State of Ohio
Environmental Protection Agency

Division of Surface Water

Biological and Water Quality Study of the White Oak Creek Watershed, 2006

Highland and Brown Counties

White Oak Creek at Bethel-New Hope Road (RM 20.7)

December 31, 2008

Ted Strickland, Governor
Chris Korleski, Director

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OHIO EPA Technical Report EAS/2008-12-12

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

Ted Strickland
Governor, State of Ohio
Chris Korleski
Director, Ohio Environmental Protection Agency

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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. 1989a. 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. 1989b. 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. 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.

Ohio Environmental Protection Agency. 2008a. 2008 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. 2008b. 2008 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.

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

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

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

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

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

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

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

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

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

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

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

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

or

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

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

Ohio EPA
Division of Surface Water
Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8781

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 300-375 sampling sites.

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

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

Hierarchy of Indicators

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

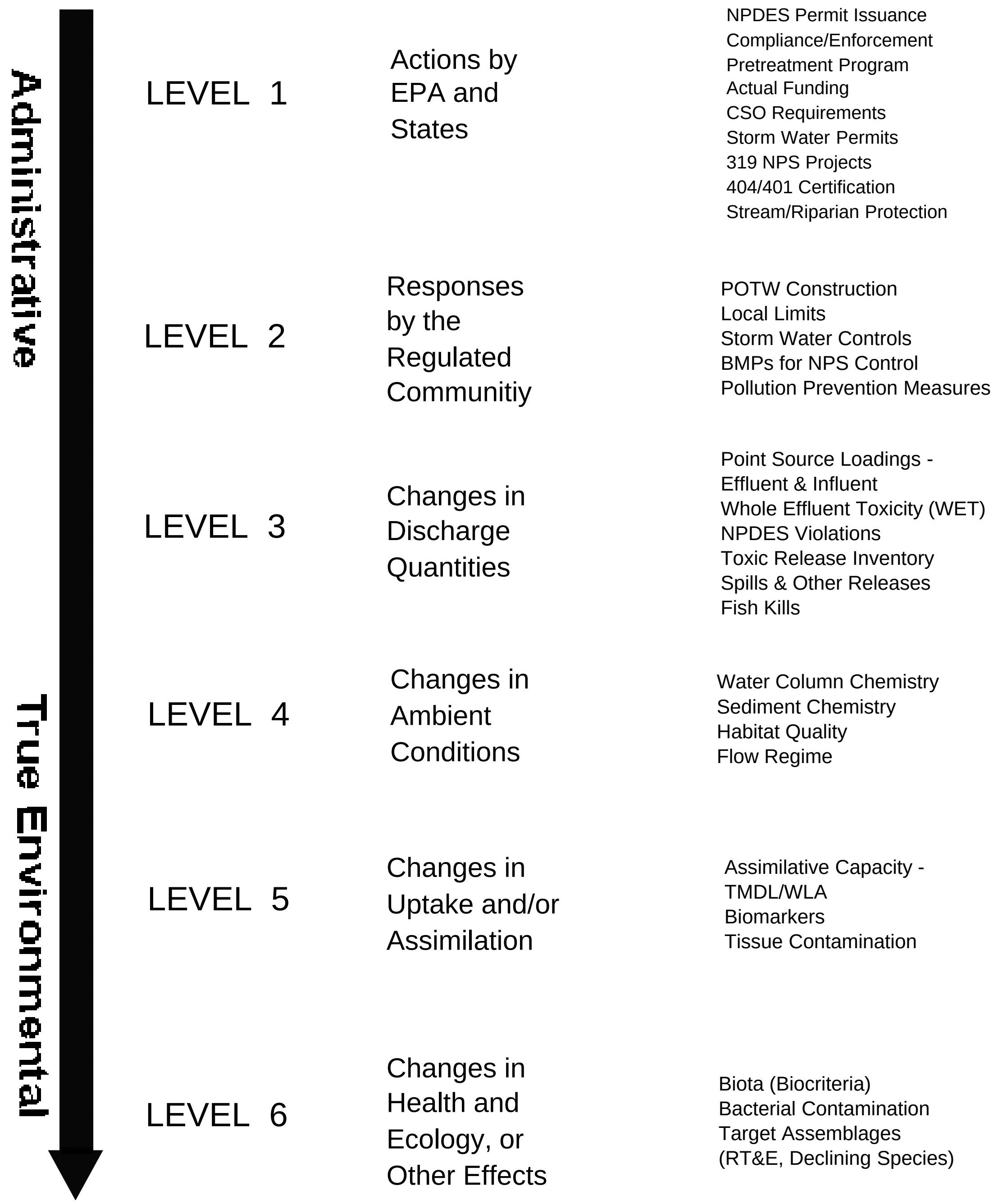


Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

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

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

Ohio Water Quality Standards: Designated Aquatic Life Use

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

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

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

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

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

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

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

Ohio Water Quality Standards: Non-Aquatic Life Uses

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

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

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

MECHANISMS FOR WATER QUALITY IMPAIRMENT

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

Habitat and Flow Alterations

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

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

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

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

Siltation and Sedimentation

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

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

Nutrient Enrichment

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

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

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

Organic Enrichment and Low Dissolved Oxygen

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

Ammonia

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

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

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

Metals

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

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

Bacteria

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

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

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

Sediment Contamination

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

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

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

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

Biological and Water Quality Study of

The White Oak Creek Watershed, 2006

Highland and Brown 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 White Oak Creek study area from June through September, 2006. The White Oak Creek watershed is located in south central Ohio with its headwaters originating in Highland County and flows generally south past the communities of Sardinia, Mount Orab and Georgetown before flowing into the Ohio River. A list of the mainstem and tributary sites evaluated in this study are included in Table 1.

Objectives of the study were to:

1) Monitor and assess the chemical, physical and biological integrity of the water bodies within the White Oak 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, urban and suburban community development; and

4) Evaluate the biological potential to support the Warm Water Habitat (WWH) aquatic life use designation in any subsequently identified candidate WWH stream.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g., NPDES permits, Director's Orders, or the Ohio Water Quality Standards (OAC 3745-1)), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 2006b) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989a, 1989b, 2008a, 2008b), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995, 2006a) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in Table 1.

Determining Use Attainment Status

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

Habitat Assessment

Physical habitat was evaluated using the QHEI developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995, Ohio EPA 2006a). 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 an Ohio EPA contract lab. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions as outlined in the Associations document (Ohio EPA 1999), or published literature. Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000) and Ohio Specific Reference Values (2003).

Recreational Use Assessment

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

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). Stations with insufficient flow to place artificial substrates or where the artificial substrates were missing were only sampled qualitatively from the natural substrates. These stations were evaluated and assigned a narrative evaluation based on community attributes such as EPT (Ephemeroptera – mayfly, Plecoptera – stonefly, and Trichoptera – caddisfly) diversity and predominance, sensitive taxa diversity and predominance, and tolerant taxa predominance. Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b) and 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities (Ohio EPA 2008b).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b) and 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities (Ohio EPA 2008b).

Primary Headwater Habitat Sampling

Streams which have been determined to not have sufficient habitat to support a viable fish community and had a drainage area of about one mi^2 or less were sampled using the methods in Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams (Ohio EPA 2002).

Causal Associations

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

Table 1. Sampling locations for the White Oak Creek study area, 2006. **M** - macroinvertebrate quantitative sample, M - macroinvertebrate qualitative sample, **F** - fish sample (2 passes), F - fish sample (1 pass), Sa – salamanders, C - conventional water chemistry parameters (5 runs), B - bacteria (5 runs), S - sediment sample (conventional and organics), D - datasonde monitor, O - organic water chemistry (2 runs). Latitude/longitude coordinates are provided in WGS84 datum.

Stream* RM	**Sample Type**	**Lat/Long (DD)**	**Location**	**USGS Quad**
East Fork White Oak Creek				
18.69	C,F,M	39.1178 / -83.6885	Leninger-Haigh Rd.	Sugar Tree Ridge
16.50	C,B,F,M	39.0972 / -83.708	dst. Sorg Rd., dst. tributary	Sugar Tree Ridge
10.48	C,B,D,**F**,**M**	39.0398 / -83.7438	ust. Mowrystown Delphi Park dam	Sugar Tree Ridge
5.81	C,S,O,**F**,**M**	39.0153 / -83.7953	Sardinia-Mowrystown Rd.	Sardinia
3.30	C,B,S,D,O,**F**,**M**	39.0086 / -83.8319	adj. Tri-County Highway	Sardinia
Tributary to East Fork White Oak Creek (RM 15.52)				
2.10	C,B,F	39.1168 / -83.7315	New Market Rd.	Sugar Tree Ridge
0.26	C,F,M	39.0935 / -83.7207	Robinson Rd.	Sugar Tree Ridge
Tributary to East Fork White Oak Creek (RM 14.35)				
0.01	C,F,M	39.0791 / -83.7378	From Edwards Rd., near mouth	Sugar Tree Ridge
Tributary to East Fork White Oak Creek (RM 12.38)				
2.42	C,M	39.0761 / -83.7075	Ridge Rd.	Sugar Tree Ridge
Plum Run				
0.95	C,M	39.0388 / -83.7308	Wildcat Rd.	Sugar Tree Ridge
0.32	C,F,M	39.0349 / -83.7403	Fenwick Rd.	Sugar Tree Ridge
Bells Run				
1.97	C,B,F,M	39.0354 / -83.7843	TR 142A (Winkle Rd.)	Sardinia
Slabcamp Run				
2.93	C,F,M	38.9908 / -83.7848	Fite Hauck Rd.	Ash Ridge
1.13	C,F,M	39.0038 / -83.8085	Purdy Rd., ust. Sardinia WWTP	Sardinia
0.98	C,B,O	39.0047 / -83.8108	Sardinia WWTP effluent	Sardinia
Browns Run				
0.10	C,F,M	38.9968 / -83.8541	Stephan Rd.	Ash Ridge
North Fork White Oak Creek				
19.67	C,F,M	39.1708 / -83.7583	Cochran Rd.	Lynchburg
18.10	C,S,O,F,M	39.1657 / -83.781	Dawson Rd.	Lynchburg
15.36	C,B,F,M	39.1418 / -83.8053	dst. SR 131 and dst. Barr Run	Lynchburg
9.7	**F**,M	39.09437 / -83.84714	dst. SR 134 and dst. L. North Fork	Sardinia
6.98	C,B,S,D,O,**F**,**M**	39.0646 / -83.8499	Sicily Rd.	Sardinia
1.48	C,B,S,D,O,**F**,**M**	39.016 / -83.8711	CR 24B (Tri-County Highway)	Sardinia
Little North Fork White Oak Creek				
5.06	C,F,M	39.1594 / -83.8419	SR 134	Lynchburg
2.94	C,S,O,F,M	39.1312 / -83.84403	SR 131	Lynchburg
0.28	C,B,F,M	39.0963 / -83.8424	Rosselott Rd.	Sardinia
Flat Run				
4.80	C,F,M	39.0486 / -83.8124	Kelch Rd.	Sardinia
3.39	C,S,O,F,M	39.0383 / -83.8303	SR 134	Sardinia
0.15	C,B,F,M	39.0166 / -83.8681	Tri-County Highway	Sardinia
White Oak Creek				
27.55	C,D,**F**,M	38.9901 / -83.8896	New Hope White Oak Station Rd.	Hamersville

Stream* RM	**Sample Type**	**Lat/Long (DD)**	**Location**	**USGS Quad**
20.65	C,B,S,D,O,**F**,M	38.9594 / -83.9157	Bethel New Hope Rd.	Hamersville
16.57	C,D,**F**,M	38.9261 / -83.9254	McMall Rd.	Hamersville
12.40	C,B,S,D,O,**F**,**M**	38.8918 / -83.92027	End of Miller Ring Rd.	Hamersville
7.54	C,B,D,O,**F**,M	38.8581 / -83.9286	Adj. SR 221, dst. Georgetown WTP dam, ust. Town Run	Higgensport
6.7	**M**	38.84497 / -83.92145	SR 221, dst. Town Run	Higgensport
2.3	C,O,**F**,**M**	38.8059 / -83.9573	Adj. SR 221, ust. Ohio River backwater	Higgensport
Sterling Run				
11.35	C,S,F,M	39.0923 / -83.8914	Moon Rd.	Mount Orab
9.65	C,S,O,F,M	39.0693 / -83.8973	Greenbush East Rd.	Mount Orab
6.74	C,B,S,D,O,F,M	39.0394 / -83.9194	US 68	Mount Orab
6.47	C,B,S,O	39.0343 / -83.9204	At Mt Orab water intake	Mount Orab
3.08	C,D,**F**,M	38.9962 / -83.929	SR 774, dst. Lake Grant	Hammersville
0.59	C,B,S,O,**F**,M	38.968 / -83.9203	Sterling Rd. (southern ford)	Hammersville
0.05	D	38.96116 / -83.91629	Near mouth	Hammersville
Lake Grant				
L-1	C,O	38.99928 / -83.92941	Near dam	Hammersville
L-2	C,O	39.00906 / -83.93425	Mid lake, dst. Plum Cr.	Mount Orab
Tributary to Sterling Run (RM 6.68)				
2.41	C,S,F,M	39.0661 / -83.9271	Waits Rd., ust. Trib. at RM 2.40	Mount Orab
0.68	C,S,O,F,M	39.047 / -83.9247	Bardwell West Rd.	Mount Orab
Snapping Turtle Run				
0.55	C,M	38.9939 / -83.9211	Ust. Mount Orab WWTP	Hammersville
0.46	C,B,O	38.9926 / -83.9216	Mount Orab WWTP effluent	Hammersville
0.42	C,S	38.9922 / -83.9222	Dst. Mount Orab WWTP	Hammersville
Miranda Run				
0.69	C,F,M	38.9342 / -83.94009	Dst. Smoky Row Rd., dst. Trib.	Hammersville
Walnut Creek				
1.40	C	38.9021 / -83.9046	Adj. Sunshine Rd., dst. Rumpke Georgetown Landfill	Hammersville
0.76	C,Sa,M	38.9064 / -83.91477	Sunshine Rd.	Hammersville
Tributary to Walnut Creek (RM 1.20)				
0.33	C	38.9022 / -83.908	Sunshine Rd.	Hemmersville
Town Run				
0.81	C,Sa,M	38.8522 / -83.91	Ust. Georgetown WWTP	Higgensport
0.80	C,B,O	38.852 / -83.9103	Georgetown WWTP effluent	Higgensport
0.63	C,S,Sa,M	38.8514 / -83.9125	Dst. Georgetown WWTP	Higgensport

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

SUMMARY

A summary of monitoring results, attainment status for current or recommended aquatic life uses, and causes and sources of impairment to attainment in the White Oak Creek study area can be found in Table 2. A graphic representation of the attainment status at the collection stations is presented in Figure 2. Biological, physical habitat, and surface water chemistry information was collected from 46 stations (43 stations with an assigned attainment status) in 18 streams in the White Oak Creek watershed. Of these, 25 were fully attaining (58%) their existing or recommended aquatic life use, eight were partially attaining (19%), and 10 were not attaining (23%). Three stations were sampled only with qualitative macroinvertebrate methods and did not receive a use attainment status. The state listed (Threatened) fish bigeye shiner (*Notropis boops*) was found at 23 stations during this study.

The White Oak Creek watershed is located in the Interior Plateau ecoregion. Highly erodible Avonburg, Blanchester, and Clermont (ABC) soils make up 68.4 % of the soils in this watershed. Avonburg, Blanchester, and Clermont soils allow immediate flushing of farm soils and attached agricultural chemicals into surface water. Due to the impervious nature of ABC soils, subsurface drainage is ineffective. Drainage ditches are run through farm fields to prevent ponding of surface water and to allow for quick removal of surface water. The accumulation of sediment in the watershed from this farming practice impacts water quality. As ABC soils are farmed with heavy equipment, the interstitial pore space is compressed and prevents moisture retention and fertilizer to migrate into the soil. Lowered soil water retention from deforestation and loss of native forest soil structure cause interstitial stream flow conditions to occur due to loss of base flow during the summer months. The majority of stream stations that were not in full attainment of their aquatic life use were impacted by low stream flow conditions. While the fish communities sampled were found to be mostly intact and apparently adapted to the changes in flow regime, the macroinvertebrate communities did not fare as well. In these cases, most sensitive taxa that would normally be present in a flowing stream with riffle/run complexes were not found.

Median water column phosphorus values were found to be over the reference levels established in "Association Between Nutrients, Habitat, and Aquatic Biota in Ohio Rivers and Streams" (Ohio EPA 1999), henceforth referred to as the Associations document, in 94% (48/51) of the stations sampled across the entire watershed.

Recreational Use Attainment

Bacteriological samples (fecal coliform and *E. coli*) were collected from 16 stations in the White Oak Creek watershed to evaluate attainment of their existing or recommended recreational use designations. Of these, 11 were attaining the Primary Contact Recreation (PCR) use and five were not. The non-attainment at East Fork White Oak Creek (RM 16.50), Tributary to East Fork White Oak Creek @ RM 15.52 (RM 2.10), and Bells Run (RM 1.97) were due to cattle with unrestricted access to the stream upstream from the sampling areas. The station on the North Fork White Oak Creek (RM 15.36) was located downstream from Barr Run and the unsewered community of Pricetown. Failing septic systems in Pricetown may be the source of the non-attainment at this station. The non-attainment at Sterling Run (RM 6.74) was located downstream from a sanitary sewer overflow (SSO) location that was discovered on 7 July and sealed by 2 August during this study. However, the sludge from the discharge was not removed, and remained in the stream at the time of the sampling (14-18 August).

Thirteen of the 16 stations sampled in this watershed had exceedences of the *E. coli* standard. The major source of most of these exceedences was probably failing home septic systems. The Highland County Health Department states in the Home Sewage Treatment Management Plan that conventional septic systems installed in ABC soils are highly likely to experience failures. The age, design, and lack of maintenance of many septic systems in this county result in malfunctioning systems and nuisance complaints.

White Oak Creek Mainstem

The biological communities sampled in the White Oak Creek mainstem were evaluated as very good to exceptional with the exception of the fish communities at two stations. Increased abundance of the herbivorous (feeds on algae) central stoneroller minnow and the detritivorous bluntnose minnow in conjunction with the absence or low numbers of several sensitive species, compared to upstream stations, were indications of nutrient enrichment at Bethel New Hope Road (RM 20.7) and at the end of Barnes Road (RM 12.8). There were no obvious water chemistry parameters to verify nutrient enrichment. However, the Bethel New Hope Road station had an unusually high diel D.O. swing along with the highest supersaturation of D.O. (18-20 July Datasonde® sample) on the White Oak Creek mainstem and was the only station on this stream with the median nitrate-nitrite-N concentration (0.75 mg/l) higher than the reference value (0.5 mg/l). This station is located downstream from Sterling Run which had elevated nitrate-nitrite-N concentrations at the downstream most station (median of 5.37 mg/l at RM 0.59) due to inputs from the Mt. Orab WWTP.

East Fork White Oak Creek Watershed

East Fork White Oak Creek was fully attaining the WWH aquatic life use designation with biological communities evaluated as marginally good to exceptional. However, there were two situations on the stream that posed a threat to attainment. Cattle had unrestricted access to the stream upstream from Sorg Road (RM 16.50), which led to non-attainment of the PCR use and one D.O. concentration (3.47 mg/l) below the minimum Warmwater Habitat (WWH) criterion of 4 mg/l. Biological communities sampled within the Mowrystown Delphi Park impoundment (RM 10.6) were limited by the lake-like conditions. The fish community dropped to very good (IBI=47, MIwb=8.9) compared to exceptional upstream (IBI=54). The macroinvertebrate community EPT (8 compared to 13 upstream) and sensitive taxa (10 compared to 13 upstream) diversity declined and the ICI scored (26) at the low end of non-significant departure from the WWH criterion (30).

Plum Run at Wildcat Road (RM 0.9) and Bells Run at Winkle Road (RM 2.0) were impacted by cattle with unrestricted access to the stream. Both of these stations had violations of the ammonia-N criterion and very low D.O. concentrations. The impairment in Bells Run resulted in poor fish and macroinvertebrate community evaluations. The station on Tributary to East Fork White Oak Creek @ RM 15.52 at New Market Road (RM 2.10) had similar water chemistry impacts due to cattle with unrestricted access to the stream; however, the fish community was not impaired and macroinvertebrates were not sampled. Two biological stream sampling stations were located in Slabcamp Run upstream from the Sardinia WWTP. The macroinvertebrate communities at both of these stations were impaired by low to interstitial stream flows. Low D.O. concentrations were recorded at these two stations on 31 August due to the interstitial stream flows.

North Fork White Oak Creek Watershed

Macroinvertebrate communities in the headwaters of the North Fork White Oak Creek were impacted by low flow and sedimentation. The upstream most station at Cochran Road (RM 19.6) was also impacted by channelization and enrichment, as evidenced by excessive algal growth and unbalanced community structure. Community performance improved at downstream stations with improved flow and mostly intact riparian areas.

Macroinvertebrate communities in the headwaters of the Little North Fork White Oak Creek and Flat Run were impacted by low flow and sedimentation. The upstream most station on Little North Fork at SR 134 (RM 5.1) was also impacted by channelization and enrichment, as evidenced by excessive algal growth and unbalanced community structure. Community performance improved in both streams at the downstream station due to improved flow.

Tributaries to the White Oak Creek Mainstem

Biological communities throughout the upper Sterling Run subbasin displayed evidence of enrichment and the affects of drainage modification. Although small streams in this region are prone to become dry, agricultural land use has exacerbated this. Removal of forest, wetland, and other natural areas has changed normal groundwater stream recharge. Installation of road and field drainage networks has expedited water removal from land surfaces. As a result, small streams have functionally become smaller with larger proportional catchments.

The macroinvertebrate community (RM 0.5) sampled upstream from the Mt. Orab WWTP discharge (RM 0.46) on Snapping Turtle Run was impacted by low D.O. (low of 2.75 mg/l) and siltation. Snapping Turtle Run (RM 0.42) downstream from the Mt. Orab WWTP discharge had high concentrations of phosphorus-T (median of 1.32 mg/l) and nitrate-nitrite-N (median of 18.9 mg/l).

Biological sampling in Town Run (RM 0.9 in 2008) found a marginally good community of macroinvertebrates and a reproducing population of the cold water indicator two-lined salamander upstream from the Georgetown WWTP discharge (RM 0.80). Downstream from the WWTP discharge (RM 0.7 in 2008) the macroinvertebrate community was very poor and there was no observed reproduction of the two-lined salamander. High concentrations of ammonia-N (median of 3.24 mg/l), phosphorus-T (median of 3.04 mg/l), and nitrate-nitrite-N (median of 6.39 mg/l) were recorded downstream from the WWTP discharge in 2006.

Public Water Supplies
Water Quality Standards (WQS) established for the Public Water Supply (PWS) beneficial use (OAC 3745-1-33) currently apply within 500 yards of drinking water intakes and for all publicly owned lakes. Ohio EPA has developed a new assessment methodology for this beneficial use which focuses on source water contaminants not effectively removed through conventional treatment methods. Impaired source waters may contribute to increased human health risk or treatment costs. There is one public water system directly served by a surface water source within the White Oak study area.

The Village of Mt. Orab operates a community public water system that serves approximately 3,600 persons and has 1,860 service connections. A community public water system is a system that regularly supplies drinking water from its own sources to at least 15 service connections used by year-round residents of the area or regularly serves 25 or more people throughout the entire year. The water treatment plant is designed to treat 670,000 gallons per day, but current average production is about 372,000 gallons per day. Mt. Orab also purchases approximately 100,000 gallons of water per day from Brown County Rural Water Company and initiated this transfer in 2000. This water helps improve the water quality in the upground reservoirs when high total organic carbon and farm chemical levels, or taste and odor problems, are noticed by consumers.

Atrazine levels in the finished drinking water are typically below detection limits since September 2005 when the Village of Mt. Orab installed granular activated carbon filters to the treatment process. The filters were costly to install and carry an annual carbon replacement cost of approximately $50,000. The primary purpose of the GAC system is to reduce total organic carbon levels in the treated water and prevent formation of disinfection by-products. The secondary purpose is pesticide removal and the GAC filters have effectively reduced atrazine levels in the finished drinking water.

As required by the Safe Drinking Water Act, Ohio EPA completed Drinking Water Source Assessments for the Village of Mt. Orab in 2004. These reports delineate source water protection areas, inventory potential contaminant sources, and recommend protective strategies. Additional information and copies of the reports are available by contacting Ohio EPA Division of Drinking and Ground Waters at (614) 644-2752 or visit the Division's web site at:
http://www.epa.state.oh.us/ddagw/pdu/swap.html. .

The Public Water Supply beneficial use is designated for the Village of Mt. Orab's surface water supply intake on Sterling Run at River Mile 6.47. Water is pumped from Sterling Run into one of three upground reservoirs that contain 90, 30, and 8 million gallons, respectively, and then delivered to the treatment plant. Sterling Run was listed as impaired for the PWS beneficial use in Ohio EPA's 2008 Integrated Water Quality Monitoring and Assessment Report due to elevated pesticides in the source water, specifically for atrazine. In order to be listed as impaired due to pesticide levels, the annual average concentration must exceed the established WQS criterion. Individual detections above the WQS criterion do not necessarily trigger impairment, nor do they indicate that the treated water is unsafe to drink. As described in the water quality data section, Ohio EPA collected a number of samples along Sterling Run and at the Mt. Orab intake. An additional data set used for the PWS use attainment determination was from the Syngenta Crop Protection, Inc. (Syngenta) Atrazine Monitoring Program (AMP). The AMP was required as part of the January 2003 Atrazine Interim Reregistration Eligibility Decision and subsequent Memorandum of Agreement between U.S. EPA and Syngenta.

Excessive levels of atrazine in Sterling Run at the PWS intake were measured in 2005 (annual avg. = 7.92 ug/L) and 2006 (annual avg. = 10.18 ug/L), resulting in annual average concentrations above the WQS criterion for atrazine (3.0 ug/L). The maximum atrazine concentration detected was 227 ug/L on 5/23/2006. Atrazine is typically detected from May to September with maximum concentrations in the spring following agricultural application. A surface water sample collected by Ohio EPA on May 5, 2003 at the PWS intake indicated very high levels of several pesticides; atrazine at 41.4 ug/L (MCL=3.0 ug/L), simazine at 11.4 ug/L (MCL = 4 ug/L), alachlor at 5.06 ug/L (MCL = 2.0 ug/L), and metolcahlor at 12.2 ug/L (no MCL).

During the fall of 2005, the Village unknowingly pumped atrazine contaminated water to their upground reservoir. By federal law, atrazine is not permitted for fall/winter use and should not have been present in Sterling Run at that time. As a result of that incident and excessive levels of the pesticide throughout the spring season, the water system now analyzes the water in Sterling Run prior to pumping to the reservoirs. On March 20, 2007, Syngenta Crop protection, Inc. hosted an, Atrazine Stewardship meeting in Mt. Orab for local farmers. Commercial pesticide applicators provided education about atrazine application regulations and how the elevated levels of atrazine in Sterling Run are impacting the water treatment plant. The meeting was well attended and atrazine levels in Sterling Run remained low during the fall/winter of 2006 and 2007.

Table 2. Aquatic life use attainment status for stations sampled in the White Oak Creek study area based on data collected June-October 2006. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
WAU 05090201-09 (White Oak Creek watershed – Headwaters to below East Fork White Oak Creek)							
WAU 05090201-09-01 (includes Tribs to E. Fk. @ RMs 15.52, 14.35, and 12.38)							
East Fork White Oak Creek (10-420) *IP Ecoregion – WWH Existing*							
18.7[H]/18.6	54	-	G	78.0	FULL		
16.5[H]	54	-	G	74.0	FULL		
WAU 05090201-09-02 (includes Plum Run, Bells Run, Slabcamp Run, and Browns Run)							
10.6[W]	47	8.9	26[NS]	55.0	FULL		
5.7[W]/5.8	55	10.6	48	68.0	FULL		
3.3[W]	54	9.9	48	73.8	FULL		
WAU 05090201-09-01							
Tributary to East Fork White Oak Creek @ RM 15.52 (10-442) *IP Ecoregion – Undesignated / WWH Recommended*							
2.1[H]/ -	46	-	-	47.0	(FULL)		
0.3[H]/0.2	56	-	MG[NS]	71.0	FULL		
Tributary to East Fork White Oak Creek @ RM 14.35 (10-441) *IP Ecoregion – Undesignated / WWH Recommended*							
0.1[H]	42	-	MG[NS]	62.0	FULL		
Tributary to East Fork White Oak Creek @ RM 12.38 (10-440) *IP Ecoregion – Undesignated / WWH Recommended*							
2.4	-	--	MG[NS]	-	-		

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
WAU 05090201-09-02							
Plum Run (10-427) *IP Ecoregion - WWH Existing*							
- / 0.9	-	-	F*	-	-	Dissolved oxygen, ammonia-N	Unrestricted cattle access
0.3[H]	48	-	G	77.0	FULL		
Bells Run (10-426) *IP Ecoregion - WWH Existing*							
2.0[H]/1.9	24*	-	P*	48.5	**NON**	Dissolved oxygen, ammonia-N, phosphorus-T, siltation	Manure runoff, unrestricted cattle access
Slabcamp Run (10-424) *IP Ecoregion - WWH Existing*							
2.9[H]/3.0	38[NS]	-	P*	54.5	**NON**	Low flow alterations, siltation	Crop production
1.1[H]	50	-	F*	66.5	PARTIAL	Low flow alterations, siltation	Crop production, urban runoff
Browns Run (10-422) *IP Ecoregion - WWH Existing*							
0.1[H]	46	-	G	57.0	FULL		
WAU 05090201-09-03 (includes Little North Fork)							
North Fork White Oak Creek (10-430) *IP Ecoregion - WWH Existing*							
19.7[H]/19.6	36[NS]	-	LF*	45.5	PARTIAL	Low flow alterations, siltation, nutrients/eutrophication, direct habitat alterations	Channelization, loss of riparian, crop production, on-site treatment systems
18.1[H]	46	-	F*	56.5	PARTIAL	Low flow alterations, siltation	Crop production
15.3[H]/15.1	44	-	MG[NS]	63.0	FULL		
WAU 05090201-09-04 (includes Flat Run)							
9.7[W]	53	9.3	G	58.0	FULL		
7.0[W]	49	8.9	44	63.8	FULL		
1.5[W]/1.4	49	9.9	44	64.5	FULL		

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
WAU 05090201-09-03							
Little North Fork White Oak Creek (10-436) *IP Ecoregion - EWH Existing / WWH Recommended*							
5.1[H]	48	-	P*	51.5	**NON**	Low flow alterations, siltation, phosphorus-T, direct habitat alterations	Crop production, channelization, unrestricted cattle access (downstream from bridge)
2.9[H]/3.0	50	-	F*	57.5	PARTIAL	Siltation, low flow alterations	Crop production
0.3[H]	52	-	MG[NS]	62.5	FULL		
WAU 05090201-09-04							
Flat Run (10-431) *IP Ecoregion - EWH Existing / WWH Recommended*							
4.8[H]	40	-	F*	53.0	PARTIAL	Low flow alterations, siltation	Crop production
3.4[H]	54	-	LF*	59.5	PARTIAL	Low flow alterations	Crop production
0.2[H]/0.1	48	-	G	68.5	FULL		
WAU 05090201-10 (White Oak Creek watershed - Below East Fork White Oak Creek to Ohio River)							
WAU 05090201-10-02 (includes Miranda Run and Walnut Creek)							
White Oak Creek (10-400) *IP Ecoregion - EWH Existing*							
27.5[W]/27.6	51	8.9[NS]	E	64.0	FULL		
20.7[W]/20.6	42*	9.2[NS]	E	63.5	PARTIAL	Nutrient/Eutrophication, siltation	Upstream source (especially Mt. Orab WWTP)
16.5[W]	50	9.2[NS]	E	86.0	FULL		
12.8[W]/12.4	44*	8.7*	46	77.0	PARTIAL	Nutrient/Eutrophication	Upstream source
7.5[W]/7.6	52	10.2	E	74.0	FULL		
WAU 05090201-10-03 (includes Town Run)							
- / 6.7	-	-	44[NS]	-	(FULL)		
2.6[W]/2.7	48[NS]	10.5	50	81.0	FULL		

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
WAU 05090201-10-01							
Sterling Run (10-413) *IP Ecoregion - WWH Existing*							
11.4[H]	20*	-	P*	42.0	**NON**	Low flow alterations, siltation, phosphorus-T	Crop production
9.7[H]	30*	-	P*	49.0	**NON**	Low flow alterations, siltation, dissolved oxygen, phosphorus-T	Crop production
6.8[H]	30*	-	F*	51.0	**NON**	Low flow alterations, siltation, dissolved oxygen	Crop production, SSO (capped in summer of 2006)
3.0[W]	44	7.7[NS]	P*	58.0	**NON**	Low flow alterations, dissolved oxygen	Lake Grant, crop production
0.6[W]/0.4	48	8.3	G	69.5	FULL		
Tributary to Sterling Run @ RM 6.68 (10-418) *IP Ecoregion – Undesignated / WWH Recommended*							
2.4[H]	22*	-	P*	41.5	**NON**	Low flow alterations, siltation, dissolved oxygen, phosphorus-T	Crop production
0.7[H]/0.8	22*	-	P*	39.0	**NON**	Dissolved oxygen, siltation, direct habitat alterations	Crop production, channelization
Snapping Turtle Run (10-414) *IP Ecoregion - WWH Existing*							
- / 0.5	-	-	LF*	-	-	Dissolved oxygen, siltation	Crop production
WAU 05090201-10-02							
Miranda Run (10-411) *IP Ecoregion - EWH Existing / WWH Recommended*							
0.6[H]/0.7	50	-	G	76.5	FULL		
Walnut Creek (10-408) *IP Ecoregion - WWH Existing / CWH Recommended*							
- / 0.6	-	-	MG[NS]	-	FULL		

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
WAU 05090201-10-03							
Town Run (10-407)	*IP Ecoregion - LRW Existing / CWH Recommended*						
- / 0.9	-	-	MG[NS]	-	FULL		
- / 0.9[d]	-	-	MG[NS]	-	FULL		
- / 0.7[d]	-	-	VP*	-	**NON**	Ammonia-N, phosphorus-T, nitrate-nitrite-N	Georgetown WWTP

Ecoregion Biocriteria: Interior Plateau

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				30	46	22
Wading	40	50	24	8.1	9.4	6.2	30	46	22
Boat	38	48	24	8.7	9.6	5.8	30	46	22

H - Headwater site.

W - Wading site.

B - Boat site.

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

b - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

c - Attainment status is given for the existing or if a change is recommended then the recommended use designations. Attainment status was not assigned to isolated stream segments that were sampled with only qualitative macroinvertebrate methods.

d Sample collected on 7 May 2008.

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.

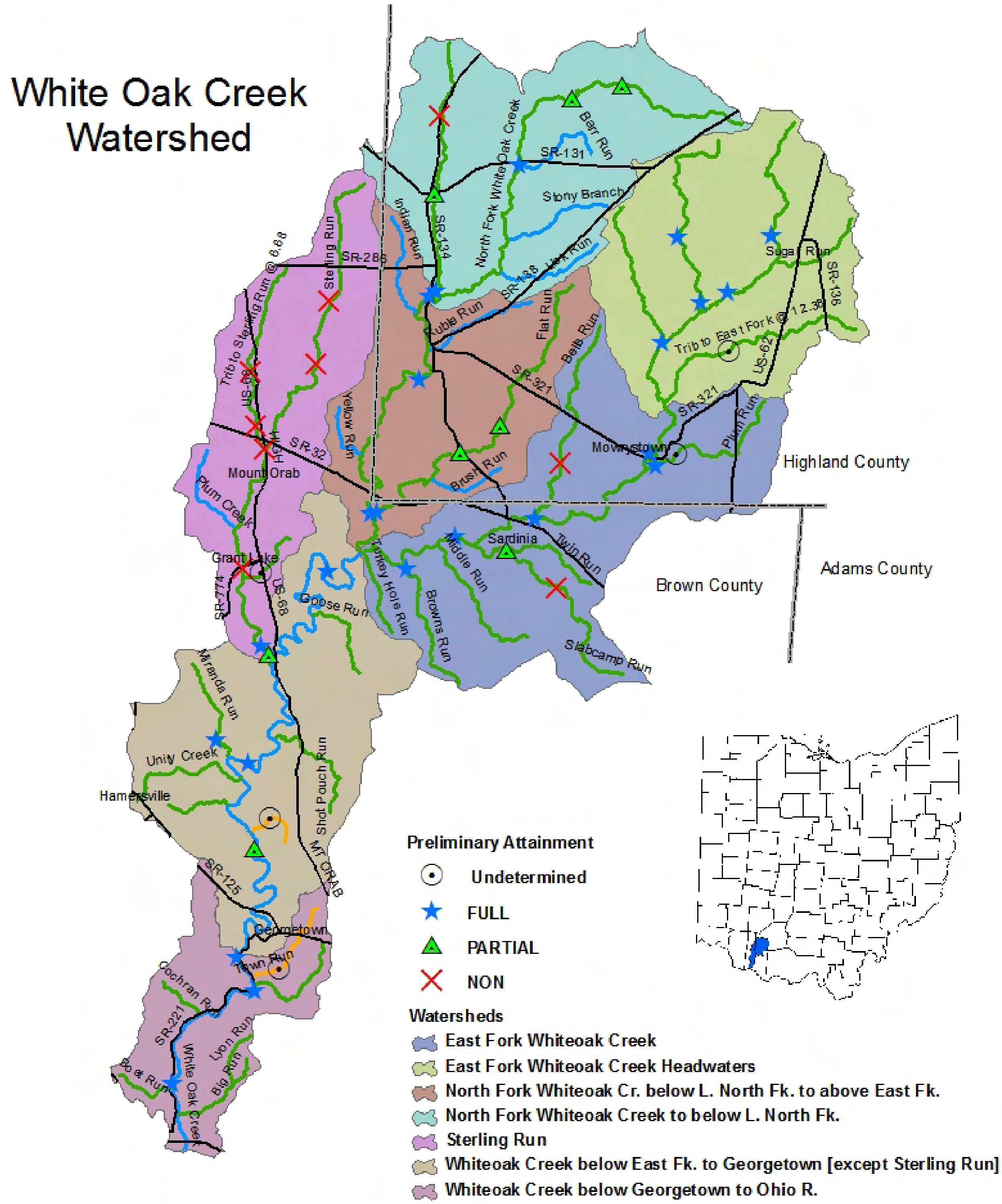


Figure 2. Attainment status of sampling locations in the White Oak Creek study area, 2006.

RECOMMENDATIONS

Changes in Aquatic Life Uses

Current and recommended aquatic life, water supply and recreation uses are presented in Table 3. A number of the tributary streams evaluated in this study were originally assigned aquatic life use designations in the 1978 and 1985 Ohio WQS based largely on best professional judgment, while others were left undesignated. The current biological assessment methods and numerical criteria did not exist then. This study, as an objective and robust evaluation of beneficial uses, is precedent setting in comparison to the 1978 and 1985 designations. Several subbasin 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 Warm Water Habitat (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.

Eleven tributaries were sampled for the first time by Ohio EPA during this study. Miranda Run, Tributary to Sterling Run @ RM 6.68, Browns Run, Bells Run, Plum Run, Tributary to East Fork White Oak Creek @ RM 12.38, Tributary to East Fork White Oak Creek @ RM 14.35, Tributary to East Fork White Oak Creek @ RM 15.52, Flat Run, and Little North Fork White Oak Creek were all identified as having the potential to support WWH communities and have, thus, been recommended for the WWH aquatic life use designation.

Walnut Creek is a small stream that is confluent with White Oak Creek at RM 13.19 and has a drainage area of about 1.4 sq mi. This stream flows just north of the Rumpke Brown County Landfill. The lower portion of this stream has a high gradient and flows through a wooded ravine. The maximum pool depth in the sampling area was 23 cm. This stream is currently designated WWH, but based on the current analysis it should be assigned to Cold Water Habitat (CWH). Due to its low potential to support a viable fish population, salamanders were used to evaluate the appropriate aquatic life use designation instead of fish. Biological sampling found 13 larval two-lined salamanders along with 33 taxa of macroinvertebrates which included 8 EPT and 3 cold water taxa.

Town Run is a small stream that is confluent with White Oak Creek at RM 6.95 and has a total drainage area of 1.74 sq mi. This stream flows through the southeast corner of Georgetown and the Georgetown WWTP effluent discharges to the stream at RM 0.80. The lower portion of this stream has a high gradient and flows through a wooded ravine that has areas of exposed bedrock that form waterfalls. The maximum pool depth in the sampling area (RM 0.9, drainage area of 1.4 sq mi) upstream from the WWTP discharge was 37 cm on 16 August 2006 and 41 cm on 7 May 2008. The habitat in Town Run is insufficient to support a balanced, viable fish community. Therefore, salamanders were used to evaluate the appropriate aquatic life use designation instead of fish. This stream is currently designated LRW, but, based on the current analysis, it should be assigned to the CWH use. Biological sampling upstream from the WWTP discharge found 14 larval two-lined salamanders along with 29 taxa of macroinvertebrates which included 9 EPT, 9 sensitive taxa, and 0 coldwater taxa in 2006. The station was resampled in 2008 when 6 larval two-lined salamanders were found along with 26 taxa of macroinvertebrates including 10 EPT, 7 sensitive taxa, and 3 cold water taxa.

Improvements to Water Quality

Improvements may be made to water quality throughout the study area by addressing the causes and sources identified within the aquatic life use attainment table (Table 2). The causes and sources associated with agricultural practices may be addressed by improving riparian buffers, proper fertilizer and pesticide application, and ceasing of traditional ‘cleaning’ of streams. Funding opportunities should be sought to improve agricultural practices and could include any of the above listed improvements. In particular, it would be beneficial to fence the cattle out of the headwaters of East Fork White Oak Creek (RM 16.50), Tributary to East Fork White Oak Creek @ RM 15.52 (RM 2.1), Plum Run (RM 0.9), and Bells Run (RM 2.0). Urbanization impairments could be addressed through a combination of regulatory, educational and funding actions including improvements at each WWTP, management of failing septic systems, advances in storm water management, controlled development and alternatives to traditional stream channelization and riparian removal. One method to reduce polluted urban runoff would be to incorporate bioretention areas into existing and new infrastructure. A summery of these structures can be found in the fact sheet http://ohioline.osu.edu/cl-fact/1000.html .

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

Water Body Segment	Use Designations														Comments
		Aquatic Life Habitat							Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	PHWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Whiteoak creek	+		+							+	+		+		
Big run		*								*	*		*		
Lyon run		*								*	*		*		
Boat run		*								*	*		*		
Cochran run		*								*	*		*		
Ross run		*								*	*		*		
Opossum run		*								*	*		*		
Town run						Δ				+	+		Δ		
Walnut creek						Δ				*/+	*/+		*/+		
Indian run	*		*							*	*		*		

Water Body Segment	Use Designations														Comments
		Aquatic Life Habitat							Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	PHWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Unity creek	*		*							*	*		*		
Miranda run	*	Δ								*/+	*/+		*/+		
Shot Pouch run	*	*								*	*		*		
Sterling run – Grant lake wildlife area (RM 5.4 to 3.0)	o		*							*	*		*		
- at RM 6.47		+							o	+	+		+		
- all other segments		+								+	+		+		
Snapping Turtle run		+								+	+		+		
Plum creek – Grand lake wildlife area (RM 0.53 to 0.0)	o		*							*	*		*		
- all other segments			*							*	*		*		
Tributary to Sterling run @ RM 6.68		Δ								Δ	Δ		Δ		
Goose run		*								*	*		*		
East fork – Middle run (RM 2.0) to North fork (RM 0.0)	*	+								+	+		+		
- at RM 5.13		+							o	+	+		+		
- all other segments		+								+	+		+		
Turkeyhole run		*								*	*		*		

Water Body Segment	Use Designations														Comments
		Aquatic Life Habitat							Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	PHWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Browns run		*/+								*/+	*/+		*/+		
Middle run		*								*	*		*		
Slabcamp run		+								+	+		+		
Twin run		*								*	*		*		
Bells run		*/+								*/+	*/+		*/+		
Plum run		*/+								*/+	*/+		*/+		
Tributary to East fork @ RM 12.38		Δ								Δ	Δ		Δ		
Tributary to East fork @ RM 14.35		Δ								Δ	Δ		Δ		
Tributary to East fork @ RM 15.52		Δ								Δ	Δ		Δ		
Sugar run		*								*	*		*		
North fork	*	+								+	+		+		
Flat run	*	Δ								*/+	*/+		*/+		
Brush run	*		*							*	*		*		
Yellow run	*		*							*	*		*		
Ruble run	*		*							*	*		*		

Water Body Segment	Use Designations														Comments
		Aquatic Life Habitat							Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	PHWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Indian run	*		*							*	*		*		
Little North fork	*	Δ								*/+	*/+		*/+		
Lick run	*		*							*	*		*		
Stony branch	*		*							*	*		*		
Barr run	*		*							*	*		*		

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

RESULTS

White Oak Creek Study Area Description

The White Oak Creek watershed is situated in southwestern Highland County and occupies most of central Brown County. It drains an area of 234.3 miles^2 (150,621 acres) and the mainstem is 49.3 miles in length. The elevation changes from 1055 ft to 463ft at the mouth with an average fall of 12 ft/mi (ODNR, 2001). Major tributaries include Sterling Run, North Fork White Oak Creek, and East Fork White Oak Creek. There are 210 miles of named streams in the watershed and another 170 miles of unnamed streams. The watershed originates in the southwest portion of Highland County and about one half of the land area is within the county. Streams generally flow southwest toward Brown County The East Fork and North Fork of White Oak Creek (Watershed Assessment Unit 09) join within Brown County to form the mainstem (Watershed Assessment Unit 10) south of Mt. Orab but upstream of the confluence with Sterling Run. The mainstem flows almost due south past Georgetown and meets the Ohio River near Higginsport.

Located in the Interior Plateau ecoregion the watershed is part of a transition zone between the Eastern Corn Belt Plains and the Western Allegheny Plateau (Omernick and Gallant, 1988). The landforms vary from flat to gently rolling glacial till plains in the upper parts of the watershed to a steeply dissected valley cutting through bedrock of shale and limestone. Streams in the upper reaches of the watershed flow through glacial till soils and have substrates of sand, silt, and gravel. Lower in the watershed streams become steeper and have cut into the limestone and shale bedrock on their way to a confluence with the Ohio River. Substrates of these streams are broken bedrock and bedrock. Original vegetation in the watershed varied with the moisture regime of the soils. Drier sites had various species of oak, hickory, tulip, maples, and ashes. Impervious soils tended to be wetter and the tree communities consisted of pin oak, Shumard oak, swamp white oak, sweetgum, beech, and cottonwood (Omernick and Gallant, 1988).

Land uses in the watershed are predominately agricultural with 58% of the area involved in row crop production and 13% used for livestock pasturage (Fig. 3). Another 25% of the watershed is covered with forest which means that all other land uses account for only 5% of the area. Watershed Assessment Unit (WAU) 09 is slightly higher in row crop agriculture (65%) than WAU 10 (45%) but is lower in forest (20% vs 32%). Both WAUs have 13% of their lands used for pasture. Residential land use in WAU 10 accounts for about 5% of the area because both Mt. Orab and Georgetown are in it. None of the communities in the watershed qualify as truly urban areas but Mt. Orab (pop. 2304) and Georgetown (pop. 3855) do have to deal with storm water runoff from new development. North of Georgetown is a regional landfill belonging to the Rumpke Corporation.

Riparian land uses within 100 feet of the streams also vary with between the assessment units. WAU 10 has considerably fewer acres in row crops and pasture than WAU 09. A common practice for pastures is to allow the cattle access to streams for water. This practice leads to damaged riparian vegetation, worn eroded banks, excessive erosion, and bacterial contamination. Fencing of cattle away from streams has been beneficial to water quality in some areas but more funding and education are needed to change overall landuse practices.

Soils in the watershed vary according to the landforms. Most soils in the upper part of the watershed where the land is flat to gently sloping formed in glacial till and wind deposited silts called loess. Most of these soils are in the Avonburg-Blanchester-Clermont association and are commonly referred to as “ABC soils”. All of them consist of fine grained silts and clays which retain water very well but do not allow for effective infiltration when managed for any use other than forest. A soil quality study conducted on Clermont soils (ODNR 2008) showed that the only land use which allowed infiltration at rainfall rates was forest. Most of the land uses, including conservation tillage practices, caused the surface to seal such that rainfall events would mostly runoff carrying soil and nutrients to streams. Because of the soil’s lack of permeability subsurface drains are not effective. Instead of that type of drainage the landowners use surface ditches to direct runoff to streams and other outlets. Soils in the southern portions of the watershed tend to be on steeper slopes and are generally better drained than the ABC soils.

The soil surveys for Brown and Highland counties both indicate that the “ABC soils” are poorly suited to building site development and septic tank absorption fields. This conclusion is reinforced in the HSTS plans developed by Brown and Highland counties which do not recommend leach fields in those soils. All of the “ABC soils” are subject to seasonal wetness and ponding that further restrict all uses. Despite these restrictions landowners do manage to successfully grow crops on these soils and with certain practices, such as wooded riparian zones, impacts on water quality can be minimized.

White Oak Creek has a successful watershed project that supports a watershed coordinator. The project has been awarded two watershed coordinator grants from the Ohio Department of Natural Resources which require the coordinator to implement the actions called for in the Watershed Action Plan. Two Clean Water Act Section 319 grants have been awarded to the project by Ohio EPA to develop the watershed plan, to install stream buffers and livestock feeding pads and replace failed septic systems. These grants also supported establishment and continuation of a school based monitoring program. Grant monies paid for equipment and supplies for student education and use. The coordinator has developed a website, watershed newsletter, and a watershed festival as education programs for the project. The Section 319 grants have totaled $493,754 and with local match total project totals exceed $800,000. In addition to these grants the project has received special project funds from the Ohio Division of Wildlife to fence livestock from streams and provide alternative water sources. The project was also given a conservation easement on a portion of White Oak Creek as a partial penalty against Rumpke by Ohio EPA.

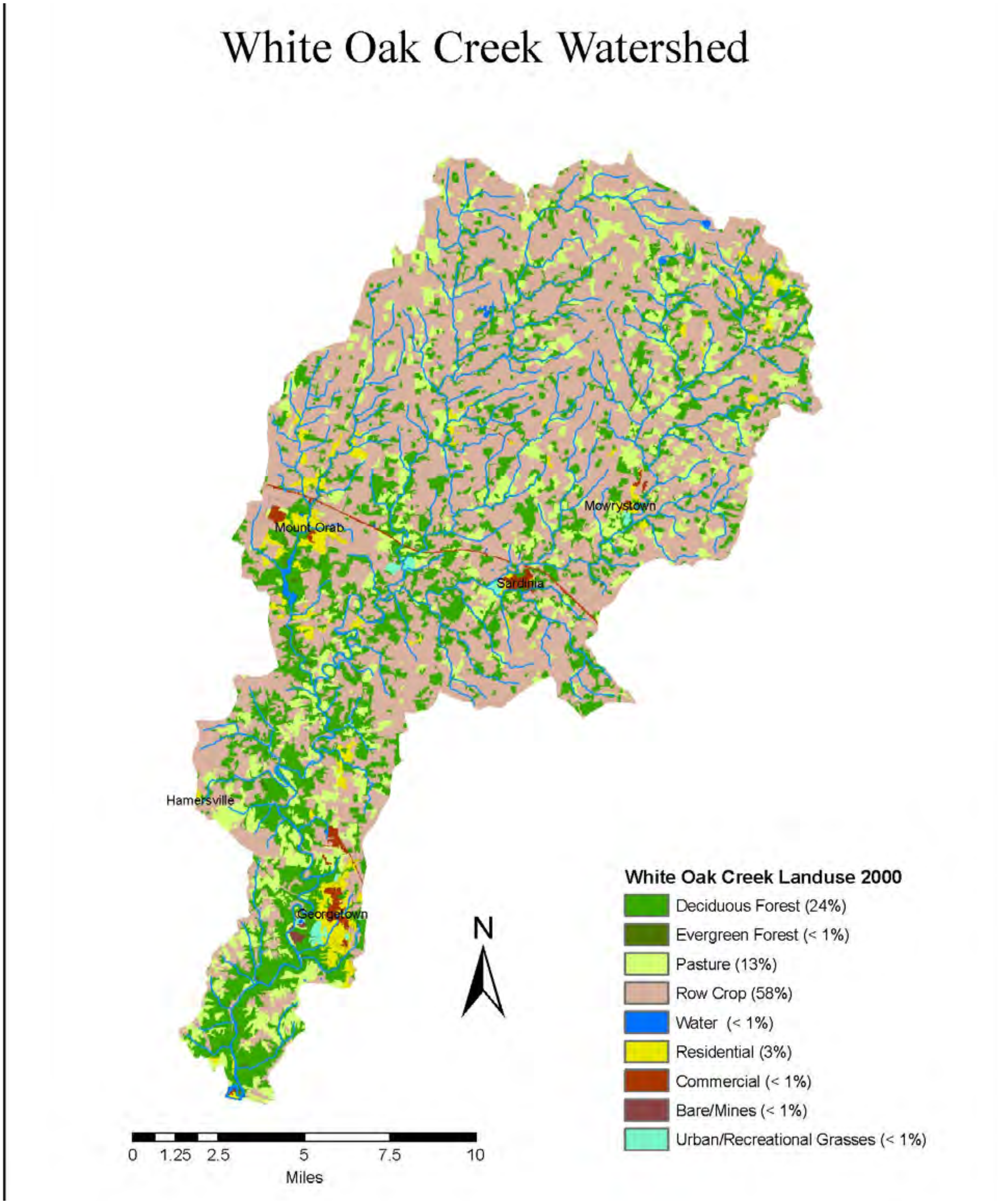


Figure 3. Land use in the White Oak Creek watershed.

Chemical Water Quality

Physical and chemical assessments were completed at 51 sites in the White Oak Creek watershed (24 in the WAU 05090201-09 (WAU 09) and 27 the WAU 05090201-10 (WAU 10). Five sets of grab samples were collected from each site for inorganic parameters from July into September, 2006. Organic parameters were collected at least twice from 19 locations in the watershed. Bacteria samples were collected five times from 16 locations from August 14-18. Lake Grant was sampled for inorganic and organic samples on one occasion.

Throughout most of the sampling season stream flow was low (10-15 CFS) in White Oak Creek for in the first four sampling events. Rainfall was a factor in the fifth sampling event (September 27 and 28). Rainfall also was encountered on the third sampling round but did not change flow in White Oak Creek. Datasonde placements occurred under low flow conditions. Bacteria sampling also occurred under low flow conditions, with days 1 and 5 having some rainfall. The rainfall on day 5 resulted in an increase in stream flow. (Figure 5)

Water quality in White Oak Creek watershed was influenced by physical habitat quality, agricultural land uses, treated wastewater effluent, and failing home septic systems. Row crop agriculture contributed to sedimentation and nutrient enrichment.

The White Oak Creek watershed is located in the Interior Plateau ecoregion. Highly erodible Avonburg, Blanchester, and Clermont (ABC) soils make up 68.4 % of the soils in this watershed. Avonburg, Blanchester, and Clermont soils allow immediate flushing of farm soils and attached agricultural chemicals into surface water. Due to the impervious nature of ABC soils, subsurface drainage is ineffective. Drainage ditches are run through farm fields to prevent ponding of surface water and to allow for quick removal of surface water. The accumulation of sediment in the watershed from this farming practice impacts water quality.

As ABC soils are farmed with heavy equipment, the interstitial pore space is compressed to prevent moisture retention and fertilizer to migrate into the soil. Lowered soil water retention from deforestation and loss of native forest soil structure cause interstitial stream flow conditions to occur due to loss of base flow during the summer months. Sterling Run, a tributary in the White Oak Creek basin, is a prime example of low flow alterations affecting water quality.

The Highland County Health Department states in the Home Sewage Treatment Management Plan that conventional septic systems installed in ABC soils are highly likely to experience failures. The age, design, and lack of maintenance of many septic systems in this county result in malfunctioning systems and nuisance complaints.

Headwater sites of East Fork White Oak Creek were impacted more frequently by livestock which had direct access to the streams, than in other subwatersheds. North

Fork White Oak Creek and Sterling Run were impacted by soil erosion from farming practices and failing septic systems. Failing septic systems are a common problem in Brown and Highland Counties. Local ordinances in Brown County do not allow land application of septage or acceptance of septic hauled wastes at Wastewater Treatment Plants (WWTP). Historically, illegal dumping by septage haulers in fields and driveways was a major problem.

U.S. EPA mandated that states adopt nutrient criteria because nutrients are consistently identified as a cause of impairment. The document Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999) (a.k.a. the Associations document) was used as the reference to evaluate nutrient concentrations in surface water in this report. The Associations document classifies Ohio streams into ecoregions and subdivides them 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). White Oak Creek is in the Interior Plateau Ecoregion and is considered a small river, draining 235 mi^2 of land at its mouth.

The Interior Plateau represents only 5.8% of Ohio's ecoregions and does not have a large database to derive statistical significance in the Associations document. Therefore, it was agreed to by consensus of Ohio EPA, DSW staff, to use the statewide target values to evaluate concentrations of phosphorus and nitrate-nitrite (Table 4). Additionally, the 90th percentile of statewide background values for ammonia and the 75th percentile of statewide background values for total suspended solids were used to assign causes of impairment. As of this publication, no instream nutrient criteria have been promulgated in Water Quality Standards (OAC 3745), but the values selected for this report are assumed to be a close approximation to the final values.

Nutrients, except under unusual circumstances, rarely approach concentrations in surface water that are toxic to aquatic life. However, excess nutrients can exert negative effects by increasing algal and macrophyte production in the water column. Overproduction of algal and macrophyte communities can increase turbidity and cause wide swings in the diel dissolved oxygen (D.O.) and pH levels. Pollution intolerant fish and macroinvertebrate species find these conditions stressful which can manifest negative impacts. Ultimately, intolerant species are replaced by more tolerant species, typical of degraded warmwater streams.

Median water column phosphorus values were found to be over the target levels established in the Associations document in 94% (48/51) of the stations sampled across the entire watershed.

Table 4. White Oak Creek has 51 chemical sites all in the Interior Plateau. The majority of chemical sites are in the headwaters (78.4%). IP headwater nutrient values from the Associations document were derived from a small dataset and are questionable. The following statewide reference values from the Associations document were used to evaluate water chemistry results.

Phosphorus	Headwater	WWH = 0.08 mg/l
		EWH = 0.05 mg/l
	Wadeable	WWH = 0.10 mg/l
		EWH = 0.05 mg/l
	Small River	WWH = 0.17 mg/l
		EWH = 0.10 mg/l
	Large River	WWH = 0.30 mg/l
		EWH = 0.15 mg/l

Reference: Statewide target values from Table 2 pg. 5 of the Associations document.

Nitrate + Nitrite	Headwater	WWH = 1.0 mg/l
		EWH = 0.5 mg/l
	Wadeable	WWH = 1.0 mg/l
		EWH = 0.5 mg/l
	Small River	WWH = 1.5 mg/l
		EWH = 1.0 mg/l
	Large River	WWH = 2.0 mg/l
		EWH = 1.5 mg/l

Reference: Statewide target values from Table 1 pg. 4 of the Associations document.

Ammonia	Headwater	0.11 mg/l
	Wadeable	0.1 mg/l
	Small River	0.1 mg/l
	Large River	0.2 mg/l

Reference: Statewide 90th percentile of background values from Appendix 1 pg. 27 Associations document.

Total Suspended Solids	Headwater	16 mg/l
	Wadeable	24.75 mg/l
	Small River	39.0 mg/l
	Large River	50.0 mg/l

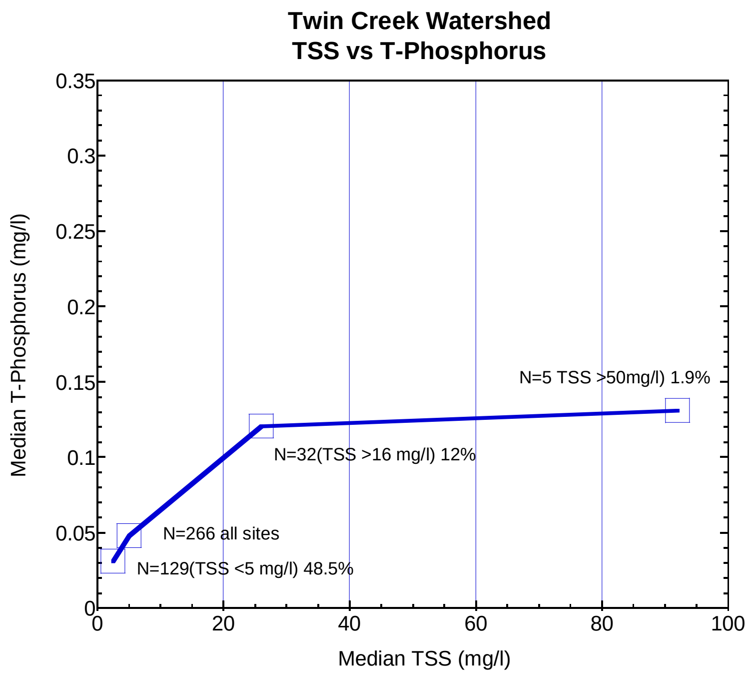
Reference: Statewide 75th percentile of background values from Appendix 1 pg. 24 Associations document

The impact of ecoregion and soil types to water quality is very evident when comparing Twin Creek, a high quality watershed in the Eastern Cornbelt Plain ecoregion in Preble County, to the White Oak Creek watershed. Both watersheds have a high percentage of agricultural land use. The White Oak Creek watershed has a high residual level of phosphorus in the water column when compared to Twin Creek, during conditions when total suspended solids (TSS) are below detection. The relationship between water column phosphorus levels and suspended solids (Figure 4) suggests dissolved phosphorus is present in the water column in White Oak Creek. However, no dissolved phosphorus samples were taken during the survey to confirm this. Speculation for the reasons for high residual phosphorus in White Oak could also be due in part to algal biomass adding phosphorus to the sample upon chemical analysis, or the parent bedrock and soil being high in phosphorus.

The speculation that the soil is naturally high in phosphorus was not shared by Matt Deaton, the ODNR soil scientist for the White Oak area. OEPA sediment total phosphorus analysis averaged 737 mg/kg for the 16 White Oak Creek tributaries and 1813 mg/kg for the three mainstem sites. Overall the sediment phosphorus was not high in the tributaries, but elevated in the mainstem. In comparison, Twin Creek total phosphorus average in 8 tributary sites was 696.5 mg/kg and the 10 mainstem sites averaged 670.6 mg/kg.

In White Oak Creek, four of the five sampling events occurred near base flow conditions when runoff from farm fields was at a minimum. However residual farm soils in the stream sediments of the watershed appear to be releasing phosphorus to clear flowing streams. Across the entire watershed during the five sampling events, 84 of 252 sites had suspended solids in the water column below the minimum detection limit. Sites that were influenced by WWTP effluent were eliminated from the calculation, leaving 66 of 233 remaining sites (28%) below the TSS detection limit. The median total phosphorus value for these 66 sites was 0.167 mg/l (above the state reference value). The median total phosphorus value for the entire 233 sites was 0.189 mg/l with the median TSS value for the same 233 sites being 9 mg/l. TSS levels over the headwater 75th percentile (>16 mg/l) were found at 75 of 233 sites with the median total phosphorus value of 0.269 mg/l. TSS levels over 50 mg/l were found in 26 sites (61%), mostly associated with rainfall during September 27-28. These higher TSS water column sites had median total phosphorus at 0.355 mg/l.

In comparison, Twin Creek had a median phosphorus value of 0.031 mg/l at TSS levels below detection (48.5% of all samples were below detection for TSS). White Oak Creek watershed had a median phosphorus level of 0.167 mg/l at TSS levels below detection. Sixty-six samples or 28% of all samples were below detection for TSS. The highest levels of TSS in Twin Creek were the same value as the lowest TSS waters of White Oak Creek.



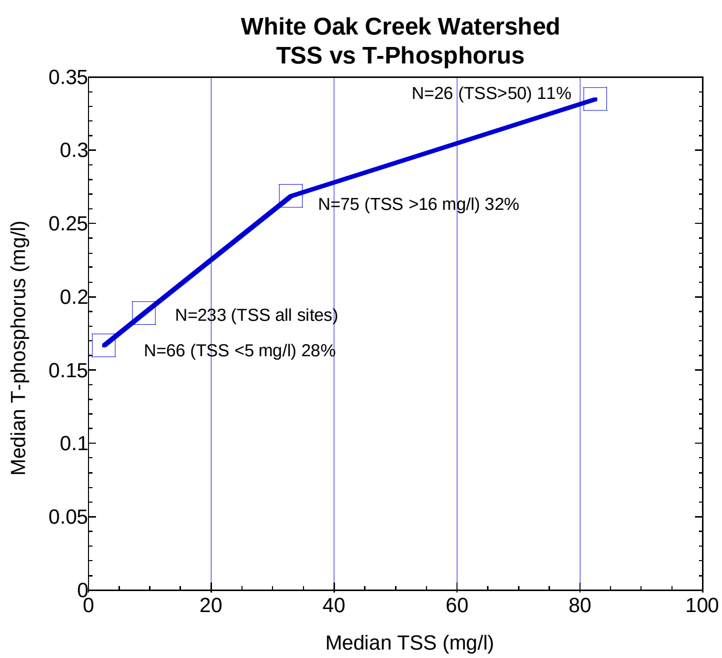


Figure 4. The relationship between Total Suspended Sediment and Total Phosphorus in White Oak Creek watershed (IP) versus Twin Creek watershed. (ECBP)

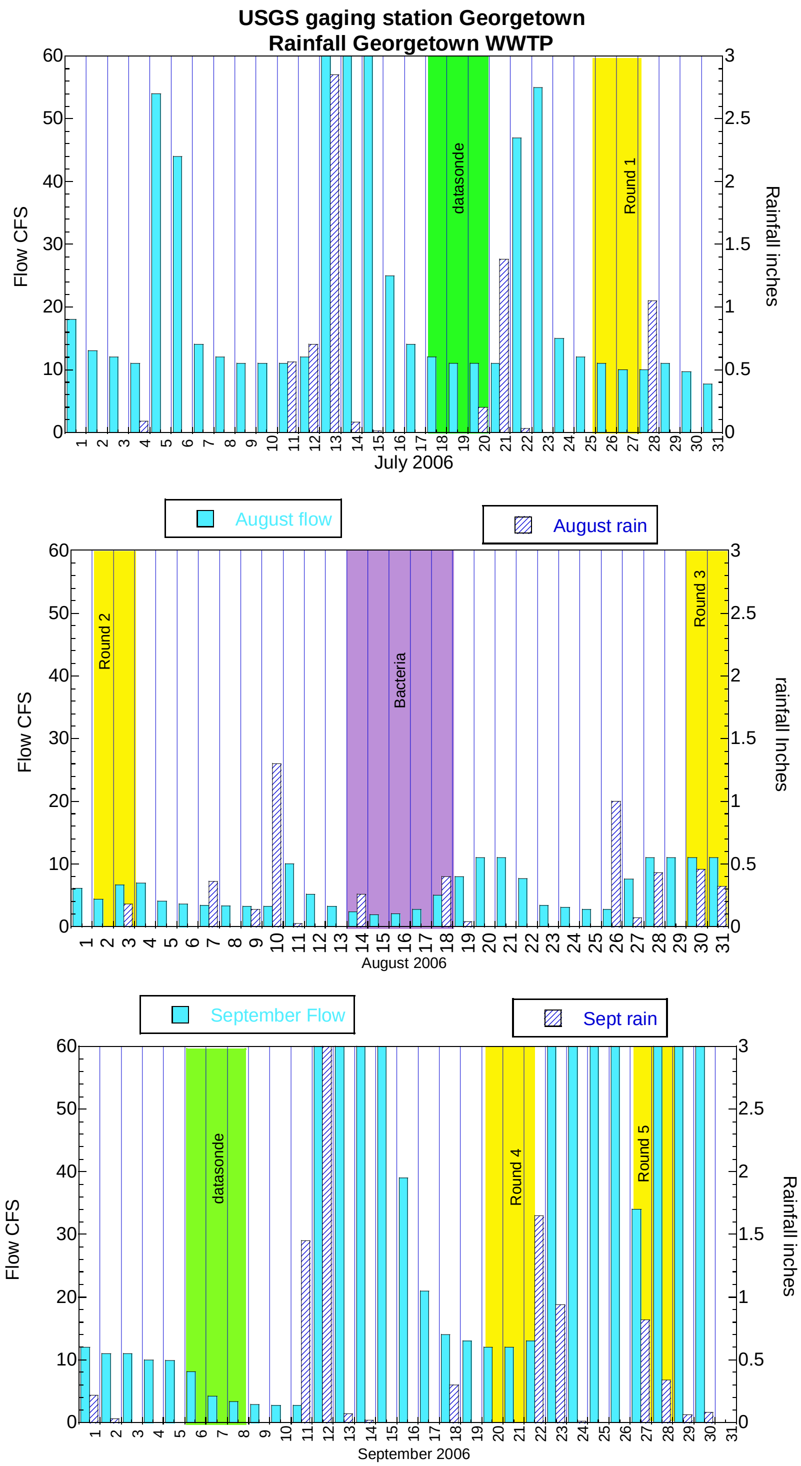


Figure 5. Rainfall and flow data in White Oak Creek during sampling season. Data from USGS gage in White Oak Creek and rainfall from Georgetown WWTP rain gage.

Bacteria

Sixteen sites were sampled in the White Oak Creek WAU 09 and 10 watersheds for bacteria. If all the bacteria sampling is combined, the White Oak Creek watershed in its entirety failed to meet the Primary Contact Recreation (PCR) designation (Table 5), specified in the Ohio Administrative Code (3745-1-07, Table 7-13). Table 6 evaluates the attainment of the PCR use by 12 digit WAUs. Four sites in WAU 09 watershed and one site in the WAU 10 watershed failed to meet the PCR criteria (Table 7).

According to Water Quality Standards, geometric mean density for the watershed after 5 rounds of sampling in a 30 day period shall not exceed 1000 colonies/100 ml for total Fecal coliform, and shall not exceed 126 colonies/100 ml 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 the Primary Contact Recreational waters.

Table 5. Results of Ohio EPA bacteriological sampling in the White Oak Creek study area by 10-digit watershed assessment unit (WAUs 05090201-09 and 05090201-10) during 2006*. Five samples were collected from select sites from August 14-18. For PCR designated streams, at least one of the two bacteriological standards (fecal coliform or *E. coli*) must be met. (Values above criteria are highlighted in red.)

	Entire Watershed** (16 sites)	WAU 09 (10 sites)	WAU 10 (6 sites)
Recreational Use Attained?	**NO**	**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 per 100 ml, ***and*** fecal coliform content shall not exceed 2000 per ml in more than ten percent of the samples taken during any thirty-day period.			
Geometric mean (#colonies/100ml)	411	831	112
% > 2000 max	**16.9%**	**24.0%**	3.7%
n =	77	50	27
Primary Contact Recreation (*E. coli*): Geometric mean *E. coli* content based on not less than five samples within a thirty-day period shall not exceed 126 per 100 ml, ***and*** *E. coli* content shall not exceed 298 per 100 ml in more than ten percent of the samples taken during any thirty-day period.			
Geometric mean (#colonies/100ml)	**247**	**471**	75
% > 298 max	**36.4%**	**48.0%**	**14.8%**
n =	77	50	27

*05090201 09 White Oak Cr - Headwaters to below East Fork (Drainage 147.5 mi^2)
05090201 10 White Oak Cr - Below East Fork to Ohio River (Drainage 87.9 mi^2)

** Excluding effluent samples from three WWTPs and including one site that did not have a recreational use designation during the 2006 survey (Tributary to East Fork White Oak Creek @ RM 15.52)

Table 6. Results of Ohio EPA bacteriological sampling in the White Oak Creek study area by 12-digit watershed assessment unit (WAUs) during 2006. Five samples were collected from select sites from August 14-18. For PCR designated streams, at least one of the two bacteriological standards (fecal coliform or *E. coli*) must be met. (Values above criteria are highlighted in red.)*

10-Digit WAU	**05090201 09_ _**				**05090201 10_ _**		
12-Digit WAU**	**01** 2 sites	**02** 3 sites	**03** 1 site	**04** 4 sites	**01** 3 sites	**02** 2 sites	**03** 1 site
Recreational Use Attained?	**NO**	**YES**	**NO**	**YES**	**YES**	**YES**	**YES**
Primary Contact Recreation (Fecal coliform): Geometric mean fecal coliform content based on not less than five samples within a thirty-day period shall not exceed 1000 per 100 ml, ***and*** fecal coliform content shall not exceed 2000 per ml in more than ten percent of the samples taken during any thirty-day period.							
Geometric mean (#colonies/100ml)	**12,285**	462	**1669**	282	382	55	25
% > max	**100%**	7%	**20%**	0%	8%	0%	0%
n =	10	15	5	20	12	10	5
Primary Contact Recreation (*E. coli*): Geometric mean *E. coli* content based on not less than five samples within a thirty-day period shall not exceed 126 per 100 ml, ***and*** *E. coli* content shall not exceed 298 per 100 ml in more than ten percent of the samples taken during any thirty-day period.							
Geometric mean (#colonies/100ml)	**6776**	**243**	**940**	**172**	**209**	39	24
% > max	**100%**	**33%**	**80%**	**20%**	**33%**	0%	0%
n =	10	15	5	20	12	10	5

* excluding effluent samples from three WWTPs and including one site that did not have a recreational use designation during the 2006 survey (Tributary to East Fork White Oak Creek @ RM 15.52)

*05090201 09-01 East Fork White Oak Cr starting at RM 23.51(Drainage 36.4 mi^2)
05090201 09-02 East Fork White Oak Cr ending at RM 23.51(Drainage 43.7 mi^2)

05090201 09-03 North Fork White Oak Cr to below Little North Fork (Drainage 37.2 mi^2)
05090201 09-04 North Fork White Oak Cr below Little North Fork to above East Fork (Drainage 30.2 mi^2)

05090201 10-01 Sterling Run (Drainage 30.0 mi^2)
05090201 10-02 White Oak Cr below East Fork to Georgetown (except Sterling) (Drainage 40.4 mi^2)
05090201 10-03 White Oak Creek below Georgetown to Ohio River (Drainage 17.5 mi^2)

Table 7. Ohio EPA bacteriological sampling results in the White Oak Creek study area during 2006. Five samples were collected from 16 sites (excludes effluent from three WWTPs) from August 14-18. For Primary Contact Recreation (PCR) designated streams to attain recreational use at least one of the two bacteriological standards (fecal coliform or *E. coli*) must be met (Ohio Administrative Code 3745-1-07, Table 7-13). Values above criteria are highlighted in red. All values are expressed as colony forming units (cfu) per 100 ml of water. Attainment status in brackets is based on fewer than 5 samples.

Stream RM	12 Digit WAU	Location	Fecal coliform		*E. coli*		Recreational Use Attained?
			Geometric Mean	% > Max	Geometric Mean	% > Max	
WAU 05090201-09 (White Oak Creek watershed- Headwaters to below East Fork White Oak Creek							
***North Fork White Oak Creek** - PCR*							
15.36	03	Dst SR 131 and Barr Run	1669	20	940	80	**NO**
6.98	04	Sicily Rd, dst bridge	270	0	168	20	**YES**
1.48	04	Dst Mt. Orab Sardinia Rd (Tri County Hwy)	310	0	129	20	**YES**
***Little North Fork White Oak Creek**- PCR*							
0.28	04	Rosselott Rd	334	0	224	40	**YES**
***Flat Run**- PCR*							
0.15	04	Tri-County Highway	226	0	180	20	**YES**
***East Fork White Oak Creek**- PCR*							
16.50	01	Dst Sorg Rd., dst. trib, adj Robinson Rd	13547	100	8402	100	**NO**
10.48	02	Mowrystown Diehl Park, upst dam	239	0	160	20	**YES**
3.30	02	6444 SR 74 (Tri County Hwy)	446	0	266	40	**YES**
***Tributary to East Fork White Oak Creek (RM 15.52)** –undesignated, assumed PCR for calculation*							
2.10	01	New Market Rd	11140	100	5465	100	**NO**
***Bells Run**- PCR*							
1.97	02	Twp Rd 142A (Winkle Rd)	923	20	335	40	**NO**
WAU 05090201-10 (White Oak Creek watershed- Below East Fork White Oak Creek to Ohio River							
***White Oak Creek**- PCR*							
20.65	02	Bethel New Hope Rd	69	0	43	0	**YES**
12.40	02	End of Miller Ring Rd	43	0	36	0	**YES**
7.54	03	Adj SR 221, dst. Georgetown waterworks dam and USGS gage	25	0	24	0	**YES**
***Sterling Run**- PCR*							
6.74	01	Upst US 68 (near McDonalds)	1766	25	951	50	**[NO]**
6.47	01	Mt Orab Water Intake	116	0	99	25	**[YES]**
0.59	01	Sterling Rd lower ford	274	0	97	25	**[YES]**

Table 8. Exceedences of Ohio EPA water quality criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the White Oak Creek study area during 2006 (units are µg/l for metals and organics, #colonies/100 ml for fecal coliform and *E. coli*, SU for pH, and mg/l for all other parameters).

Stream/Lake (*use designation* [a])		Parameter [b] (value)
12-digit WAU [c]	River Mile	
WAU 05090201-09 (Whiteoak Creek watershed-Headwaters to below East Fork Whiteoak Creek)		
North Fork White Oak Creek (*SRW, WWH, PCR, AWS, IWS*)		
03	18.10	Temperature (29.21*)
03	15.36	Fecal coliform (27000[◊◊], 1400[◊], 2000[◊]) *E. coli* (360[◊◊], 10000[◊◊], 1000[◊◊], 970[◊◊], 210[◊])
04	6.98	Dissolved Oxygen (3.81[‡‡]) *E. coli* (490[◊◊], 160[◊], 130[◊], 130[◊])
04	1.48	Dissolved Oxygen (4.83[‡‡], 3.90[‡]) *E. coli* (400[◊◊], 180[◊], 140[◊])
Little North Fork White Oak Creek (*SRW, EWH, PCR, AWS, IWS*)		
03	2.94	Dissolved Oxygen (3.05[‡‡])
03	0.28	Dissolved Oxygen (3.27[‡‡], 4.12[‡‡]) *E. coli* (550[◊◊], 310[◊◊], 130[◊], 160[◊], 160[◊]) Mercury-T (0.23[#])
Flat Run (*SRW, EWH, PCR, AWS, IWS*)		
04	4.80	Dissolved Oxygen (3.10[‡‡])
04	0.15	Dissolved Oxygen (2.64[‡‡], 3.62[‡‡] , 1.90[‡‡]) *E. coli* (360[◊◊], 210[◊], 190[◊])
East Fork White Oak Creek ***- Middle Run (RM 2.0) to North Fork (RM 0.0): SRW, WWH, PCR, AWS, IWS*** ***- RM 5.13: (WWH, PCR, PWS, AWS, IWS)*** ***- All other segments: (WWH, PCR, AWS, IWS)***		
01	16.50	Dissolved Oxygen (3.47[‡‡]) Temperature (32.25**) Fecal coliform (22000[◊◊], 20000[◊◊], 5400[◊◊], 9600[◊◊], 20000[◊◊]) *E. coli* (12000[◊◊], 14000[◊◊], 4700[◊◊], 6800[◊◊], 7800[◊◊])
02	10.48	Dissolved Oxygen (4.74[‡], 4.40[‡]) *E. coli* (300[◊◊], 160[◊], 220[◊])
02	5.81	Temperature (29.58**)
02	3.30	Fecal coliform (1100[◊]) *E. coli* (400[◊◊], 900[◊◊], 280[◊], 220[◊])

Table 8. Continued.

Stream/Lake (*use designation* [a])		Parameter [b] (value)
12-digit WAU	River Mile	
Tributary to East Fork White Oak Creek (RM 15.52) (*undesignated*)		
01	2.10	Dissolved Oxygen (0.08[‡‡], 0.09[‡‡] , 2.24[‡‡]) Temperature (27.92*) Ammonia-N (29.9**, 50.8**, 2.42*) Fecal coliform (5100[◊◊◊], 70000[◊◊◊], 18000[◊◊◊], 8900[◊◊◊]) *E. coli* (2500[◊◊◊], 54000[◊◊◊], 2500[◊◊◊], 7600[◊◊◊], 1900[◊◊◊]) Barium-T (315*, 414*)
01	0.26	Dissolved Oxygen (4.30[‡])
Tributary to East Fork White Oak Creek (RM 14.35) (*undesignated*)		
01	0.01	Dissolved Oxygen (4.18[‡], 2.84[‡‡])
Tributary to East Fork White Oak Creek (RM 12.38) (*undesignated*)		
01	2.42	Temperature (28.82*)
Plum Run (*WWH, PCR, AWS, IWS)*		
02	0.95	Dissolved Oxygen (0.36[‡‡], 3.78[‡‡] , 2.53[‡‡]) Ammonia-N (3.09*, 4.47*, 2.98*)
02	0.32	Dissolved Oxygen (4.90[‡], 3.12[‡‡])
Bells Run (*WWH, PCR, AWS, IWS)*		
02	1.97	Dissolved Oxygen (1.34[‡‡], 3.06[‡‡] , 2.20[‡‡]) Ammonia-N (19**, 13.2**, 6.67*) Fecal coliform (3700[◊◊], 1900[◊]) *E. coli* (3000[◊◊], 1300[◊◊], 150[◊], 180[◊])
Slabcamp Run (*WWH, PCR, AWS, IWS*)		
02	2.93	Dissolved Oxygen (3.05[‡‡])
02	1.13	Dissolved Oxygen (4.17[‡], 2.03[‡‡])
WAU 05090201-10 ***(White Oak Creek watershed- Below East Fork White Oak Creek to Ohio River)***		
Whiteoak Creek (*SRW, EWH, PCR, AWS, IWS)*		
02	20.65	*E. coli* (130[◊])
03	7.54	Dissolved Oxygen (5.47[‡])
Sterling Run ***- Grant Lake Wildlife Area (RM 5.4 to 3.0): SRW, EWH, PCR, AWS, IWS*** ***- RM 6.47(Mt. Orab WTP intake): WWH, PCR, PWS, AWS, IWS*** ***- All other segments: WWH, PCR, AWS, IWS***		
01	11.35	Dissolved Oxygen (3.60[‡‡], 4.15[‡])
01	9.65	Dissolved Oxygen (3.51[‡‡], 2.36[‡‡] , 1.18[‡‡]) Heptachlor epoxide (0.0029[#]) Hexachlorobenzene (0.031[#])

Table 8. Continued.

Stream/Lake (*use designation* [a])		Parameter [b] (value)
12-digit WAU	River Mile	
01	6.74	Dissolved Oxygen (3.80[‡‡], 4.73[‡]) Fecal coliform (32000[◊◊], 1300[◊]) *E. coli* (20000[◊◊], 740[◊◊], 240[◊], 230[◊]) Copper (78 ***) Dieldrin (0.0033[#]) Heptachlor epoxide (0.0029[#])
01	6.47	Dissolved Oxygen (1.72[‡‡], 1.70[‡‡], 3.28[‡‡], 4.84[‡]) *E. coli* (320[◊◊], 200[◊]) Arsenic-T (10.1[■]) Dieldrin (0.0063[#■])
01	3.08	Dissolved Oxygen (5.38[‡], 5.31[‡], 5.40[‡])
01	0.59	Dissolved Oxygen (4.20[‡]) *E. coli* (370[◊◊], 170[◊], 140[◊]) Heptachlor epoxide (0.0033[#])
Tributary to Sterling Run (RM 6.68) (*undesignated*)		
01	2.41	Dissolved Oxygen (2.40[‡‡], 2.34[‡‡])
01	0.68	Dissolved Oxygen (2.51[‡‡], 3.26[‡‡])
Snapping Turtle Run (*WWH, PCR, AWS, IWS)*		
01	0.60	Dissolved Oxygen (3.09[‡‡], 2.75[‡‡], 3.10[‡‡]) Zinc (366**[B])
Miranda Run (SRW, *EWH, PCR, AWS, IWS)*		
02	0.69	Dissolved Oxygen (5.43[‡])
Walnut Creek (*WWH, PCR, AWS, IWS)*		
02	1.40	Dissolved Oxygen (4.17[‡]) Temperature (30.26**)
Tributary to Walnut Creek (RM 1.2) (*undesignated*)		
02	0.33	Temperature (27.82*)
Town Run (*LRW, SCR, AWS, IWS)*		
03	0.63	Ammonia-N (6.58*, 2.58*, 15**, 3.24*)
Grant Lake (SRW, EWH, BWR, PWS)		
01	L-1 (near dam) Surface	Atrazine (13.2[■])
01	L-2 (Mid lake, Dst Plum Cr) Surface	Lead-T (42.5*) Atrazine (10.4[■]) Heptachlor epoxide (0.0072[#■])

Table 8. Continued.

a Use designations:
SRW - State Resource Water

Aquatic Life Habitat	Water Supply	Recreation
LRW - limited resource water	IWS - industrial water supply	PCR - primary contact
WWH - warmwater habitat	AWS - agricultural water supply	SCR - secondary contact
EWH - exceptional warmwater habitat	PWS- public water supply	BWR -bathing water
Undesignated		
└ [WWH criteria apply to 'undesignated' surface waters.]		

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

c 12-Digit WAUs
05090201-09-01 (East Fork White Oak Creek)
05090201-09-02 (North Fork White Oak Creek to below Little North Fork)
05090201-09-03 (North Fork White Oak Creek below Little North Fork to above East Fork)
05090201-10-01 (Sterling Run)
05090201-10-02 (White Oak Creek below East Fork to Georgetown (except Sterling Run))
05090201-10-03 (White Oak Creek below Georgetown to Ohio River)

- * 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).
- Δ 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 numerical criteria for the protection of human health (drinking water-public water supply).
- ∞ exceedence of agricultural water supply criterion.
- ‡ value is below the EWH minimum 24-hour average D.O. criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O. criterion (5.0 mg/l) or value is below the LRW minimum 24-hour average D.O criterion (3.0 mg/l) as applicable.
- ‡‡ value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the LRW minimum at any time D.O. criterion (2.0 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)
- ◊◊◊ value is above maximum criteria applicable to all waters (fecal coliform 5000/100ml; *E. coli* 576/100ml). [Bacteriological data are provided as a gauge for potential impacts. Requirements associated with the maximum criteria applicable to all waters were not necessarily met during sampling (i.e: 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).]
- B Analytical result is estimated. Analyte was detected in the associated field/acid blank.

White Oak Creek watershed WAU 05090201-10

White Oak Creek begins at RM 29.33 at the confluence of North Fork White Oak Creek and East Fork White Oak Creek. Three sub-watersheds were used for this assessment: Sterling Run *05090201-10-01,* White Oak Creek mainstem to Georgetown *05090201-10-02,* and White Oak mainstem from Georgetown to the Ohio River *05090201-10-03*.

Subwatershed WAU 05090201-10-01, Sterling Run

Sterling Run enters White Oak Creek at RM 20.75 and is 8.45 miles in length, draining 19198 acres (30.0 mi^2) of rolling farmland and growing urban development along US 68 and US 32. There were 11 stream monitoring sites evaluated for water chemistry; 6 stream sites on Sterling Run, 2 on Tributary to Sterling Run (RM 6.68), and 3 on Snapping Turtle Run. One site evaluated the wastewater treatment plant effluent from Mt Orab on Snapping Turtle Run at RM 0.46. The water chemistry of Lake Grant was also sampled.

Sterling Run is the most anthropogenic influenced watershed in the White Oak Creek basin. It is comprised of 84.3% highly erodible Clermont, Blanchester, and Avonburg (ABC) soils (Table 9), allowing immediate flushing of farm soils and attached agricultural chemicals into Sterling Run. Due to the low permeability of the soil, subsurface drainage, as is used for home sewage leach fields and field tiles is ineffective. Drainage ditches are constructed through farm fields to prevent ponding of surface water. The accumulation of sediment in Sterling Run requires frequent dredging to allow for proper drainage.

Table 9. Proportion of ABC soil types in the Sterling Run watershed.

Soil type	**Acres**	**Percentage**
Avonburg	1697	8.8
Blanchester	1101	5.7
Clermont	13,385	69.7
Total ABC soils	16,182	84.2

Brown County Health Department and the White Oak Creek Partners estimates that 25% of home septic systems in the Sterling Run watershed are failing, allowing untreated sewage and bacteria contamination to enter the surface water. This study was done based upon older leach fields placed in low permeable Avonburg, Blanchester or Clermont soils.

Six of the seven sites evaluated in Sterling Run watershed did not meet use designation for a Warm Water Habitat. The watershed upstream from Grant Lake is channelized, with interstitial conditions at the headwater sites in the summer. Algal blooms are frequent in the summer in the slow flowing areas.

Sterling Run is impounded in Lake Grant starting at RM 5.0 and discharges over the dam at RM 3.08. During rainfall events, the mainstem is flashy with a heavy sediment load. Increasing impervious development areas around US 32 and SR 68, upstream from Lake Grant, compound the problem. Lake Grant is filling in with sediment and the Ohio Division of Wildlife plans to allow it to revert into a wetland.

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

Nutrients (Table 10, Figures 7 & 8)
Total Phosphorus concentrations were above the statewide nutrient reference values (0.08 mg/l) in 53 of 54 samples (Ohio EPA, 1999). At all 11 sites the median phosphorus values were above the statewide nutrient reference value.

Nitrate-nitrite concentrations were below the statewide nutrient reference value (1.0 mg/l) at all sites with the exception of two sites downstream of the Mt. Orab WWTP. The two sites downstream of the Mt Orab WWTP on Snapping Turtle Run (RM 0.42) and Sterling Run (RM 0.59), had median values over the statewide nitrate-nitrite reference value and every sampling event was over the nitrate-nitrite reference value for both sites.

No exceedences of Water Quality Standards for ammonia-N were recorded in the 11 Sterling Run watershed sampling sites. Median values at both sites in Snapping Turtle Run, upstream and downstream of the Mt. Orab WWTP, were above the State ammonia-N 90th percentile reference value (Ohio EPA, 1999). Ammonia-N levels above the State nutrient 90^{th} percentile reference value were documented three of five times sampled at the site (RM 0.60) upstream of the Mt. Orab WWTP. Failed septic systems and livestock access to tributaries may be contributing to the elevated concentrations because all three documented ammonia-N events occurred during low flow conditions. The site on Snapping Turtle Run (RM 0.42) downstream of the WWTP had all five sampling events over the State ammonia-N 90^{th} percentile reference value.

The tributary entering Sterling Run (RM 6.69) at RM 2.41 on Waits Road had the median ammonia-N level over the State nutrient 90^{th} percentile reference value. Failed septic systems are suspected because 2 of the 4 sampling events over the State nutrient 90^{th} percentile reference value were collected during low flow conditions and the rocky substrate was covered with a dark algal growth.

The village of Mt. Orab extracts water from Sterling Run at RM 6.37 to fill three drinking water reservoirs, holding 128 million gallons. Farm chemicals (Triazines) and high Total Organic Carbon (TOC) from algal blooms in the raw water present a threat to drinking water quality. A Source Water Assessment of the Mt. Orab Water Treatment Plant was conducted by Ohio EPA in 2004.

High nutrient levels caused algal blooms in Sterling Run, the drinking water reservoir storage system, and in Grant Lake. When algae die, it lyses, releasing fatty acids and other organic compounds. These are measured as Total Organic Compounds (TOC). Trihalomethanes and haloacetic acids tend to form over the MCL (Maximum Contamination Level) for chlorinated byproducts in drinking waters that have TOC values greater than 6 mg/l. Ohio EPA did not measure surface water in Sterling Run for TOC during the stream survey, but two samples taken from Lake Grant documented TOC at 12 and 11 mg/l during June 2006. Mt. Orab has routinely measured TOC in Sterling Run in the 10 mg/l range and samples taken at the intake as part of the SWAP investigation in 2004 documented TOC at 14 mg/l.

Triazine (Atrazine) is a pre and post emergent broad leaf herbicide used especially in corn production. It is usually applied in May and June, when rainfall intensity peaks and, because of the types of soils in this watershed, is swept off the fields by runoff water during intense late spring and early summer storms. The Maximum Contaminant Level (MCL) for Atrazine in drinking water is 3 µg/l. This is based upon an annual average. The manufactures of Atrazine have a Memorandum of Understanding (MOU) with the USEPA to monitor Total Chlorotriazines (includes Atrazine and three degradation products) in 22 community water systems, including Mt. Orab. As a part of this MOU, watershed mitigation will be undertaken if the 90 day rolling average of TCT in a raw water intake exceeds 37.5 ppb.

Once Atrazine is in the water phase it can be shielded from photodegradation by algal growth, color in the water, and colloidal particles. Atrazine collects in the reservoirs holding Mt. Orab's raw water and Grant Lake from surface water run off. Syngenta, a major manufacturer of Atrazine, provides analyses (Figure 6) to the Mt. Orab Water Treatment Plant of Sterling Run, prior to it being pumped into the reservoir system. An activated carbon treatment system was installed at the Mt. Orab Water Treatment Plant on September 29, 2005 to remove semivolatile organic compounds, Trihalomethanes, and haloacetic acids.

Table 10. Summary statistics for selected nutrient water quality parameters in the Sterling Run subwatershed. Values above reference values in **red**.

WAU 05090201-09-01			NH_3-N		$NO_3 + NO_2$ -N		Phosphorus-T	
Stream	**River Mile**	**Area Mi²**	**# over background**	**Median mg/l**	**# over target**	**Median mg/l**	**# over target**	**Median mg/l**
Sterling Run Moon Rd	11.35	3.4	2/4	0.09	0/4	0.15	4/4	**0.51**
Sterling Run Greenbush East Rd.	9.65	6.1	2/5	0.10	0/5	0.11	5/5	**0.64**
Sterling Run US 68	6.74	11.8	1/5	0.05	0/5	0.10	5/5	**0.25**
Sterling Run Mt. Orab Water intake	6.37		2/5	0.09	0/5	0.11	5/5	**0.27**
Sterling Run dst. Lake	3.08		2/5	0.10	0/5	0.21	4/5	**0.22**
Sterling Run Sterling Run Rd (lower ford)	0.59	29.7	0/5	0.07	5/5	**5.37**	5/5	**0.23**
Tributary Sterling Run (RM 6.68) Waits Rd	2.41	3.7	2/4	**0.11**	0/4	0.14	4/4	**0.38**
Tributary Sterling Run (RM 6.68) Bardwell West	0.68	6.9	0/5	0.06	0/5	.010	5/5	**0.35**
Snapping Turtle Run	0.60	1.3	3/5	**0.13**	0/5	0.3	5/5	**0.14**
Snapping Turtle Run (Mt. Orab WWTP effluent)	0.46		5/5	**0.14**	5/5	**19.3**	5/5	**1.31**
Snapping Turtle Run	0.42	1.4	5/5	**0.14**	5/5	**18.9**	5/5	**1.32**

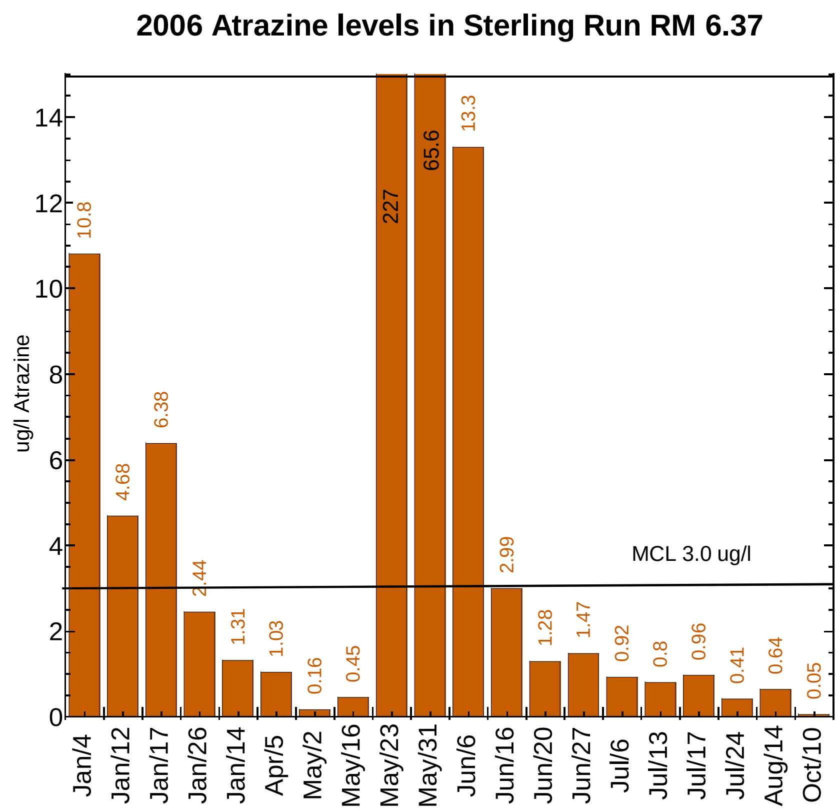


Figure 6. Atrazine concentrations in Sterling Run at the Mt. Orab water intake per Syngenta in 2006.

Mt. Orab WWTP

The Mt. Orab WWTP discharges to Snapping Turtle Run at RM 0.46, which enters Sterling Run at RM 2.78. Based on the results from this survey, the classification of Snapping Turtle Run is recommended to remain Warmwater Habitat.

The original wastewater treatment plant was built in 1965 and abandoned in 1992 when a new plant was constructed further downstream. The old plant, upstream from Grant Lake, was configured into a lift station for the sanitary sewer system. The collection system is 100% sanitary sewer and had a Sanitary Sewer Overflow (SSO) at the old treatment facility lift station that drained to Sterling Run just before entering Grant Lake. This SSO was eliminated in 2008 by an upgrade to the lift station. Population served by the sanitary sewer system is approximately 3500 persons. Cincinnati Milacron is the only industrial discharger in the system.

Historically, the city's collection system had been subjected to excessive inflow and infiltration. Rapid development is occurring near US 68 and SR 32. The development has contributed to exceedences in the design capacity of the WWTP (0.342 MGD) 80.9% of the time from 2002-2006. Median flow from 2002-2006 was 0.4397 MGD. The village completed an expansion of the WWTP in 2008, increasing capacity to 0.7 MGD. The Village expects to pursue an additional expansion in the next five years that will increase daily flow to 1.0 MGD.

Table 11 documents 165 NPDES violations of Mt. Orab's WWTP NPDES permit limits from 2002-2006. Suspended solids accounted for 45% of the violations and sewage solids were documented in Snapping Turtle Run downstream of the plant outfall during the survey. In 2007 the plant was upgraded from 0.342 MGD to 0.7 MGD and the SSO issue was corrected by installing a larger pump at the lift station in 2008.

Table 11. Number of Mt. Orab WWTP NPDES Violations from 2002-2006.

Parameter	**# of 30-Day Violations**	**# of 7-Day Violations**	**Total Violations**
TSS	26	48	74 (44.8%)
NH_3-N	17	37	54 (32.7%)
$CBOD_5$	9	17	26 (15.7%)
Fecal Coliform		5	5 (3%)
pH		5 daily limit	5 (3%)
D.O.		1 daily limit	1 (0.6%)

A sentinel site at Sterling Run, RM 0.59, and (Table 12) was established to sample throughout the year to capture varying flow events. Nine sampling events were conducted. The discharge from the Mt. Orab WWTP enters upstream from this sentinel site and tends to influence the nutrient concentrations. Higher flows tend to dilute the effects of nutrients from Mt. Orab WWTP, but all total phosphorus levels and 8 of 9 nitrate-nitrite samples were above the nutrient reference value (Ohio EPA, 1999). The one ammonia-N value over nutrient reference value appears to be caused by sources other than the Mt. Orab WWTP. Elevated Atrazine levels were not documented but, Figure 6 documents extreme Atrazine levels sampled at the Mt. Orab WTP intake on Sterling Run by Syngenta.

Table 12. Sentinel site sampling at Sterling Run RM 0.59.

Date	Discharge ft^3/sec	Velocity ft/sec	NO_3-NO_2-N mg/l	P total mg/l	NH_3-N mg/l	Atrazine µg/l
2/09/2006	ND	ND	**1.28**	**0.182**	<0.05	ND
4/10/2006	14.094	0.365	0.38	**0.117**	<0.05	0.90
5/18/2006	8.453	0.222	**7.37**	**0.209**	0.08	0.35
7/26/2006	0.556	0.045	**1.47**	**0.229**	**0.65**	ND
8/02/2006	0.380	0.033	**5.35**	**0.191**	0.099	ND
8/30/2006	0.459	0.034	**11.5**	**0.377**	0.064	0.49
9/20/2006	1.803	0.111	**6.58**	**0.619**	0.056	<0.22
9/27/2006	2.904	0.222	**1.17**	**0.173**	0.061	ND
12/14/2006	7.577	0.374	**1.64**	**0.364**	<0.05	<0.22

ND- not done
Red indicates numbers above the nutrient reference values in wadeable (20-200 mi^2) streams (Ohio EPA, 1999)
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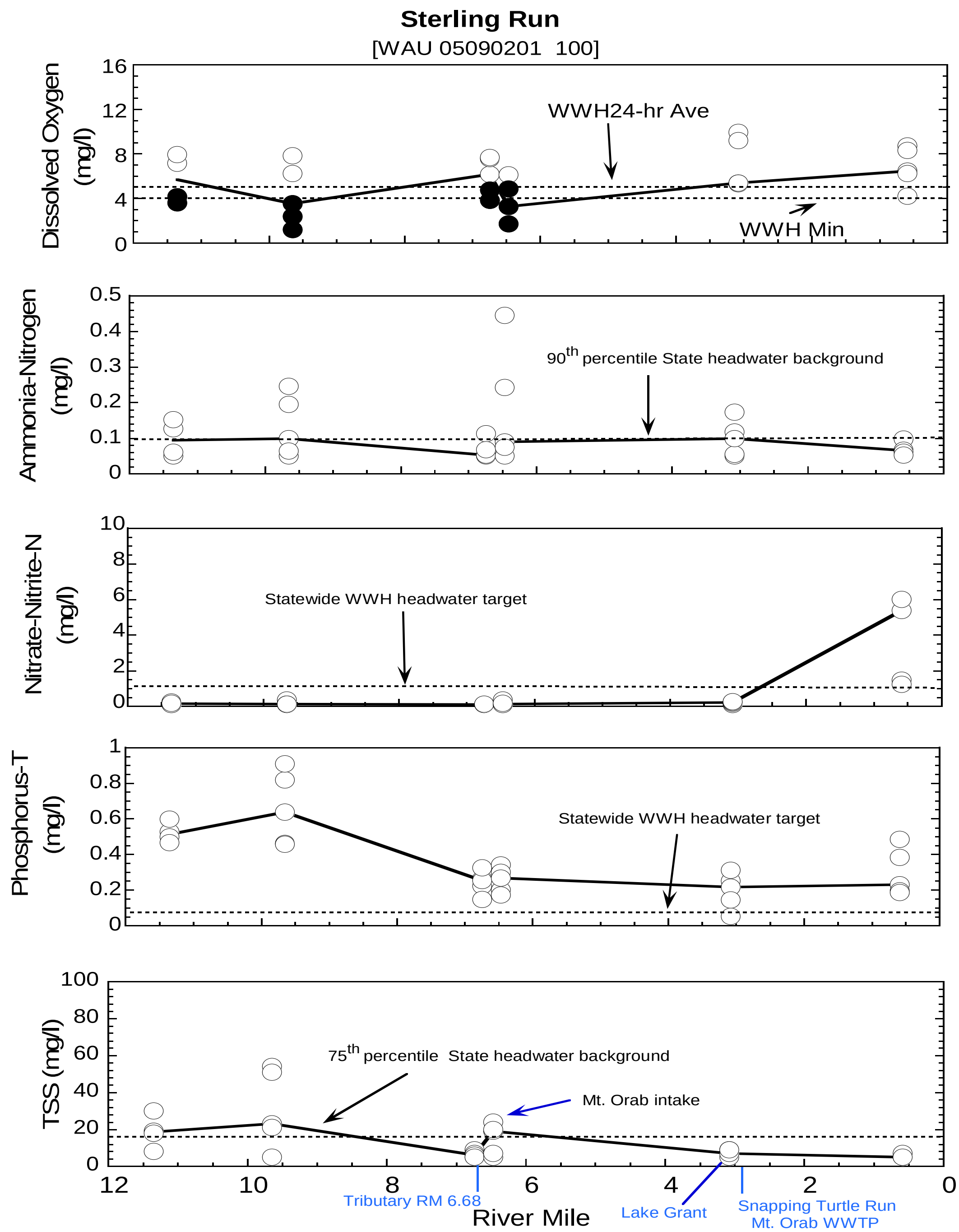


Figure 7. Longitudinal plots of water chemistry daytime grabs in Sterling Run during the 2006 survey. The solid line depicts the median value at each river mile. WQS criteria are shown in the dissolved oxygen plot, dark circles are exceedences. Dotted lines in the other plots represent state target and background values.

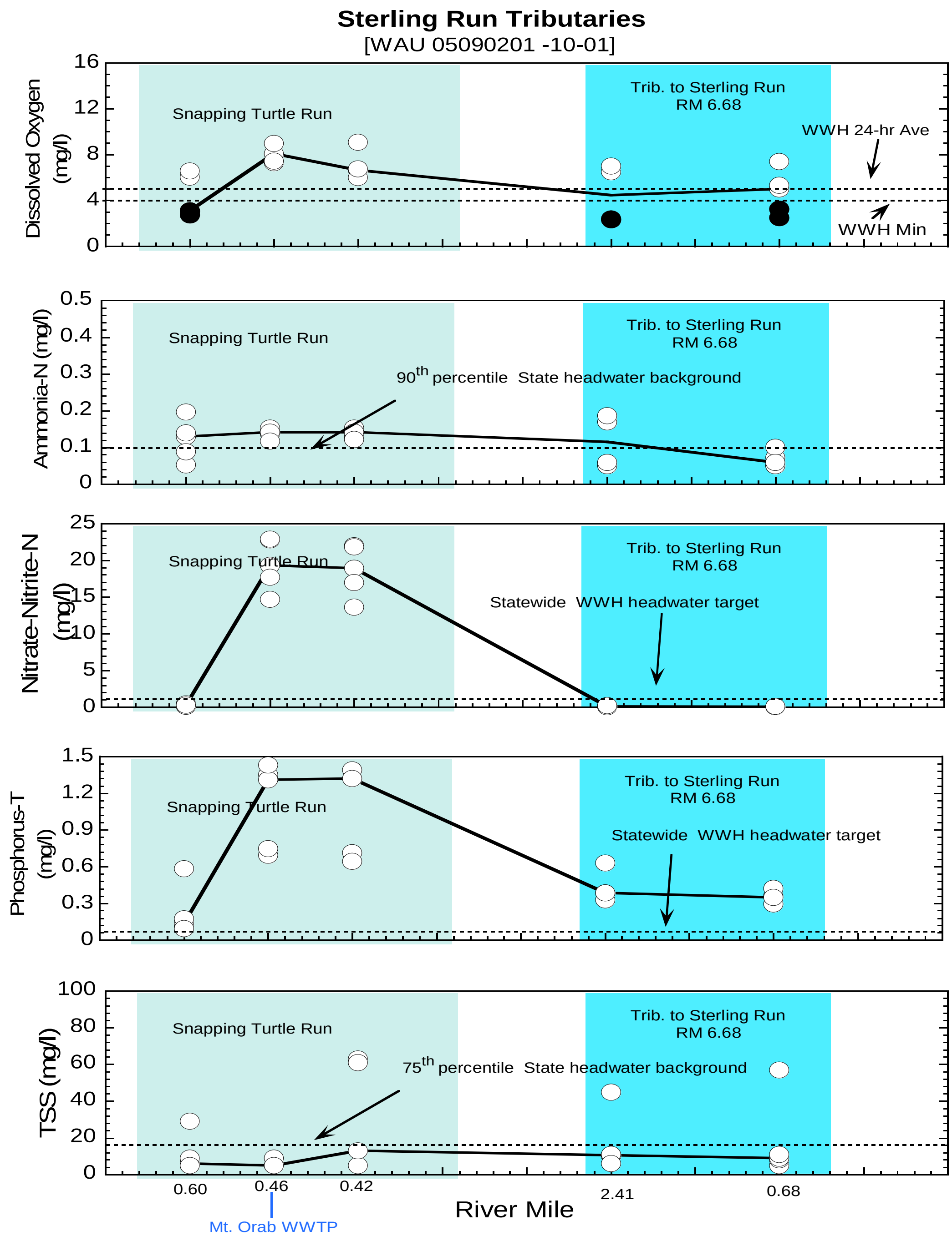


Figure 8. Longitudinal plots of water chemistry daytime grabs in Sterling Run Tributaries during the 2006 survey. The solid line depicts the median value at each river mile. WQS criteria are shown in the dissolved oxygen plot, dark circles are exceedences. Dotted lines in the other plots represent state target and background values.

Grant Lake

Grant Lake impounds 1250 acre feet of water draining from 25.75 mi^2 of the Sterling Run watershed. Water column samples taken in Lake Grant documented historic high flow loading of sediment and agricultural chemicals from Sterling Run. A sampling event at two locations in Grant Lake was conducted on June 29, 2006. The surface sample location L-2 documented ammonia-N (0.104 mg/l) and phosphorus (0.354 mg/l) over State Lake 90^{th} percentile reference value for ammonia-N and phosphorus. Total suspended solids were high (290 mg/l), which led to a Water Quality Exceedence of lead (42.5 mg/l) (Table 8).

Water column organics were sampled at two locations on June 29, 2006. Most noticeable were exceedences for Atrazine (13.2 and 10.4 µg/l) which are over the Drinking Water MCL of 3 µg/l. Other farm chemicals detected below Water Quality Standards were Lindane (γ-hexachlorocyclohexane) and its isomers (αand δ -hexachlorocyclohexane). Simazine (3.07 and 2.97 µg/l) and Metolachlor (2.48 and 2.41µg/l) were also detected below MCL and Water Quality Standards.

Water column exceedence of Heptachlor epoxide was documented over drinking water and fish bioaccumulation criteria. Heptachlor epoxide is the metabolic byproduct of heptachlor. Heptachlor is an insecticide that was banned from use by EPA in 1987. This legacy compound is still found in the environment in decreasing numbers.

During the sampling for the SWAP report of Mt. Orab WTP on May 5, 2003, a rainfall event was captured at the Mt. Orab intake. Results of this wet weather sampling documented concentrations of Atrazine (41.4 µg/l), Alachlor (2.15 µg/l) and Simazine (11.4 µg/l), exceeded the MCL for drinking water. In addition, Acetochlor (5.06 µg/l) and Metolachlor (12.2 µg/l) were detected, but have no MCL.

Exceedences (Table 8)

Exceedences of the dissolved oxygen Water Quality Standard (OAC 3745-1) criteria were documented at all 6 mainstem sites, Tributary to Sterling Run (RM 6.68) site, and the site downstream of the Mt. Orab WWTP on Snapping Turtle Run (RM 0.60). *Escherichia coli* recreational criteria exceedences were documented at Sterling Run (RMs 6.74, 6.37, and 0.59). Heptachlor epoxide exceedences of WQS criteria for protection of human health were documented at Sterling Run (RMs 9.65, 6.74, and 0.59).

Sediment (Tables 13 & 14)

Eight sites in this watershed were sampled for sediment contamination; 5 on Sterling Run, 2 on a tributary to Sterling Run, and 1 on Snapping Turtle Run downstream from the Mt. Orab WWTP. Sediments in the Sterling Run watershed were free of organic contamination with the exception of the site on Snapping Turtle Run (RM 0.42) downstream of the Mt. Orab WWTP.

The Snapping Turtle Run site documented low levels of Acetone (0.112 mg/kg), most likely a lab contaminant. Bis (2-ethylhexyl) phthalate, a common plasticizer, was detected at a low level (2.06 mg/kg). The cresol, 3 & 4 Methylphenol was detected at a low level of 2.03 mg/kg. 3&4 Methylphenol is used as a wood preservative.

None of the 18 metals evaluated in the eight Sterling Run watershed sites exceeded the Ohio Sediment Reference Values (SRV) or the MacDonald Sediment Quality Guidelines. Six of eight sediment sites failed to meet the 30% fine grained material guideline for sediment samples.

The sediment results from Snapping Turtle Run at RM 0.42 documented sediment ammonia-N at 160 mg/kg. This exceeded the Ontario Open Water Disposal Guideline of 100 mg/kg (Persuad and Wilkins, 1976). Black sewage sludge was present in the sediments of Snapping Turtle Run downstream from the Mt. Orab WWTP. The facility and lift station were upgraded in 2007 and 2008.

The other five Sterling Run mainstem and 2 tributary sites met all applicable nutrient guidelines.

Table 13. Sediment concentrations of organic compounds (priority pollutant scan) detected in the White Oak Creek watershed assessment unit (WAU 05080002 030) during 2006. Individual compounds were evaluated by the MacDonald Sediment Quality Guidelines (2000).

River / Landmark	**Analysis Performed**	**Compound Detected**	**Result** mg/kg unless noted
White Oak Creek RM 20.65 Bethel-New Hope Rd TOC= 2.0 % Fine Grain Material = 26.1 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
White Oak Creek RM 12.40 Miller Ring Rd. TOC= not done Fine Grain Material = 18.4 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
White Oak Creek RM 7.54 Dst Georgetown Dam TOC= not done Fine Grain Material = 7.0 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
N. Fk. White Oak Creek RM 18.10 Dawson Rd. TOC= 1.8 % Fine Grain Material = 24.9 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
N. Fk. White Oak Creek RM 6.98 Sicily Rd. TOC= 2.4 % Fine Grain Material = 37.4 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	Acetone Toluene	0.104 0.080 BDL BDL BDL
N. Fk. White Oak Creek RM 1.48 Tri-County Hwy. TOC= 1.1 % Fine Grain Material = 26.6 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Bis(2-Ethylhexyl)phthalate	BDL 0.59 BDL BDL
Little N. Fk. W. Oak Ck RM 2.94 S.R. 131 TOC= 2.5 % Fine Grain Material = 25.5 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Flat Run. RM 3.39 S.R. 134 TOC= 1.6 % Fine Grain Material = 34.4 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Benz(a)anthracene Benzo(a) pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene Benzok)fluoranthene Chrysene Fluoranthene Indeno(1,2,3)pyrene Phenanthrene Pyrene **Total PAH's**	BDL 1.20 1.15 1.66 0.82 0.63 1.37 3.19 0.90 2.66 2.37 **15.95** BDL BDL

Table 13 (Continued). Sediment concentrations of organic compounds (priority pollutant scan) detected in the White Oak Creek watershed assessment unit (WAU 05080002 030) during 2006. Individual compounds were evaluated by the MacDonald Sediment Quality Guidelines (2000).

River / Landmark	Analysis Performed	Compound Detected	Result mg/kg unless noted
E. Fk. White Oak Ck RM 5.81 Sardinia-Mowreystown Rd. TOC= 1.0% Fine Grain Material = 21.4 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
E. Fk. White Oak Ck RM 3.30 S.R. 74 TOC= 1.3 % Fine Grain Material = 13.9 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Sterling Run RM 11.35 Moon Rd. TOC= 1.0 % Fine Grain Material = 25.2 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Sterling Run RM 9.65 Greenbush-East Rd. TOC= 1.9 % Fine Grain Material = 23.2 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Sterling Run RM 6.74 U.S.68 TOC= 1.6 % Fine Grain Material = 16.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Sterling Run RM 6.47 Mt. Orab intake TOC= 1.5 % Fine Grain Material = 32.1 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Sterling Run RM 0.59 Sterling Rd. TOC= 1.7 % Fine Grain Material = 13.1 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Trib. Sterling Run RM 2.41 Waits Rd. TOC= 1.4 % Fine Grain Material = 29.4 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Trib. Sterling Run RM 0.68 Bardwell Rd. TOC= 1.5 % Fine Grain Material = 53.0 %	1) VOC 2) BNA 3) Pesticides 4) PCBs		BDL BDL BDL BDL
Snapping Turtle Run RM 0.42 Dst. Mt. Orab WWTP TOC= 5.0 % Fine Grain Material = 23.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	Acetone Bis(2-Ethylhexyl)phthalate 3&4 Methylphenol	0.112 2.06 2.03 BDL BDL
Town Run RM 0.63 Dst. Georgetown WWTP TOC= not done Fine Grain Material = 18.3 %	1) VOC 2) BNA 3) Pesticides 4) PCBs	 Bis(2-Ethylhexyl)phthalate Fluoranthene	BDL 0.66 0.70 BDL BDL

Table 13 (Continued).

* 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 14. Concentrations (mg/kg) of metals and nutrients in sediment samples collected in the White Oak Creek watershed assessment unit (WAU) 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 Interior Plateau	
	White Oak Creek RM 20.65 Bethel-New Hope Rd. #2	**White Oak Creek** RM 12.40 Miller Ring Rd. #4	**White Oak Creek** RM 7.54 D/S Georgetown Dam #5	**N. Fk.White Oak Creek** RM 18.10 Dawson Rd #8	**N. Fk White Oak Creek** RM 6.98 Sicily Rd. #10	**N. Fk White Oak Creek** RM 1.48 Tri-County Hwy. #11		
							Ohio	**MacD**
Al-T [O]	4090	8790	4900	4190	6010	2820	28000	*
As-T [OM]	3.30	6.53	7.13	6.95	3.68	2.51	11	9.79-33
Ba-T [O]	32.4	78.9	62.6	53.7	50.0	30.9	170	*
Ca-T [O]	13300	30800	31300	13500	11000	8590	94,000	*
Cd-T [OM]	0.098	0.183	0.154	0.182	0.148	<0.083	0.3	0.99-4.98
Cr-T [OM]	<13	<17	<15	<15	<14	<12	30	43.4-111
Cu-T [OM]	4.8	9.1	5.2	5.6	5.7	<4.1	25	31.6-149
Fe-T [O]	8750	17100	17400	14200	10600	6850	31000	*
Hg-T [OM]	<0.035	<0.029	<0.032	<0.031	<0.034	<0.029	0.12	0.18-1.06
K-T [O]	<873	<1150	<994	<1010	<956	<828	5900	*
Mg-T [O]	3300	5910	3130	2840	3480	1720	9900	*
Mn-T [O]	311	762	1270	1410+	318	171	1400	*
Na-T *	<2180	<2880	<2480	<2520	<2390	<2070	*	*
Ni-T [OM]	<18	<23	<20	<20	<19	<17	33	22.7-48.6
Pb-T [OM]	<18	<23	31	<20	<19	<17	47	35.8-128
Se-T [O]	<0.87	<1.15	<0.99	<1.01	<0.096	<0.83	1.6	*
Sr-T [O]	27	55	70	<15	18	18	NA	*
Zn-T [OM]	32.1	54.1	43.7	30.2	38.5	22.3	100	121-459
								Pers.
NH_3-N [P]	54	74	28	49	79	34	*	100
TOC [P]	2.0	---	---	1.8	2.4	1.1	*	10.0%
pH *	7.2	7.7	8.1	7.3	7.0	7.4	*	*
P-T [P]	1670	1670	2100	481	735	1030	*	2000
%FGM [O]	26.1 ↘	18.4 ↘	7.0 ↘	24.9 ↘	37.4	26.6 ↘	30.0%	*

Table 14. (Continued)

Parameter	Site Location (RM)							
	Little N. Fk White Oak Creek RM 2.94 S.R. 131 #13	**Flat Run** RM 3.39 SR 134 #16	**E. Fk White Oak Creek** RM 5.81 Sardinia-Mowreystown Rd. #21	**E. Fk White Oak Creek** RM 3.30 SR 74 #22	**Sterling Run** RM 11.35 Moon Rd #34	**Sterling Run** RM 9.65 Greenbush-East Rd #35	**Reference**	
							Ohio	**MacD**
Al-T O	3180	7440	2850	2260	3090	3300	28000	*
As-T OM	3.71	4.42	2.80	3.20	6.44	5.44	11	9.79-33
Ba-T O	24.6	52.5	26.4	20.7	51.5	48.7	170	*
Ca-T O	57400	14000	9330	9950	13400	13600	94,000	*
Cd-T OM	0.144	0.176	0.099	<0.097	0.193	0.232	0.3	0.99-4.98
Cr-T OM	<15	<16	<13	<15	<14	<16	30	43.4-111
Cu-T OM	<5.0	6.5	<4.5	<4.9	5.7	<5.2	25	31.6-149
Fe-T O	6750	12400	6370	5840	10600	10100	31000	*
Hg-T OM	<0.022	<0.036	<0.020	<0.025	<0.021	<0.026	0.12	0.18-1.06
K-T O	<1000	<1040	<897	<974	<927	<1050	5900	*
Mg-T O	29200	3870	2990	3280	3920	5540	9900	*
Mn-T O	158	247	169	175	399	280	1400	*
Na-T *	<2510	<2600	<2240	<2430	<2320	<2620	*	*
Ni-T OM	<20	<21	<18	<20	<19	<21	33	22.7-48.6
Pb-T OM	<20	<21	<18	<20	<19	<21	47	35.8-128
Se-T O	<1.00	<1.04	<0.90	<0.97	<0.93	<1.05	1.6	*
Sr-T O	33	32	<13	<15	15	17	NA	*
Zn-T OM	47.3	59.1	20.2	17.4	30.8	33.1	100	121-459
								Pers.
NH_3-N P	37	52	39	26	18	43	*	100
TOC P	2.5	1.6	1.0	1.3	1.0	1.9	*	10.0%
pH *	7.3	7.1	7.6	7.4	7.4	7.2	*	*
P-T P	467	811	330	437	374	382	*	2000
%FGM O	25.5 ↘	34.4	21.4 ↘	13.9 ↘	25.2 ↘	23.2 ↘	30.0%	*

Table 14. (Continued)

Parameter	Site Location (RM) Sterling Run RM 6.74 U.S 68 #36	Sterling Run RM 6.47 Mt. Orab intake #37	Sterling Run RM 0.59 Sterling Rd. #39	Trib. Sterling Run RM 2.41 Waits Rd #40	Trib. Sterling Run RM 0.68 Bardwell West #41	Snapping Turtle Run Rm 0.42 Dst. Mt. Orab WWTP #44	Town Run RM 0.63 Dst. G'town WWTP	Reference Ohio	Reference MacD
Al-T [O]	2080	3970	4380	3630	9800	6550	3800	28000	*
As-T [OM]	3.64	3.48	4.93	3.14	6.20	5.49	7.49	11	9.79-33
Ba-T [O]	27.4	43.3	38.0	49.4	90.1	53.6	43.2	170	*
Ca-T [O]	19200	10200	16200	6550	17000	26700	45100	94,000	*
Cd-T [OM]	<0.099	0.142	<0.108	0.144	0.175	0.197	0.106	0.3	0.99-4.98
Cr-T [OM]	<15	<16	<16	<14	<18	29	13	30	43.4-111
Cu-T [OM]	<4.9	6.9	<5.4	6.2	9.4	31.3	4.9	25	31.6-149
Fe-T [O]	6870	8000	11600	7950	14900	10600	15100	31000	*
Hg-T [OM]	<0.025	<0.023	<0.027	<0.027	<0.035	<0.036	0.033	0.12	0.18-1.06
K-T [O]	<985	<1060	<1080	<927	<1200	<1420	<891	5900	*
Mg-T [O]	6000	3970	4100	2220	5960	7040	2930	9900	*
Mn-T [O]	254	147	494	217	389	480	763	1400	*
Na-T *	<2460	<2640	<2700	<2320	<2990	<3540	<2330	*	*
Ni-T [OM]	<20	<21	<22	<19	<24	<28	<18	33	22.7-48.6
Pb-T [OM]	<20	<21	<22	<19	<24	<28	21	47	35.8-128
Se-T [O]	<0.99	<1.06	<1.08	<0.93	<1.20	<1.42	<0.89	1.6	*
Sr-T [O]	21	<16	32	<14	28	38	89	NA	*
Zn-T [OM]	23.7	30.4	31.9	32.6	53.0	62.3	41.1	100	121-459
									Pers.
NH_3-N [P]	27	44	56	29	58	160	33	*	100
TOC [P]	1.6	1.5	1.7	1.4	1.5	5.0	---	*	10.0%
pH *	7.4	7.3	7.2	7.4	7.3	7.3	7.7	*	*
P-T [P]	399	388	1640	434	549	1650	1680	*	2000
%FGM [O]	16.3 ↘	32.1	13.1 ↘	29.4 ↘	53.0	23.3 ↘	18.3 ↘	30.0%	*

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

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

Ontario Sediment Guidelines (Persuad (1993)
L > Open Water Disposal Guidelines; equivalent to the Lowest Effect Level (LEL)-applicable to 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

Datasonde

Datasonde© continuous recorders were placed in three locations on the Sterling Run to determine the diel swings in pH, temperature, conductivity, and dissolved oxygen (Figures 9 &10, Table 11). The first sonde placement (July 18-20) was located at the mouth of Sterling Run (RM 0.05), downstream of Lake Grant (RM 3.08), and, upstream from the Mt. Orab water intake (RM 6.74). The second Datasonde© placement took place on September 6-8, 2006 and only recorded the site at the mouth, RM 0.05.

The upstream site on Sterling Run (RM 6.74) demonstrated a classic dissolved oxygen response curve to the photoperiod, with dissolved oxygen maximums at 1600 hrs and minimums at 0700 hours. The effects of algae were evident in the wide diel swings ranging from supersaturation (13.64 mg/l or 176.7%) to below the WWH dissolved oxygen minimum (2.89 mg/l or 34%). Temperature and pH also followed the same minimum-maximum pattern as the dissolved oxygen. Conductivity tended to gradually increase with time from 0.50 to 0.57 Siemens.

The site at RM 3.08 was immediately downstream from Lake Grant. Very little flow was coming across the spillway during deployment of the sonde on July 18 and flow slowed to almost nothing by July 20. The dissolved oxygen levels were below the WWH minimum for the entire deployment, maximum dissolved oxygen was 2.76 mg/l and minimum levels was 1.07 mg/l (Figure 9).

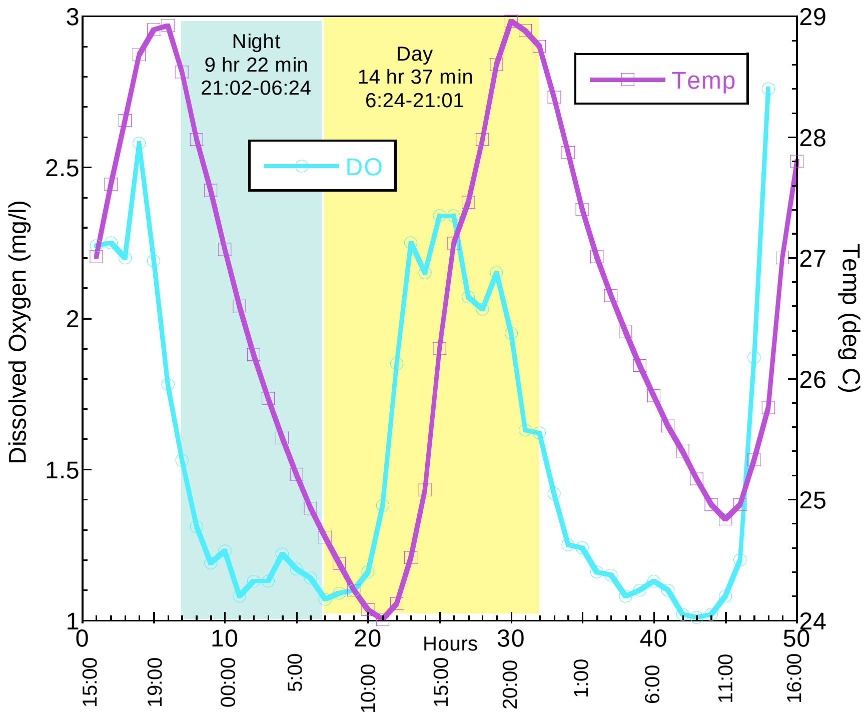


Figure 9. Datasonde© graphics (July 18 – 20, 2006) for Sterling Run RM 3.08 (dst. Lake Grant) showing the effect of photoperiod on diel swings for Dissolved Oxygen and Temperature. Dissolved Oxygen remained below the WWH minimum criterion.

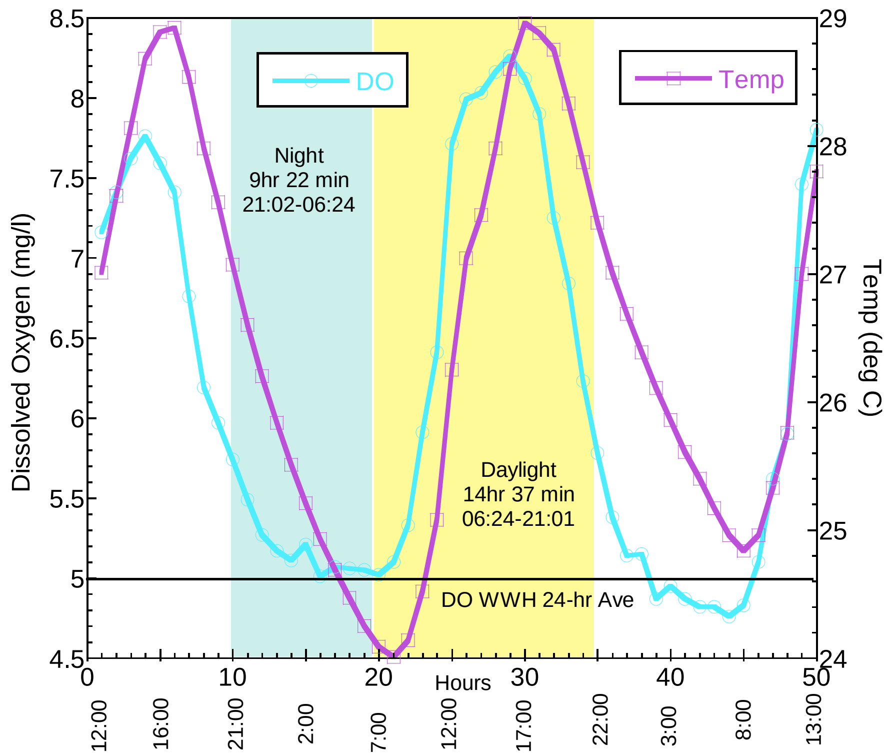


Figure 10. Datasonde© graphics (July 18 – 20) for Sterling Run RM 0.05 showing the effect of photoperiod on diel swings on Dissolved Oxygen and Temperature.

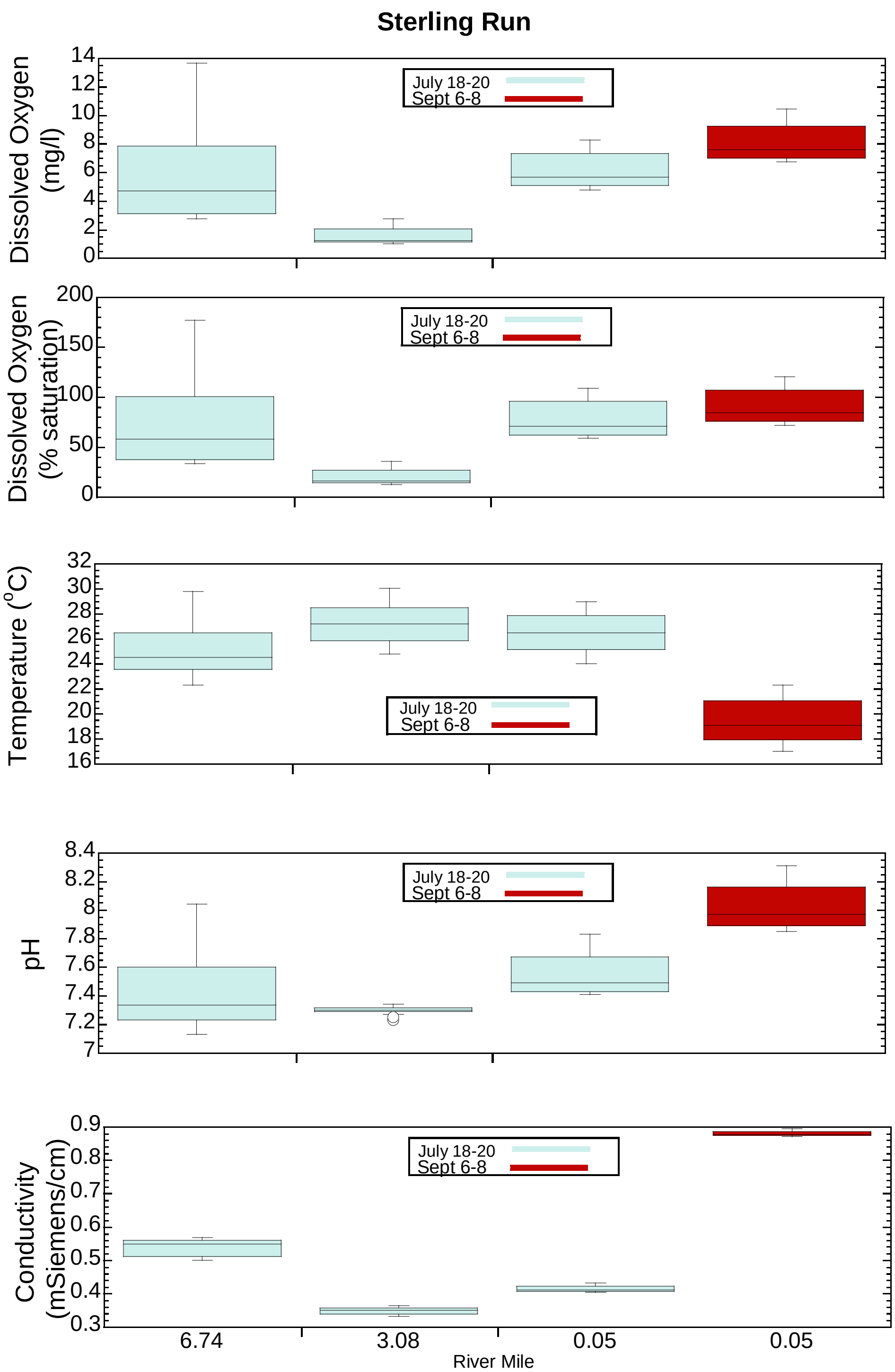


Figure 11. Distributions of dissolved oxygen, temperature, pH, and conductivity recorded hourly with Datasonde© monitors in Sterling Run 2006. Each box encloses 50% of the data with the median value displayed as a line. The top and bottom of the box mark the 75th and 25th percentile. The lines extending 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.

Bacteria
Three bacteria sites were sampled on Sterling Run (RMs 6.74, 6.47, and 0.59) five times from August 14-18, 2006. The results (Table 7), indicate one site upstream of US 68 in Mt. Orab failed to meet `Primary Contact Recreation standards. The fecal coliform geometric mean was 1669 colonies/ 100 ml. and *E. coli* geometric mean was 940 colonies/ 100ml. This site was downstream from an open sewer line that was reported as a spill on July 7, 2006. The sewer line was sealed by August 2, 2006, but sewage sludge remained in the stream at time of sampling. There was also a farm adjacent to the Sterling Run with livestock that were fenced out of the stream.

Subwatersheds WAU 05090201-10-02, White Oak Creek to Georgetown, and WAU 05090201-10-03, Georgetown to Ohio River
Water quality in the mainstem of White Oak Creek was generally very good with the exception of total phosphorus. Phosphorus was above the nutrient reference (Ohio EPA 1999) value across the entire watershed. Water column cadmium, chromium, mercury, nickel and selenium were found at or below the detection limit at all sites watershed. Water column calcium, iron, manganese, magnesium, zinc, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

The presence of Avonburg, Blanchester, and Clermont (ABC) soils in the upper watershed influenced the water quality by allowing nutrients and sediment to rapidly leave the fragile soils during rain events. In the lower reaches of the White Oak Creek mainstem, the presence of ABC soils decreases (Tables 15 & 16). The surface drainage patterns in the White Oak Creek valley were established from an ancient non glaciated terrain with steep dendritic tributaries. The steepness of the land limits farming, which resulted in wider riparian corridors compared to the upper watershed and tributaries.

Table 15. Proportion of ABC soil types in the White Oak Creek mainstem watershed origin to Georgetown (25,853 acres; 40.4 mi^2).

Soil type	Acres	Percentage
Avonburg	3633	14.1
Blanchester	444	1.7
Clermont	12253	47.4
Total ABC Soils	16331	63.2

Table 16. Proportion of ABC soil types in the White Oak Creek mainstem watershed Georgetown to Ohio River (11,224 acres; 17.5 mi^2).

Soil type	Acres	Percentage
Avonburg	924	8.2
Blanchester	1.7	0.01
Clermont	4114	36.7
Total ABC Soils	5041	44.9

Nutrients (Figure 12, Table 18)
Mainstem total phosphorus concentrations were above the Statewide EWH wadeable reference value (0.05 mg/l) in all three wadeable sites sampled on White Oak Creek (RMs 27.55, 12.4 and 16.57). Statewide EWH small river reference value (0.10 mg/l) was exceeded in all three sites sampled on the lower part of White Oak Creek (RM12.4, 7.54 and 2.30).

Nitrate-nitrite concentrations in White Oak Creek were above the Statewide EWH wadeable reference value (0.5 mg/l) at all three wadeable sites (RM 27.55, 20.65, and 16.57) during the September 27 sampling event. This was in association with a 0.82 inch rainfall. The wadeable site at RM 20.65, downstream from Sterling Run and the Mt. Orab WWTP, was above the Statewide EWH wadeable reference value 3 of 5 times it was sampled. This site was the only site on the mainstem with median and mean nitrate-nitrite values over the statewide EWH reference value.

The 3 lower White Oak Creek small stream sites (RMs 12.4, 7.54 and 2.30) had one event over the nitrate-nitrite reference value at the RM 7.54. This was not associated with a rain event or high flow.

Ammonia-N levels were below the 90^{th} percentile (0.10 mg/l) reference value at all sampling events (30/30). All median samples for the 6 sites were below the reference value.

Bacteria
Three bacteria sites were sampled on White Oak Creek (RMs 20.65, 12.4, and 7.54) five times from August 14-18, 2006. The results (Table 7), indicate one bacteria exceedence for *E. coli* occurred at RM 20.65. Based on the statistical analysis of the data, Primary Contact Recreation use was attained at all three sites.

Sentinel

A sentinel site at White Oak Creek RM 7.7 downstream from the Georgetown Dam (Table 17) was established to sample throughout the year to capture varying flow events. A total of 9 sampling events were conducted. The results did not show the usual flow to nutrient/agricultural chemical relationship seen in other subwatersheds in the White Oak Creek basin. Throughout the survey White Oak Creek mainstem approached base flow and the effects of farm field runoff was minimal even during a rainfall event on September 27.

Total phosphorus data were above the nutrient reference value on 6 of 9 sampling events. The phosphorus levels below the reference value were on of 3 of the 4 highest flow events.

Farm chemicals, as represented by Atrazine, were below 1 μg/l on all sampling events. All other farm chemicals (i.e.: Simazine, Metolachlor) followed this trend.

Table 17. Sentinel site sampling at White Oak Creek RM 7.7 demonstrating the relationship between stream flow and water column nutrients.

Date	Discharge ft^3/sec	NO_3-NO_2-N mg/l	P total mg/l	NH_3-N mg/l	Atrazine(μg/l)
2/09/2006	107	**1.16**	0.092	0.050	ND
4/10/2006	120	0.39	**0.155**	0.050	0.55
5/18/2006	55	0.12	0.040	0.050	0.26
7/26/2006	11	0.10	**0.171**	0.050	ND
8/2/2006	6.7	**1.59**	**0.130**	0.063	ND
8/30/2006	10	0.17	**0.123**	0.062	0.43
9/20/2006	12	0.31	**0.141**	0.050	ND
9/27/2006	34	0.63	**0.173**	0.050	ND
12/14/2006	165	0.76	0.08	0.05	0.27

ND- not done
Red indicates above the nutrient target values in small river(>200 mi^2) (Ohio EPA, 1999)

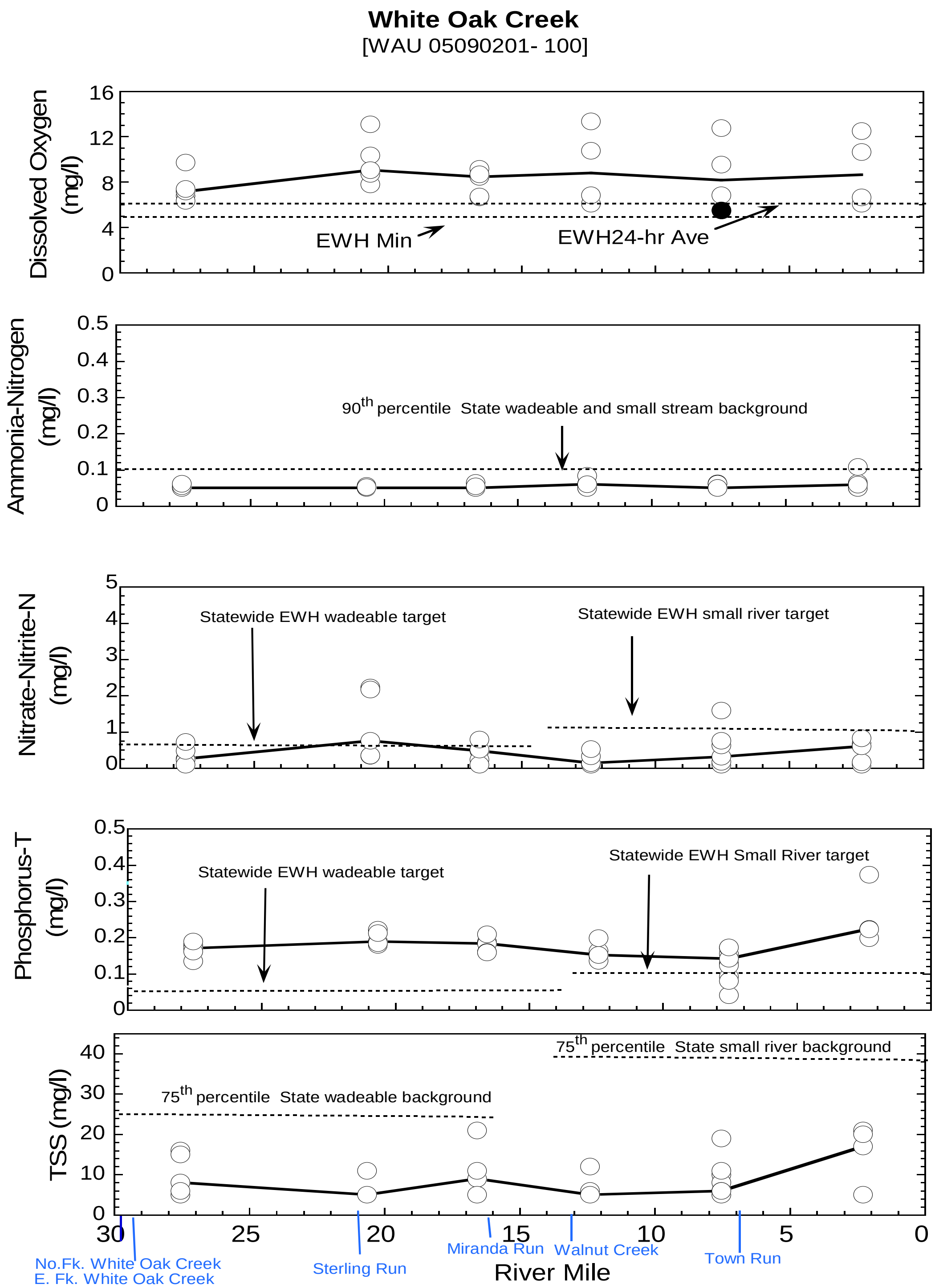


Figure 12. Longitudinal plots of water chemistry daytime grabs in White Oak Creek during the 2006 survey. The solid line depicts the median value at each river mile. WQS criteria are shown in the dissolved oxygen plot, dark circles are exceedences. Dotted lines in the other plots represent state nutrient target and background values (Ohio EPA, 1999).

Table 18. Summary statistics for selected nutrient water quality parameters in the White Oak Creek sub watershed 05090201-10-02 and 03. Values above reference condition in **red**.

			NH_3-N		$NO_3 + NO_2$-N		Phosphorus-T	
Stream	**River Mile**	**Area Mi²**	**# over background**	**Median mg/l**	**# over target**	**Median mg/l**	**# over target**	**Median mg/l**
White Oak Creek[E]	27.55	150	0/5	0.05	1/5	0.26	5/5	**0.17**
White Oak Creek[E]	20.65	188	0/5	0.05	3/5	**0.75**	5/5	**0.19**
White Oak Creek[E]	16.57	190	0/5	0.05	2/5	0.48	5/5	**0.18**
White Oak Creek[E]	12.40	213	0/5	0.06	1/5	0.14	5/5	**0.15**
White Oak Creek[E]	7.54	222	0/5	0.05	2/5	0.31	5/5	**0.14**
White Oak Creek[E]	2.30	232	1/5	0.06	3/5	0.61	5/5	**0.22**
Miranda Run	0.69	5.8	0/5	0.05	1/5	0.24	5/5	**0.10**
Walnut Creek	1.40	0.4	1/5	0.05	0/5	0.10	1/5	0.06
Walnut Creek	0.76	0.4	0/5	0.05	0/5	0.40	1/5	0.07
Tributary Walnut Creek (RM 1.2)	0.33	0.2	0/4	0.06	1/4	0.20	2/4	0.07
Town Run[C]	0.81	1.3	0/5	0.05	0/5	0.25	4/5	**0.10**
Town Run (Georgetown WWTP effluent)	0.80	---	5/5	**4.07**	5/5	**6.47**	5/5	**3.28**
Town Run[C]	0.63	1.4	5/5	**3.24**	5/5	**6.39**	5/5	**3.66**

E = Exceptional Warmwater Habitat
C = Coldwater Habitat
All others Warmwater Habitat
Bold Lettering indicates WAU 05090201-10-03, all others in WAU 05090201-10-02
Headwater stream <20mi² Wadeable stream 20-200 mi² Small River 200-1000mi²

Datasonde

Datasonde© continuous recorders were placed in five locations on White Oak Creek to determine the diel swings in pH, temperature, conductivity and dissolved oxygen (Figure 13). The first sonde deployment (July 18-20) was at four locations on White Oak Creek, RMs 27.55, 20.65 (dst. Mt. Orab discharge), 12.4 (dst. Rumpke discharge), and 7.54 (dst. of the dam). The second Datasonde© placement took place on September 6-8, 2006 and only recorded the site at RM 20.65 and a new site at RM 16.57. Most datasonde results were normal with nothing unusual to note. Temperatures were cooler during the September placement.

During the July deployment at RM 20.65, results exhibited supersaturation with characteristic diel D.O. and temperature swings (Figure 14). Algal photosynthesis and respiration caused D.O. to swing from supersaturation at 3:00 PM to minimum values by dawn at 6:00 AM. Temperature followed the same pattern. The September placement did not exhibit as strong of a diel swing with D.O. remaining above 6.0 mg/l at all times.

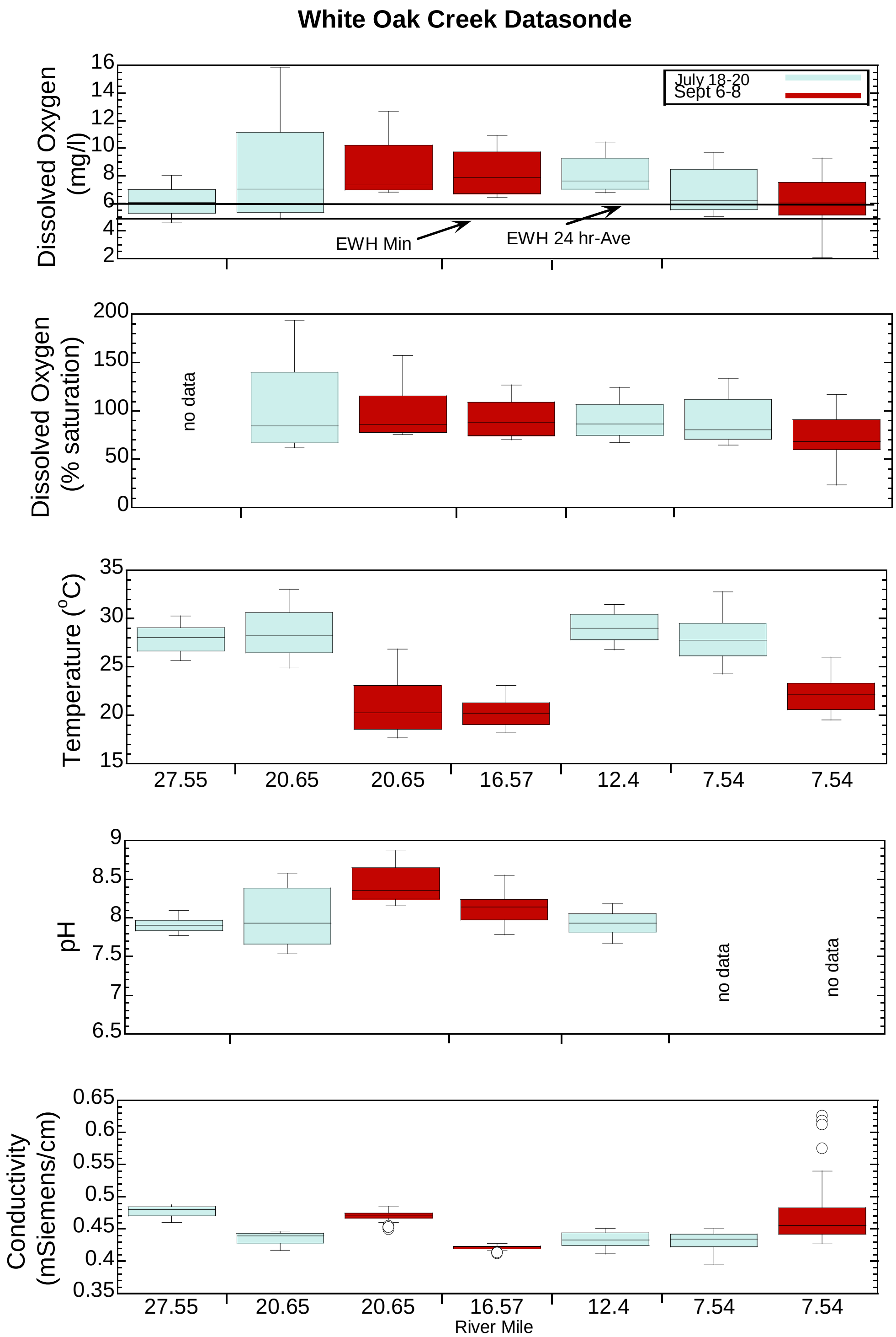
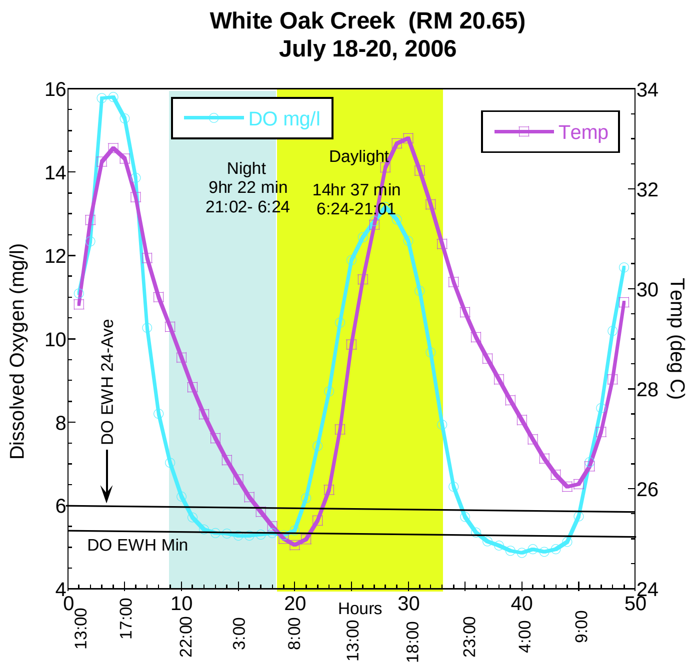


Figure 13. Distributions of dissolved oxygen, temperature, pH, and conductivity recorded hourly with Datasonde© monitors in White Oak Creek 2006. Each box encloses 50% of the data with the median value displayed as a line. The top and bottom of the box mark the 75th and 25th percentile. The lines extending 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.



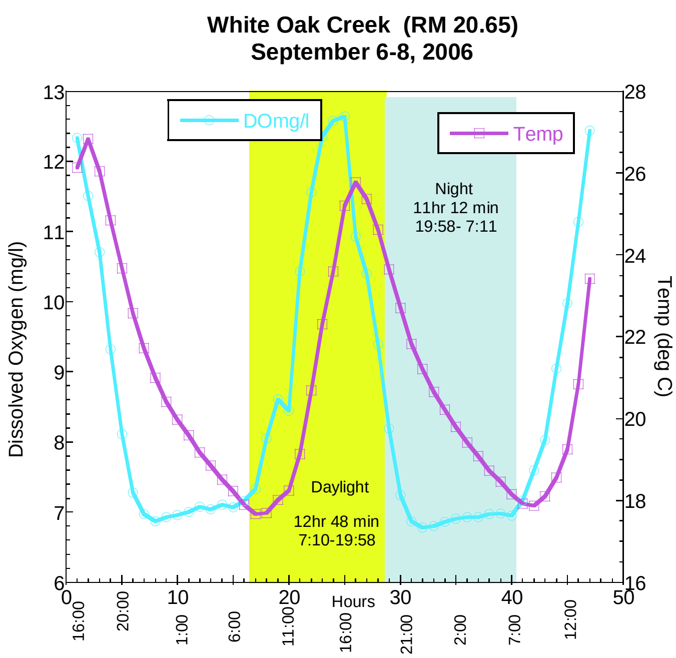


Figure 14. Datasonde© graphics for White Oak Creek RM 20.65 showing the effect of photoperiod on diel Dissolved Oxygen and Temperature swings.

Organics (Appendix Table A 3)
Water column organics were sampled at four locations on the White Oak Creek mainstem; RM 20.65 (dst of Mt. Orab WWTP), 12.40 (dst Rumpke discharge), 7.54 (dst of the dam) and RM 2.45. Water column organic compounds were mainly agricultural chemicals Atrazine, Simizine, Metolachlor and 2,4-D all at low levels (<1 μg/l). The plasticizer Bis(2-ethylhexyl) phthalate was detected at all sites at very low levels below Water Quality Standards.

Three organic compounds were detected in the Georgetown WWTP final effluent. The farm chemical dieldrin (0.10 µg/l) was detected at a level exceeding the water quality standard for protection of human health. The metabolite of the insecticide Carbosulfan (3-hydroxycarbofuran) was detected at 1.52 µg/l. There are no criteria for this compound. The plasticizer, Bis (2-ethylhexyl)phthalate, was discharged at 2.16 µg/l, below any Water Quality Standard.

Sediment (Tables 13 & 14)
Four sites in the two sub watershed were sampled for sediment contamination, 3 in White Oak Creek, 1 in Town Run. Sediments in the White Oak Creek mainstem were free of organic contamination. None of the 18 metals evaluated in the 3 White Oak Creek watershed sites exceeded the Ohio Sediment Reference Values (SRV) or the MacDonald Sediment Quality Guidelines (Table 14). Sediment phosphorus was 2100 mg/l at White Oak Creek RM 7.54, downstream of the Georgetown Dam. This level of sediment phosphorus is above the Ontario open water sediment disposal guideline of 2000 mg/l (Persuad and Wilkins, 1976). This was the only site in the entire survey to have high sediment phosphorus levels.

Town Run (RM 0.63) downstream of the Georgetown WWTP had Bis(2-ethylhexyl) phthalate, a common plasticizer, detected at a low level (0.66 mg/kg). The PAH, Fluoranthene was detected at a low level of 0.70 mg/kg (Table 13). None of the 18 metals evaluated in Town Run watershed sites exceeded the Ohio Sediment Reference Values (SRV) or the MacDonald Sediment Quality Guidelines.

All four sediment sites failed to meet the 30% fine grained material guideline for sediment samples.

***Georgetown WWTP* 1PB00101 WAU 05090201-10-02**

The city of Georgetown WWTP discharges to Town Run RM 0.80 which enters White Oak Creek at RM 6.95. During the 2006 survey period, Town Run was designated as a Limited Resource Water resulting in relaxed permit limits at the wastewater treatment plant. Redesignation of Town Run to Coldwater Habitat as a result of the 2006 survey results will cause readjustment of the permit limits (Table 19).

Table 19. Changes in the NPDES permit limits for the Town Run WWTP with a change in use designation of Town Run from Limited Resource Water to Coldwater Habitat.

	Current NPDES Permit Limits (Town Run-Limited Resource Water)		NPDES Permit Limits (Town Run-Coldwater Habitat)	
Parameter	**7-day limit**	**30-day limit**	**7-day limit**	**30-day limit**
Nitrogen-Ammonia (summer)	5.3 mg/l	4.7 mg/l	0.9 mg/l	0.6 mg/l
Nitrogen-Ammonia (winter)	8.0 mg/l	5.3 mg/l	2.9 mg/l	1.93 mg/l
Dissolved Oxygen	5.0 mg/l (minimum)		7.0 mg/l (minimum)	

The treatment plant was constructed in 1972 with major modifications in 1991. Plant improvements were undertaken in 2007. The collection system is 100% sanitary sewer with no bypasses or overflows. Population served is approximately 3691 persons. There are two industrial users, Stanley Mac Tool and leachate from Rumpke landfill.

Wastewater treatment involves raw sewage entering the plant through a 24 inch gravity main that is mechanically cleaned by a 1 inch bar screen. Normal flows enter the Aeration basin then flow to advanced secondary treatment and finally UV disinfection prior to discharge into Town Run. Sewage sludge from the aerobic digesters is land applied at a rate of 69 tons per year.

Historically, the city's collection system was subject to excessive inflow and infiltration. When wet weather flows exceed 1,000,000 gallons per day, the flow is diverted into two Equalization (EQ) basins. The flow from the EQ basins can reintroduced into the plant for treatment during normal wet weather conditions. It is estimated that the inflow and infiltration flow rate is 200,000 gallons per day. During excessively heavy rainfall events (approximately 9 times per year.), partially treated effluent is discharged through the equalization tank system to Town Run. This results in the discharge of objectionable floatable materials (sanitary hygiene products, and other sewage solids) to the stream.

Ohio EPA conducted two bioassays on Georgetown's final effluent, upstream and mixing zone waters on December 16-17, 1996 and July 14-15, 1997. The results of these two bioassays indicated that the effluent of the July 1997 bioassay was found to be toxic to *C. dubia*. No bioassay was conducted during the 2006 survey season. However, numerous violations were noted during the 2006 survey season due to releases of sewage solids, paper solids and, foam from the effluent to Town Run.

A total of 46 violations of the NPDES permit were recorded from 2002-2006 (Table 20). Total Suspended solids accounted for 54% (25) and Fecal coliform 39%(18) accounted for the majority of violations. Bypasses of the EQ basin are not in this calculation.

This number of violations is misleading because the ammonia-N permit limit is very high and very difficult to violate due to Town Run being classified as a Limited Resource Water (LRW). The TSS violations are related to wet weather overload to the system which allows the activated sludge to be flushed from the aeration basin. This loss of activated sludge to Town Run also decreases the effectiveness of the ammonia-N removal of the WWTP.

The median flow from 2002-2006 was 0.4685 million gallons with 23.8% (420/1764) of the flow dates being over the design capacity of 0.80 million gallons. Median ammonia-N value from 2002-2006 (n=504) was 0.45 mg/l. Monthly phosphorus monitoring was begun in 2005. The median phosphorus concentration for 18 months was 5.785 mg/l.

Table 20. Georgetown WWTP NPDES Violations from 2002-2006.

Parameter	**Limit Type – 30 Day # of violations**	**Limit Type – 7 Day # of violations**	**Total Violations**
TSS	10-concentration	7-concentration 8-quantity	25(54.3 %)
NH_3-N		1-concentration	1 (0.02 %)
pH		(Daily Limits) 1 - concentration	1 (0.02 %)
Fecal Coliform	4 -concentration	14-concentration	18(39.1 %)
$CBOD_5$		1-concentration	1 (0.02 %)

***Highland County Southwest WWTP* 1PA00029 WAU 05090201-09-02**
Historically the city of Mowrystown had approximately 300 area residents releasing an estimated 20,000 gallons/day of raw sewage to storm water sewers which discharged to White Oak Creek. In 2006 a new wastewater treatment plant was constructed to remedy this unsanitary condition.

Treatment consists of 2-5000 gallon trash tanks, a 44,000 gallon flow equalization basin with aeration, three extended aeration treatment units (2-27,500 gallons and 1-56,000 gallons), 2 secondary clarification tanks, activated sludge holding tanks, chlorination followed by dechlorination and storage in a 8.12 million gallon controlled discharge lagoon.

The new plant was designed to have an average daily design flow of 95,000 gallons into an 8.12 million gallon controlled discharge lagoon. Average daily flow at start up was estimated to be 46,000 gallons per day. Discharge is into White Oak Creek at RM 9.82 during the non-recreational season (November – April), when the stream flow is in excess of 1 ft^3/sec. Estimated annual discharge to White Oak Creek is 19.17 million gallons. No discharge of effluent to White Oak Creek will occur from May 1 to October 31, but effluent will be land applied to crop land by spray irrigation with an annual discharge being 18.62 million gallons. There is an estimated 100 days storage capacity of effluent in the lagoon.

On October 2007 the Highland County Southwest WWTP was made operational. The estimated 2010 population served will be 862 residents, 462 from Mowrystown and 400 from the surrounding area. At start up a total of 322 people will be served. The system is 100% Separate Sanitary Sewer with 1 lift station and no bypasses. No monthly operational data is available.

***Rumpke Waste, Inc.* 1IN00142 WAU 05090201-10-02**
The Rumpke Landfill in Georgetown has a storm water discharge to a Tributary of Walnut Creek from their Storm water retention ponds. Leachate is trucked to the Georgetown WWTP.

On June 11, 2004, Director's Final Findings and Orders (F&O's) were signed by Rumpke to resolve Solid Waste and Surface water violations of the Ohio Revised and Administrative codes. As a resolution of the F&O's, Rumpke agreed to prevent sediment laden water from entering Walnut Creek and White Oak Creek by improving storm water treatment. Conservation easements on White Oak Creek riparian downstream of Rumpke were purchased as part of the Supplemental Environmental Project.

A total of 7 violations of the NPDES permit were recorded from 2002-2006. Total Suspended solids accounted for 1 violation, two Oil and Grease violations, and pH accounted for four violations.

North Fork White Oak Creek *(WWH, PCR, AWS, IWS) WAU 05090201-09-03 and 04*
The North Fork White Oak Creek watershed drains 67.2 square miles of agricultural land. The majority of the watershed is located in Highland County. The North Fork White Oak Creek watershed has been divided into 2 -12 digit Watershed Assessment Units (WAU). The land is flat to slightly rolling with highly erodible Avonburg, Blanchester, and Clermont (ABC) soils that are difficult to drain with subsurface drainage. This causes difficulties in farming and home septic leach fields.

In the Highland County Home Sewage Treatment Management Plan, the Health Department states conventional septic systems that are installed in areas of Avonburg, Clermont, and Blanchester soils are highly likely to experience failures. The age, design, and lack of maintenance of many septic systems in this county result in malfunctioning systems and nuisance complaints.

WAU 05090201-09-03 drains the North Fork White Oak Creek from RM 9.11 to RM 0.0. This subwatershed has the highest percentage of highly erodible Avonburg Blanchester and Clermont soils (ABC soils) in the entire White Oak Creek watershed (Table 21). These soils end up in the waterways and continual leach phosphorus attached to sediment. This phosphorus is found in the water column across the watershed, even in low flow conditions.

Table 21. Proportion of ABC soil types in the lower North Fork White Oak Creek watershed (23789 acres; 37.1 mi^2).

Soil type	Acres	Percentage
Avonburg	4578	19.2
Blanchester	937	3.9
Clermont	16,111	67.7
Total ABC soils	21627	90.9

WAU 05090201-09-04 drains the North Fork White Oak Creek from its headwaters to RM 9.11 and Little North Fork White Oak Creek. This watershed is also comprised of highly erodible Avonburg, Blanchester, and Clermont soils (Table 22).

Table 22. Proportion of ABC soil types in the upper North Fork and Little North Fork White Oak Creeks watershed (19,301 acres; 30.1 mi^2).

Soil type	Acres	Percentage
Avonburg	4380	22.7
Blanchester	392	2.0
Clermont	11,458	59.4
Total ABC soils	16,230	84.1

Figure 15. A power ditch in highly erodible Clermont soil of the North Fork White Oak Creek watershed.

Due to the impervious nature of the ABC soils, “Power ditches” (drainage channels placed directly in the row crop field) are used to remove water from farm fields (Figure 15). This results in rapid runoff of land applied farm chemicals and soils to waterways during rain events.

Water Column Chemistry
Water column cadmium, chromium, copper, lead, nickel and selenium were found to be at or below the detection limit at all 11 sites in the North Fork White Oak Creek watershed. Water column calcium, iron, manganese, magnesium, zinc, hardness, BOD_5, chloride, and sulfate were within acceptable ranges.

In general median phosphorus levels were above the Associations document reference values (Ohio EPA 1999) at all 11 sites sampled in the North Fork White Oak Creek watershed (Table 23, Figures 17 & 18). Both animal husbandry and row crop practices were responsible for the nonpoint phosphorus levels.

Exceedences
Water column mercury was below the detection limit (0.20 µg/l) at all but one site. Little North Fork at RM 0.28 had one detection of mercury at 0.23 µg/l on July 27. This was an exceedence of the numerical criterion for protection of human health.

Bacterial exceedences of Water Quality Standards (OAC 3745-1) in the North Fork White Oak Creek watershed were documented at all five sites sampled. The North Fork White Oak had four *E. coli* exceedences at RM 6.98 and three *E. coli* exceedences at RM 1.48. *Escherichia coli* exceedences were also documented at Little North Fork White Oak Creek RM 0.28 during all 5 sampling events and Flat Run RM 0.15, 3 sampling events.

Dissolved oxygen exceedences were documented on August 3 and 31, at all five bacteria sites plus headwater sites in Little North Fork (RM 2.94) and Flat Run (RM 4.80) (Table 8, Figures 17 &18). One temperature exceedence (29.21C^o) was recorded in the headwater site of North Fork White Oak Creek (RM 18.10) on August 3.

Figure 16. Residence adjacent North Fork White Oak Creek.

Bacteria

Only one site, North Fork White Oak Creek RM 15.36, failed to meet the PCR use status (Table 7). This watershed has many older homes and trailers that may not have septic systems or have failing septic systems (Figure 16). The Avonburg, Blanchester, and Clermont soils in this watershed are not recommended for leach field design due to their impervious nature.

Rubble Run enters North Fork White Oak Creek at RM 7.98 and both streams flow through the unincorporated community of Buford. No water column sampling was conducted in or near Buford during the survey. The Highland County Health Department had already identified Buford as needing a centralized sewage collection system. A cursory inspection by the Health Department identified 14 of the 93 homes in Buford with failing septic systems. The number of failing systems is expected to grow upon a door to door survey planned by the Health Department.

North Fork White Oak Creek, RM 15.36, had 3 fecal coliform and 5 *E.coli* exceedences. In addition, it was the only site in the North Fork watershed failing to meet the PCR use criteria. The site is downstream from Barrs Run and the unincorporated community of Pricetown. Barrs Run was filled with filamentous green algae during the 2006 survey, which indicated nutrient enrichment. The Highland County Health Department documented 44 homes in Pricetown, two homes have known failing septic systems. A door to door survey by the Health Department is expected to uncover more failing systems.

Table 23. Summary statistics for selected nutrient water quality parameters in the North Fork White Oak Creek subwatershed. Values above reference condition in **red**.

			NH_3-N		NO_3 - NO_2 -N		Phosphorus-T	
Stream	**River Mile**	**Area Mi^2**	**# over background**	**Median mg/l**	**# over target**	**Median mg/l**	**# over target**	**Median mg/l**
North Fork White Oak Creek	19.67	4.40	1/5	0.08	0/5	0.10	3/5	**0.09**
North Fork White Oak Creek	18.10	7.20	0/5	0.08	0/5	0.11	5/5	**0.12**
North Fork White Oak Creek	15.36	12.0	1/5	0.10	2/5	0.30	5/5	**0.14**
North Fork White Oak Creek	6.98	46	0/5	0.06	0/5	0.10	5/5	**0.23**
North Fork White Oak Creek	1.48	53.6	0/5	0.07	0/5	0.14	5/5	**0.25**
L North Fork White Oak Creek)	5.06	3.6	2/5	0.05	2/5	0.5	4/5	**0.19**
L. North Fork White Oak Creek	2.94	7.3	0/5	0.06	1/5	0.17	5/5	**0.22**
L. North Fork White Oak Creek	0.28	13.8	1/5	0.08	1/5	0.28	5/5	**0.27**
Flat Run	4.80	3.9	0/5	0.07	2/5	0.15	5/5	**0.38**
Flat Run	3.39	7.4	2/5	0.08	2/5	0.38	5/5	**0.37**
Flat Run	0.15	12.3	0/5	0.09	0/5	0.18	5/5	**0.23**

All WWH except where indicated WAU 05090201-09-03 **WAU 05090201-09-04**
Nutrient evaluation during 2006 survey using Table #1 of this document for reference values from
Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999).

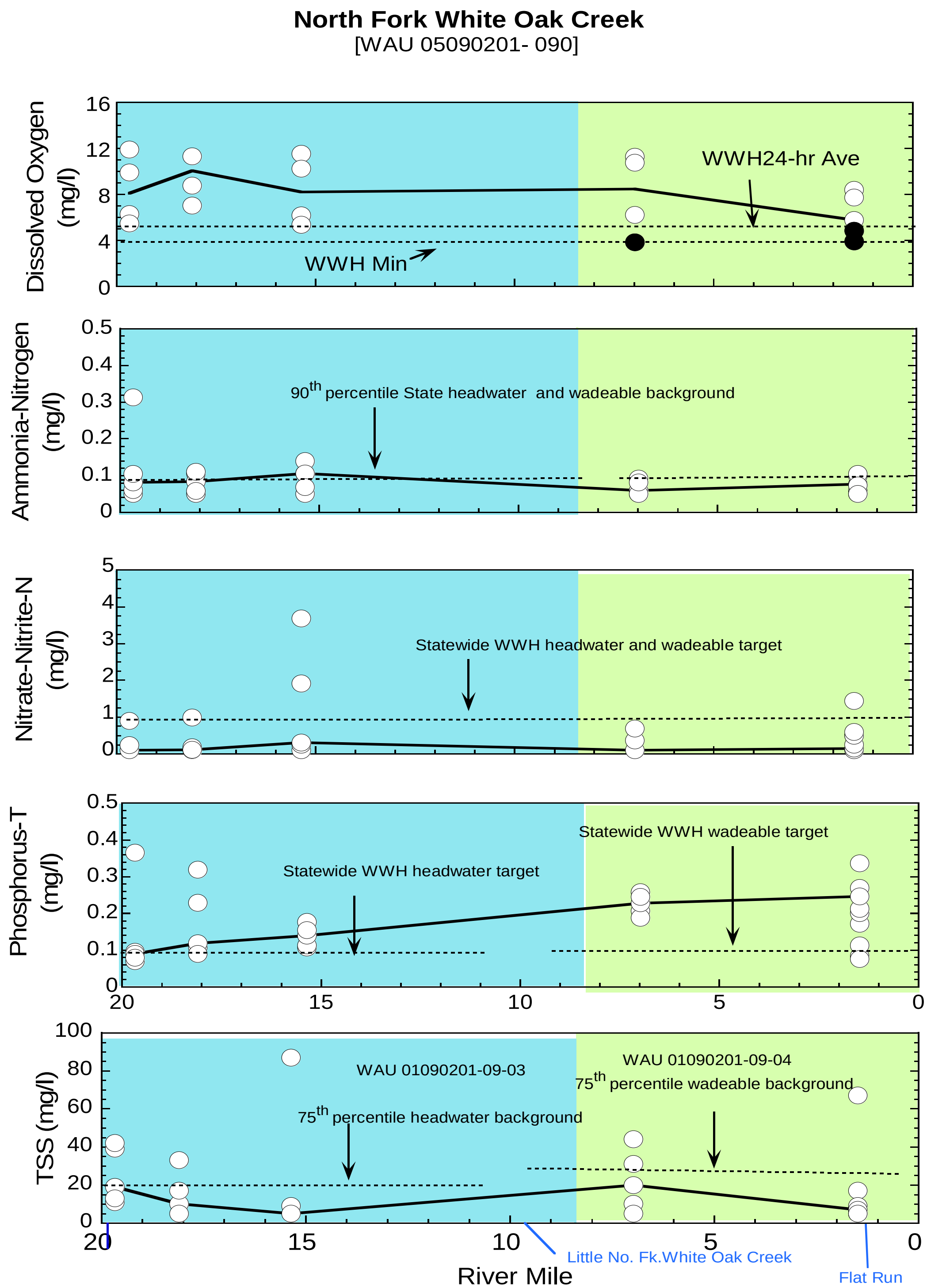


Figure 17. Longitudinal plots of water chemistry daytime grabs in North Fork White Oak Creek during the 2006 survey. The solid line depicts the median value at each river mile. Dotted lines in the Dissolved Oxygen plot indicate WQS criteria, dark circles are exceedences. Dotted lines in the other plots represent state nutrient target background values.

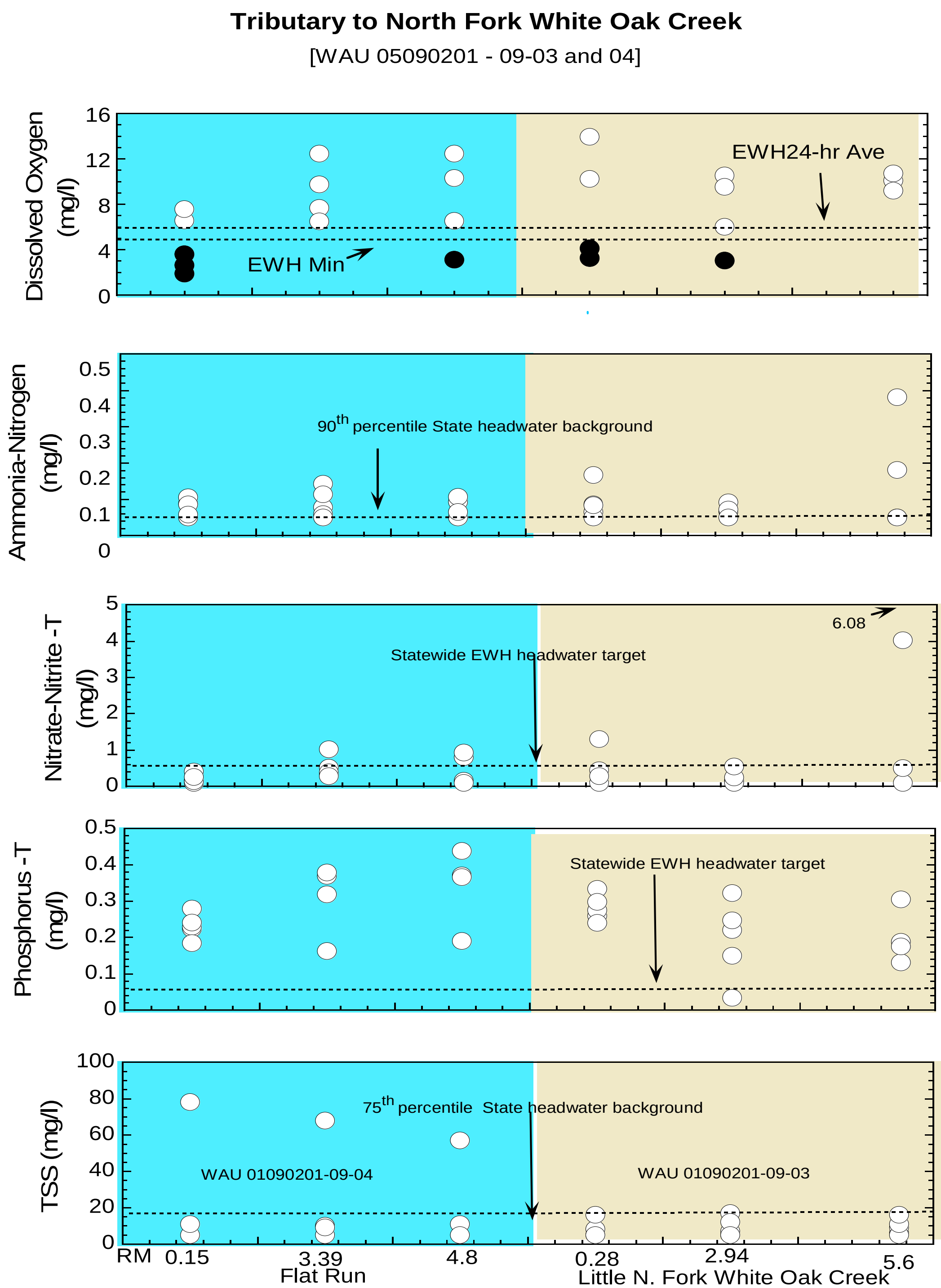


Figure 18. Longitudinal plots of water chemistry daytime grabs in two Tributaries of North Fork White Oak Creek during the 2006 survey. The solid line depicts the median value at each river mile. Dotted lines in the Dissolved Oxygen plot indicate WQS criteria, dark circles are exceedences. Dotted lines in the other plots represent state nutrient target and background values.

Organic Compounds
Five sites in the watershed were sampled for water column organic compounds (Appendix Table A 3). North Fork White Oak Creek had three sites at RM 18.10 (sampled once), RM 6.98 (sampled twice), and the sentinel site at RM 1.48 (sampled 5 times). Little North Fork White Oak Creek RM 2.91 at SR 131 and Flat Run RM 3.39 at SR 134 were both sampled once.

The majority of compounds documented in 4 of 5 sites were herbicides including Simazine, Atrazine, and Metolachlor, detected below Water Quality Standards at levels less than 1 µg/l. The banned pesticide Lindane (0.0026 µg/l) was detected below Water Quality Standards and the herbicide 2, 4-D (1.03 µg/l) which does not have a Water Quality Standard was also detected in Little North Fork White Oak Creek, RM 2.94.

Bromodichloromethane, Chloroform (Trichloromethane) and Dichloromethane all were detected in Flat Run, RM 3.39, at levels below Water Quality Standards. All three organic compounds are drinking water disinfection byproducts. This class of compounds suggests that a public water supply is entering the water column either through a water line leak or from home sewage discharge.

Sediment Chemistry
Five sites were evaluated once for sediment organics. North Fork White Oak Creek RM 18.10, RM 6.98, the sentinel site at RM 1.48, Little North Fork White Oak Creek RM 2.94 and Flat Run RM 3.39 were sampled (Table 13).

Only one site, North Fork White Oak Creek RM 18.10, had a sediment metal (manganese 1410 mg/kg) over the Ohio Sediment Reference Value (SRV) (1400 mg/kg) (Table 14). All the other four sites did not have any metals over the Ohio SRV. None of the five sediment sites had sediment nutrient levels over the Ontario open disposal guidelines.

No organic compounds were detected in sediments from North Fork White Oak Creek, RM 18.10, and Little North Fork White Oak Creek, RM 2.94.

Results from North Fork White Oak Creek, RM 6.98, detected low levels of Toluene (0.080 mg/kg) and Acetone 0.104 mg/kg in sediment. Acetone may be a lab contaminant.

Sediment samples from North Fork White Oak Creek RM 1.48 detected the plasticizer Bis (2-Ethylhexyl) phthalate (0.59 mg/kg) at low levels below standard.

Results from Flat Run, RM 3.39, detected 10 different Polyaromatic hydrocarbons (PAH) in the sediment sample. The total PAH concentration of 15.95 mg/kg was between the MacDonald Probable Effect Concentration of 22.8 mg/kg and Threshold Effect Concentration of 1.61 mg/kg (MacDonald et al., 2000). Polyaromatic hydrocarbons at this level indicate that adverse effects to benthic organisms frequently occur. The 10 PAH compounds detected are part of the characteristic PAH fingerprint associated with asphalt and coal tar asphalt sealers used in roadways.

Sentinel site (Table 24)
A sentinel site at North Fork White Oak Creek, RM 1.48, was established to sample throughout the year to capture varying flow events. A total of 9 sampling events were conducted.

Water column phosphorus was detected above the nutrient target value of 0.10 mg/l (Ohio EPA, 1999) in 7 of 9 sampling events. Phosphorus was also over the target value during low flow conditions which suggests a discharge from failing septic systems or dissolved background levels from soil conditions.

One sampling event on February 9, 2006 documented a nitrate-nitrite concentration over the nutrient target value of 1.0 mg/l. High flow events during the crop growing season were not captured, and the overall nutrient and organic farm chemical instream concentrations were not elevated.

Table 24. Sentinel site sampling results at North Fork White Oak Creek RM 1.48 (53.6 mi^2).

Date	**Discharge ft^3/sec**	**Velocity ft/sec**	**NO_3-NO_2 mg/l**	**P-T mg/l**	**NH_3-N mg/l**	**Atrazine µg/l**
2/09/2006	ND	ND	**1.44**	0.084	<0.050	ND
4/10/2006	26.6	1.053	0.50	**0.172**	<0.050	0.49
5/18/2006	8.69	0.576	<0.10	**0.112**	0.053	0.97
7/27/2006	0.497	0.057	0.10	**0.200**	0.077	ND
8/03/2006	0.415	0.044	<0.10	**0.212**	0.099	ND
8/31/2006	0.282	0.039	0.14	**0.269**	0.104	0.55
9/21/2006	1.273	0.120	0.24	**0.246**	0.058	0.24
9/27/2006	ND	ND	0.49	**0.336**	0.073	ND
12/14/2006	17.65	0.425	0.59	0.075	<0.050	0.39

ND- not done
Red = above the nutrient target values 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)
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East Fork White Oak Creek
WAU 05090201-09-01 (WAU 09-01) and WAU 05090201-09-02 (WAU 09-02)

East Fork White Oak Creek lies 2.7 miles east of Lake Grant and originates in Highland County. It is 22 miles in length, a major tributary to White Oak Creek, and has a drainage area of 80.1 square miles. Land use across the entire watershed is 65% row crop agriculture (61,140 acres) and 19.7% deciduous forest (18,594 acres). Land use along a 100 foot riparian corridor for the major streams in the watershed is made up of 47% row crop and 40.5% deciduous forest.

The mainstem of East Fork White Oak Creek exhibited good water quality. Cadmium, chromium, mercury, nickel and selenium were found below the detection limit at all 5 sites. Water column calcium, iron, manganese, magnesium, zinc, hardness, BOD_5, chloride, and sulfate were within acceptable ranges. The rainfall event on September 28 elevated total suspended solids to give higher readings of lead, iron and zinc, but at levels below Water Quality Standards. In general the mainstem of White Oak Creek was not chemically impacted by cattle access in the tributaries.

Five of the seven tributaries to East Fork White Oak Creek are impacted by unrestricted cattle access. The WAU 09-01 watershed has some of the best quality soils in the entire White Oak Creek watershed but the effects of cattle in the stream caused localized water quality problems.

Organics
Three sites in WAU 09-02, East Fork White Oak Creek RMs 5.81 and 3.30 and the Sardinia WWTP on Slabcamp Run, were evaluated for water column organic chemicals (Appendix Table A3). Both East Fork White Oak Creek sites had Atrazine and Metolachlor detected below Water Quality Standards. East Fork White Oak Creek at RM 3.30 also had Simazine below the Water Quality Standard. The plasticizer Bis (2-Ethylhexyl) phthalate was detected less than 1 µg/l which was below the Water Quality Standard.

The Sardinia WWTP effluent was sampled on August 31, 2006. Aldrin (0.0018 µg/l) and Dieldrin (0.016 µg/l) were detected in the outfall over the Water Quality Standards criteria (0.0014 µg/l for both chemicals) for protection of human health. Metolachlor and Lindane were detected below the Water Quality Standard. The plasticizer, Bis (2-Ethylhexyl) phthalate, was detected below the Water Quality Standard.

No sites in WAU 09-01 were evaluated for organic chemicals.

Bacteria
Five sites in the East Fork White Oak Creek watershed were evaluated for *E. coli* and fecal coliform (Table 7). Three of the five sites failed to meet the PCR use, all because of cattle in the stream. These included East Fork White Oak Creek RM 16.50 (WAU 09-

01), Tributary to East Fork White Oak Creek (RM 15.52) RM 2.10 (WAU 09-02), and Bells Run RM 1.97 (WAU 09-02).

Watershed Assessment Unit (WAU) 05090201-09-01 drains 23285 acres (36.4 mi^2) of the northern part of East Fork White Oak Creek. This subwatershed is comprised of 42.3% highly erodible Avonburg, Blanchester, and Clermont soils (Table 25). Six sites were evaluated in this WAU, two sites on East Fork White Oak Creek and four on three tributaries. No official names were found for the tributaries so they are identified by the location of their confluence with the mainstem (e.g., Tributary to East Fork White Oak Creek RM 15.52)

Landuse in subwatershed 09-01 is mostly row crop agriculture in the rural part of Highland County. A common animal husbandry practice of allowing cattle unrestricted access to the stream is damaging stream bank integrity and degrading water quality.

Two mainstem sites are in this subwatershed. Both sites are considered to be headwater sites, with drainage areas less than 20 square miles.

Table 25. Proportion of ABC soil types in the upper East Fork White Oak Creek watershed starting at RM 23.51 (23789 acres; 37.1 mi^2).

Soil type	**Acres**	**Percentage**
Avonburg	5737	24.6
Blanchester	214	0.9
Clermont	3901	16.7
Total ABC soils	9853	42.3

In general median phosphorus levels were above the Associations document reference values (Ohio EPA, 1999) in 15 of 16 sites sampled in the East Fork White Oak Creek watershed (Table 26, Figures 22, 23, & 24). Both animal husbandry and row crop practices were responsible for the nonpoint phosphorus levels.

Unrestricted cattle access was documented at East Fork White Oak Creek, RM 16.5, at Robinson Road (WAU 09-01) (Figure 19). Water color was brownish and flow was slow. Dense mats of floating algae were observed at the sampling location. The PCR use was not attained as this site had the highest geometric mean for fecal coliform and *E. coli* in the entire White Oak Creek watershed. Water Quality exceedences were documented for dissolved oxygen, temperature, *E. coli* and fecal coliform. Water column phosphorus and ammonia concentrations were above the Associations document (Ohio EPA 1999) nutrient reference values (4 of 5) and (2 of 5) times, respectively (Table 26).

Figure 19. East Fork White Oak Creek at Robinson Road (RM 16.5).

An unnamed tributary enters East Fork White Oak Creek at RM 15.52 on New Market Road. The upstream site at RM 2.1 was impacted by cattle in the stream. Exceedences to Water Quality Standards were documented three times for dissolved oxygen, one time for temperature, three times for ammonia, four times for fecal coliform, five times for *E. coli*, and two times for barium (Table 8). In addition there are elevated levels of BOD_5, COD, iron, lead, manganese, and arsenic.

Nutrient values were over the Associations document statewide reference values for phosphorus (0.11 mg/l) 5 of 5 times and nitrate nitrite (1.0 mg/l) 1 of 5 times.

Figure 20 illustrates the stream on a dry August 3 sampling event. The stream flow was minimal and wastes from numerous cattle collected in and around the culvert. Water color was black and ammonia–N was 50.8 mg/l. Dissolved oxygen was 0.09 mg/l and phosphorus was 5.31 mg/l.

Table 26. Summary statistics for selected nutrient water quality parameters in the East Fork White Oak Creek subwatershed. Values above reference condition in **red**.

			NH_3-N		NO_3 - NO_2 -N		Phosphorus-T	
Stream	**River Mile**	**Area Mi^2**	**# over background**	**Median mg/l**	**# over target**	**Median mg/l**	**# over target**	**Median mg/l**
East Fork White Oak Creek	18.69	6.7	0/5	0.05	1/5	0.47	5/5	**0.34**
East Fork White Oak Creek	16.5	12.7	2/5	0.10	0/5	0.16	4/5	**0.14**
East Fork White Oak Creek...	10.48	39	0/5	0.06	1/5	0.17	3/5	**0.15**
East Fork White Oak Creek.	5.81	52	0/5	0.05	0/5	0.15	2/5	**0.17**
East Fork White Oak Creek.	3.30	70	0/5	0.05	0/5	0.28	5/5	**0.20**
Tributary East Fork (RM 15.52)	2.10	4.6	4/5	**2.42**	1/5	0.27	5/5	**0.46**
Tributary East Fork (RM 15.52)	0.26	7.1	0/5	0.06	3/5	**1.22**	5/5	**0.12**
Tributary East Fork (RM 14.35)	0.01	3.2	2/4	0.09	0/5	0.35	2/4	**0.10**
Tributary East Fork (RM 12.38)	2.42	3.4	0/5	0.07	0/5	0.42	2/5	0.04
Plum Run	0.95	4.2	3/5	**2.98**	2/5	0.16	5/5	**0.43**
Plum Run	0.32	6.3	3/5	**0.16**	0/5	0.41	3/5	**0.12**
Bells Run	1.97	4.0	5/5	**6.67**	2/5	0.20	5/5	**1.83**
Slabcamp Run	2.93	3.3	0/5	0.05	0/5	0.10	3/5	**0.09**
Slabcamp Run	1.13	7.80	2/5	0.10	1/5	0.20	4/5	**0.17**
Slabcamp Run (Sardinia Effluent)	0.98	---	4/4	**0.27**	4/4	**15.0**	4/4	**3.47**
Browns Run	0.10	3.9	0/5	0.05	0/5	0.20	5/5	**0.18**

Nutrient evaluation during 2006 survey using Table #1 of this document for reference values from Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA, 1999).

Normal font = WAU 05090201-09-01

Bold font = WAU 05090201-09-02

Figure 20. Tributary East Fork White Oak Creek (RM 15.52) at New Market Road (RM 2.1).

The Primary Contact Recreation designation was not attained at this site. The geometric mean was 11,140 colonies/ 100 ml. for fecal coliform and 5465 colonies/ 100 ml for *E. coli*. Despite the poor water quality this segment was determined to be in full attainment for WWH aquatic use designation. The area for biological sampling was upstream from the cattle access, in a less impacted segment of the stream. The segment with cattle access was degraded both in physical habitat and chemically.

The site downstream at RM 0.26 flowed through 1.8 miles of wooded riparian corridor and also met its use designation. The water was clear with no algae and flow was good despite the lack of rain. Temperature of the water was up to 4^oC cooler than the upstream site, suggesting good riparian cover and possibly some groundwater recharge. No ammonia was found over the reference value of the association document (0.11 mg/l). Median nitrate-nitrite in the water column was detected over the associations document value (1.0 mg/l) 3 of the 5 times sampled. Ammonia from upstream is being oxidized to nitrate-nitrite at this location.

WAU 05090201-09-02 drains 27,971 acres (43.7 mi^2) of the lower part of East Fork White Oak Creek starting at the mouth with White Oak Creek and ending at RM 23.5. This subwatershed is comprised of 63.9% highly erodible Avonburg, Blanchester, and Clermont soils (Table 27). Eleven sites were sampled during the survey, three on the

East Fork White Oak Creek, two on Plum Run, three on Slabcamp Run, including the Sardinia WWTP, and one on Browns Run.

Table 27. Proportion of ABC soil types in the lower East Fork White Oak Creek watershed (23789 acres; 37.1 mi^2).

Soil type	Acres	Percentage
Avonburg	6704	24.0
Blanchester	137	0.4
Clermont	11033	39.4
Total ABC soils	17876	63.9

Plum Run RM 0.95 at Wildcat Road had cattle in the stream upstream from the sampling location. During the hot dry part of summer (the first three sampling events), the water flow was slow, tea colored and covered with duckweed and filamentous algae. Water quality exceedences of ammonia and dissolved oxygen were documented during the first three dry hot sampling events (Table 8). Twelve dead white suckers were observed on July 27th at this location. Dissolved oxygen and ammonia levels improved in September after rain events, but nitrate-nitrite was over the Associations reference value the last two wet weather events. This suggested that the upstream cattle influenced the water quality during the dry weather period and farm field run off contributed to nitrate-nitrite during wet weather. Phosphorus was over the Associations reference value on all five sampling events. No bacteria were sampled at this site.

The downstream site at Plum Run RM 0.32 had two water quality exceedences of dissolved oxygen during August. Ammonia levels were much lower than the upstream site but were above the Associations document reference value during the first three dry weather sampling events. Phosphorus was over the Associations reference value on three of five sampling events. This site was the location of the Mowreystown WWTP which was under construction during the survey. No elevated TSS was observed with the exception of the September 28 sampling event where high flows made the water sediment laden at both sites.

Bells Run RM 1.97 was another site with cattle having unrestricted access to the stream (Figure 21), upstream from the sampling location. The banks of the stream were broken down and green algae and sediment covered the shallow streambed. Recreational use was not attained at this site (Table 7). WQS criteria exceedences were documented for dissolved oxygen (3 times), Ammonia (3 times), E. coli (2 times) and fecal coliform (4 times). (Table 8). Water column phosphorus was above the Associations document nutrient target 5 of 5 times with the median value (1.83 mg/l) also above the target (0.08 mg/l). Water column ammonia concentrations were above the Associations document nutrient reference value 5 of 5 times, with the median value (6.67 mg/l) also above the state 90th percentile reference value (0.11 mg/l) (Ohio EPA, 1999) (Table 26).

Figure 21. Bells Run at Winkle Road (RM 1.97).

Continuous Monitoring

Continuous monitoring was conducted at two sites in the watershed (Figure 25). East Fork White Oak Creek, RM 10.48, was evaluated on July 18-20 and RM 3.30 was evaluated on July 18-20 and September 6-8, 2006. The results for conductivity, pH, and temperature were within acceptable ranges during the sampling events. Dissolved oxygen at RM 10.38 and 3.30 showed supersaturation, exceeding 150% diel swings and approached the Water Quality Standard D.O. minimum (4.0 mg/l) at RM 10.48.

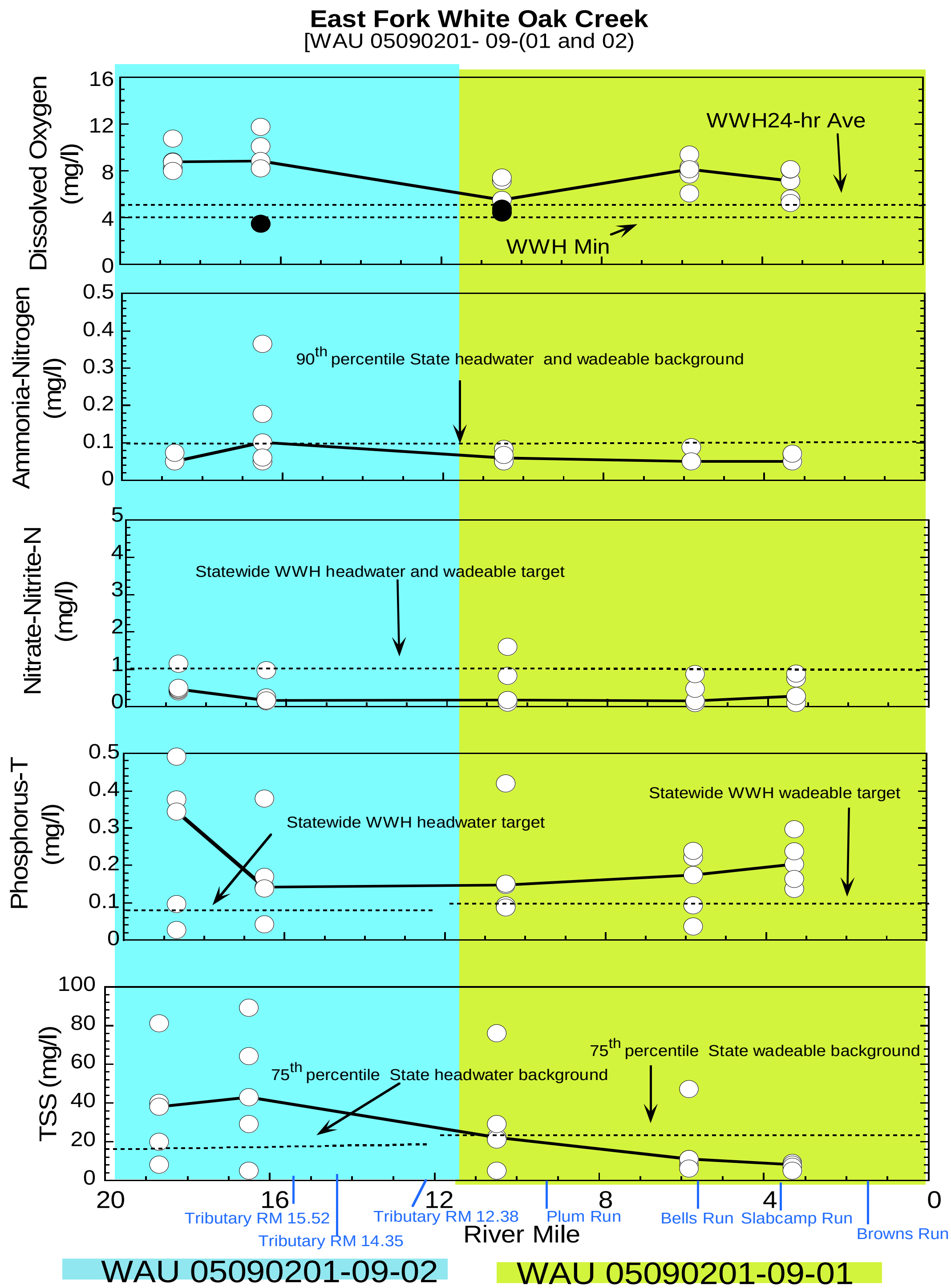


Figure 22. Longitudinal plots of water chemistry daytime grabs of East Fork White Oak Creek during the 2006 survey. The solid line depicts the median value at each river mile. Dotted lines in the Dissolved Oxygen plot indicate WQS criteria, dark circles are exceedences. Dotted lines in the other plots represent statewide nutrient target and background values.

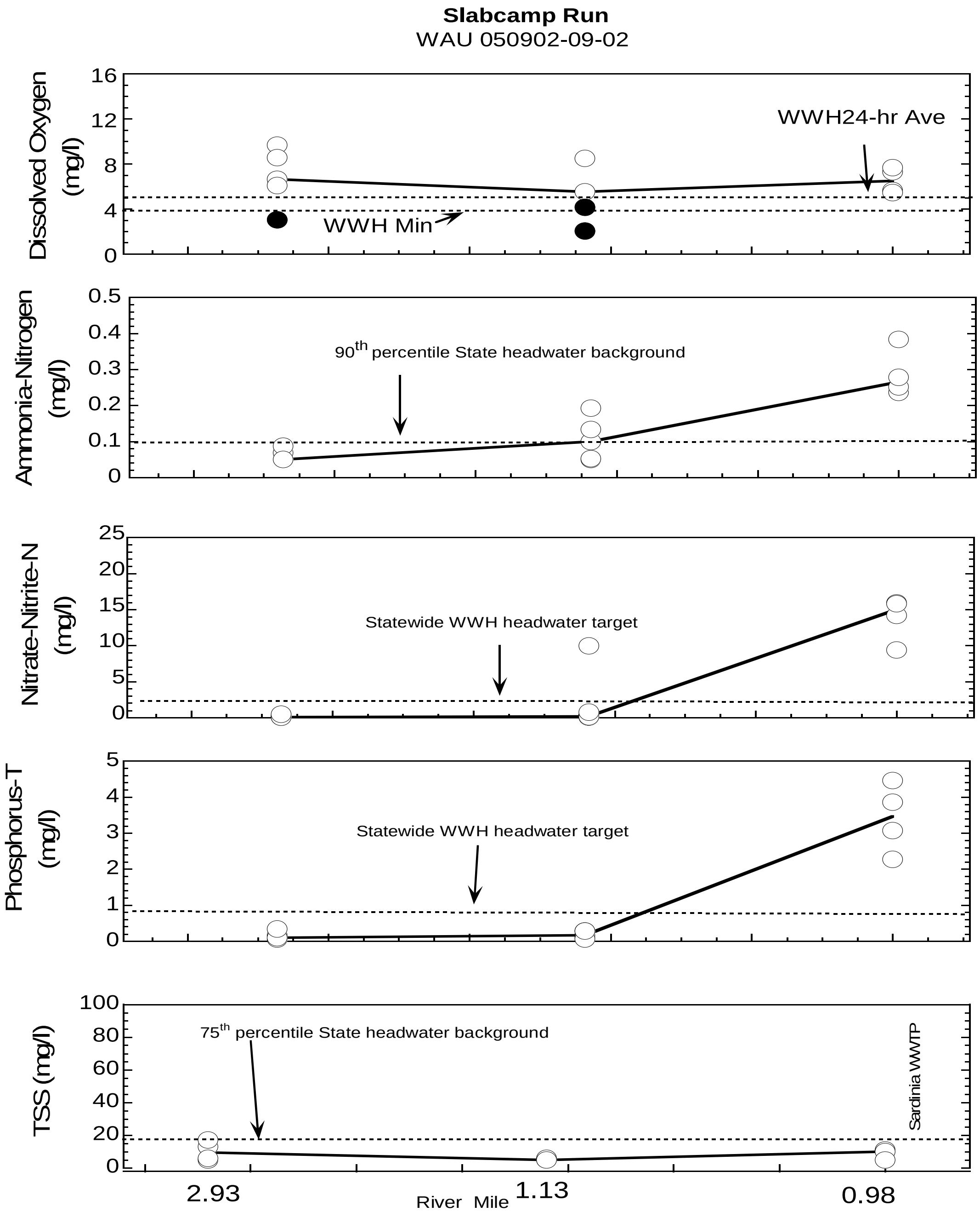


Figure 23. Longitudinal plots of water chemistry daytime grabs in Slabcamp Run during the 2006 survey. The solid line depicts the median value at each river mile. Dotted lines in the Dissolved Oxygen plot indicate WQS criteria, dark circles are exceedences. Dotted lines in the other plots represent statewide nutrient target and background values.

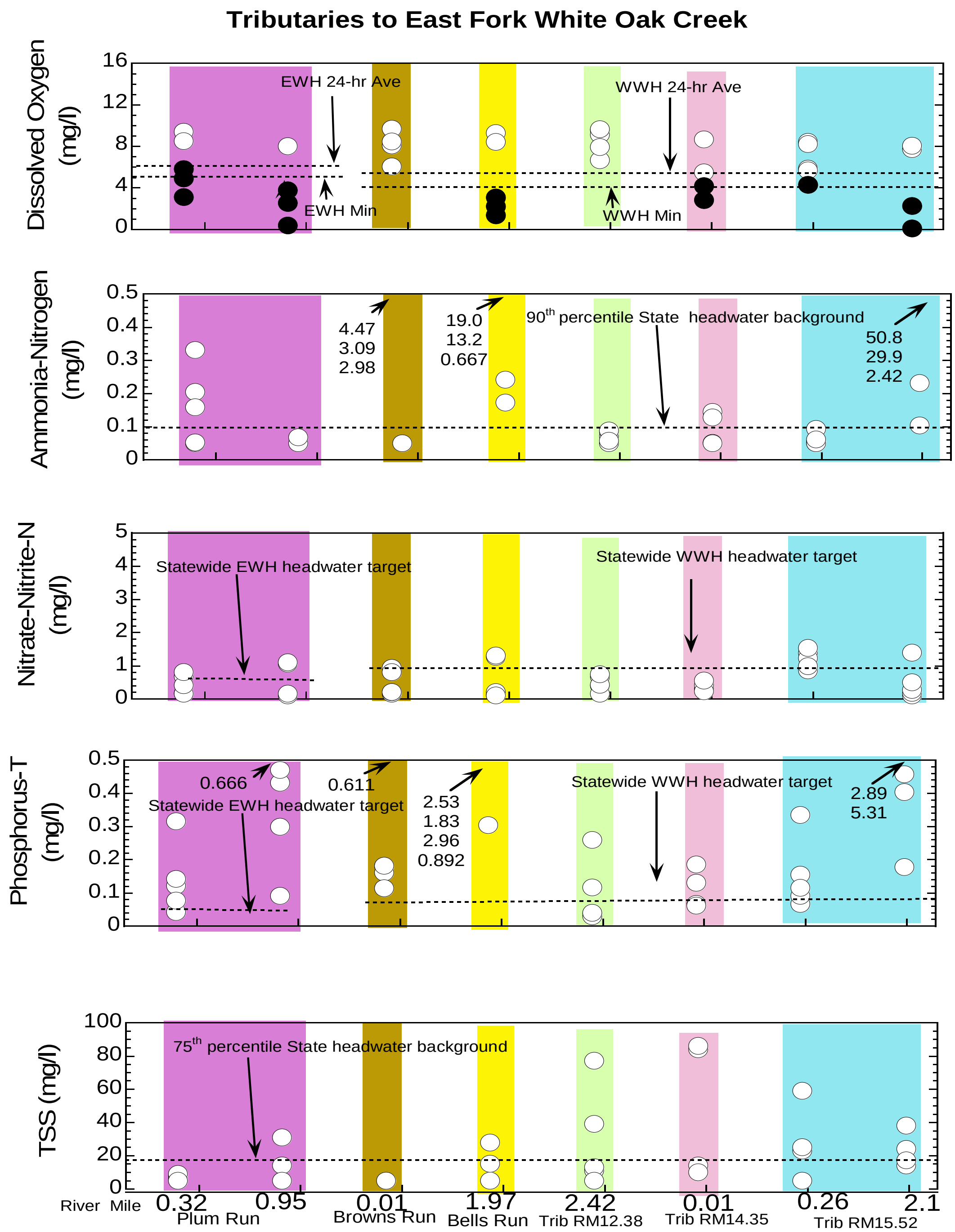


Figure 24. Longitudinal plots of water chemistry daytime grabs of Tributaries to East Fork White Oak Creek during the 2006 survey. The solid line depicts the median value at each river mile. Dotted lines in the Dissolved Oxygen plot indicate WQS criteria, dark circles are exceedences. Dotted lines in the other plots represent statewide nutrient target and background values.

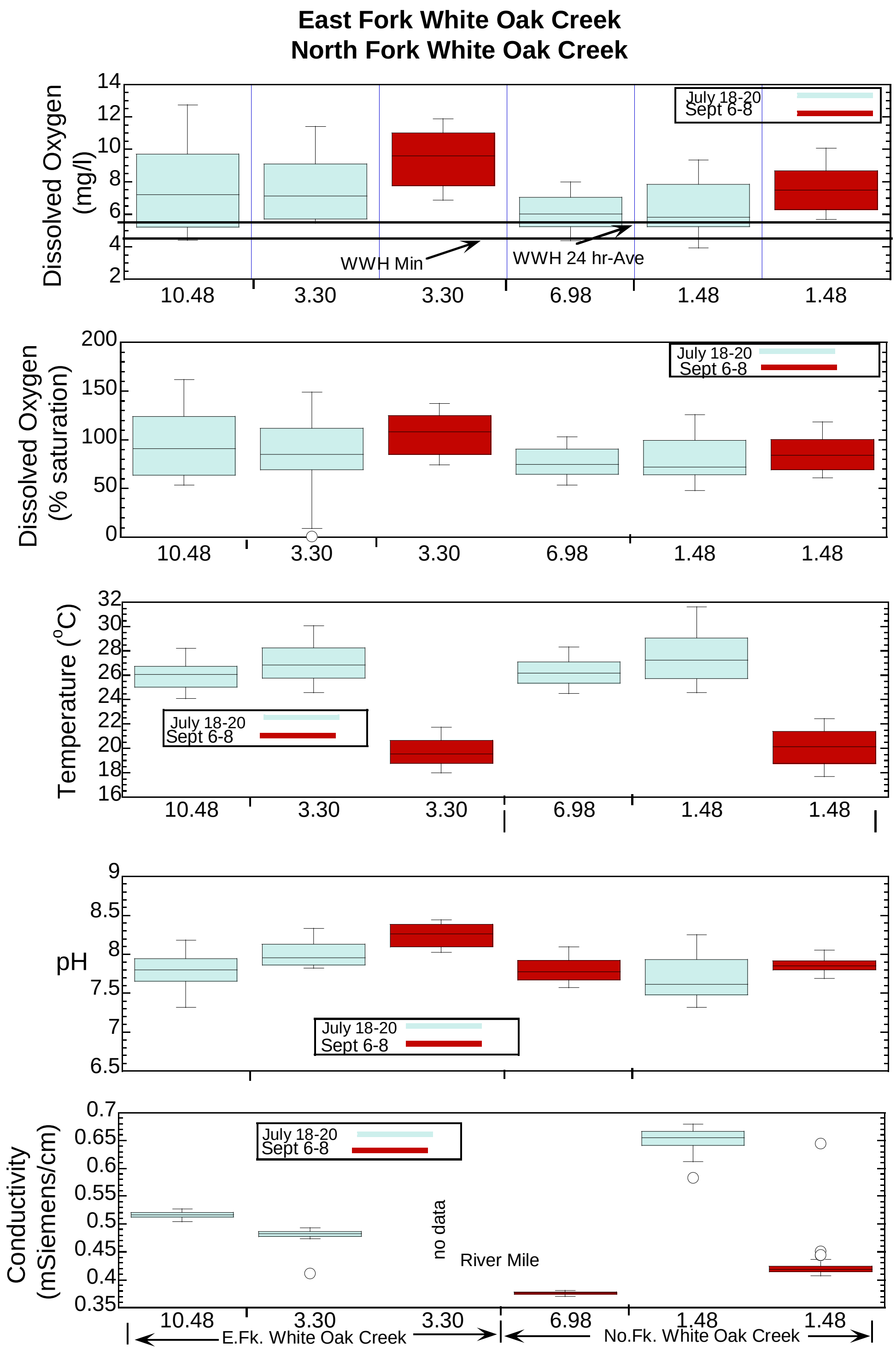


Figure 25. Distributions of dissolved oxygen, temperature, pH, and conductivity recorded hourly with Datasonde© monitors in 2006. Each box encloses 50% of the data with the median value displayed as a line. The top and bottom of the box mark the 75th and 25th percentile. The lines extending from the 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.

Sardinia WWTP 1PB00108 WAU 05090201-09-02

The Village of Sardinia WWTP and collection system was constructed in 1969. There are five lift stations in the collection system serving approximately 943 residents. Historically, the Sardinia WWTP experienced precipitation inflow and infiltration into the collection system. Wet weather flow caused sewer system bypasses into Slabcamp Run.

Prior to a late 2007 upgrade, the plant treatment consisted of screening, comminution and scum removal. After preliminary treatment, the raw wastewater was pumped into two secondary treatment units. Secondary treatment at each treatment unit was comprised of an aeration tank, an aerobic digestion tank, and a final clarifier, all within a circular concrete tank. Initially, the facility used a chlorine tank for disinfection, but now uses ultraviolet disinfection. Sludge is stabilized by aerobic digestion and is dried on sludge beds.

During a 1997 survey, sewage sludge was discovered knee deep in Slabcamp Run downstream of the Sardinia WWTP outfall. Improper operation was documented and the operator was removed for falsification of reports.

Sewage sludge was observed in Slabcamp Run downstream from the Sardinia WWTP during the 2006 survey. All stream sampling locations were above the WWTP outfall. In 2006, Slabcamp Run went interstitial upstream from the Sardinia WWTP during August. This caused the Dissolved Oxygen levels to fall below the WWH WQS criterion of 4.0 mg/l on two occasions at RM 1.13 and once at RM 2.93.

Conduit flow median average was 80,000 gallons per day from 2002-2006 with 27.7% (180 of 1623) of flow days being over the design capacity of 150,000 gallons per day.

A total of 137 NPDES permit violations were documented from 2002-2006. Violations are listed in Table 28.

Table 28. Sardinia WWTP NPDES Violations from 2002-2006.

Parameter	**Limit Type – 30 Day**	**Limit Type – 7 Day**	**Total Violations**
	# of violations	**# of violations**	
TSS	8-concentration 8-quantity	22-concentration 12-quantity	50 (36.5%)
NH_3-N	7-concentration 4-quantity	21-concentration 4-quantity	36 (26.3%)
$CBOD_5$	1-concentration	1-concentration	2 (1.5%)
Fecal Coliform	1 -concentration	10-concentration	11 (8.0%)
Oil/Grease	1 - concentration		1 (0.7%)
pH	20-conc (Daily Limits)		20 (14.6%)
D.O.	17concentration (Daily Limits)		17 (12.4%)

The ODOT Rest Area WWTP was connected to the Sardinia WWTP in 2007. An upgrade of the Sardinia wastewater treatment facility is scheduled for completion by March 2008. The 0.15 MGD package treatment system was upgraded to a 0.3 MGD Sequencing Batch Reactor (SBR) capable of handling peak hourly flows of 1.2 MGD. The SBR came on line August 28^{th} 2007. The existing treatment tanks will be converted to sludge holding tanks. The system is designed for a 2030 population of 1354 persons.

Improvements for the upgrade and expansion include the following: influent pump station, mechanical bar screen, manual bar screen, grit removal, Sequencing Batch Reactor, ultraviolet disinfection, post aeration, sludge holding tanks, and sludge holding pad. The historic inflow and infiltration problems within the collection system have not been addressed, although a study of the problem is underway.

Physical Habitat for Aquatic Life

In 2006 stream habitat conditions were evaluated at 40 fish sampling sites in the White Oak Creek watershed (Table 30). Good habitat conditions (QHEI $\bar{X}$ = 61.8) were typical and generally improved with increasing drainage area (Table 29).

Table 29. Summary of QHEI scores for the White Oak Creek study area, 2006.

Mi^2	Sites	QHEI $\bar{X}$	QHEI Range	Fair Sites (QHEI < 60)
< 5 mi^2	11	50.1	41.5 - 62	10
5 - 20 mi^2	15	63.3	39 - 78	6
> 20 mi^2	14	68.3	55 - 86	3

Habitat conditions were similar at White Oak Creek mainstem sites (QHEI $\bar{X}$ = 74.3, n=6). Bedrock with boulders or cobbles were the principal substrates across this high gradient reach. Good instream cover and adjacent riparian zone conditions contributed to an overall natural appearance. Flow conditions were somewhat limiting especially during the second sample pass when the effects of an ongoing drought were more evident. Despite this, habitat was sufficient to support an Exceptional Warmwater Habitat (EWH) aquatic life use designation.

Habitat conditions were conducive to good water quality across both the North Fork and East Fork. Six North Fork sites (QHEI $\bar{X}$ = 59.3) displayed an improving downstream trend. Sand and gravel substrates and good instream cover offset some of the low flow conditions. Riffle quality across this reach was functionally limited due to the lack of current.

East Fork habitat quality was better (QHEI $\overline{X}$ = 70.4, n=6). Limestone bedrock and glacial outwash substrates combined with good cover and channel morphology provided good habitat across the reach. Slightly more flow in the East Fork evident during the later part of the sample period helped some riffles to remain functional.

The presence of two dams on the East Fork influenced water quality and the health of the fish community. Streams in this region are prone to become flow limited annually. Impounding the limited flow promotes further water loss through evaporation and reduces downstream dissolved oxygen capacity. The likelihood that these dams are fish passage barriers could be inferred from the absence of black redhorse upstream from the lower dam. Compared to the North Fork, lower numbers of bigeye shiners collected in the East Fork might be related to the dams as well.

The presence of these dams is an obstacle to EWH aquatic life use attainment potential. The fish community upstream from the Morrystown dam achieved significantly lower IBI scores than did communities from other East Fork sites. Removal of this dam should be a prerequisite to any discussion regarding assignment of the EWH aquatic life use for the East Fork.

Sterling Run and an unnamed tributary to it (RM 6.68) were evaluated at seven locations. Fair habitat conditions (QHEI $\overline{X}$ = 50.0) in this sub basin were due in part to channel modification for agricultural drainage and substrates which were moderately silty. The ongoing drought effects were readily apparent in Sterling Run where few riffles exhibited any function.

Sterling Run was impounded by Lake Grant. No water was observed flowing from the lake on several occasions during the 2006 sample period. Algal growth on stream substrates downstream from the lake was sufficient to represent a nuisance condition. Large diel swings in dissolved oxygen were probable given the hypereutrophic situation.

Livestock encroachment instream and within the riparian corridor was evident at several study area locations. The resultant degraded conditions resulted in fair QHEI scores at four sample sites within the Little North Fork, Bells Run, and East Fork subbasins. The combined effects of livestock induced physical stream disturbance and nutrient input exacerbated by low flow conditions were factors which precluded better aquatic community performance in these tributaries.

The low flow conditions observed in 2006 throughout the White Oak Creek watershed were a product of more than an extreme natural event. Aquatic communities are adapted to annual reduced summer flows. Despite the ongoing drought, there were many sample sites in the White Oak basin that exhibited flows which seemed disproportional with drainage area or geologically derived expectations.

Table 30. A matrix of macrohabitat features and QHEI scores for the White Oak Creek study area, 2006.

Key: QHEI Components

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	MWH Attributes, High Influence: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(10-400) White Oak Creek																																		
Year: 2006																																		
27.5	64.0	2.62	■					■		■	■		4						0		●			●	●			●	●		●	6	0.20	1.40
20.7	63.5	7.04	■			■	■	■		■	■		6						0		●			●	●	●		●		●		6	0.14	1.00
16.5	86.0	11.63	■			■	■	■	■	■	■	■	8						0													0	0.11	0.11
12.8	77.0	20.83	■		■	■	■	■		■	■	■	8						0									●				1	0.11	0.22
7.5	74.0	35.09	■			■	■	■	■	■	■	■	8						0							●						1	0.11	0.22
2.6	81.0	11.70	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
(10-411) Miranda Run																																		
Year: 2006																																		
0.6	76.5	38.46	■	■		■	■	■		■	■	■	8			◆			1									●				1	0.22	0.33
(10-413) Sterling Run																																		
Year: 2006																																		
11.4	42.0	11.11	■				■						2				◆	◆	2				●	●			●	●	●		●	6	1.00	3.00
9.7	49.0	10.20	■	■						■			3			◆	◆	◆	3				●	●				●			●	4	1.00	2.00
6.8	51.0	5.10	■	■			■				■		4				◆		1		●			●				●	●		●	5	0.40	1.40
3.0	58.0	12.99	■					■			■		3						0		●			●	●			●	●	●		6	0.25	1.75
0.6	69.5	23.26	■	■		■	■	■		■	■	■	8						0					●				●				2	0.11	0.33
(10-418) Trib. to Sterling Run (RM 6.68)																																		
Year: 2006																																		
2.4	41.5	6.67		■				■					2			◆		◆	2	●	●		●	●				●	●		●	7	1.00	3.33
0.7	39.0	10.00						■			■		2	◆	◆	◆			3	●	●		●	●				●	●		●	7	1.33	3.67
(10-420) East Fork White Oak Creek																																		
Year: 2006																																		
18.7	78.0	25.00	■	■		■	■	■	■	■	■	■	9						0										●			1	0.10	0.20
16.5	74.0	12.35	■	■		■	■	■		■	■	■	8			◆			1		●							●	●			3	0.22	0.56
10.6	55.0	4.48						■			■		2	◆					1		●			●	●			●	●		●	6	0.67	2.67
5.7	68.0	3.91	■					■		■	■		4						0					●	●			●	●	●		5	0.20	1.20
3.3	79.0	4.13	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
3.3	68.5	4.13	■	■		■	■	■			■		6				◆		1					●				●	●	●		4	0.29	0.86
(10-422) Browns Run																																		
Year: 2006																																		
0.1	57.0	13.51	■	■			■	■			■		5						0				●	●				●	●	●		5	0.17	1.00

Table 30. 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
(10-424) Slabcamp Run																																		
Year: 2006																																		
2.9	54.5	21.28	■	■				■		■			4			◆		◆	2				●	●				●			●	4	0.60	1.40
1.1	66.5	12.82	■	■		■		■			■	■	6			◆			1				●	●				●	●			4	0.29	0.86
(10-426) Bells Run																																		
Year: 2006																																		
2.0	48.5	26.32		■				■			■		3	◆		◆			2	●	●		●	●				●	●	●		7	0.75	2.50
(10-427) Plum Run																																		
Year: 2006																																		
0.3	77.0	15.63	■		■	■	■	■		■	■	■	8						0									●				1	0.11	0.22
(10-430) North Fork White Oak Creek																																		
Year: 2006																																		
19.7	45.5	5.43						■			■		2	◆	◆	◆			3		●			●				●	●	●		5	1.33	3.00
18.1	56.5	7.58	■	■				■			■		4			◆			1		●			●				●	●	●		5	0.40	1.40
15.3	63.0	10.42		■	■			■		■	■	■	6			◆			1	●				●				●				3	0.29	0.71
9.7	58.0	7.04	■	■		■	■	■			■		6						0		●			●				●	●	●	●	6	0.14	1.00
7.0	65.0	3.68	■	■				■			■		4						0					●	●			●	●	●		5	0.20	1.20
7.0	62.5	3.68	■			■	■	■	■		■	■	7						0		●			●	●				●	●		5	0.13	0.75
1.5	64.5	2.27	■	■			■	■		■	■	■	7						0				●	●				●				3	0.13	0.50
(10-431) Flat Run																																		
Year: 2006																																		
4.8	53.0	13.51	■	■			■	■			■		5				◆		1				●	●				●	●		●	5	0.33	1.17
3.4	59.5	9.09	■	■				■			■		4			◆			1				●	●				●	●		●	5	0.40	1.40
0.2	68.5	6.33	■	■			■	■			■		5						0					●				●	●	●		4	0.17	0.83
(10-436) Little North Fork																																		
Year: 2006																																		
5.1	51.5	14.71		■				■			■		3	◆		◆			2		●			●				●	●		●	5	0.75	2.00
2.9	57.5	11.63	■	■				■			■		4			◆			1		●			●				●	●	●		5	0.40	1.40
0.3	62.5	7.35	■	■			■	■		■		■	6					◆	1					●				●				2	0.29	0.57
(10-441) Trib. to E. Fk. White Oak Cr. (RM 14.35)																																		
Year: 2006																																		
0.1	62.0	24.39	■	■			■	■		■	■		6						0		●			●				●	●	●		5	0.14	0.86
(10-442) Trib. to E. Fk. White Oak Cr. (RM 15.52)																																		
Year: 2006																																		
2.1	47.0	11.63	■	■			■				■		4				◆		1		●			●				●	●	●		5	0.40	1.40
0.3	71.0	17.54	■	■		■	■	■			■		6						0		●			●				●	●	●		5	0.14	0.86

Fish Community

In 2006, fish community performance was evaluated at 40 sampling sites in the White Oak Creek watershed. Among 51 fish community evaluations (11 locations were sampled twice), 35 (69%) achieved the EWH IBI criterion and 10 (20%) others achieved the WWH criterion (Table 2). Performance at 6 (12%) locations was less than ecoregional WWH expectations. Five of the 6 sites where IBI scores were subpar were located in the Sterling Run subbasin. The other underachieving fish community was in Bells Run.

In total, 45,217 fish comprised by 61 species and 6 hybrids were collected. Forty percent of all sampled fish were either bluntnose minnow (14%), creek chub (13%), or central stoneroller minnows (13%). Eight species were represented by one or two individuals, while five other species were present as three to eight individual fish. Biomass was mostly comprised by golden redhorse (20%), northern hogsucker (11%), and central stoneroller minnows (8%).

Bigeye shiners were present at 21 sites. Situated on the fringe of its range, this central Mississippi oriented species has always been uncommon in Ohio. Due to its silt intolerance and preference for warm quiet pool habitat, this state threatened species has become rare. The Ohio Division of Natural Areas and Preserves assessed Ohio's bigeye shiner status in the winter of 1990 (Rice, et. al. 1998). Populations were present in the Sunfish (Scioto River), Turkey (Ohio River), O'Bannon (Little Miami River), and White Oak Creek systems.

In White Oak Creek, the bigeye shiner population appears to be stable. Ohio EPA documented their presence in the basin in 1987, 1997, and in 2006. In 2004, University of Southern Mississippi student, John Spaeth collected bigeye shiners at eight of nine sample locations. Spaeth's project was sponsored by the White Oak Creek Watershed Group using 319 funds. He verified a relatively large bigeye shiner population in the North Fork.

In 2006, the North Fork bigeye shiner population remained numerically more abundant than populations in other White Oak Creek tributaries. Overall, 643 individual fish were collected in 28 samples ($\bar{X}$ =23, 7 sites were sampled twice). Five North Fork locations accounted for 329 individuals ($\bar{X}$ =41, n=8). Interestingly, significant discrepancies in abundance were observed between passes at locations which were sampled twice. This variability did not follow an obvious trend.

Individual and total numerical variance between sample passes is a normal occurrence. Many of the second pass 2006 White Oak basin fish samples were numerically less abundant than the first pass samples from the same site. Through late summer and early fall, drought conditions were evident across the watershed. In some cases, different equipment was employed for the second pass because the stream had physically diminished in pool size and flow volume. Further study to discover why bigeye shiners exhibited disproportionate variability compared to other species is suggested.

White Oak Creek Mainstem

Ohio EPA previously evaluated White Oak basin fish communities in 1997, 1987, and 1983. Subsequent to the 1997 survey, the 1978 inferred Exceptional Warmwater Habitat (EWH) aquatic life use designation was included in a comprehensive Water Quality Standards rule. Although no part of the White Oak Creek mainstem ever achieved the relevant biological criteria, this expectation was nevertheless confirmed in the Standards. Regardless of the appropriateness of this use, in 2006 the mainstem fish community failed to achieve EWH at two of six sample locations.

Fish community performance in White Oak Creek has improved. The margin between fully achieving the EWH criteria in 2006 at the two specific locations was quite literally a matter of a few fish. Determining the significance of the absence of particular species in context with habitat and an ongoing drought was necessarily a bit speculative. Fundamental to this hypothesis is an acceptance that EWH performance was precluded by plausible causes. And, that if the sources of such were diminished, then a more robust community would exist.

The herbivorous central stoneroller minnow is uniquely adapted to scrape algae from rock surfaces. Its disproportionate presence in a fish community can influence water quality index scores and it is often regarded as an indication of excessive nutrient loading. Bluntnose minnow are detritivores. They are most numerous where they may feed on waste from other fish or downstream from livestock or wastewater treatment facilities. Stoneroller abundance due to nutrient enrichment can influence bluntnose abundance. Organic enrichment from a poorly functioning treatment system can disproportionately support bluntnose abundance and exert other population influences.

The same location was sampled at RM 27.5 in 2006 and in 1997. Fish community scores here were exceptional in 2006 (IBI = 51, MIWb = 8.9) and marginally good in 1997 (IBI = 37, MIWb = 7.7). Among 31 species and 800 individual fish, 62 were stonerollers and 28 were bluntnose in 2006. In 1997, 26 species and 579 individual fish included 1 stoneroller and 68 bluntnose. Otherwise, the improvement documented in 2006 was due to the presence of more pollution intolerant species.

In 2006, RM 20.7 was sampled whereas RM 20.2 was evaluated in 1997. A ten point difference in habitat scores was due to better substrate and flow conditions at the downstream location (2006, RM 20.7 QHEI = 63.5, 1997, RM 20.2 QHEI = 73.0). This sample area is downstream from the Sterling Run confluence.

In 2006, 25 species and 2367 individual fish included 666 stonerollers and 240 bluntnose present in the upper reach. Downstream among 31 species and 1285 individuals, 263 were stonerollers and 229 were bluntnose minnows in 1997. The 2006

RM 20.7 fish community achieved good index scores (IBI = 42, MIWb = 9.2) as did the 1997 RM 20.5 community (IBI = 43, MIWb = 9.3).

Given the EWH expectation and the substantial improvement between surveys upstream from Sterling Run, it may be asserted that the 2006 RM 20.7 fish community was precluded from similar advancement due to nutrient enrichment limitations. The fact that 2006 fish community performance throughout the Sterling Run subbasin was only fair added further weight to the perspective that it acted as a nutrient source.

Aside from the subtle and perhaps weakly significant population shifts in stoneroller and bluntnose abundance at RM 20.7 in 2006, other species were also atypically absent. Pollution intolerant black redhorse were missing and golden redhorse were only collected during the second pass. This and the lack of other sucker species resulted in an abnormally low metric score.

Likewise, other pollution sensitive species were also collected in one but not both sample passes. Thus, this metric scored low and fostered the supposition that if brindled or stonecat madtoms, or if scarlet or bigeye shiners had been present in both samples and if suckers were better represented then this site would have achieved EWH status.

Essentially, the aggregate of fish community information pertinent to RM 20.7 favors an opinion that the 2006 good performance would have been exceptional if not for perturbations emanating from Sterling Run. The influence of drought and habitat merit weight and can reasonably be asserted to have also been factors. However, those effects were not as apparent here as they were at other sites including some which achieved EWH fish communities.

The other mainstem White Oak Creek site which failed to achieve the EWH criterion was RM 12.8. This ecoregional reference site has remained mostly unchanged since it was evaluated in 1983. A very good QHEI score abstracted from field notes in 1983 (QHEI = 82.0) compared favorably with those from 1997 (QHEI = 77.5) and 2006 (QHEI = 77.0).

An appreciable water quality improvement was detected between 1983 (IBI = 35, MIWb = 8.8) when fair community performance rose to good in 1997 (IBI = 44, MIWb = 8.6). This community remained good in 2006 (IBI = 44, MIWb = 8.7). Again, the absence of a few species present in one sample but not in the other was influential.

In 2006, an exceptional fish community was present at RM 16.5 (IBI = 50, MIWb = 9.2). Very good habitat conditions (QHEI = 86.0) likely influenced the community stability noted between sample passes. Despite the drought conditions, a constricted reach retained better flow conditions throughout the sample period. Important pollution intolerant species were present during both sample events and there were few differences between the collections.

An exceptional fish community was also present at RM 7.5 (IBI = 52, MIWb = 10.2) in 2006. While good habitat conditions here (QHEI = 74.0) were less diverse than displayed at the two upstream locations, this site included a reach with better flow as well. As a result, the fish community appeared stable with most species represented in both passes. Sucker species were numerous, in part due to the proximity of the Ohio River, and this metric registered high marks.

In between RM 16.5 and RM 7.5, the RM 12.8 reference site did not include a reach with reliable flow. Even so, 23 species present in the August sample comprised a very good community (IBI = 48, MIWb = 9.2) which did achieve the EWH expectation. In September, conditions had changed and only 21 species were collected. This good community (IBI = 40, MIWb = 8.4) did not include previously collected sunfish and sensitive species.

Flow conditions contributed to the fact that goldern redhorse and northen hogsuckers were the only sucker species collected at this site. The first pass sunfish abundance might imply that pool quality was good but the variability demonstrated by the second sample suggested otherwise. This was the only mainstem location where johnny darters were not collected. These species often inhabit shallows adjacent to pool edges.

Ultimately, the abundance of stonerollers was deemed more diagnostic. They comprised 47% and 50% respectively, of the sampled fish in each pass. Apparently, conditions at RM 12.8 favored algal growth and limited piscivore presence. Nutrient input, slower glide like qualities, sunlight, warmer water temperatures and associated factors appeared to have benefited stonerollers and stressed other species. Reduction of the nutrient load should enable a more balanced community to remain viable through stress events.

Sterling Run Subbasin

The fish community throughout the Sterling Run subbasin displayed evidence of enrichment and the affects of drainage modification. Only four species and 72 individual fish were present at RM 11.4 on Sterling Run. Although small streams in this region are prone to become dry, agricultural land use has exacerbated this. Removal of forest, wetland, and other natural areas has changed normal groundwater stream recharge. Installation of road and field drainage networks has expedited water removal from land surfaces. As a result, small streams have functionally become smaller with larger proportional catchments. The poor fish community at RM 11.4 (IBI = 20) reflected these assimilative capacity challenges.

Fair fish communities downstream at RM 9.7 (IBI = 30) and 6.8 (IBI = 30) continued to show indications of flow alteration and enrichment. Creek chub are tolerant of water pollution. They comprised 79% of the fish at RM 9.7 and were 46% of those at RM 6.8. Twenty percent of the other fish at RM 6.8 were pollution tolerant bluntnose minnows.

Other species at these sites were also tolerant. Simple lithophilic fish, which need clean substrates to successfully spawn, accounted for just 2% and 1% of the fish at these locations, respectively.

Poor fish communities were present at two locations on a tributary which joins Sterling Run at RM 6.68. This stream was also silt covered, channelized and enriched. Both sample sites were comprised by tolerant assemblages. Only 79 individual fish were collected upstream at RM 2.4 (IBI = 22) including 34 creek chub (43%). At a downstream site at RM 0.7, 34% of the catch were creek chub and 42% were bluntnose minnows (IBI=22).

Downstream from the tributary confluence, Sterling Run was impounded by Lake Grant. Good quality fish communities at two Sterling Run sites downstream from Lake Grant were more diverse but also included significant numbers of stonerollers. Little water was observed flowing from the lake outfall; 50% of the fish collected at RM 3.0 (IBI = 40, MIWb = 8.4) and 30% at RM 0.6 (IBI = 40, MIWb = 8.4) were stonerollers. Large numbers of hybrid sunfish were collected at these sites as well.

Sunfish hybridization occurs when suitable nesting habitat is limited. While the implications of this vary, it is yet another sign of aquatic environmental stress. This combined with an absence of intolerant species, near absence of sucker species, and poor lithophilic presence supported a view that Sterling Run is a prominent pollution source in the White Oak basin.

Other Tributaries

The fish community in Bells Run at RM 2.0 was similar to those in the upper Sterling Run reaches. Creek Chub comprised 81% of the Bells Run fish. The sample location within a cattle pasture was home to a few other pollution tolerant fish. Overall, a poor community index score (IBI = 24) seemed consistent with the obvious pollution source.

Other streams in the White Oak Creek basin supported fish communities consistent with assigned aquatic life uses. The East Fork, North Fork, and Little North Fork were supportive of exceptional fish communities. Low numbers of pollution tolerant fish inhabited these reaches. Insectivorous fish were predominant and simple lithophils were abundant.

The contrast between these streams and the Sterling Run streams made it clear that water quality issue in the White Oak watershed are not pervasive to the entire area. Furthermore, recognizing the amount of exceptional achievement made it difficult to suggest that the two White Oak Creek mainstem locations which fell short of this goal should not be expected to do so. Instead, it appeared that focused effort to remediate water quality issues in Sterling Run would have downstream consequence.

Macroinvertebrate Community

Macroinvertebrate communities were evaluated at 44 stations in the White Oak Creek study area (Tables 2 & 31). The community performance was evaluated as exceptional at eight stations, very good at three, good at eight, marginally good at six, fair at nine, and poor at eight stations. Two stations were on Primary Headwater Habitat (PHWH) streams and therefore did not receive a use attainment evaluation. The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT) was on White Oak Creek at SR 221 (RM 6.7) with 26 taxa. The station with the highest number of total sensitive taxa was on White Oak Creek at Miller Ring Road (RM 12.4) with 44 taxa. Sensitive taxa found in this study area which are noteworthy because they are not commonly collected were the mayflies *Acentrella turbida* in White Oak Cr. (RMs 12.4, 6.7) and *Paracloeodes* sp. 3 in White Oak Cr. (RM 12.4), E. Fk. White Oak Cr. (RM 5.8), and N. Fk. White Oak Cr. (RM 1.4); the stonefly *Neoperla clymene* complex in White Oak Cr. (RMs 7.6, 6.7, 2.7); the caddisfly *Protoptila sp.* in White Oak Cr. (RMs 12.4, 2.7); and the midge *Nanocladius downesi* in White Oak Cr. (RMs 20.6, 12.4).

White Oak Creek
Macroinvertebrate community performance in White Oak Creek was consistently in the exceptional range (Figure 26). The three valid ICI scores ranged from 44 to 50. Qualitative EPT counts were at or above 20 at every site. The number of sensitive taxa were generally above the number of EPT taxa. The station at the end of Miller Ring Road (RM 12.4) had the highest performing community in the entire study area with the highest number of qualitative (35) and total (44) sensitive taxa, tied for the highest number of qualitative EPT (25), the most number of qualitative (65) and total (77) taxa, and the most number of uncommonly collected sensitive taxa with four. There was no discernable impact from the confluence of Sterling Run (RM 20.75) which receives discharge from the Mount Orab WWTP (RM 5.35), adjacent to the Rumpke Brown County Landfill (upstream from RM 12.4), or downstream from Town Run (RM 6.95) which receives discharge from the Georgetown WWTP (RM 0.8). The decline in number of sensitive taxa downstream from Town Run at RM 6.7 may reflect the gorge-like nature of the stream channel at this site which created a high-energy bedrock and boulder stream channel to the exclusion of other microhabitats.

East Fork White Oak Creek
Macroinvertebrate community performance in the East Fork White Oak Creek was generally good in the headwaters. The community downstream from Sorg Road (RM 16.5) may have been mildly impacted by organic/nutrient enrichment from the open pasture upstream from Sorg Road. The EPT remained the same as the upstream site (13) but the number of sensitive taxa dropped to 13 compared to 18 at the upstream site (Fig. 27). Considering that this site had improved riffle habitat, it would be expected that diversity measures would have increased. The community sampled within the Mowrystown Delphi Park impoundment (RM 10.6) was limited by the impounded nature of the stream. Community performance at the two downstream stations improved into

the very good to exceptional range with 22 total EPT and 35 total sensitive taxa collected downstream from the Tri-City Highway and Slabcamp Run (RM 3.3).

Tributaries to East Fork White Oak Creek

Macroinvertebrate communities were sampled from nine stations in seven tributaries to East Fork White Oak Creek. Five stations were meeting or marginally meeting the expectations of their existing or recommended aquatic life use designations. The communities in Plum Run at Wildcat Road (RM 0.9) and Bells Run at Winkle Road (RM 1.9) were impacted by water quality impairments from upstream open pastures. Bells Run in particular was highly impacted by a large concentration of cattle with unrestricted access to the stream. The community at this site had low diversity metrics (4 EPT, 3 sensitive taxa) and was predominated by tolerant taxa. The communities in Slabcamp Run were limited by low flow conditions. The downstream station was also potentially impacted by urban runoff from the town of Sardinia.

North Fork White Oak Creek

Macroinvertebrate communities in the headwaters of North Fork White Oak Creek were limited by low flow conditions. The stream at Cochron Road (RM 19.6) and Dawson Road (RM 18.1) was barely flowing on 31 July with less than an inch water depth in the riffles. The station at Cochron Road was also impacted by channelization, riparian removal, and siltation. Thick growths of algae and macrophytes were observed at this station, which were indications of nutrient enrichment. Indications of enrichment, along with low flow, in the macroinvertebrate community were low diversity metrics (4 EPT, 3 sensitive taxa) and high relative abundance of the tolerant taxa *Glyptotendipes (G.) sp.* (midge) and *Physella sp.* (snail) along with facultative flatworms. The impacts at these two stations were directly the result of the agricultural practices associated with the adjacent row crops. Community performance improved at downstream stations due to increased flow and mostly intact riparian areas (Figure 28).

Tributaries to North Fork White Oak Creek

Macroinvertebrate communities in the headwaters of Little North Fork White Oak Creek were limited by low flow conditions. The stream at SR 134 (RM 5.1) was barely flowing on 19 July with less than an inch water depth in the riffle. The station at SR 134 was also impacted by channelization, riparian removal, and siltation. Thick growth of algae was observed at this station, which was an indication of nutrient enrichment. Indications of enrichment, along with low flow, in the macroinvertebrate community were low diversity metrics (1 EPT, 3 sensitive taxa) and high relative abundance of tolerant taxa of snails (*Physella sp.*, *Planorbella pilsbryi*), leeches (*Helobdella stagnalis*, *Helobdella triserialis*), and midges (*Polypedilum illinoense*, *Glyptotendipes (G.) sp.*). The impacts to the headwaters of this stream were directly the result of the agricultural practices associated with the adjacent row crops and potentially an open pasture located downstream from the SR 134 station. Community performance improved at the downstream station (RM 0.3) due to increased flow and mostly intact riparian areas.

Macroinvertebrate communities in the headwaters of Flat Run were limited by low flow conditions. The stream at Kelch Road (RM 4.8) was barely flowing with less than an inch water depth in the riffle and the station at SR 134 (RM 3.4) was interstitial, both on 1 August. Siltation was noted as above normal at Kelch Road. Community performance improved at the downstream station (RM 0.1) due to increased flow.

Tributaries to the White Oak Creek Mainstem
Macroinvertebrate communities sampled in Sterling Run upstream from Lake Grant were limited by low flow conditions. The stream at Moon Road (RM 11.4) had interstitial flow while the others were barely flowing, all sampled on 18 July. Other factors that may have been detrimental to the biota at these stations were siltation, low dissolved oxygen, and elevated phosphorus-T concentrations. The community sampled downstream from SR 774 (RM 3.0) was impacted by low flow, low dissolved oxygen, and nutrient enrichment. Very little flow was discharging from Lake Grant on 15 August. Thick growth of algae observed at this station was an indication of nutrient enrichment. Community performance improved at the downstream station (RM 0.4) due to increased flow. This was the only station with a community that was meeting WWH expectations with a marked increase in diversity metrics (17 EPT, 16 sensitive taxa). However, the community was largely predominated by facultative taxa which may be an indication of a mild impact.

The macroinvertebrate community sampled in the Tributary to Sterling Run @ RM 6.68 at Waits Road (RM 2.4) was limited by intermittent flow conditions on 18 July. Communities sampled at both stations on this stream were probably impacted by the low dissolved oxygen concentrations recorded during the study. This would be an explanation for the unusually low community performance (Poor) at Bardwell West Road (RM 0.8) which had normal stream flow on 18 July.

Snapping Turtle Run was sampled at RM 0.5 upstream from the Mount Orab WWTP discharge (RM 0.46) to ascertain if this stream should be redesignated as a Primary Headwater Habitat (PHWH) instead of Warmwater Habitat (WWH). Considering that the maximum pool depth was greater than 40 cm and the 1997 sampling at this station was marginally meeting the WWH biocriteria (IBI = 36, marginally good macroinvertebrates), it was decided to leave the stream WWH. The macroinvertebrate community sampled for this study was not meeting WWH expectations. Diversity metrics were low (4 EPT, 2 sensitive taxa) and mostly facultative taxa were predominant. Thick silt deposits were observed at this site, apparently emanating from the upstream fields supporting row crop agriculture. Low D.O. concentrations were also recorded for this site.

Miranda Run was meeting WWH expectations for macroinvertebrates. This is the first time this stream has been sampled. The stream is currently designated as EWH, but since it does not support a EWH community, it is recommended that the use be changed to WWH.

Walnut Creek is a small stream that is confluent with White Oak Creek at RM 13.19 and has a drainage area of about 1.4 sq mi. This stream flows just north of the Rumpke Brown County Landfill. The lower portion of this stream has a high gradient and flows through a wooded ravine. The maximum pool depth in the sampling area was 23 cm. This stream is currently designated WWH, but based on the current analysis it should be assigned to Coldwater Habitat (CWH). Due to its low potential to support a viable fish population, salamanders were used to evaluate the appropriate aquatic life use designation instead of fish. Biological sampling found 13 larval two-lined salamanders along with 33 taxa of macroinvertebrates which included 8 EPT and 3 coldwater taxa.

Town Run is a small stream that is confluent with White Oak Creek at RM 6.95 and has a total drainage area of 1.74 sq mi. This stream flows through the southeast corner of Georgetown and the Georgetown WWTP effluent discharges to the stream at RM 0.80. The lower portion of this stream has a high gradient and flows through a wooded ravine that has areas of exposed bedrock that form waterfalls. The maximum pool depth in the sampling area (RM 0.9, drainage area of 1.4 sq mi) upstream from the WWTP discharge was 37 cm on 16 August 2006 and 41 cm on 7 May 2008. This stream is currently designated Limited Resource Water (LRW), but based on the current analysis it should be assigned to the CWH use. Biological sampling upstream from the WWTP discharge found 14 larval two-lined salamanders along with 29 taxa of macroinvertebrates which included 9 EPT, 9 sensitive taxa, and 0 coldwater taxa in 2006. The station was resampled in 2008 when 6 larval two-lined salamanders were found along with 26 taxa of macroinvertebrates including 10 EPT, 7 sensitive taxa, and 3 coldwater taxa. The macroinvertebrate community in Town Run upstream from the WWTP discharge may be impacted by urban runoff and sewer overflows from Georgetown. The WWTP operator says that the system has had problems with hydraulic overloading which resulted in sewage overflows into Town Run upstream from the collection area. Accumulations of floatable trash on the banks of Town Run was evidence of runoff. Macroinvertebrate sampling in 1997 found a very poor community downstream (RM 0.7) from the Georgetown WWTP discharge that had low diversity metrics (2 EPT, 0 sensitive taxa) and was highly predominated by midges of the very tolerant *Chironomus riparius* group. A similar community was found in 2008.

Trend Assessment: Macroinvertebrate Community

Macroinvertebrate communities were evaluated in the White Oak Creek mainstem, East Fork White Oak Creek, and select sites on other tributaries in 1997. The longitudinal trend for ICI, number of EPT taxa, and number of sensitive taxa for White Oak Creek is presented in Figure 29 and for East Fork White Oak Creek in Figure 30. Generally, the macroinvertebrate communities during the present study (2006) were performing at a comparable level or higher than in 1997. The same is also true for the remaining stations sampled in 1997 except for the differences already discussed for Snapping Turtle Run.

Table 31. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the White Oak Creek study area, July to October, 2006.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
White Oak Creek (10-400)										
27.6	150	-	60	23	27	L-M	0	Caddisflies (F,MI), mayflies (F,MI), midges (F,MI,MT)	-	Exceptional
20.6	187	-	45	20	25	M	0	Caddisflies (MI,F), mayflies (F,I,MI), midges (F,MI)	-	Exceptional
16.5	190	15	50	20 / 20	28 / 32	M / 252	1	Caddisflies (MI), mayflies (F,I), midges (F)	(38)	Exceptional
12.4	213	-	65	25 / 25	35 / 44	M / 331	0	Caddisflies (F,MI), mayflies (F,I,MI), midges (F,MI)	46	
7.6	218	-	48	23	27	L-M	0	Caddisflies (MI,F), baetid mayflies (F), midges (F,MI)	-	Exceptional
6.7	222	-	44	25 / 26	24 / 29	M / 453	0	Caddisflies (MI), mayflies (I,MI), midges (F)	44	
2.7	231	-	56	21 / 23	27 / 35	M / 349	0	Caddisflies (F,MI,I), mayflies (I,F,MI), midges (F,MI)	50	
East Fork White Oak Creek (10-420)										
18.6	6.7	-	52	13	18	L	1	Midges (F,MI), hydropsychid caddisflies (F), mayflies (F)	-	Good
16.5	12.7	-	49	13	13	M-H	0	Midges (F,MI,MT), baetid mayflies (F), hydropsychid caddisflies (F,MI)	-	Good
10.6	39.0	2,15	44	8 / 11	10 / 14	L / 266	0	Midges (MT,F), heptageniid mayflies (F)	26	

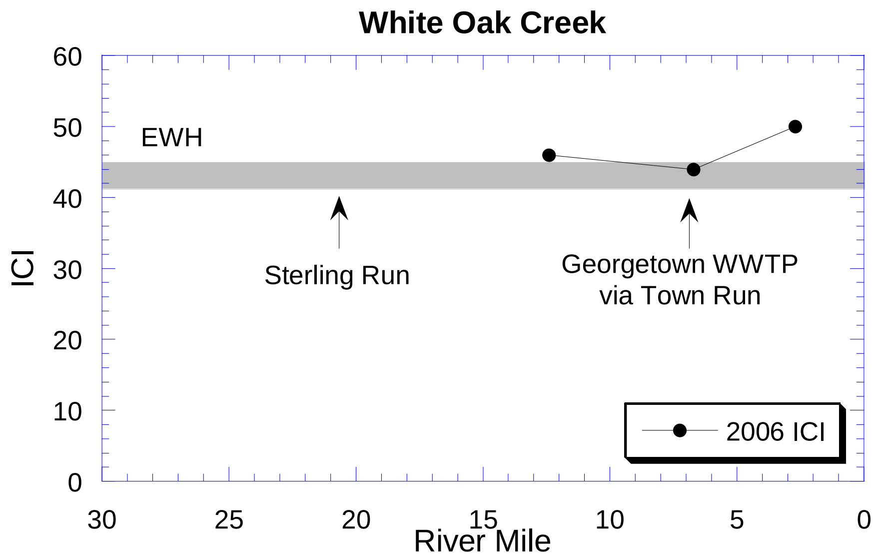
Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
5.8	52	-	57	16 / 21	20 / 28	H / 1271	0	Caddisflies (F,MI), midges (F,MT)	48	
3.3	70	5	61	22 / 22	28 / 36	L-M / 420	0	Caddisflies (F,MI), mayflies (F,I,MI), midges (F,MI)	48	
Tributary to East Fork White Oak Creek (@ RM 15.52) (10-442)										
0.2	7.1	-	45	11	18	L	0	Midges (F,MI), caddisflies (F,MI)	-	Marg. Good
Tributary to East Fork White Oak Creek (@ RM 14.35) (10-441)										
0.1	3.2	-	56	10	10	M	0	Midges (F,T,MI), hydropsychid caddisflies (F)	-	Marg. Good
Tributary to East Fork White Oak Creek (@ RM 12.38) (10-440)										
2.4	3.4	-	46	9	13	M	2	Caddisflies (MI,F), midges (F,MI)	-	Marg. Good
Plum Run (10-427)										
0.9	4.2	-	44	8	6	M	1	Midges (F,MI), hydropsychid caddisflies (F)	-	Fair
0.3	6.3	-	49	15	15	L	2	Hydropsychid caddisflies (F), midges (MI,F)	-	Good
Bells Run (10-426)										
1.9	4.0	-	40	4	3	H	1	Midges (VT,F,T), *Physella* snails (T)	-	Poor
Slabcamp Run (10-424)										
3.0	3.3	9	29	2	2	M	0	*Caenis* mayflies (F), midges (MT,T,MI)	-	Poor
1.1	7.8	-	45	8	7	L	0	Midges (F), hydropsychid caddisflies (F), riffle beetles (F)	-	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)	ICI[a]	Narrative Evaluation
Browns Run (10-422)										
0.1	3.9	-	52	13	18	L-M	0	Midges (F,MI), hydropsychid caddisflies (F)	-	Good
North Fork White Oak Creek (10-430)										
19.6	4.4	-	39	4	3	M	0	Hydropsychid caddisflies (F), midges (MT,F,MI), *Physella* snails (T)	-	Low Fair
18.1	7.2	-	42	5	6	M	0	Flatworms (F), fingernail clams (F)	-	Fair
15.1	12.0	-	45	12	12	M	0	Midges (F,MI,MT), flatworms (F), hydropsychid caddisflies (F)	-	Marg. Good
9.7	36	-	60	12	21	M	0	Caddisflies (F,MI), midges (F,MI,MT)	-	Good
7.0	46	-	45	12 / 13	17 / 26	M / 504	0	Caddisflies (F,MI), midges (F,MT)	44	
1.4	53.6	15	49	16 / 16	23 / 33	L / 648	0	Midges (MI), riffle beetles (F), caddisflies (F,MI)	44	
Little North Fork White Oak Creek (10-436)										
5.1	3.6	-	22	1	3	L	0	Snails (T), leeches (T), midges (T,MT,MI)	-	Poor
3.0	7.3	-	42	5	8	M	1	Hydropsychid caddisflies (F), midges (MI,F)	-	Fair
0.3	13.8	-	55	10	16	L-M	1	Midges (F,MI), hydropsychid caddisflies (F), baetid mayflies (F)	-	Marg. Good
Flat Run (10-431)										
4.8	3.9	-	26	7	6	L	0	*Elimia* snails (MI), hydropsychid caddisflies (F)	-	Fair
3.4	7.4	-	32	4	3	L	0	*Elimia* snails (MI), sow bugs (F,MT)	-	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)	ICI[a]	Narrative Evaluation
0.1	12.3	-	40	13	14	L-M	0	Hydropsychid caddisflies (F), midges (MI,F)	-	Good
Sterling Run (10-413)										
11.4	3.4	9	24	1	2	L-M	0	Midges (T,F), *Physella* snails (T)	-	Poor
9.7	6.1	-	28	2	3	L	0	Midges (F,MI), hydropsychid caddisflies (F), *Physella* snails (T)	-	Poor
6.8	11.8	-	29	5	4	L-M	0	Midges (F), hydropsychid caddisflies (F), riffle beetles (F)	-	Fair
3.0	26.3	-	27	3	1	M	0	Flatworms (F)	-	Poor
0.4	29.7	-	45	17	16	L	0	Baetid mayflies (F), water penny beetles (MI), riffle beetles (F)	-	Good
Tributary to Sterling Run (@ RM 6.68) (10-418)										
2.4	3.7	9	27	0	3	L-M	0	Snails (T), fingernail clams (F), scuds (F)	-	Poor
0.8	6.9	-	29	2	4	L-M	0	*Rheotanytarsus* midges (MI), hydropsychid caddisflies (F), *Physella* snails (T)	-	Poor
Snapping Turtle Run (10-414)										
0.5	1.3	-	33	4	2	L	1	Flatworms (F), midges (F,MI,T), riffle beetles (F)	-	Low Fair
Miranda Run (10-411)										
0.7	5.8	-	44	16	14	M	0	Caddisflies (MI,F), midges (F,T), flatworms (F)	-	Good

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Walnut Creek (10-408)										
0.6	1.4	29	33	8	15	L	3	Water penny beetles (MI), hydropsychid caddisflies (F), midges (MI)	-	Marg. Good
Town Run (10-407)										
0.9	1.4	29	29	9	9	L	0	Midges (F,MT), hydropsychid caddisflies (F), baetid mayflies (F,I)	-	Marg. Good
0.9[b]	1.4	29	26	10	6	L	3	Blackflies (F), aquatic sow bugs (F), midges (MT)	-	Marg. Good
0.7[b]	1.4	29	17	1	1	M-H	0	Midges (MT,VT), blackflies (F)	-	Very Poor

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 2=Dam Pool, 5=3 HD Only, 8=Non-Detectable Current, 9=Intermittent or Near-Intermittent Conditions, 15=Current >0.0 fps but <0.3 fps.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
CW: Coolwater/Coldwater.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant
a: ICI values in parentheses are invalidated due to insufficient current speed over the artificial substrates. The station evaluation is based on the qualitative sample narrative evaluation.
b: Sample was collected on 7 May 2008.



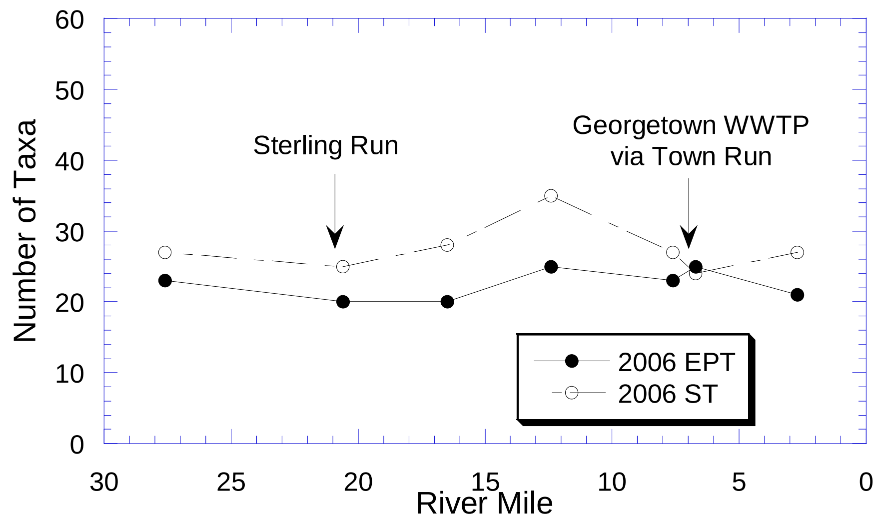
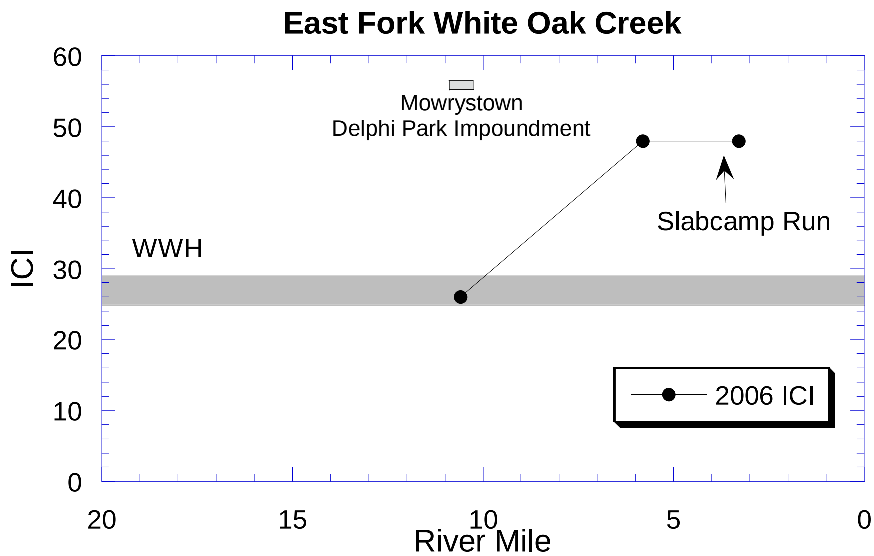


Figure 26. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in White Oak Creek, 2006.



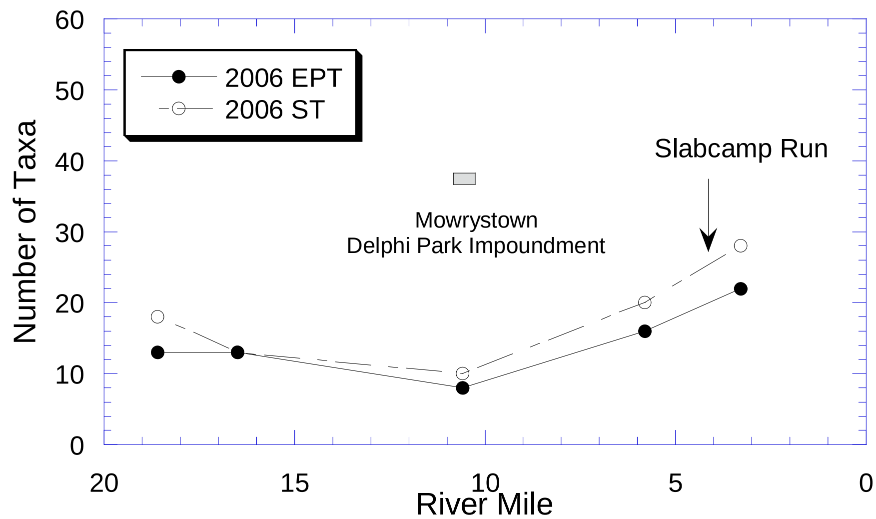


Figure 27. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in the East Fork White Oak Creek, 2006.

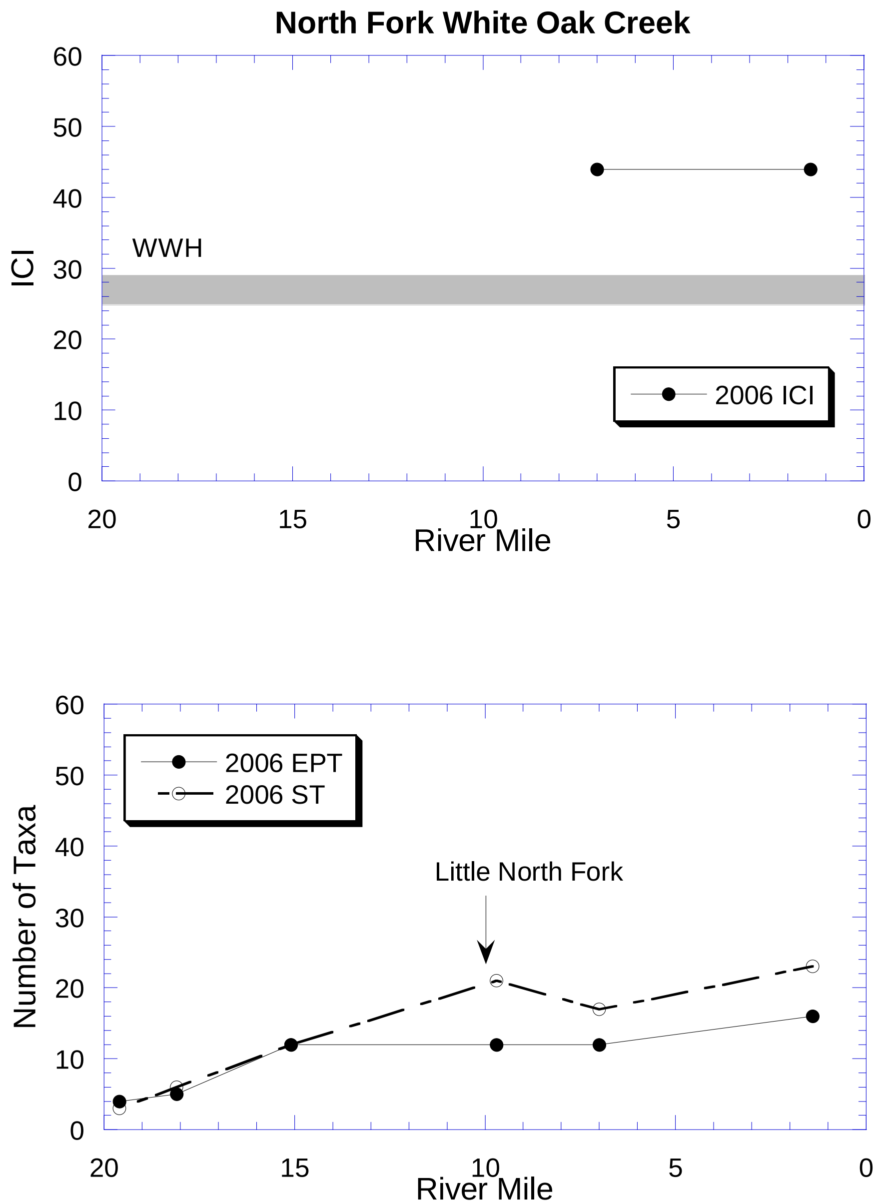


Figure 28. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in the North Fork White Oak Creek, 2006.

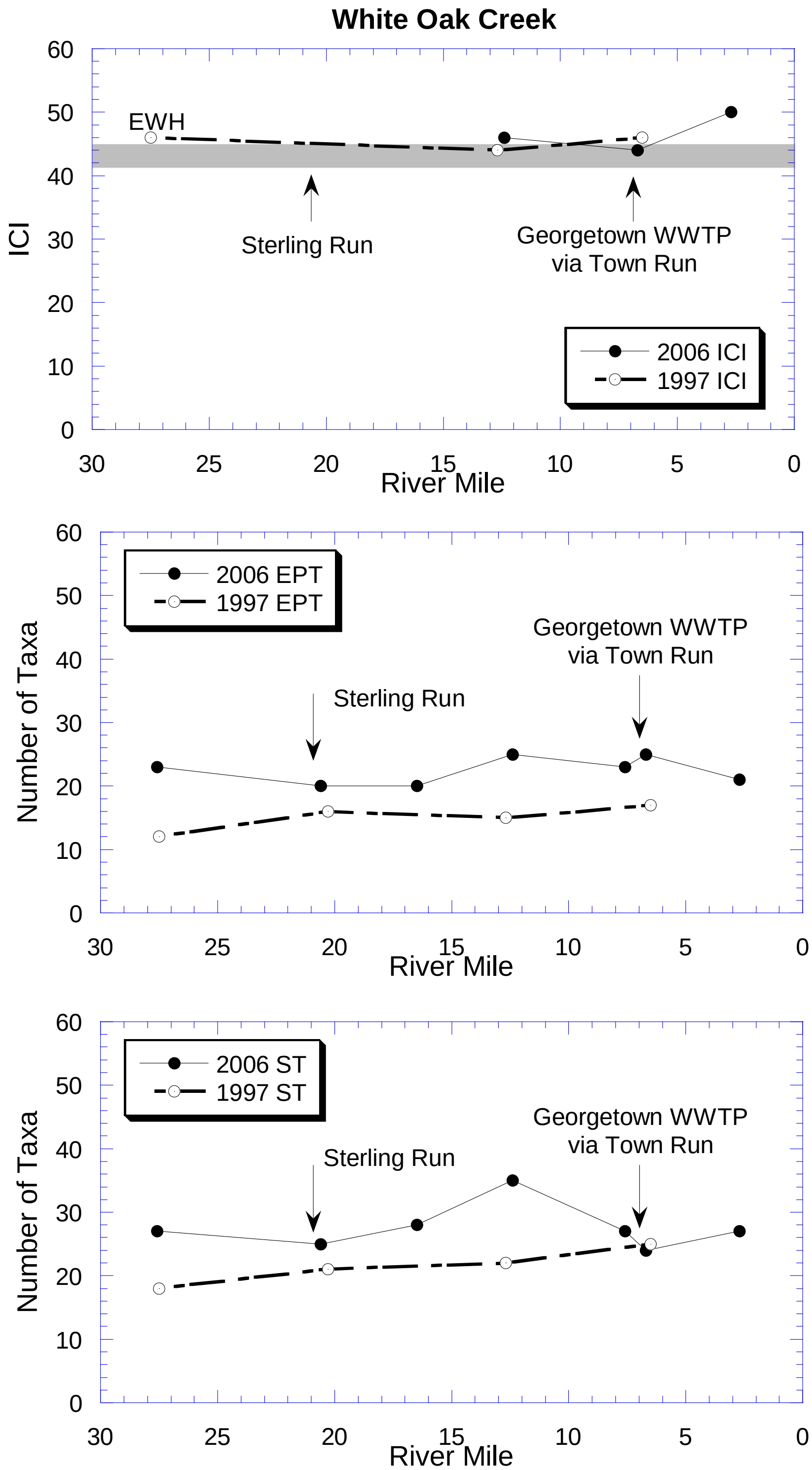


Figure 29. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in White Oak Creek, 1997-2006.

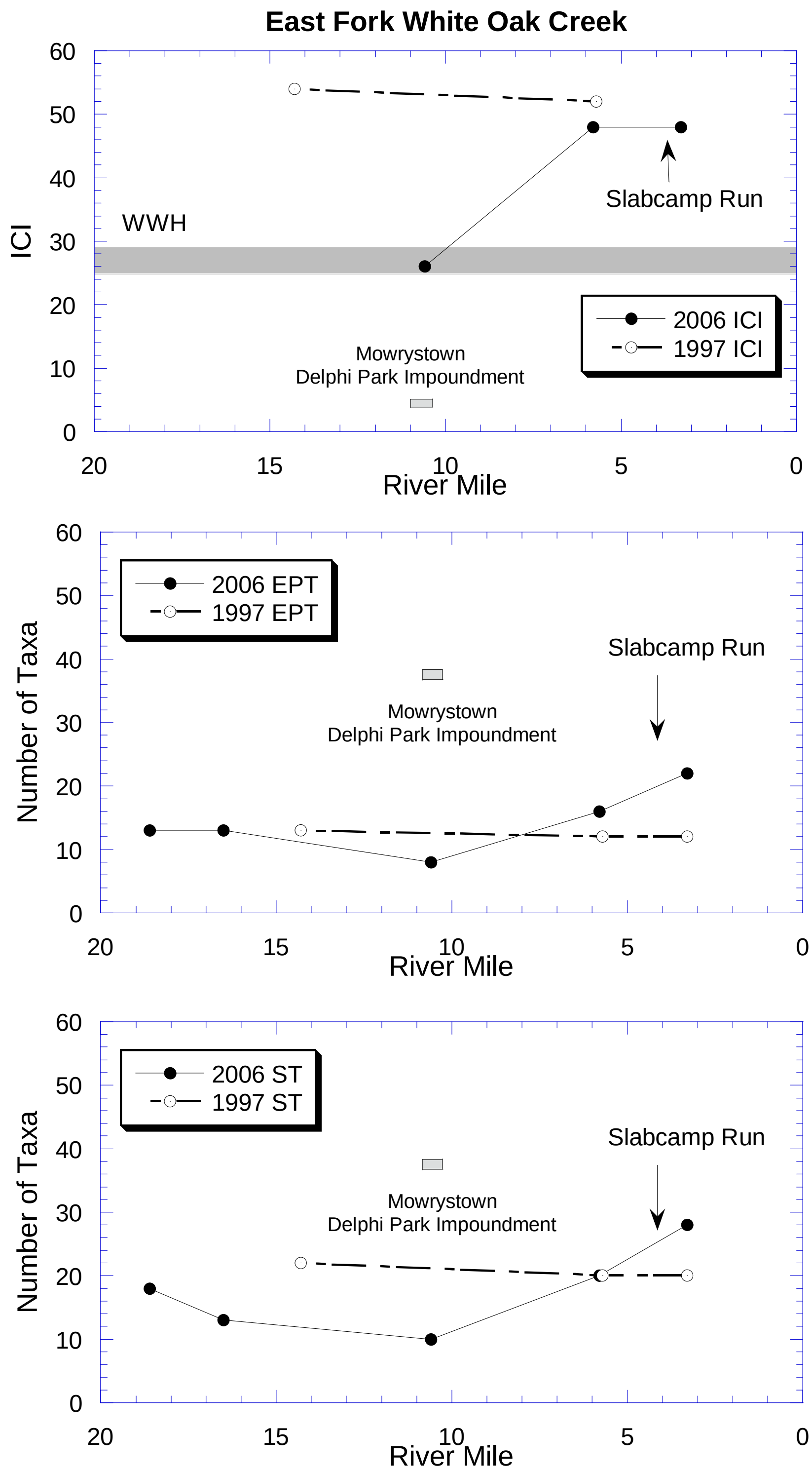


Figure 30. Longitudinal trend of the Invertebrate Community Index (ICI), qualitative EPT, and qualitative sensitive taxa (ST) in the East Fork White Oak Creek, 1997-2006.

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