately four mile stream reach downstream from the Price Creek confluence. The first area of concern is significant because the lower tenth mile of the mainstem was relocated to an abandoned channel so as to protect an adjacent public water supply well-field. The river was actively eroding and threatened to undermine several well-heads. The channel work was done in 1998, so the site at RM 0.1 in 1995 was located in the now filled and dry channel. The 2005 station at RM 0.1 was placed within the new, relocated channel. Comparison between pre and post channel work survey results revealed no biological impact associated with this project. Full attainment of the EWH criteria was indicated in both the 1995 and 2005 results.

The second area of concern on the mainstem included a short segment downstream from Price Creek. Departure from the EWH biocriteria was observed here in 1995, and was attributed to nutrient enrichment (Ohio EPA 1997). This reach was revisited in 2005 and found to support a fully exceptional fish assemblage. Field indicators of nutrient enrichment were observed through this segment, but the nutrient load has either lessened or is now assimilated without significant impact to the community.

Among the tributaries, the greatest meaningful discrepancy between 1995 and 2005 was observed on Price Creek (Figure 37). Over the past 10 years, sampling efforts from Price Creek have yielded significantly different results. The first area showing difference between survey years was RM 3.8/3.9 (Jims Run Rd.). Nearly half of the IBI metrics at this site performed better in 1995 than 2005. Specific difference included, greater net species richness, significantly greater proportion of top carnivores, twice the proportion of insectivorous taxa, and a greater number and proportion of sensitive species. Additionally, macrohabitat quality, as measured by the QHEI, was found to considerably better in 1995 (87.0) in comparison with the 2005 (65.5) assessment. The original description indicated a meandering stream, with good channel development, coarse substrates, a diversity of cover types, and depth heterogeneity, including deep pools. Similarly, the 2005 assessment found a stream course that appeared unmodified, with coarse (unembedded) substrates. However, in 2005 the reach was found to lack both deep pools and much in the way of instream cover.

These observations were consistent with the broader habitat features typically associated with bedrock streams. 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 stream are thus naturally limited, and rarely support strongly exceptional fish assemblages. Furthermore, where adequate species richness and functional organization are found, IBI scores may reach a narrative of very good-exceptional, but the MIwb, a structural measure, often lags far behind. This is due to the relative low productivity and monotonous nature of bedrock substrates. In fact, this was observed in 1995 – exceptional IBI and fair MIwb.

The trends assessment suggests that Price Creek at RM 3.8/3.9 may have been subjected to some degree modification between 1995 and 2005. This is inferred from measures of both, instream biology and macrohabitat quality. Perhaps, the segment is privately maintained, brush, trees and accumulations of bedload materials being regularly removed by adjacent land owner(s). This may explain both the drop in QHEI score and decline in the fish assemblage. It should be noted, however, that no direct evidence of this type of activity was observed in 2005 (spoil piles, artificial channel morphology, tree stumps, etc.).

It is also possible that the drop in both the habitat quality and instream biological performance may represent a sampling error related to final station placement. A slight change in sampling zone location typically yields no significant difference in the fish assemblage or resulting site evaluation, as the central tendency of habitat conditions drives or controls instream biological performance under most circumstances. However, the biological performance of a bedrock stream is more susceptible to localized habitat conditions, particularly if a reach contains an

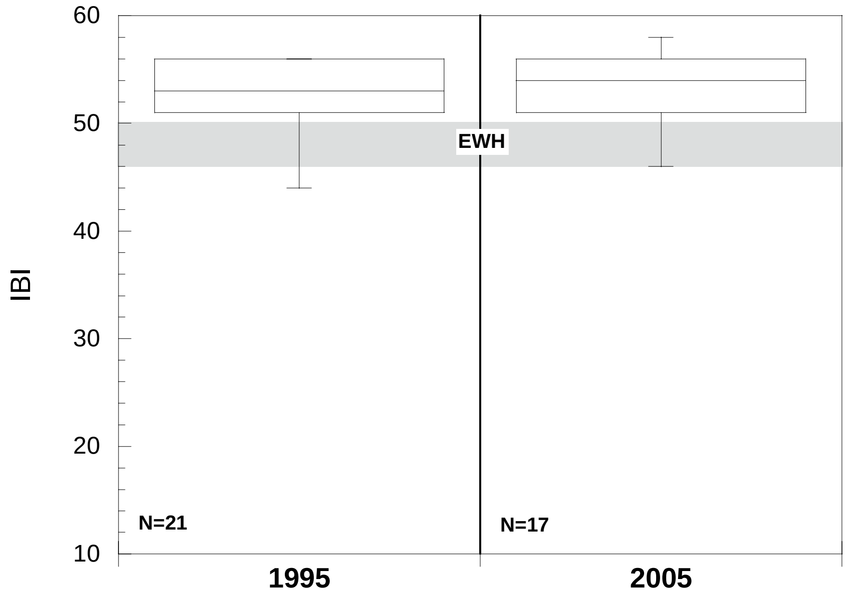


Figure 33. Aggregated Index of Biotic Integrity (IBI) scores from Twin Creek (mainstem), 1995 and 2005. Shaded area represents the EWH biocriteria and area of nonsignificant departure for the Eastern Corn Belt Plains (ECBP) ecoregion.

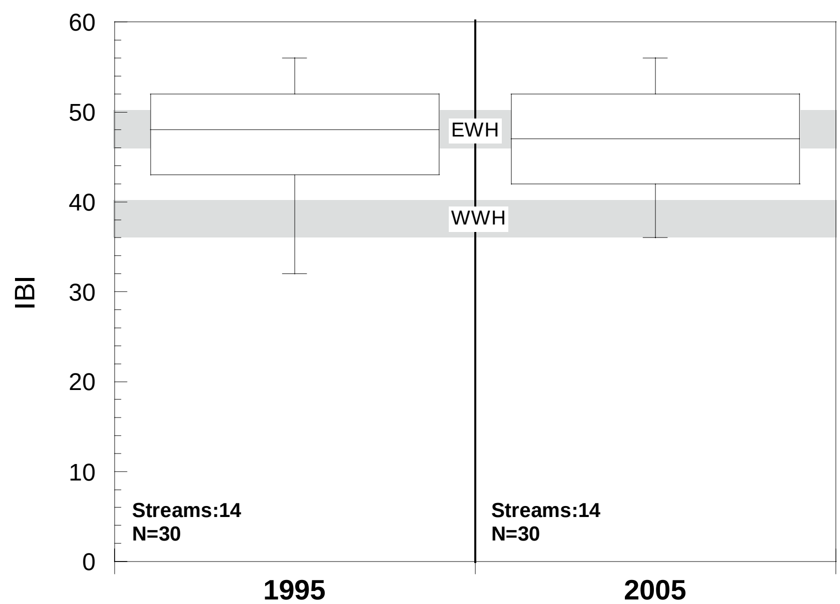


Figure 34. Aggregated Index of Biotic Integrity (IBI) scores from all Twin Creek tributaries, 1995 and 2005. Shaded areas represent the EWH and WWH biocriteria and areas of nonsignificant departure for the Eastern Corn Belt Plains (ECBP) ecoregion.

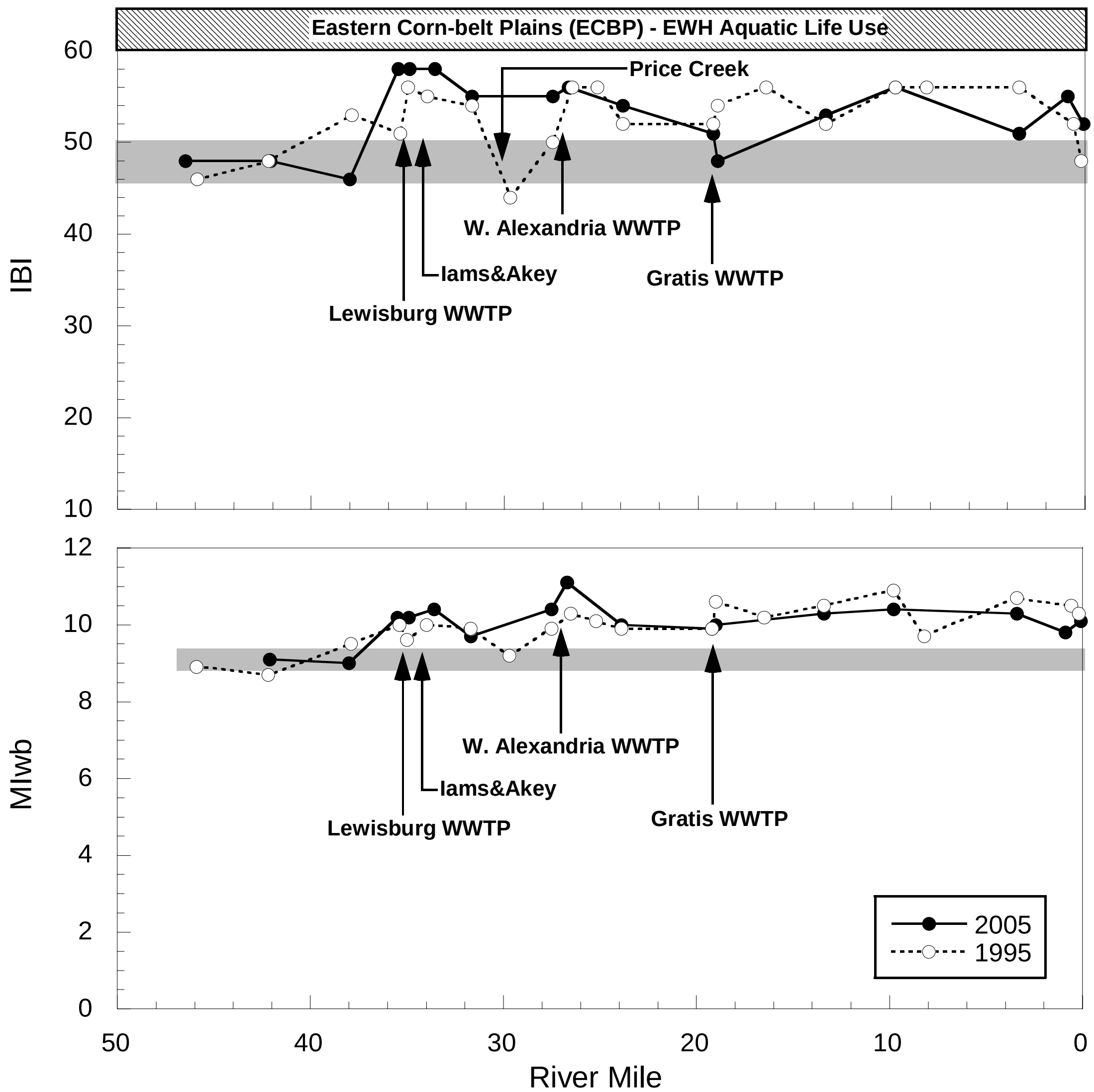


Figure 35. Longitudinal performance of the Index of Biotic Integrity (IBI) and the Modified Index of well-being (MIwb) from Twin Creek (mainstem), 1995 and 2005. Shaded areas represent the applicable biocriteria in support of the existing EWH Aquatic life use, Eastern Corn Belt Plains (ECBP) ecoregion. Arrows identify points of discharge for significant NPDES permitted entities.

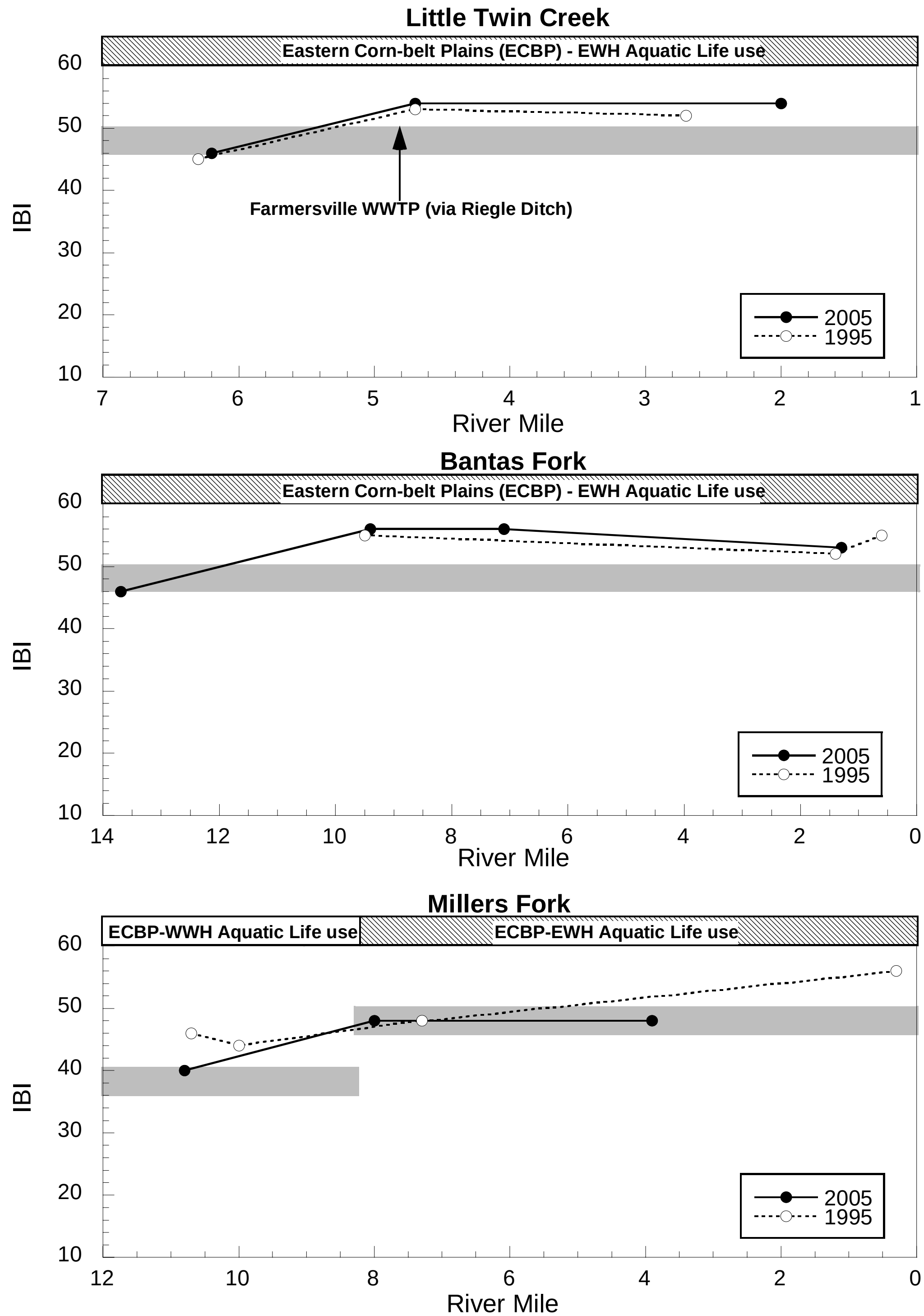


Figure 36. Longitudinal performance of the Index of Biotic Integrity (IBI) from selected Twin Creek tributaries, 1995 and 2005. Shaded areas represent the applicable biocriteria in support of the aquatic life use designations, Eastern Corn Belt Plains (ECBP).ecoregion.

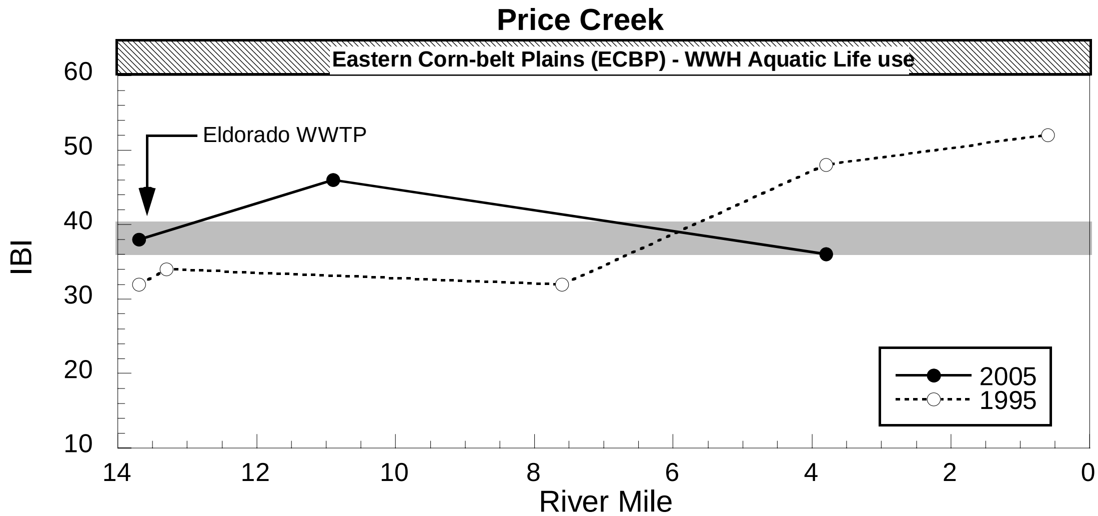


Figure 37. Longitudinal performance of the Index of Biotic Integrity (IBI) from Price Creek, 1995 and 2005. Shaded area represents the WWH biocriterion, Eastern Corn Belt Plains (ECBP) ecoregion.

anomalous deep pool or other important and typically rare physical feature. The location of the 1995 sampling zone (RM 3.9) apparently contained well-developed pool with abundant in-stream cover, where the 2005 zone (RM 3.8) did not. In this event, said pool and associated cover would be adequate to boost both habitat and community appraisals, at least up to a point. As stated previously, the MIwb at RM 3.9/3.8 never fully met the EWH criterion.

In contrast to the lower segment, improved conditions were indicated through the upper reaches of Price Creek, when compared against the 1995 results (Figure 37). Impairment of the WWH use through this area was attributed principally to nutrient enrichment from multiple sources: Eldorado WWTP, agricultural activities, and failing on-site septic systems. Deficient macrohabitat appeared to exacerbate the negative effects of existing nutrient loads (Ohio EPA 1997). The 2005 results indicated full restoration of WWH fish communities to upper Price Creek. Apparently, either nutrient loads have been reduced or the native assimilative capacity of Price Creek has been enhanced (through habitat recovery over the intervening ten years), or both. Regardless, the upper sampling station stations now support fish assemblages consistent with the WWH biological criteria.

The entire length of Price Creek (14 miles) now supports WWH fish communities. This is in stark contrast to the results of the 1995 survey, which found only 0.6 miles meeting the applicable biocriteria. This is a result of both the redesignation of lower Price Creek to the more appropriate WWH use, and improved environmental conditions in the headwaters.

Macroinvertebrate Community

Twin Creek

The study of the Twin Creek mainstem in 2005 essentially replicated the effort exerted in 1995. Fourteen of the seventeen stations sampled for macroinvertebrates in 2005 were repeated in 1995. Overall, the longitudinal performance of the benthos has held steadfast over the past 10 years (Figure 38). Sensitive and EPT taxa numbers have also revealed no appreciable differences between both studies (Figure 40). The only notable difference occurred at RM 34.9, where the ICI fell below EWH expectations with a score of 38. Phosphorus input from either the Lewisburg WWTP, runoff from an upstream municipal park, or contaminated stormwater are suspected causes of this decline in ICI.

Findings from the 1995 survey expressed some concern regarding nutrient inputs into Twin Creek, as evidenced by local spikes in the relative densities of macroinvertebrates. Sampling in 2005 revealed overall lower densities when compared to those of 1995 (Figure 39), indicating that either nutrient loadings to Twin Creek are declining or are now better-assimilated into the stream. The large spikes in density exhibited in 1995, particularly between RMs 34 and 19 where most point source influences are located, were absent in 2005. Of particular note is a drop in density over 2½ times the level recorded in 1995 ($658/ft^2$ vs.$1722/ft^2$) at the station downstream of the West Alexandria WWTP. This reduction is attributed to the dissolution of Twin Valley Mobile Home Park, which in 1995 was operating a non-permitted and problematic wastewater package plant.

Since the last survey in 1995, the mouth of Twin Creek has been relocated by Warren County, in order to accommodate a new wellfield in the area. However, the benthic community seems to have adapted and still performed to an exceptional level, scoring an ICI of 46. Qualitatively, the community at RM 0.1 (at the mouth) compared similarly to the 1995 site at RM 0.3 (upstream of the mouth), showing no appreciable differences in either sensitive, EPT, or tolerant taxa.

Miller's Fork

In 1995, the benthic community of Miller's Fork experienced impacts from siltation as a result of runoff from construction at the Beechwood Golf Course. In spite of such pervasive siltation, the downstream sites (RMs 7.3 and 0.4) were evaluated favorably with regard to the EWH designation of the stream; while the two sites directly bracketing the construction (RMs 10.75 and 10.1) demonstrated impairment. Miller's Fork in 2005 did not experience such an obvious impact as in 1995, yet none of the three sites sampled met the current EWH aquatic life use. The upper segment of the stream, down to RM 9.6 (at Otterbine-Ithaca Road), is recommended for re-designation to WWH as a result of the findings at the Grubbs-Rex Road site for both years. Maintenance activities (channelization) in that area preclude the possibility that macroinvertebrate communities would be able to meet EWH expectations, and the assemblages encountered in both 1995 and 2005 support that notion. The other downstream impaired sites in 2005 were impacted by either natural habitat limitations (RM 8.0) or by siltation attributed to agriculture (RM 3.9).

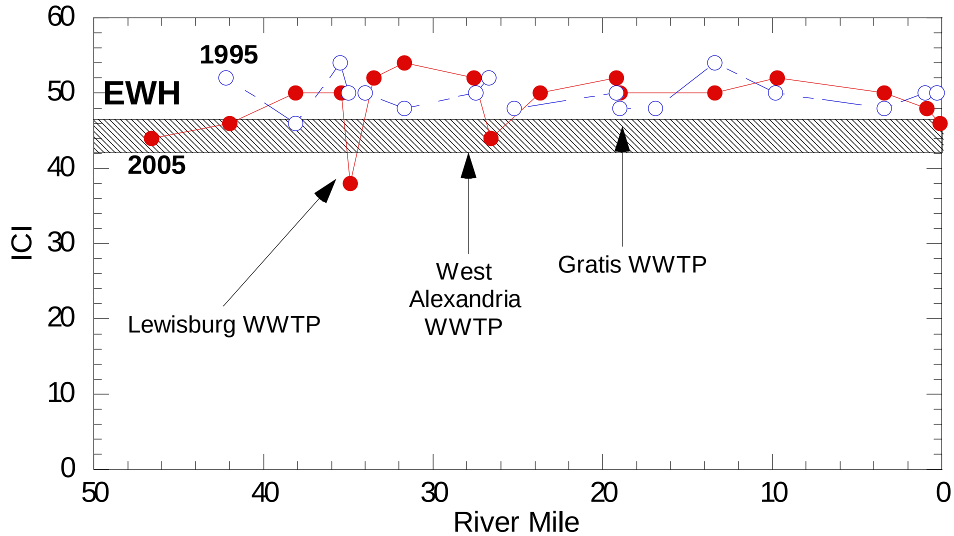


Figure 38. Longitudinal trend of ICI scores on Twin Creek, 1995-2005.

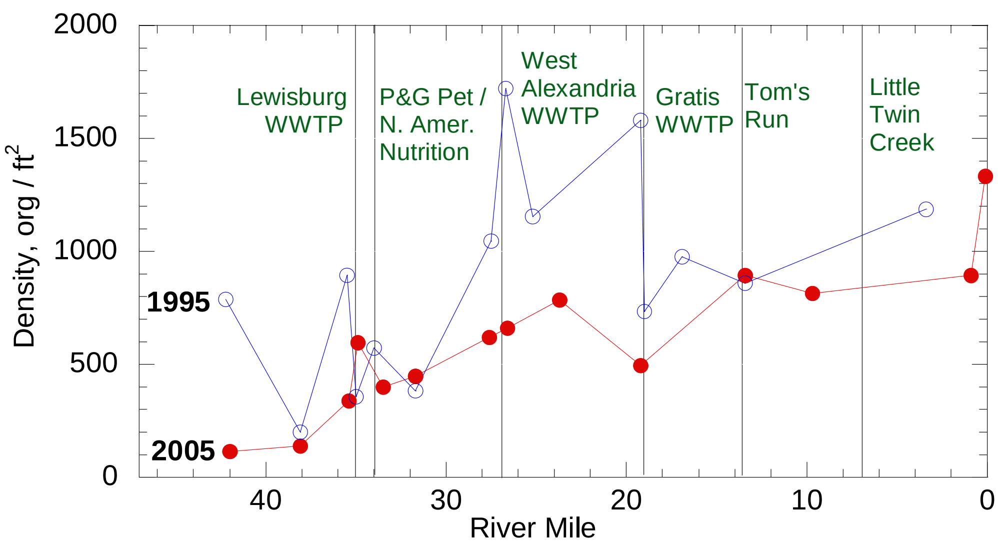


Figure 39. Longitudinal trend of relative density of macroinvertebrate populations in Twin Creek, 1995 and 2005.

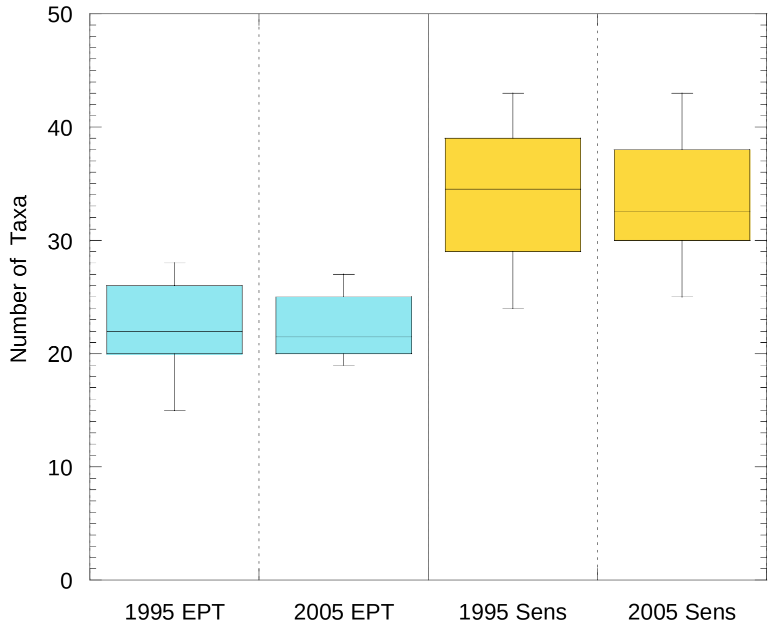


Figure 40. Aggregated Invertebrate Community Index (ICI) scores comparing EPT and sensitive taxa numbers for the 14 repeated Twin Creek stations sampled in both 1995 and 2005.

Swamp Creek

The macroinvertebrate community sampled upstream of Verona in 2005 performed similarly to that of 1995. Poor habitat from prior channelization and nutrient enrichment were affecting community performance both years. A sample was not collected immediately downstream of Verona in 2005 as in 1995, where the community was rated poor. Verona, an unsewered community, is in the process of constructing a wastewater treatment facility at the time of this report, which may aid in the recovery of the benthos at this location upon future sampling. A trend could not be determined regarding EWH performance in the downstream segment, as the sampling station in 2005 at RM 0.2 experienced frequent desiccation, and the community responded accordingly.

Price Creek

Two stations sampled in 1995 were repeated in the 2005 survey. The first station, at RM 13.6 upstream of the Eldorado WWTP, was evaluated as low fair in 2005. This is a significant departure from the marginally good community found in 1995. In both surveys, this site was sampled when flow conditions were near interstitial, rendering riffles to subterranean flow. In

1995, modest communities of sensitive *Chimarra* and hydropsychid caddisflies were encountered, along with nearly equal numbers of sensitive and tolerant taxa. In contrast, the 2005 community saw scarce numbers of EPT taxa, and twice the number of tolerant versus sensitive taxa. These findings indicate further degradation beyond that of flow condition. The site at RM 3.9 at Jim's Run Road performed similarly (exceptional) in both surveys with regard to qualitative total, sensitive and EPT taxa. The attainment of the macroinvertebrate community of WWH criteria at RM 10.9 is considered an improvement downstream of the Eldorado WWTP, which was cited as a cause of impairment in the 1995 survey immediately downstream of the outfall.

Lesley Run
The common threads that link the sites sampled in Lesley Run in 1995 and 2005 was their susceptibility to agricultural runoff due to surrounding land uses, and their tendency to become interstitial to intermittent. The macroinvertebrate communities sampled in both years were, at minimum, reflective of the latter.

Bantas Fork
The 2005 survey was the first time Bantas Fork was sampled in a smaller (<10 mi^2) headwater drainage, at RM 13.7, which drains 6.6 square miles. The performance of the macroinvertebrate community here was depressed, in lieu of EWH expectations, due to flows nearing interstitial conditions. A similar scenario was encountered at RM 1.2, which was a repeat of the station sampled in 1995 that scored superiorly (ICI=56). Both communities were narratively evaluated as good. The other two sites sampled in 2005 performed exceptionally, which is on par with the entire performance of the benthic community sampled on Bantas in 1995.

Goose Run
The communities sampled at the Scheyhing Road station performed similarly in both 1995 and 2005 with regard to total, sensitive, and EPT taxa. However, the 2005 community was evaluated slightly less favorably (fair, vs. good in 1995) due to the more facultative constituency of the EPT taxa. Nutrient enrichment from the upstream wastewater package plants, combined with low to near interstitial flows, were faulted in both surveys. The Eaton-Lewisburg Road site continues to meet EWH criteria.

Aukerman Creek
Aukerman Creek was sampled more extensively in 2005 than it was in 1995. A repeat visit to the Fudge Road site (RM 0.4-0.5) revealed similar exceptional communities both years. Further sampling upstream to RMs 1.8 and 3.3 found good to very good communities that easily met the WWH criteria for the stream.

Tom's Run

All three stations sampled in 1995 were resampled in 2005. RMs 12.1/12.0 (Amity Road) and 8.3/8.5 (Bull Road) performed similarly in both surveys with regard to total, sensitive, and EPT taxa numbers. However, tolerant taxa showed a marked decrease at both sites: Amity Road dropped from 11 in 1995 to 5 in 2005, and Bull Road showed a decline from 9 in 1995 to 5 in 2005. This may indicate that polluted agricultural runoff, a factor in the sub par performance of the benthos in 1995, may be less of an issue in 2005. Additionally, filamentous algae, an indicator of nutrient enrichment, were not observed at Bull Road in 2005 as in 1995. The limited performance of the upper reach benthic communities of Tom's Run in 2005, therefore, is attributed mostly to stagnant waters induced by interstitial to intermittent flows.

A quantitative sample was collected at the most downstream site at RM 0.4 in 2005, which netted a marginally good ICI of 34, a non-significant departure of WWH criteria. While this does seemingly contrast with the exceptional narrative score garnered in 1995, when the qualitative samples only are compared side-by-side, both are of nearly identical composition in terms of taxa numbers and quality. Slow current (<0.3ft/s) over the artificial substrates precluded the capture of any caddisflies, and also contributed to low numbers of mayflies as well. This phenomena is primarily responsible for what appears to be an artificially low ICI influenced by poor flow conditions.

Little Twin Creek

Little Twin Creek at RM 6.3 (upstream of Hemple Road) was encountered with similar conditions in both 1995 and 2005, with low flows resulting in slow currents over the artificial substrates. The 2005 macroinvertebrate community responded accordingly, scoring an ICI of 36, below EWH criteria. The 1995 macroinvertebrate community, however, seemed less affected by ambient conditions and scored an exceptional ICI of 52. A significant difference in relative density ($46/ft^2$ vs. $204/ft^2$) lends some credence to the notion that flow conditions may have had a greater effect on the community in 2005. The reasons for this, however, remain unclear.

Conversely, a marked improvement occurred at the site downstream of Reigle Ditch. Historically, the site has performed only marginally good in the preceding 1995 and 1986 surveys (34 and 32 ICIs, respectively). In 2005, ICI metrics revealed a recovery of the benthic community to exceptional quality with a score of 50. The organic enrichment and consequent increases in relative densities that were present in 1995 had diminished in 2005, and qualitative tolerant taxa had also decreased from 8 in 1995 to only 1 in 2005. These improvements are attributed to decreases in organic inputs, via Reigle Ditch, from the Farmersville WWTP. The site adjacent to Little Twin Road has sustained its exceptional community performance from 1995 in 2005.

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