State of Ohio Environmental Protection Agency

2006 Biological and Water Quality Study of the Muskingum River

March 30, 2007

Ted Strickland, Governor
Chris Korleski, Director

Biological and Water Quality Study of the Muskingum River

2006

Coshocton, Muskingum, Morgan, Washington Counties, Ohio
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prepared by

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NOTICE TO USERS

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

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

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

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

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

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

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

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

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

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

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) 836-8786

or

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

FOREWORD

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

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

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

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

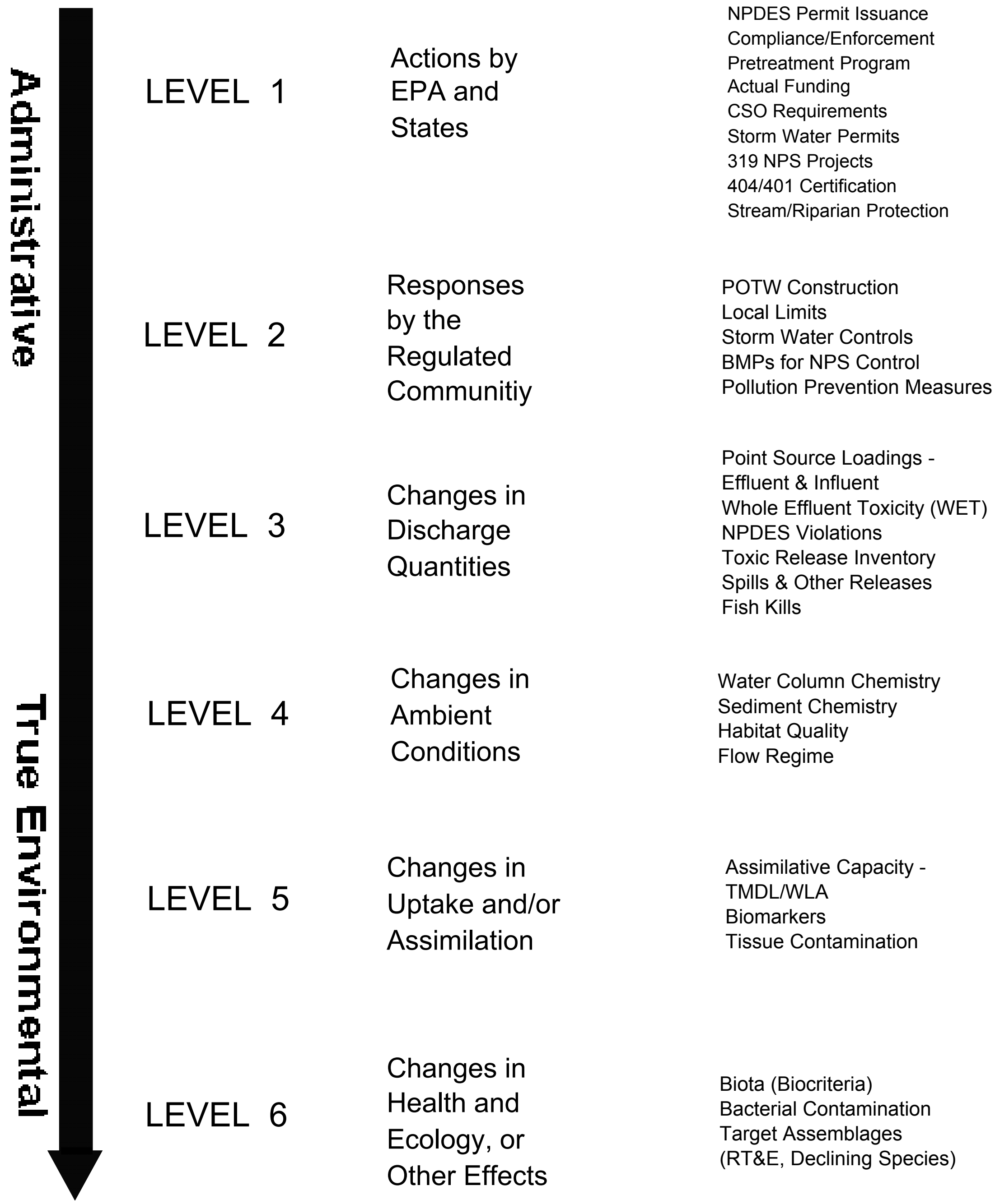

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

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.

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Report preparation and analysis: David Altfater, Mike Gray, Kelly Capuzzi, Mike Sherron
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INTRODUCTION

The Muskingum River drains the largest watershed in Ohio, encompassing 8,051 square miles. Ten locks and dams are currently located on the mainstem of the lower 85 miles of the Muskingum River. This system of dams and locks, built for easier steamboat travel, was one of the earliest slack water systems in the United States. The Muskingum River is no longer used for commercial navigation. The damage from the catastrophic flood of 1913, combined with the growth of roads and railroads, marked the beginning of the end of commercial navigation on the Muskingum River. Today, recreational boaters use the river, with more than 5,800 boats "locking through" the river's 90 mile navigation system annually.

The Muskingum River also has an impressive natural heritage. Freshwater mussels are mollusks that belong to the same group of animals as clams and oysters. Mussels serve an important role in the ecosystem by filtering water and providing food for other wildlife. Ohio historically had one of the richest populations of mussels, with some 80 species living in its rivers and streams at one time. The Muskingum River at one time included over 60 species. The lower Muskingum River is home to two federally endangered mussels—the fanshell and the pink mucket pearly mussel—and to three of Ohio's endangered mussels—Ohio pigtoe, the butterfly mussel and the washboard mussel. Ohio's threatened species—the three-horned warty-back mussel and fawn's foot—are also found in this river.

During 2006, Ohio EPA conducted a water resource assessment of the entire 112 miles of the Muskingum River. Included in this study is an assessment of the biological, surface water, sediment, and recreational (bacterial) conditions. A total of 28 biological, 15 water chemistry, 15 bacterial, 12 sediment, and 17 fish tissue stations were sampled in the Muskingum River.

Specific objectives of the evaluation were to:

- establish the present biological conditions in the Muskingum River by evaluating fish and macroinvertebrate communities,
- assess conditions in both impounded sections of river and free-flowing segments,
- assess physical habitat influences on stream biotic integrity,
- identify the relative levels of organic, inorganic, and nutrient parameters in the sediments and surface water,
- determine recreational water quality,
- evaluate influences from NPDES outfalls directly discharging to the Muskingum River,
- determine the attainment status of the Warmwater Habitat aquatic life use designation,
- compare present results with historical conditions, and
- collect fish samples for the Ohio Sport Fish Consumption Advisory Program (used to assess chemical contaminant levels in fish).

The Muskingum River is located in the Western Allegheny Plateau (WAP) ecoregion and is currently assigned the Warmwater Habitat (WWH) aquatic life use designation in the Ohio Water Quality Standards (WQS).

EXECUTIVE SUMMARY

Biological sampling in the Muskingum River during 2006 demonstrated that the entire length of river is fully attaining the Warmwater Habitat aquatic life use designation. This achievement reflects a high level of biological integrity, and meets the biological goals of the Clean Water Act. Surveys of the fish and macroinvertebrate (aquatic insects and mussels) communities of the Muskingum River revealed healthy populations of numerous pollution sensitive species, along with localized populations of rare, threatened, and endangered species. Most of the free-flowing and tailwater sites supported exceptional biological communities, and revealed the exceptional biological potential for the entire river if the dams were removed. The last major biological study of the entire Muskingum River occurred in 1988, and this study documented that substantial improvement in biological conditions has occurred over the last 20 years.

Seven sections of the Muskingum River are currently listed as Superior High Quality Waters (SHQW) in the Ohio Water Quality Standards. Based on sampling conducted during 2006, two additional sections are recommended to be designated SHQW. Because the SHQW designation is used for exceptional quality streams, it offers added protections from pollutant loadings to the river.

Chemical water testing results were generally reflective of good water quality. Nutrients, metals, and organic parameters were within reference levels at most sampling locations. Slightly elevated ammonia-nitrogen levels, a chemical often associated with wastewater discharges, were noted downstream from the Zanesville WWTP. Summer temperature readings in the Muskingum River documented values elevated above water quality criteria downstream from the AEP Muskingum River Electrical Generating Station. However, biological communities at this location and further downstream were meeting biological criteria. River sediments were tested for heavy metals and organic compounds, and results were within acceptable ecological levels.

The Muskingum River is designated as a Primary Contact Recreation (PCR) use in OAC Rule 3745-1-24. To meet the recreational use water quality criteria applicable to the Muskingum River, at least one of the two bacteriological standards (fecal coliform or *E. coli*) must be met. Evaluation of fecal coliform and *E. coli* results revealed all but two locations fully attaining the recreational use. The two locations not attaining the recreational use include the ODNR boat ramp area in McConnelsville, which is located downstream from the McConnelsville WWTP discharge, and the Beverly area at State Route 339. The source of the elevated bacteria levels in McConnelsville were found to be untreated sewage discharged to the river from the McConnelsville sewer system. The source of bacteria in Beverly is unknown but is suspected to be from agricultural sources in the Wolf Creek watershed.

Samples collected during high flow river conditions also revealed high bacteria levels, with most samples above PCR recreational criteria. The elevated bacteria levels were largely associated with elevated suspended solids levels in the river, resulting from high river flows. Sediments in aquatic systems can be a significant reservoir for pathogenic organisms and indicator bacteria. Sediment resuspension can significantly increase bacteria counts in overlying waters. Runoff from farm fields and discharges from combined sewer overflows could also contribute bacteria to the river during rain events.

Tests for PCBs, pesticides, and several heavy metal chemicals in fish collected from the Muskingum River will characterize current levels of these contaminants in sport fish caught and consumed by area fisherman. Testing results will be reported in Ohio's Sport Fish Consumption Advisory Program (http://www.epa.state.oh.us/dsw/fishadvisory/index.html), which includes yearly fish consumption updates for rivers, streams, lakes, and reservoirs throughout Ohio. The advisories are typically updated during February.

RECOMMENDATIONS

The current Warmwater Habitat aquatic life use designation should be maintained for the Muskingum River. The Muskingum River shows the potential to attain the Exceptional Warmwater Habitat use designation in the upper 20 miles of free-flowing river, and this possibility should be further investigated when the next survey is completed. Physical habitat features are adequate for supporting the EWH use, and biological communities were nearly fully achieving the EWH biocriteria during 2006 (all macroinvertebrate sites were exceptional). Non-aquatic life uses of Agricultural Water Supply, Industrial Water Supply, and Primary Contact Recreation should be retained.

Seven segments of the Muskingum River are listed as Superior High Quality Waters in the Antidegradation Rule (OAC 3745-1-05) of the Ohio Water Quality Standards (Table 1). These segments were designated based on the presence of threatened or endangered species and a high level of biological integrity. Included in evaluating exceptional biological value was a determination of declining fish species, high quality habitat to support declining and threatened fish species, and a display of biological integrity equivalent to the Exceptional Warmwater Habitat Index of Biotic Integrity and/or Invertebrate Community Index criteria listed in rule 3745-1-07 of the Ohio Administrative Code.

Based on biological sampling conducted during this study, two additional segments of the Muskingum River are recommended for designation as Superior High Quality Waters (Table 1). The segment from Ellis Dam to Blunt Run (RMs 84.87 to 83.38) contained three declining fish species, a stable population of river redhorse – a special interest fish, very good to exceptional biological index scores, and high quality river habitat. The segment from Luke Chute Dam to Meigs Creek (RMs 33.66 to 29.42) contained one threatened mussel (fawnsfoot), one declining fish species, a stable population of river redhorse, very good to exceptional biological index scores, and high quality river habitat. Additionally, the SHQW segment from Salt Creek (RM 67.03) to Branch Run (RM 52.58) should have the upper end extended to Philo Dam (RM 67.52), to encompass high quality habitat and exceptional biological diversity located downstream from the dam.

Table 1. List of current and recommended Superior High Quality Water (SHQW) segments for the Muskingum River.

Muskingum River Segment	River Mile	Antidegradation Category
Confluence of Tuscarawas and Walhonding Rivers to State Route 208 (Dresden)	111.13 – 92.0	SHQW - Current
Ellis Dam to Blunt Run	84.87 – 83.38	SHQW - Recommended
Licking River to Moxahala Creek	76.20 – 73.50	SHQW - Current
Salt Creek to Branch Run (Philo Dam to Branch Run)	67.03 – 52.58 (67.52 – 52.58)	SHQW – Current (SHQW – Recommended)
McConnelsville Dam to Madison Run	49.0 – 34.4	SHQW – Current
Luke Chute Dam to Meigs Creek	33.66 – 29.42	SHQW - Recommended
Beverly Dam to Cushing Run	24.9 – 18.77	SHQW - Current
Lowell Dam to Rainbow Creek	14.1 – 7.7	SHQW - Current
Devola Dam to the mouth	5.77 – 0.0	SHQW - Current

Recommendations for Recreational Use Attainment

Two areas of the Muskingum River were found to be in non-attainment of the Primary Contact Recreation use, based on bacteria samples (Table 6). These areas include McConnelsville at the Ohio DNR boat ramp and Beverly at SR 339. The public should be aware that there is a high potential of being exposed to bacteria at these locations and they should take precautions to minimize exposure, especially for children, pregnant woman, the elderly, and anyone with a compromised immune system. The public should also be aware that during high flow conditions, bacteria levels will most likely be elevated throughout the river potentially due to discharges from combined sewer overflows, runoff from non-point sources such as farm fields, or resuspension of bacteria that may be trapped in sediment.

McConnelsville at the Ohio DNR Boat Ramp
Ohio EPA recommends that the Village of McConnelsville erect a sign at the ODNR boat ramp to warn the public about the potential for bacteria exposure at the boat ramp. Both the Village of McConnelsville and Malta has several combined sewer overflows located upstream from the boat ramp. These overflow regularly, and often for extended periods, discharging untreated sewage to the Muskingum River during periods of dry weather. Until these dry weather overflows are eliminated, they will present an increased risk for bacteria exposure to recreationists.

Beverly at SR 339
High bacteria levels were found in Beverly at the SR 339 bridge from an unknown source. Ohio EPA recommends further studies in the Beverly area to determine the source of high bacteria levels at this location. Wolf Creek enters the river just upstream from SR 339 and in the past, manure spills have been reported to Ohio EPA. Numerous farms are located on this tributary to the Muskingum River and could be a potential source of bacteria, especially if there are farms with highly concentrated livestock or poor manure management. Ohio EPA will conduct a bacteria study of Wolf Creek during the summer of 2007 and will make further recommendations to correct this problem.

Table 2. Aquatic life use attainment status for sampling locations in the Muskingum River, 2006. The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biological community. The Muskingum River is located in the Western Alleghany Plateau (WAP) ecoregion and is designated a WWH waterbody. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted.

Sample Site River Mile	Attainment Status	IBI	MIwb	ICI[a]	QHEI	Location	Cause	Source
110.7	FULL	45	9.4	E	71.0	Upstream Coshocton WWTP	None	None
107.6	FULL	48	9.5	E	83.0	Downstream Coshocton WWTP	None	None
105.0	FULL	47	9.3	48	83.5	Downstream AK Steel – Coshocton	None	None
101.8	FULL	43	9.5	56	82.0	Downstream Conesville EGS	None	None
97.4	FULL	44	9.5	E	86.0	Stillwell Road	None	None
92.2	FULL	46	8.8	E	83.0	State Route 208 - Dresden	None	None
87.0	FULL	36[ns]	6.8[b]	42	60.5	Ellis dam pool	None	None
84.6	FULL	46	10.1	48	79.0	Ellis dam tailwaters	None	None
80.2	FULL	40	9.0	42	60.5	Zanesville dam pool	None	None
77.6	(FULL)	40	7.1[b]	26[b]	54.0	Downstream AK Steel – Zanesville	None	None
75.8	FULL	43	9.4	50	82.0	Zanesville dam tailwaters	None	None
72.4	FULL	46	9.0	42	60.5	Downstream Zanesville WWTP	None	None
67.3	FULL	46	9.7	48	85.0	Philo dam tailwaters	None	None
63.7	FULL	42	8.9	44	57.0	Rokeby dam pool	None	None
56.4	FULL	44	8.9	38	75.5	Rokeby dam tailwaters	None	None
52.1	FULL	44	9.6	G	61.0	McConnelsville dam pool	None	None
48.8	FULL	50	9.8	44	81.0	McConnelsville dam tailwaters	None	None
43.2	FULL	38[ns]	8.5[ns]	44	63.5	Stockport dam pool	None	None
39.5	FULL	46	9.4	48	84.5	Stockport dam tailwaters	None	None
36.2	FULL	44	8.7	40	63.5	Luke Chute dam pool	None	None
33.5	FULL	47	9.8	44	84.0	Luke Chute dam tailwaters	None	None
29.2	FULL	48	10.2	50	64.0	Upstream Muskingum EGS	None	None
26.2	FULL	44	9.3	46	64.5	Downstream Muskingum EGS	None	None
24.7	FULL	48	9.8	48	85.5	Beverly dam tailwaters	None	None
20.9	FULL	40	9.1	50	62.0	Lowell dam pool	None	None
13.9	FULL	42	10.3	42	86.0	Lowell dam tailwaters	None	None
9.4	FULL	44	9.6	36	60.0	Devola dam pool	None	None
5.6	FULL	38[ns]	9.7	50	86.0	Devola dam tailwaters	None	None

Ecoregion Biocriteria: Western Alleghany Plateau (WAP)		
INDEX - Site Type	WWH	EWH
IBI: Boat	40	48
MIwb: Boat	8.6	9.6
ICI	36	46

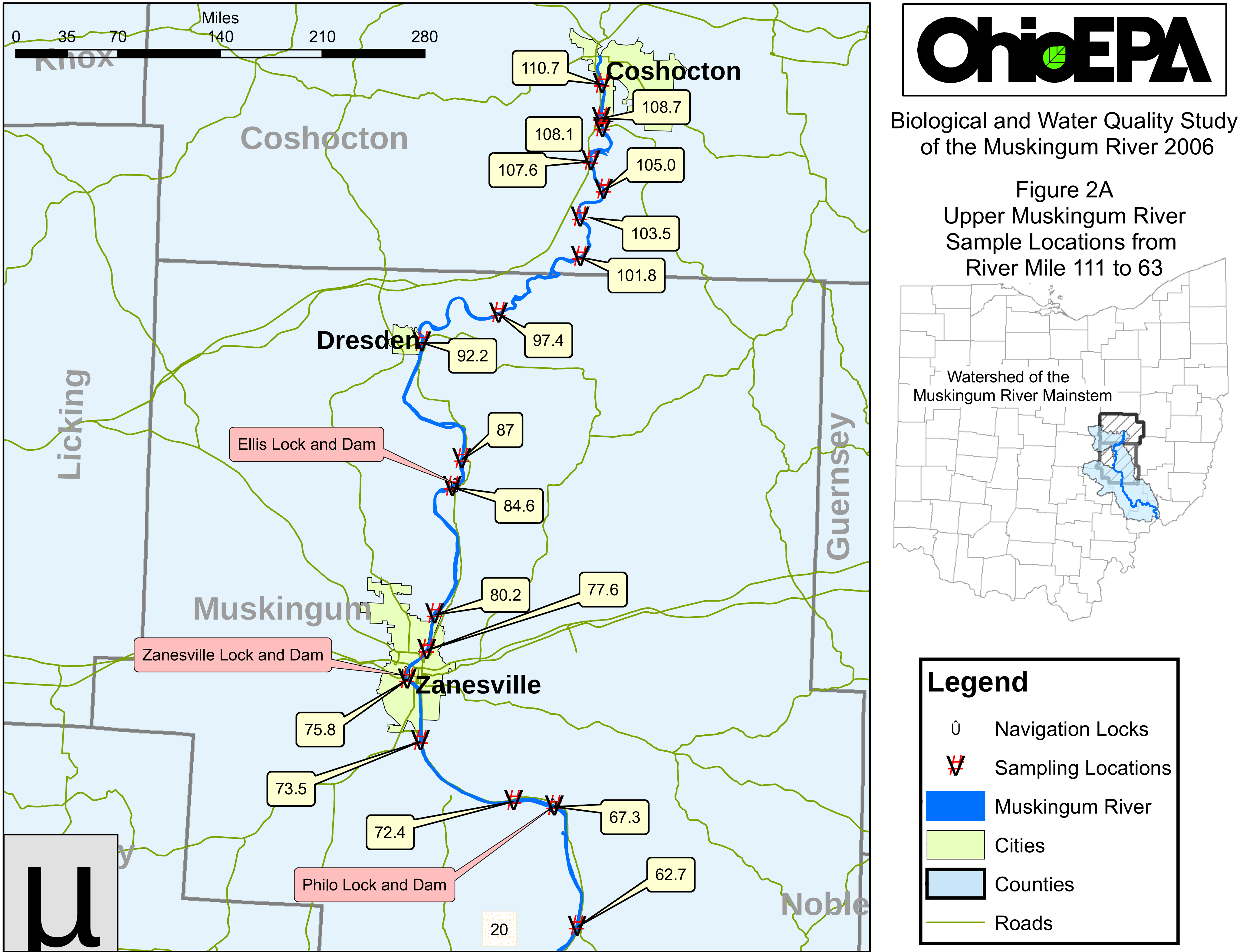
[ns] Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
[a] Narrative evaluation used in lieu of ICI (E=Exceptional; G=Good).
[b] Due to unsuitable sample conditions, results were not used in the use attainment evaluation (see text).

Table 3. Sampling locations in the Muskingum River, 2006. Type of sampling included fish community (F), macroinvertebrate community (M), sediment (S), sediment organics (SO), surface water (W), surface water organics (WO), bacteria (B), fish tissue (T), HOBO© continuous temperature recorder (TR), and Datasonde© continuous water quality recorder (D).

Stream/ River Mile	Type of Sampling	Latitude	Longitude	Landmark
Muskingum River				
110.7	F, M	40.268833	81.875722	Upstream Coshocton WWTP
108.7	W, B, S	40.241387	81.872798	Coshocton Boat Ramp
108.1	W, B, T	40.236327	81.871701	SR 83 Dst Coshocton WWTP
107.6	F, M	40.227611	81.865639	Downstream Coshocton WWTP and State Route 83
106.4	D	40.217806	81.880611	Tyndall area
105.0	F, M, TR	40.199694	81.872194	Downstream AK Steel – Coshocton Plant, Ust. Conesville EGS
103.5	W, WO, B	40.18780	81.88790	CR 273 - Conesville
102.2	T	40.17076	81.88191	Downstream Conesville EGS
101.8	F, M, S, SO, TR	40.166389	81.887500	Downstream Conesville EGS
97.4	F, M, D, W, S	40.138361	81.940694	Stillwell Road
92.2	F, M, W, B	40.123306	81.999194	State Route 208 - Dresden
91.8	T	40.118931	82.000717	Downstream State Route 208 - Dresden
88.6	TR	40.079306	81.997306	Downstream Dresden Energy
87.0	F, M	40.070889	81.970194	Ellis dam pool
86.0	S	40.05730	81.97250	Ellis dam pool
84.6	F, M, W, B, T	40.041139	81.981472	Ellis dam tailwaters
80.2	F, M	39.988917	81.976861	Upstream AK Steel – Zanesville, Zanesville dam pool
77.6	F, M, S, T	39.955028	81.997833	Downstream AK Steel – Zanesville, Zanesville dam pool
75.8	F, M, W, WO, B, T	39.936806	82.008139	Zanesville dam tailwaters, Upstream Zanesville WWTP, US 22
73.5	W, B, T	39.906650	82.003563	Immediately upst. Moxahala Creek, Dst. Zanesville WWTP
72.4	F, M	39.890639	81.995611	Philo dam pool, downstream Zanesville WWTP
72.0	S,SO	39.87210	81.93740	Near Frazier, Dst. Zanesville WWTP, Philo dam pool
67.3	F, M, W, B	39.868500	81.906694	Philo dam tailwaters, @Bridge St. (CR 32)
63.7	F, M	39.819056	81.889417	Rokeby dam pool - near Gaysport
62.7	W, B, S, T	39.803957	81.893614	CR 66 – Gaysport
56.4	F, M	39.731889	81.907194	Rokeby dam tailwaters
52.1	F, M	39.676889	81.886694	McConnelsville dam pool
49.8	W, B	39.648123	81.857069	Between wells at McConnelsville; McConnelsville dam pool
49.4	T	39.646856	81.857028	Downstream Malta boat ramp
48.8	F, M	39.643111	81.847806	McConnelsville dam tailwaters
48.0	B	39.634790	81.837034	Dst. McConnelsville @ ODNR boat ramp
43.2	F, M, T	39.590028	81.788944	Stockport dam pool
42.2	S	39.577741	81.787132	Dst Taylor Hollow Tributary, Stockport dam pool
39.7	W, B	39.547906	81.788709	SR 266 – Stockport, Stockport dam pool
39.5	F, M, T	39.546250	81.790861	Stockport dam tailwaters
36.2	F, M	39.526278	81.744778	Luke Chute dam pool

Table 3. Continued.

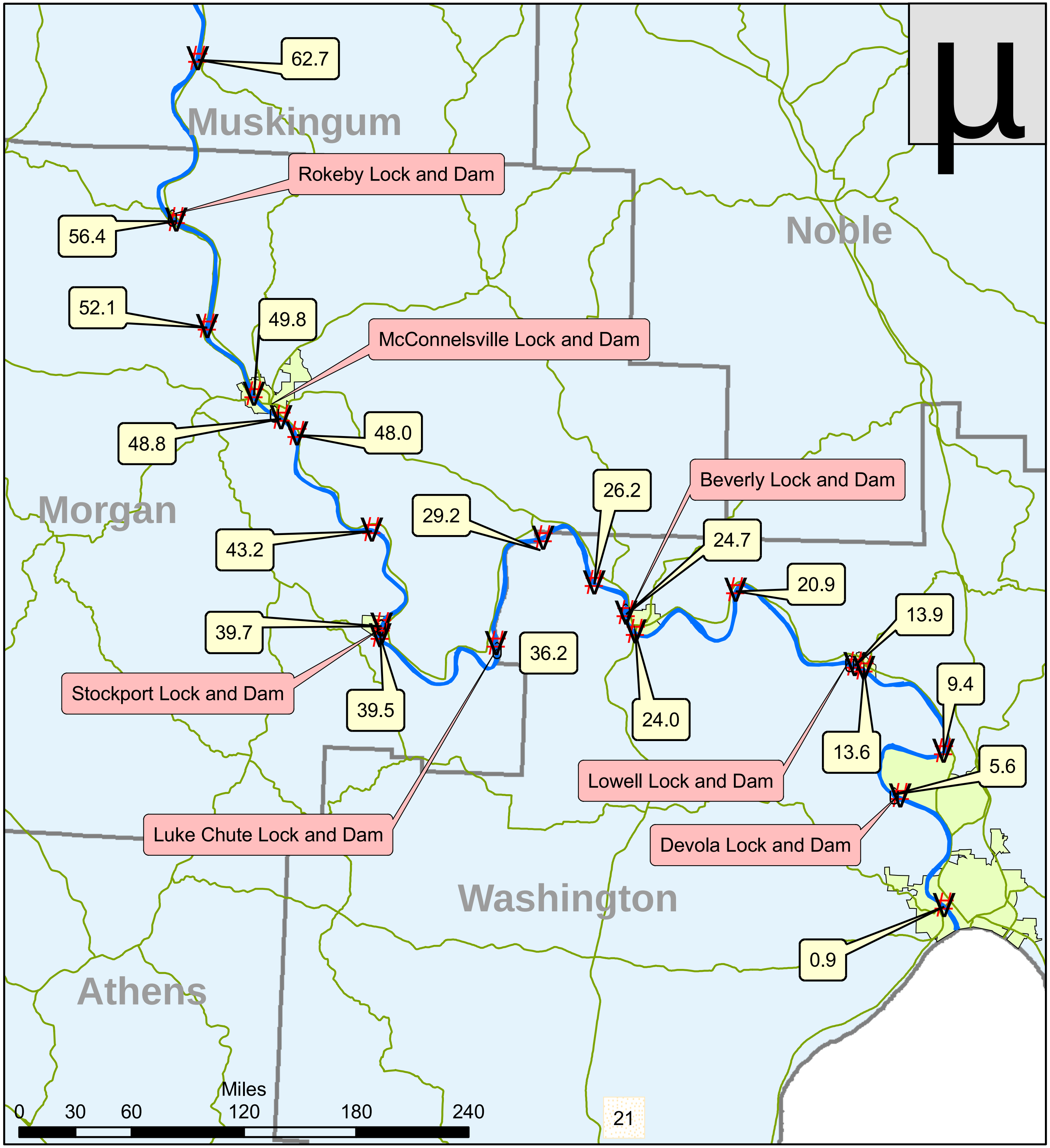
Stream/ River Mile	Type of Sampling	Latitude	Longitude	Landmark
Muskingum River				
33.5	F, M	39.539389	81.723611	Luke Chute dam tailwaters
29.2	F, M, TR, D	39.586917	81.693889	Beverly dam pool, Dst. Meigs Creek, Ust. Muskingum EGS
26.2	F, M, TR, S, SO	39.564972	81.660556	Beverly dam pool, Dst. Muskingum EGS
25.0	D	39.553306	81.647806	Beverly dam pool near dam
24.7	F, M, T	39.552056	81.645583	Beverly dam tailwaters
24.0	W, WO, B, T	39.543611	81.641413	SR 339 – Beverly
20.9	F, M	39.541056	81.597722	Lowell dam pool
19.0	S	39.562613	81.569524	Near Coal Run, Lowell dam pool
18.5	T	39.565778	81.576556	Near Coal Run
13.9	F, M	39.527639	81.513333	Lowell dam tailwaters
13.6	W, B, T	39.526835	81.507132	New Bridge St. – Lowell
9.4	F, M, T	39.489111	81.462500	Devola dam pool
8.1	S	39.489808	81.487389	Devola boat launch, Devola dam pool
5.6	F, M, T	39.468889	81.489694	Devola dam tailwaters
0.9	W, WO, B, S, SO, T	39.419696	81.462541	Washington St. – Marietta


Biological and Water Quality Study of the Muskingum River 2006
Figure 2A
Upper Muskingum River
Sample Locations from
River Mile 111 to 63
Miles
0 35 70 140 210 280
Knox
Coshocton
Licking
Muskingum
Guernsey
Noble
Coshocton
Dresden
Zanesville
110.7
108.7
108.1
107.6
105.0
103.5
101.8
97.4
92.2
87
Ellis Lock and Dam
84.6
80.2
77.6
Zanesville Lock and Dam
75.8
73.5
72.4
67.3
Philo Lock and Dam
62.7
20
Watershed of the
Muskingum River Mainstem
Legend
Navigation Locks
Sampling Locations
Muskingum River
Cities
Counties
Roads

Ohio EPA

Biological and Water Quality Study of the Muskingum River 2006

Figure 2B
Lower Muskingum River
Sample Locations from
River Mile 63 to Ohio River



Legend

- Navigation Locks
- Sampling Locations
- Muskingum River
- Cities
- Counties
- Roads

METHODS

All chemical, physical, and biological field, EPA laboratory, data processing, and data analysis methods and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 2006a), Manual of Laboratory Operating Procedures, Volumes I-IV (Ohio EPA 2002), Biological Criteria for the Protection of Aquatic Life, Volumes II-III (Ohio Environmental Protection Agency 1987b, 1989a, 1989b) including the 2006 updates, The Qualitative Habitat Evaluation Index (QHEI); Rationale, Methods, and Application (Rankin 1989) for habitat assessment, Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001), and Ohio EPA Fish Collection Manual (Ohio EPA 2005).

Determining Use Attainment

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 Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (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 1) 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. All biological results were compared to WWH biocriteria for the Western Allegheny Plateau ecoregion.

Stream Habitat Evaluation

Physical habitat is evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, diverse aquatic faunas. Evaluations of type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient are among the metrics used to evaluate the characteristics of a stream segment, not just the characteristics of a single sampling site. As such, individual sites may have much 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 higher than 60 were generally conducive to the establishment of warmwater faunas while those which scored in excess of 75-80 often typify habitat conditions which have the ability to support exceptional faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples were collected multi-incrementally in the upper four inches of bottom material at each location using decontaminated stainless steel scoops. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment incremental samples were homogenized in stainless steel pans, transferred into glass jars with teflon lined lids, placed on ice (to maintain $4^{o}C$) in a cooler, and delivered to Ohio EPA's Environmental Services laboratory. Sediment data is reported on a dry weight basis. Surface water samples were collected directly into appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Surface water samples were collected five times from each location from the upper 12 inches of water over the course of the field sampling season. Collected water was preserved using appropriate methods, as outlined in Parts II and III of the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 2006a). DataSonde© continuous recorders were placed at four locations to evaluate diel measurements of dissolved oxygen, pH, temperature, and conductivity. HOBO© continuous recorders were placed at five locations to measure water temperatures over a six week period. Bacteriological samples were collected 11 times at each location. Bacteriological samples were collected directly from the river into sterilized polyethylene containers, cooled to 4°C, and transported to the Ohio EPA laboratory for analysis within 6 hours of sample collection. All samples were analyzed for fecal coliform and *E. coli* bacteria using U.S.EPA approved methods.

Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature. Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000), along with a comparison of metals results to Ohio Sediment Reference Values (Ohio EPA 2003).

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats at the Muskingum River sampling locations (Table 3). 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). At 3 of the 28 sampling sites (RM 110.7, 107.6, and 97.4) the artificial substrate samplers were not collected as declining flow left them out of the water. At these locations, the qualitative sample was used to assess the macroinvertebrate community condition. At each macroinvertebrate sampling site within a dam pool, two composite artificial substrate samples were used. One was placed in a wading accessible location near the shoreline in a manner consistent with OEPA historical sampling methods. The other was set on the bottom in mid-channel in water from 8-14 feet deep. 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 1989a), including the 2006 update.

Fish Community Assessment

Fish were sampled once or twice at each site using pulsed DC electrofishing methods. Night electrofishing occurred once at each impounded sampling location. All free-flowing sites were sampled twice during daylight hours. The Muskingum River was sampled using the boat electrofishing method, with sampling distances of 500 - 550 meters. 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 1989a).

Fish Tissue

Tissue fillet samples were collected from fish of edible size, and species collected for analysis included common carp, smallmouth buffalo, flathead catfish, channel catfish, freshwater drum, spotted bass, saugeye, white x striped bass, white bass, smallmouth bass, and largemouth bass. When possible, composite samples (by species) were collected using a minimum of three fish and a minimum of 150 grams of material. At each sampling location, an attempt was made to collect five fish species for tissue analysis. Fish were sampled using boat electrofishing methods. Sampling locations are listed in Table 2.

Fish samples were filleted in the field using decontaminated stainless steel fillet knives. Filleted samples were wrapped in aluminum foil, placed in a sealed plastic bag, and placed on dry or wet ice. Sampling and decontamination protocols followed those listed in the Ohio EPA Fish Collection Manual (2005); however, it is not necessary to clean aluminum foil which was used directly from the roll. Fish tissue samples were delivered to Ohio EPA's Environmental Services laboratory.

Field Instrument Calibration

Field instruments are calibrated using manufacturer recommended procedures along with procedures noted in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (2006a) and Biological Criteria for the Protection of Aquatic Life, Volume III (1989b). pH, conductivity, and dissolved oxygen meters were calibrated daily before the start of field work. Datasonde© recorders were calibrated at the Ohio EPA Groveport Field Facility before placement in the field. Laser rangefinders, used to measure sampling distance, were calibrated once at the Groveport Field Facility prior to summer field sampling activities. Fish weighing scales were checked against certified weights once per week during the field season. Calibration of pH, conductivity, dissolved oxygen, fish weighing scales, and laser rangefinders were recorded in a logbook maintained by Ohio EPA, Ecological Assessment Section and Southeast District Office.

Causal Associations

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

RESULTS

Surface Water Quality

Surface water grab samples were collected from the Muskingum River at 15 locations (Figure 2) between June 15 and October 17, 2006. Stations were established in free-flowing, impounded, and tailwater sections of the river, and were primarily collected from bridge crossings.

River flows measured at two United States Geological Survey (USGS) gages on the Muskingum River are presented in Figures 3 and 4. Dates when water samples and bacteria samples were collected in the Muskingum River are noted on each graph. Flow conditions during the 2006 sampling season were mostly above the historical monthly median flows. Both water and bacteria samples captured a variety of flow conditions in the Muskingum River during the survey.

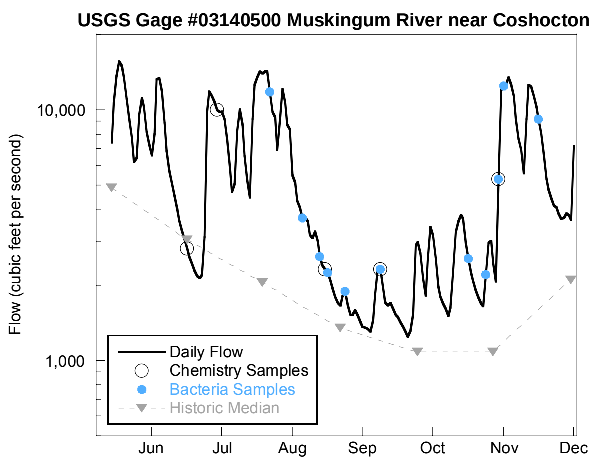


Figure 3. River flow conditions in the Muskingum River near Coshocton during the 2006 Ohio EPA survey.

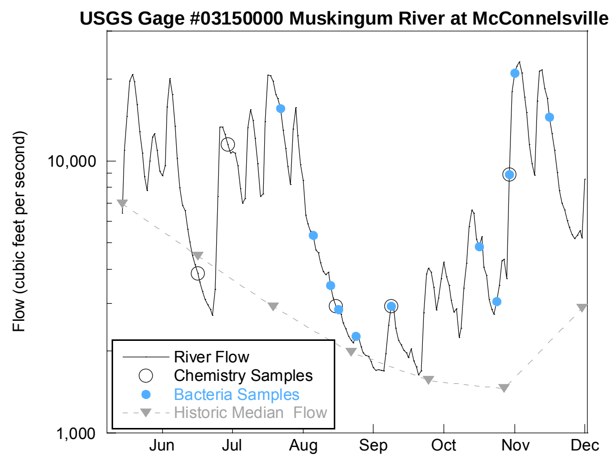


Figure 4. River flow conditions in the Muskingum River at McConnelsville during the 2006 Ohio EPA survey.

Surface water samples were analyzed for metals, nutrients, suspended and dissolved solids, PCBs, semivolatile organic compounds, and organochlorinated pesticides (Appendix Tables 1 and 2). Parameters which were in exceedance of Ohio WQS criteria are reported in Table 4. Bacteriological samples were collected from 15 locations, and the results are reported in the Recreational Use section. DataSonde© water quality recorders were placed at four locations (upstream and downstream from two power plants) to monitor hourly levels of dissolved oxygen, pH, temperature, and conductivity. Measurements were conducted from August 29 - 31, 2006 (Appendix Table 5). HOBO© temperature recorders were placed in the Muskingum River at five locations to assess temperature regimes upstream and downstream from two major power plants, and also downstream from a natural gas power plant near Dresden (Appendix Table 6).

Organic chemical analyses were conducted on water samples collected from four locations (Table 3). All PCBs and pesticide measurements were reported as not detected. Aside from the chemical hexachlorobenzene, all analyses for semivolatile organic compounds were reported as not detected. The one detectable hexachlorobenzene measurement was below the Ohio WQS criterion.

Metals were measured at 15 river locations, with 17 parameters tested (Appendix Table 1). One lead value exceeded the Ohio WQS aquatic life outside mixing zone average criterion. Mercury exceedances were noted at five locations (Table 4), with values reported above the Human Health drink and non-drink criteria. River flows and suspended solids levels were compared to concentrations of lead and zinc in the Muskingum River (Figures 5 and 6).

Table 4. Exceedances of Ohio Water Quality Standards criteria (OAC3745-1) for chemical/physical parameters measured in the Muskingum River, 2006. Excludes bacteria values.

River Mile	Parameter (value – ug/l)
RM 108.7	None
RM 108.1	Mercury (0.26[a])
RM 103.5	None
RM 97.4	None
RM 92.2	None
RM 84.6	None
RM 75.8	Lead (13.3[b])
RM 73.5	None
RM 67.3	Mercury (0.24[a])
RM 62.7	None
RM 49.8	Mercury (0.39[a])
RM 39.7	Mercury (0.22[a])
RM 24.0	Temperature (29.47[c])
RM 13.6	Temperature (29.60[c])
RM 0.9	Mercury (0.26[a]), Temperature (29.93[c])

[a] Exceedance of the Human Health drink and non-drink criteria.
[b] Exceedance of the aquatic life Outside Mixing Zone Average water quality criterion.
[c] Exceedance of the average river temperature criterion, August 1-31.

Analysis of the relationship between TSS and total zinc concentrations in the Muskingum River indicate a strong positive correlation (Figure 5). Elevated TSS levels were recorded at sampling locations during the two sampling days when river flows were highly elevated above normal. A similar condition was observed with lead levels and river flows (Figure 6). During normal and low flow conditions in the Muskingum River, lead and zinc levels are low. When rainfall events contribute soils and surface runoff to the river, an increase in these chemicals was observed.

Aside from the above noted exceedances, metals concentrations were very low at all river sampling locations, with nearly half of the tested parameters less than lab detection limits. Metal parameters (excluding the above noted measurements) with detectable concentrations were below applicable Ohio WQS aquatic life criteria.

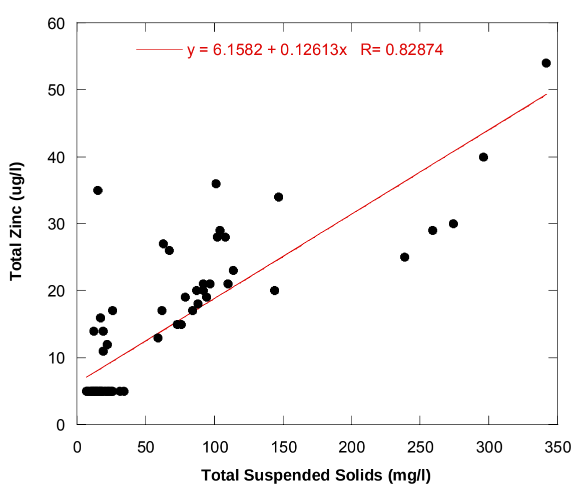


Figure 5. Plot of total zinc against corresponding total suspended solids (TSS) values for water samples collected from the Muskingum River, 2006.

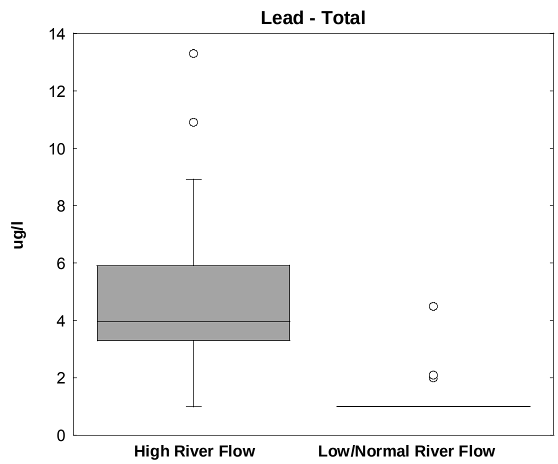


Figure 6. Box plots of total lead concentrations in surface water samples collected from the Muskingum River, 2006. High river flows were greater than 8900 cfs at the McConnelsville USGS gage. Low/normal flows ranged between 2910 and 3810 cfs.

Nutrients were measured at each water sampling location, and included ammonia-N, nitrate+nitrite-N, total phosphorus, and total Kjeldahl nitrogen (TKN). Summary statistics for nutrients measured in the Muskingum River are detailed in Table 5, and graphically presented in Figures 7, 8, and 9. Nutrient levels were low at all river monitoring locations. Ammonia-N values were substantially below the Ohio WQS average criterion at all locations, and all but one station (RM 73.5 – 0.6 miles downstream from the Zanesville WWTP effluent discharge; also see Figure 21 for Zanesville loadings) had ammonia-N concentrations below large river reference conditions (Figure 7). Nitrate+nitrite-N concentrations at all

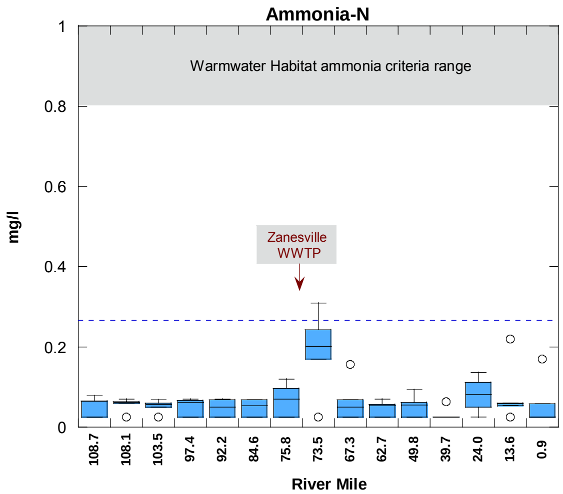


Figure 7. Box plots of ammonia-nitrogen concentrations in surface water collected from the Muskingum River during June - October, 2006. The 90th percentile value (dashed line) from large river reference sites is shown for comparison.

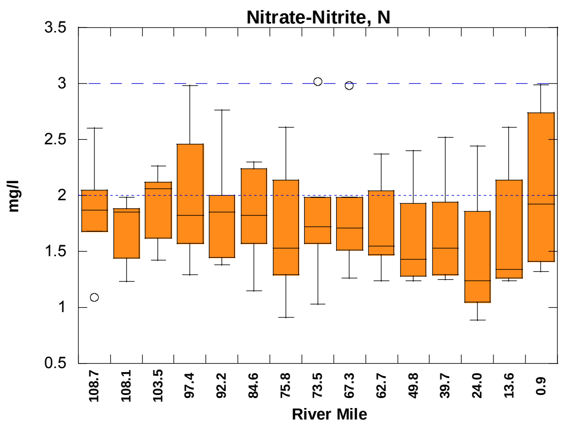


Figure 8. Box plots of nitrate-nitrite nitrogen concentrations in surface water collected from the Muskingum River during June - October, 2006. The 90th percentile value (dashed line) from large river reference sites is shown for comparison. The dotted line is the recommended target level.

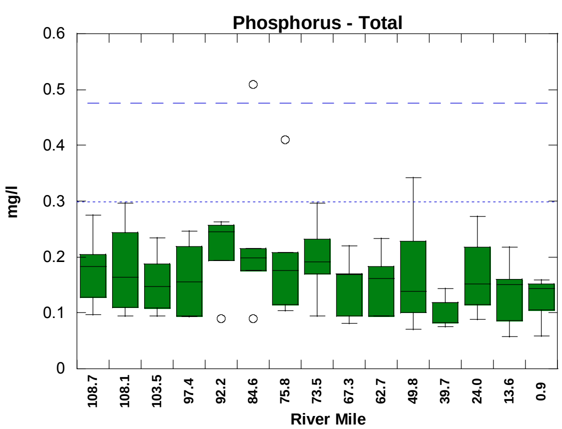


Figure 9. Box plots of total phosphorus concentrations in surface water collected from the Muskingum River during June - October, 2006. The 90th percentile value (dashed line) from large river reference sites is shown for comparison. The dotted line is the recommended target level.

Muskingum River sampling locations were at or below 90th percentile reference conditions (Figure 8). Total phosphorus measurements by sampling location are presented in Figure 9. Results were reflective of good water quality, with all but one sample below the 90th percentile reference value for large rivers. There were no significant trends in phosphorus levels among the sampling locations.

Although nitrate and phosphorus water quality criteria for the protection of aquatic life have not been incorporated into the Ohio WQS, the Ohio EPA has identified target levels for maintaining biological integrity in rivers (Ohio EPA 1999). Results of this analysis recommended nitrate and phosphorus target levels of 2.0 mg/l and 0.3 mg/l, respectively, for large rivers designated with the Warmwater Habitat aquatic life use. An evaluation of the Muskingum River nitrate and phosphorus data displayed in Figures 8 and 9 indicates that most of the nitrate samples were below the target level of 2.0 mg/l, and nearly all of the phosphorus measurements were below the target level of 0.3 mg/l.

DataSonde© hourly monitoring results for dissolved oxygen, temperature, pH, and conductivity at four Muskingum River locations are listed in Appendix Table 5. Conductivity and pH levels were well within acceptable environmental levels, and no discernible difference in measurements was observed between sites located upstream and downstream from the two AEP power plants (Conesville and Muskingum River) discharging to the Muskingum River.

Dissolved oxygen measurements were indicative of good water quality, with all values above the average WWH (5.0 mg/l) water quality criterion (Figure 10). A notable decline in D.O. was observed downstream from the Muskingum River EGS outfall; however, values were still above the water quality criterion. Diurnal swings in D.O. were minimal at all four monitoring stations. Summarized hourly measurements of water temperature using DataSonde© recorders are presented in Figure 11. Water temperatures in the Muskingum River upstream and downstream from the Conesville EGS were comparable, with all values below Ohio WQS average and maximum criteria (the downstream site is located 5.5 miles downstream from the Conesville EGS). A substantial increase in river water temperature was observed in the Muskingum River downstream from the Muskingum EGS. The median temperature value at RM 25.0 from August 29-31, 2006 was 29.9^{o}C, above the average Ohio WQS criterion of 29.4^{o}C. Median and 95th percentile 2006 summer temperatures from the Muskingum River EGS outfall 001 were 31.3 °C and 36.3 °C, respectively.

More extensive monitoring of river water temperatures from early August to mid-September, 2006 occurred at five locations. Data were collected every half hour over a six week period using HOBO© temperature recorders attached to cinder blocks placed on the river bottom. Monitoring locations included stations upstream and downstream from the Conesville EGS and Muskingum EGS, and one station located downstream from Dresden Energy. Dresden Energy was not discharging to the Muskingum River during the 2006 study. Summarized water temperature results are presented in Appendix Table 6. Temperature measurements in the Muskingum River upstream and downstream from the Conesville EGS were well within Ohio WQS criteria (Figure 12). Temperature differences between upstream and downstream monitoring locations of the Muskingum EGS discharge were substantially different, particularly during mid to late August (Figure 13). Nearly all of the August temperature results from the downstream location at RM 26.2 exceeded the Ohio WQS average criterion. Several days exceeded the maximum temperature criterion. RM 26.2 was located approximately two miles downstream from the thermal discharge at the AEP Muskingum River EGS plant. The upstream temperature results at RM 29.2 were all below the Ohio WQS average and maximum criteria.

Table 5. Summary statistics for select nutrient water quality parameters sampled in the Muskingum River, 2006. The 90th percentile value from large river reference sites from the Western Allegheny Plateau ecoregion is shown for comparison. Values above reference conditions are shaded.

	Ammonia—N		Nitrate+Nitrite-N		Phosphorus-T	
River Mile	Mean	Median	Mean	Median	Mean	Median
RM 108.7	0.052	0.065	1.86	1.87	0.177	0.183
RM 108.1	0.056	0.061	1.68	1.85	0.182	0.164
RM 103.5	0.052	0.057	1.90	2.06	0.154	0.147
RM 97.4	0.050	0.062	2.02	1.82	0.162	0.156
RM 92.2	0.048	0.050	1.89	1.85	0.210	0.245
RM 84.6	0.048	0.053	1.82	1.82	0.238	0.199
RM 75.8	0.067	0.070	1.70	1.53	0.203	0.176
RM 73.5	0.190	0.202	1.86	1.72	0.197	0.191
RM 67.3	0.065	0.050	1.89	1.71	0.147	0.168
RM 62.7	0.046	0.054	1.73	1.55	0.154	0.162
RM 49.8	0.052	0.055	1.66	1.43	0.176	0.139
RM 39.7	0.033	0.025	1.71	1.53	0.107	0.118
RM 24.0	0.081	0.081	1.45	1.24	0.166	0.152
RM 13.6	0.083	0.059	1.72	1.34	0.135	0.151
RM 0.9	0.061	0.025	2.08	1.92	0.124	0.144
Reference Value	0.090		3.005		0.478	

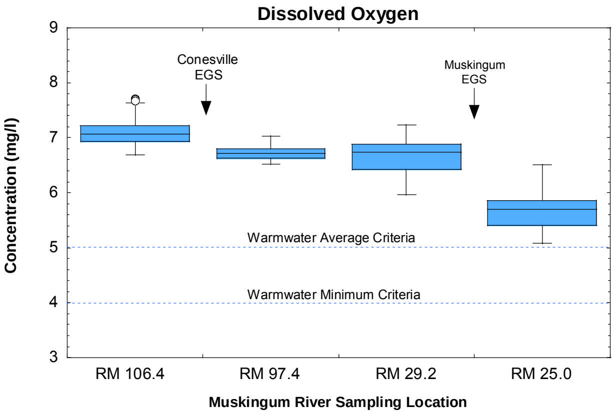


Figure 10. Box plots of hourly dissolved oxygen measurements from four Muskingum River locations, collected August 29-31, 2006. Aquatic life Warmwater Habitat water quality criteria are noted.

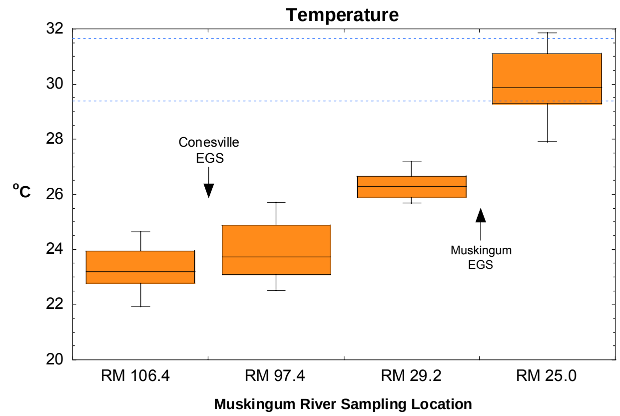


Figure 11. Box plots of hourly temperature measurements from four Muskingum River locations, collected August 29-31, 2006. Temperature water quality criteria are noted (daily maximum and average).

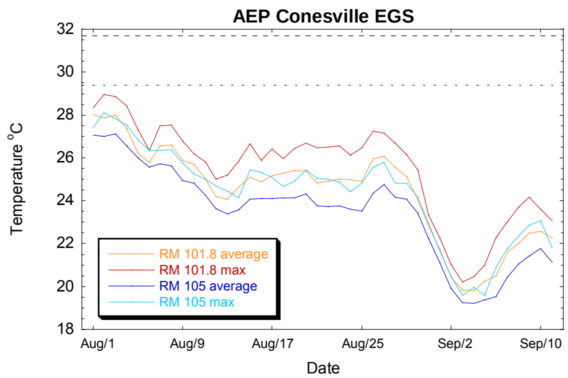


Figure 12. Daily maximum and average temperature measurements (based on half-hourly monitoring) in the Muskingum River upstream (RM 105.0) and downstream (RM 101.8) from the AEP Conesville EGS discharge, August 1 - September 11, 2006. Temperature criteria are indicated by dashed lines (daily maximum and average).

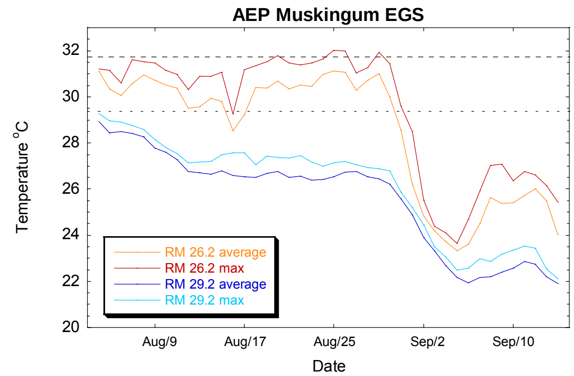


Figure 13. Daily maximum and average temperature measurements (based on half-hourly monitoring) in the Muskingum River upstream (RM 29.2) and downstream (RM 26.2) from the AEP Muskingum EGS discharge, August 4 - September 14, 2006. Temperature criteria are indicated by dashed lines (daily maximum and average).

Foaming on the Muskingum River

Ohio EPA has received numerous complaints about foaming on the Muskingum River. During the 2006 Muskingum River survey, field staff observed foam in October on the Muskingum River in Beverly at SR 339 . It is uncertain what is causing the foaming but it does not seem to have an impact to the biological community. However, because the foam is aesthetically unappealing, this could impact the desire to recreate on the river due to misconceptions from the public that the foam indicates polluted waters. It is very likely that this is a naturally occurring process of organic material such as leaf litter breaking down in the water. If the public observes foam on the water, they are encouraged to contact Ohio EPA so that further investigations can be done to determine the source.

Recreational Use

Water quality criteria for determining whether rivers and streams are suitable for recreational uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators in the water column. Indicator organisms used for these determinations are fecal coliform bacteria and *Escherichia coli*.

Fecal coliform bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but there is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more practicable. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. Fecal coliform bacteria, including *E. coli*, by themselves are usually not pathogenic. However, some strains of *E. coli* can be toxic, causing serious illness. Although not necessarily agents of disease, fecal coliform bacteria and *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When fecal coliform bacteria or *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

The Muskingum River is designated as a Primary Contact Recreation (PCR) use in OAC Rule 3745-1-24. Water bodies with a designated recreational use of Primary Contact Recreation (PCR) "...are waters that, during the recreation season, are suitable for fullbody contact recreation such as ... swimming, canoeing, and SCUBA diving with minimal threat to public health as a result of water quality" [OAC 3745-1-07 (B)(4)(b)]. The recreational use water quality criteria applicable to the Muskingum River are reported in Table 7-13 of OAC 3745-1-07. At least one of the two bacteriological standards (fecal coliform or *E. coli*) must be met. These criteria apply outside of the mixing zone. For the Primary Contact use, the following applies: fecal coliform - geometric mean fecal coliform

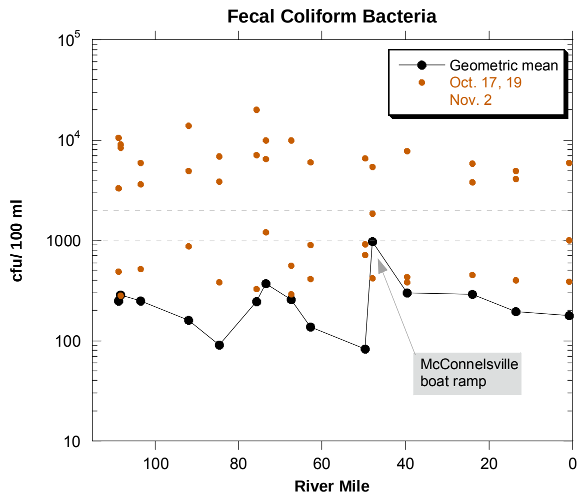


Figure 14. Fecal coliform bacteria levels (geometric mean) from 15 locations in the Muskingum River, July 18 - October 12, 2006. Samples collected after the recreational season are plotted individually. Dashed lines indicate Primary Contact Recreation criteria levels (mean and maximum).

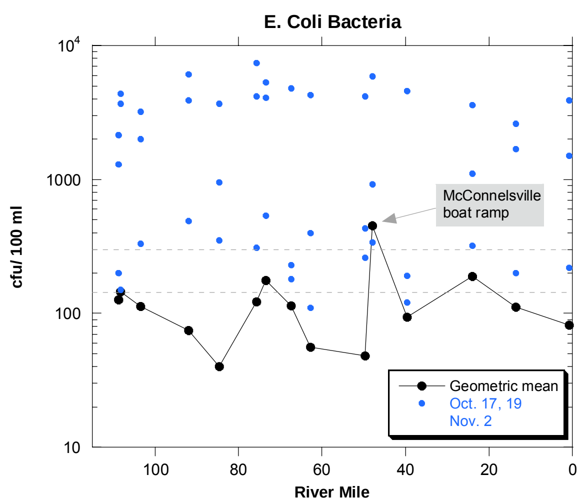


Figure 15. E. coli bacteria levels (geometric mean) from 15 locations in the Muskingum River, July 18 - October 12, 2006. Samples collected after the recreational season are plotted individually. Dashed lines indicate Primary Contact Recreation criteria levels (mean and maximum).

content (either MPN or MF), based upon not less than five samples within a thirty-day period, shall not exceed 1,000 per 100 ml and fecal coliform content (either MPN or MF) shall not exceed 2,000 per 100 ml in more than ten percent of the samples taken during any thirty-day period. *E. coli* - geometric mean *E. coli* content (either MPN or MF), based upon not less than five samples within a thirty-day period, shall not exceed 126 per 100 ml and *E. coli* content (either MPN or M F) shall not exceed 298 per 100 ml in more than ten percent of the samples taken during any thirty-day period. Bacteriological results from environmental samples are typically reported as colony forming units (cfu) per 100 ml of water.

Summarized bacteria results are listed in Table 6, and the complete dataset is reported in Appendix Table 1. Fifteen locations along the Muskingum River were tested for bacteria levels on 11 different dates, from July 18 – November 2, 2006. Only data collected between July and October 15 were used in the recreational use attainment analysis. Evaluation of fecal coliform and *E. coli* results revealed all but two locations fully attaining the recreational use. The two locations not attaining the recreational use include the ODNR boat ramp area in McConnelsville, which is located downstream from the McConnelsville WWTP discharge, and the Beverly area at State Route 339. Three bacteria sample collections (October 17 and 19, November 2) were not included in the recreation use attainment evaluation, since these dates were outside of the recreational use period noted in the Ohio Water Quality Standards. However, an evaluation of the data revealed high bacteria levels, with most samples above PCR recreational criteria (Figures 14 and 15). The elevated bacteria levels were largely associated with elevated suspended solids levels in the river, resulting from high river flows. Sediments in aquatic systems can be a significant reservoir for pathogenic organisms and indicator bacteria. Sediment resuspension can significantly increase bacteria counts in overlying waters (Ohio EPA 2006b).

Table 6. Summary fecal coliform and E. coli bacteria data for 15 locations in the Muskingum River, July 18 – October 12, 2006. Attainment status is based on comparing the geometric mean and 90th percentile values to the Primary Contact Recreation (PCR) criteria (Ohio Administrative Code 3745-1-07, Table 7-13). All values are expressed as colony forming units (cfu) per 100 ml of water. Gray shaded values exceed PCR criteria.

		Geometric Mean		90th Percentile		Recreational Attainment Status
Location	River Mile	Fecal Coliform	E. Coli	Fecal Coliform	E. Coli	
Coshocton boat ramp	108.7	249	126	498	331	FULL
State Route 83	108.1	287	145	975	678	FULL
CR 273-Conesville	103.5	248	113	431	220	FULL
SR 208 - Dresden	92.2	160	75	358	219	FULL
Ellis Dam	84.6	91	40	204	126	FULL
US 22-Zanesville	75.8	244	122	823	376	FULL
Dst. Zanesville WWTP	73.5	370	176	1101	617	FULL
Bridge St.-Philo	67.3	256	114	1074	535	FULL
Gaysport	62.7	136	56	923	404	FULL
McConnelsville	49.8	83	48	439	243	FULL
ODNR boat ramp-McConnelsville	48.0	964	452	2010	716	**NON**
SR 266-Stockport	39.7	298	94	651	343	FULL
SR 339 – Beverly	24.0	292	189	5530	4020	**NON**
New Bridge St. – Lowell	13.6	194	112	530	356	FULL
Washington St. – Marietta	0.9	178	82	1431	635	FULL

Sediment Quality

Sediment samples were collected at 12 locations in the Muskingum River by the Ohio EPA in September and November, 2006. Nine of the twelve sampling sites were located within impounded sections of the river, which are areas where fine grained material would more likely accumulate. All sediment sampling locations are indicated by river mile in Figure 2. Samples were analyzed for semivolatile organic compounds (four locations only), PCBs (four locations only), total analyte list inorganics, and nutrients. Specific chemical parameters tested and results are listed in Appendix Tables 3 and 4. Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et.al*. 2000), and *Ohio Specific Sediment Reference Values (SRVs)* for metals (Ohio EPA 2003). The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed.

Sediment samples were conservatively sampled by focusing on depositional areas of fine grain material. These areas typically are represented by higher contaminant levels, compared to sands and gravels. All Muskingum River sediment sampling sites were in nearshore areas along the river bank, which were represented by moderate deposits of fine grained material. However, these nearshore areas comprised only a small fraction of the bottom substrates of the Muskingum River. River substrates were predominated by gravel, cobble, sand, and boulder material.

Select detectable levels of metals, semivolatile organic compounds, pesticides, and PCBs are presented in Table 7. Values above ecological screening guidelines are noted with various colors of shading.

Two metal parameters (cadmium and manganese) had one sample each above Ohio SRV levels. These two parameters were within levels protective of river biology. Four metal parameters (arsenic, chromium, lead, zinc) were noted at levels above TECs, but far below PEC values. Although some arsenic and lead concentrations were above TEC guidelines, all reported values were at or below Ohio SRV levels. Nickel levels were reported above TEC levels from 10 of 12 locations, with the remaining two sites elevated above PEC guidelines. However, it should be noted that except for one sampling location, all of the nickel measurements were below the Ohio SRV guideline. The one nickel measurement (64 mg/kg) above the Ohio SRV, only slightly exceeded the guideline (61 mg/kg).

PCBs were documented in sediment samples collected from two of four sampling locations. PCB results for all four samples were below Threshold Effect Concentration guidelines, indicating acceptable ecological levels. Hexachlorobenzene was the only pesticide detected in sediment samples from the Muskingum River. All four locations tested for pesticides reported detectable levels of hexachlorobenzene, and historically, this parameter has been detected in sediments throughout the Muskingum River (and in the Tuscarawas River, a major tributary to the Muskingum River).

Semivolatile organic compounds were measured in sediments collected from four sampling locations. Of these parameters, three polycyclic aromatic hydrocarbons (PAHs) were measured at levels exceeding TEC benchmarks (Table 7). These elevated levels occurred at one location (RM 101.8), a location largely composed of gravel and cobble substrates, with minor amounts of fine grain sediment.

Table 7. Select chemical compounds detected in sediment samples collected by Ohio EPA from the Muskingum River, September and November, 2006. Shaded numbers indicate values above the following screening guidelines: Ohio Sediment Reference Values for metals (green), Threshold Effect Concentration - TEC (blue), and Probable Effect Concentration - PEC (red). Screening guidelines were not available for hexachlorobenzene. Sampling locations are indicated by river mile (RM). NA – not analyzed.

	Muskingum River Sampling Locations											
Parameter	**RM 108.7**	**RM 101.8**	**RM 97.4**	**RM 86.0**	**RM 77.6**	**RM 72.0**	**RM 62.7**	**RM 42.2**	**RM 26.2**	**RM 19.0**	**RM 8.1**	**RM 0.9**
Arsenic (mg/kg)	9.85	9.31	9.31	13.4	14.2	13.6	13.4	12.3	9.42	7.98	10.5	8.69
Cadmium (mg/kg)	0.591	0.500	0.475	0.674	0.907	0.624	0.688	0.709	0.469	0.398	0.510	0.456
Chromium (mg/kg)	28	19	21	39	69	32	45	30	24	19	26	23
Lead (mg/kg)	<23	25	<23	30	48	39	47	<34	<31	24	37	26
Nickel[a] (mg/kg)	32	26	30	50	64	41	52	47	40	32	40	34
Zinc (mg/kg)	145	117	116	172	202	163	176	183	133	108	138	120
Manganese (mg/kg)	1060	1290	1640	2080	2340	2020	1830	3030	2200	1250	2210	1730
Fluoranthene (ug/kg)	NA	1380	NA	NA	NA	<780	NA	NA	<790	NA	NA	<750
Phenanthrene (ug/kg)	NA	770	NA	NA	NA	<780	NA	NA	<790	NA	NA	<750
Pyrene (ug/kg)	NA	1020	NA	NA	NA	<780	NA	NA	<790	NA	NA	<750
Hexachlorobenzene (ug/kg)	NA	119	NA	NA	NA	67.7	NA	NA	45.3	NA	NA	74.2
PCB-1254 (ug/kg)	NA	37	NA	NA	NA	47.2	NA	NA	<39.2	NA	NA	<37.2

J – The analyte was positively identified, but the quantification was below the reporting limit.
< - Not detected at or above the method detection limit (MDL value reported with the less than symbol).
[a] - Sediment Reference Value is 61 mg/kg. All but one value were below the SRV for nickel.

Effluent Discharges

A total of 29 National Pollution Discharge Elimination System (NPDES) permitted facilities discharge wastewater, process water, and/or cooling water into the Muskingum River mainstem (Table 8). Included in this list are two large power plants, three peak power plants, eight municipal wastewater plants (plus one CSO collection system for Malta), four private sanitary wastewater plants, seven industrial facilities (which includes two specialty steel mills), two water treatment plants and two ground water treatment systems. Each facility is required to monitor their effluent discharge(s), and report the results to the Ohio EPA on a monthly basis. Summarized effluent results are listed in Appendix Table 7.

Table 8. Muskingum River permitted effluent discharge locations, 2006. Median discharge flows are based on data reported from 2000 – 2006. MGD= million gallons per day.

Facility Name	Ohio EPA Permit No.	County	River Mile	Median Discharge Flow (MGD)	Type of Discharge
Coshocton WWTP	0PD00004	Coshocton	108.56	1.8	Wastewater
AK Steel – Coshocton Works	0ID00014	Coshocton	105.88	1.782	Process – stainless steel
AEP Conesville	0IB00013	Coshocton	102.89	259.9	Cooling
Dresden WWTP	0PB00012	Muskingum	91.6	0.158	Wastewater
Dresden Energy	0IB00031	Muskingum	89.8	No discharge	Cooling
United Technologies	Superfund Site	Muskingum	78.3	-	Ground water treatment
AK Steel – Zanesville Works	0ID00002	Muskingum	78.06	1.39	Process - steel
Zanesville WTP	0IY00090	Muskingum	78.0	0.17	Water treatment plant
Zanesville WWTP – CSOs	0PE00000	Muskingum	76.25-74.5	-	Sewer overflows
Zanesville WWTP	0PE00000	Muskingum	74.07	6.6	Wastewater
Riverview Manor	0PV00029	Muskingum	74.07	0.005	Wastewater
Dun-Falls Association	0PX00000	Muskingum	67.3	0.033	Wastewater
Gould	0IN00256	Morgan	51.9	Draft Permit	Ground water treatment
Miba Bearings US	0IC00000	Morgan	51.74	0.12	Process and sanitary wastewater, Cooling
Glacier Vandervell N. American	0IC00027	Morgan	51.7	0.007	Process and sanitary wastewater
Malta Well Field	0IN00155	Morgan	50.2	0.3	Contaminated well field
Malta CSO Collection System	0PA00095	Morgan	50.48-48.15	Not reported	Combined Sewer Overflows
McConnelsville WWTP	0PC00000	Morgan	48.10	0.15	Wastewater
Morgan Jr. & Sr. High School	0PT00058	Morgan	45.9	0.006	Wastewater
Morgan County Care Center	0PR00145	Morgan	45.8	0.0053	Wastewater
Stockport WWTP	0PA00005	Morgan	39.26	0.063	Wastewater
Columbus Southern (Waterford Energy Facility)	0IB00027	Washington	33.8	0.605	Cooling
AEP (Ohio Power Company) Muskingum River Plant	0IB00003	Washington	28.53-27.09	753.9	Cooling, fly ash
Globe Metallurgical, Inc.	0ID00005	Washington	27.81	0.034	Cooling & wastewater
CG & E Beverly Plant	0IB00028	Washington	27.1	0.037	Cooling
BP Oil, Beverly Plant	0IN00134	Washington	25.8	Insignificant	Stormwater
Beverly WWTP	0PB00002	Washington	23.25	0.172	Wastewater
Lowell WWTP	0PB00022	Washington	13.1	0.065	Wastewater
Devola WWTP	0PG00019	Washington	4.36	0.077	Wastewater
RJF International	0IQ00020	Washington	3.39	0.77	Mfg - vinyl plastic products
Marietta WTP	0IW00080	Washington	1.8	0.346	Water treatment plant

Smurfit-Stone Container Enterprises, Inc.
(Ohio EPA # 0IA00005)
Smurfit-Stone Container is located at 500 North Fourth Street, Coshocton, Ohio. The facility is a privately owned paper mill which has three permitted outfalls that discharge to the Tuscarawas River and tributaries to the Tuscarawas River (river mile 1.17-0.4). The Coshocton Mill makes paper from virgin wood and recycled fiber. Soda ash is used to cook the chips in the pulping or paper making process. The cooked chips and recycled fiber are blended and sent to one of two paper machines. Together, both paper machines produce about 900 tons of paper per day. The main outfall for Smurfit-Stone Container is 003 which discharges an average of 23.5 MGD of treated process wastewater to the Tuscarawas River at river mile 1.04. Outfall 002 and 004 consist of cooling water and storm water runoff.

Even though Smurfit-Stone Container does not discharge directly to the Muskingum River, it is included in this discussion because the facility discharge is considered to be interactive (for permitting purposes) with several other facilities on the Muskingum River and also has the potential to significantly impact the Muskingum River. The discharge from outfall 003 enters the river through a diffuser located just under the water surface and has a distinctive dark brown color. Under low flow conditions, discoloration of the receiving water can extend into the Muskingum River. The biological community was sampled in 2005 in the Tuscarawas River just downstream from Smurfit-Stone Container by Ohio EPA and was found to meet the Exceptional Warmwater Habitat (EWH) criteria. Biological samples collected further downstream on the Muskingum River also met the EWH criteria indicating that Smurfit-Stone Container is not impacting the biological community. However, the discoloration of the river by Smurfit-Stone Container is aesthetically unappealing and could impact recreational activities such as fishing and boating.

Coshocton WWTP (Ohio EPA Permit # 0PD00004)
Coshocton WWTP is located at 2742 CR 271, Coshocton, Ohio in Coshocton County and is a publicly owned treatment works providing wastewater treatment for the City of Coshocton. The population served by this treatment plant is estimated at 11,600 people. The design flow is 4.4 MGD with an annual average flow of 1.8 MGD for 2006. The plant was constructed in

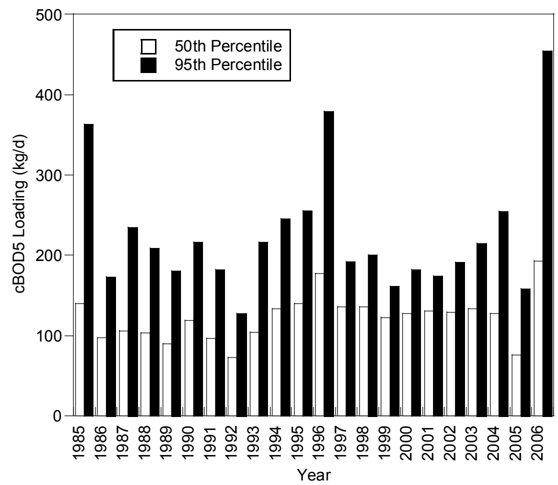


Figure 16. Annual median and 95th percentile loadings of cBOD5 from the Coshocton WWTP, 1985-2006.

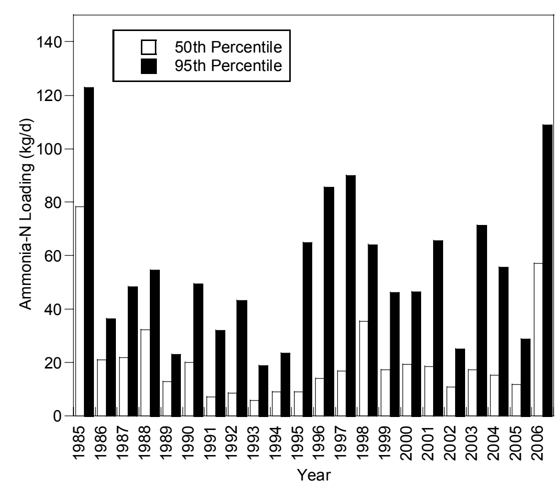


Figure 17. Annual median and 95th percentile loadings of ammonia-nitrogen from the Coshocton WWTP, 1985-2006.

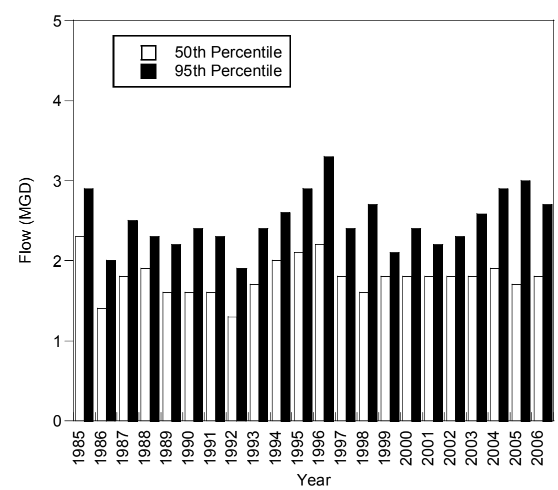


Figure 18. Annual median and 95th percentile conduit flow from the Coshocton WWTP, 1985-2006.

1954 and is currently undergoing a major upgrade to remove the trickling filter-rock media which will be replaced with a high efficiency PVC media. The upgrade is scheduled for completion by June 2007. Treatment includes influent pumping, bar screen, grit removal, primary sedimentation, trickling filter-rock media (currently being replaced with a high efficiency PVC media), secondary clarification, chlorination and dechlorination.

Coshocton WWTP is required to submit monthly operating reports (MORs) to Ohio EPA as part of their permit requirements. Annual median and 95th percentile data collected by Coshocton WWTP show that median plant performance has been fairly consistent from 1985 to 2005 for ammonia and cBOD5. However major plant upsets were evident in 2006 with both median and 95th percentile data elevated higher than most other years (Figures 16 and 17). Flows remained consistent and well under the design flow of 4.4 MGD (Figure 18).

Ohio EPA conducted a compliance sampling inspection and bioassay of the Coshocton WWTP on May 1-2, 2006 from outfall 001. The results from the composite sample found that the permit limit was exceeded for both TSS and $CBOD_5$. The bioassay from outfall 001 resulted in acute toxicity to *Pimphales promelas* (fathead minnows).

Odor complaints were also received by Ohio EPA from local residents during the spring of 2006. It was determined that the trickling filter-rock media had exceeded its life expectancy and was no longer providing sufficient treatment. These issues should be resolved after the plant finishes with the upgrade and will be inspected again by Ohio EPA to determine if further action is needed to address the problems.

AK Steel Corporation Coshocton Works (Ohio EPA Permit # 0ID00014)
AK Steel Corporation Coshocton Works is located at 17400 State Route 16, Coshocton, Ohio in Coshocton County and is a specialty steel finishing mill. Operations consist of salt bath descaling, acid pickling and cleaning, cold rolling and alkaline cleaning. Ancillary operations consist of shot blasting, grinding, buffing and slitting. Average flows of treated process wastewaters were 1.782 MGD in 2006.

Ohio EPA conducted a compliance sampling inspection and bioassay at the AK Steel Corporation Coshocton Works on January 23-24, 2006. The effluent from outfall 001 was found to be acutely toxic to *Ceriodaphnia dubia*. No mortality or adverse affects were found in *P. promelas* and no other permit limit violations were found in the composite sample. The composite sample did have a total dissolved solids (TDS) of 2340 mg/l which could be the cause of the mortality of the *Ceriodaphnia dubia* (water quality standards for TDS is 1500 mg/l).

AEP Conesville EGS- Columbus Southern Power (Ohio EPA Permit # 0IB00013)
AEP Conesville EGS is located at 47201 County Road 273, Conesville, Ohio in Coshocton County. The AEP Conesville Plant is a pulverized coal-fired steam electric generating facility consisting of six units, with a total generating capacity of 1945 megawatts. The average flow of the cooling water discharge was 259.9 MGD in 2006.

Ohio EPA conducted a compliance sampling inspection and bioassay at the AEP Conesville Plant on November 28-29, 2005. No permit violations were found in the composite sample and the outfall was not found to be acutely toxic to either *Ceriodaphnia dubia* or *P. promelas*.

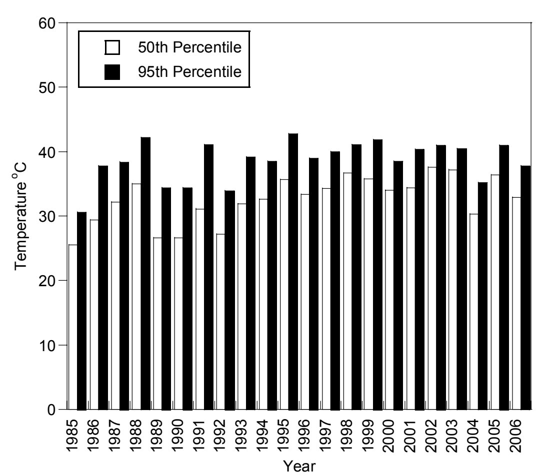


Figure 19. 3rd Qurater (July, August, and September) median and 95th percentile temperature from the AEP-Conesville EGS.

Even though the AEP Conesville plant discharges a large volume of water to the Muskingum River, median and 95th percentile temperature levels of the cooling water in the summers from 1985 to 2006 have been consistently low (Figure 19) and did not exceed temperature water quality standard levels downstream from the facility in 2006 (Figure 12).

Village of Dresden WWTP (Ohio EPA Permit # 0PB00012)
The Village of Dresden WWTP is located at 30 Lock Street, Dresden, Ohio and is a publicly owned treatment works providing wastewater treatment for the Village of Dresden and surrounding areas. The population served is estimated to be 2,064 people. The design flow is 0.24 MGD with an annual average flow rate of 0.158 MGD in 2006. The approximate year of the plant construction was 1930 and the last major modification occurred in 1990. Treatment includes an Imhoff tank, trickling filter media, and chlorination.

AK Steel Corporation - Zanesville Works (Ohio EPA Permit # 0ID00002)
The AK Steel Corporation Zanesville Works is located at 1724 Linden Avenue, Zanesville, Ohio in Muskingum County. This facility is a finishing mill of silicon electrical and stainless steels and has two permitted outfalls that discharge to the Muskingum River (outfalls 001 and 002). Operations include annealing, rolling, acid pickling, coil coating and packaging. Outfall 001 is a combination of treated sanitary waste, process water and non-contact cooling water with an approximate flow of 2 MGD. Outfall 002 is non-contact cooling water and storm water with a flow of 0.032 MGD. Measured flows in 2006 were 1.39 MGD.

Zanesville Wastewater Treatment Plant (Ohio EPA Permit # 0PE00000)
The Zanesville WWTP is located at 1730 Moxahala Avenue, Zanesville, Ohio in Muskingum County and is a publicly owned treatment works providing wastewater treatment for the City of Zanesville and surrounding areas in Muskingum County. The total population served by the Zanesville WWTP is approximately 84,585 people (24,586 in Zanesville and 58,999 in Muskingum County). Zanesville is one of the most rapidly developing cities along the Muskingum River and in southeastern Ohio. Numerous sewer expansion projects are currently underway that will increase flows to the plant.

The design flow of the WWTP is 7.75 MGD with an average flow of 6.6 MGD in 2006. The facility was constructed in 1959 and is currently being upgraded for a design flow of 11 MGD with the ability to handle a peak hourly flow of 36.2 MGD. All flows in excess of 27 MGD will receive primary treatment and be sent to disinfection before being discharged. This upgrade should be completed by 2009. Treatment includes influent pumping, bar screen, grit removal, primary sedimentation, trickling plastic media,

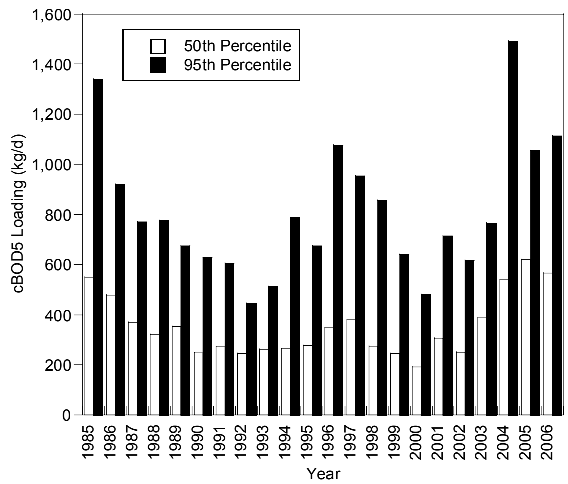


Figure 20. Annual median and 95th percentile loadings of cBOD5 from the Zanesville WWTP, 1985-2006.

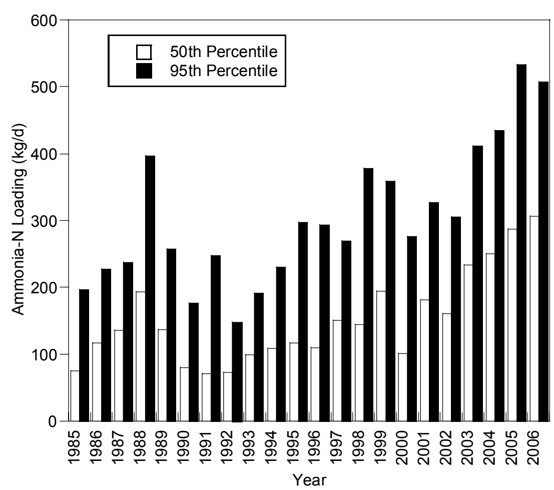


Figure 21. Annual median and 95th percentile loadings of ammonia-nitrogen from the Zanesville WWTP, 1985-2006.

secondary clarification, chlorination and dechlorination.

Zanesville also has combined sewer overflows (CSOs) located throughout the city that discharge to the Muskingum River or tributaries to the Muskingum River. The City of Zanesville has submitted plans to eliminate these CSOs by 2020; however these plans have not yet been approved by Ohio EPA. The first phase of the plan is scheduled to begin in 2007 with the Southend Sewer Rehab Project which is estimated for completion by 2011. The second phase is scheduled to begin in 2013 and the third phase by 2017.

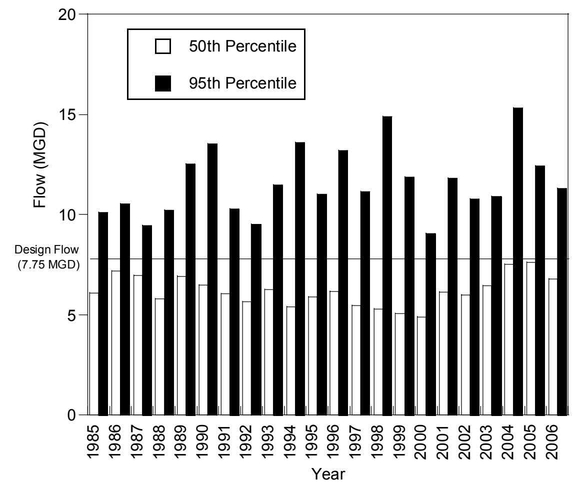


Figure 22. Annual median and 95th percientile conduit flow from the Zanesville WWTP, 1985-2006.

Annual loading data shows that both ammonia-N and cBOD5 loads have been steadily increasing since the 1990s most likely due to an increase in flows to the plant (Figure 20 and 21). Ammonia-N values in the Muskingum River at RM 73.5 (0.6 miles downstream from the Zanesville WWTP effluent discharge) were above large river reference conditions during 2006 (Figure 7). Zanesville currently does not have ammonia-N limits in their permit but due to the increased concentration of ammonia that the plant has been discharging, ammonia-N limits have been issued for their renewed permit. Annual median flows from 1985 to 2006 have been fairly consistent and below the design flow but the 95th percentile flows have continuously exceeded the design flow of 7.75 MGD (Figure 22). Upgrades at the WWTP should resolve these exceedances and will allow for treatment during peak flows.

Ohio EPA conducted a compliance sample and bioassay at the Zanesville WWTP on February 23-24, 2004. The effluent was found to be acutely toxic to *P. promelas*. The mixing zone was also found to be acutely toxic to *P. promelas*. No mortality or other adverse effects to *Ceriodaphnia dubia* were observed. Ammonia-N levels in the composite sample were 10.1 mg/l, which most likely caused the acute toxicity to *P. promelas*.

Riverview Manor MHP (Ohio EPA # 0PV00029)
The Riverview Manor Mobile Home Park is located at 1710 South River Road, Zanesville, Ohio, in Muskingum County and is a privately operated activated sludge package treatment plant. There are 25 lots and two apartments that are served by Riverview Manor MHP. The treatment plant discharges approximately 0.005 MGD and treatment includes trash trap, aeration, settling, chlorination and dechlorination.

Dun-Falls Association (Ohio EPA # 0PX00000)
The Dun-Falls Association is located on Water St, Duncan Falls, Ohio in Muskingum County and is a privately operated extended aeration activated sludge package treatment plant. Dun-Falls Association discharges approximately 0.07 MGD and services subdivision/housing with some small commercial connections. Treatment includes screening, aeration, sedimentation, tablet chlorination, de-chlorination, and flow monitoring.

Gould Electronics Inc (Ohio EPA # 0IN00256)
Gould Electronics Inc. is located at 5045 N. State Route 60, McConnelsville, Ohio in Morgan County. The facility formerly manufactured electro-formed copper foil used in the printed circuit board industry. No current manufacturing operations are performed by Gould. Ohio EPA conducted monitoring surveys of the Gould Facility in 1992 and 2003 and found that historical operational practices resulted in impacts to the surrounding sediment, soil, groundwater, and surface water from chlorinated solvents and metals (Ohio EPA 1993, 2004). Due to the contaminated groundwater, Gould continues to operate a groundwater extraction and treatment system installed on the property pursuant to Ohio EPA Director's

Final Findings and Orders. Discharges and numerous spills from the Gould facility in the 1970's had a major impact on the indigenous mussels of the Muskingum River. In 1975, Gould was fined $260,000 for killing more than 43 million mussels in the Muskingum River from 1971 through 1974.

Miba Bearings US LLC (Ohio EPA #0IC00000)
Miba Bearings US LLC is located at 5037 N. State Route 60, McConnelsville, Ohio in Morgan County. Miba Bearings US LLC manufactures engine parts for locomotive, diesel and aircraft engines as well as bearings related to gas and oil compression. Processes include milling, casting, drilling, broaching, and forming. Electroplating activities involve acid plating, alkaline plating, acid and alkaline cleaning and stripping, and degreasing. Buffing and burring operations also take place. Outfall 002 is sanitary wastewater and outfall 004 is a combination of industrial process water, stormwater and non-contact cooling water. The average discharge from Miba Bearings US LLC was 0.12 MGD in 2006.

Glacier Vandervell – formerly DANA (Ohio EPA # 0IC00027)
Glacier Vandervell is located at 5130 N. State Route 60, McConnelsville, Ohio in Morgan County. Glacier Vandervell is a strip steel alloy coating operation. Outfall 001 is a combination of industrial process water and treated sanitary waste water. The average discharge from Glacier Vandervell outfall 001 was 0.007 MGD in 2006.

Village of Malta Well Field (Ohio EPA # 0IN00155)
Village of Malta Well Field is located at 449 Main Street, Malta, Ohio in Morgan County. The Village of Malta Well Field is part of an old well field which is no longer in use. The well is contaminated with the solvent trichloroethylene (TCE) and is treated and continuously pumped to the Muskingum River. The average flow was 0.3 MGD in 2006.

Village of Malta CSO Collection System (Ohio EPA # 0PA00095)
The Village of Malta has a sanitary waste water collection system which is pumped across the Muskingum River to the McConnelsville WWTP for treatment. The number of people served by this collection system is approximately 784. The design flow is 0.5 MGD. The average flow for 2006 is unknown because it was not reported by the Village of Malta.

During the 2006 survey, Ohio EPA found that McConnelsville was not always treating the waste from the Village of Malta Collection System but was instead directly discharging untreated waste into the Muskingum River just upstream from the Ohio DNR boat ramp in McConnelsville. As a result, high in-stream bacteria numbers were documented at the boat ramp (see Figures 14 and 15).

McConnelsville WWTP (Ohio EPA # 0PC00000)
The McConnelsville WWTP is located at State Route 376, McConnelsville, Ohio in Morgan County and is a publicly owned treatment works providing wastewater treatment for the City of McConnelsville and the Village of Malta. The number of people served by the McConnelsville WWTP is approximately 2,592. The design flow for the McConnelsville WWTP is 0.5 MGD with an average flow of 0.15 MGD for 2006. Treatment includes influent pumping, communition, activated sludge-contact stabilization, clarifier, chlorination and dechlorination.

During the 2006 survey, Ohio EPA found that McConnelsville was not always treating the waste from the Village of Malta Collection System but was instead directly discharging untreated waste into the Muskingum River just upstream from the Ohio DNR boat ramp in McConnelsville. The McConnelsville WWTP often by-passed untreated waste if they felt that the plant could not handle the flows. However, by-passing occurred even when plant flows were low enough to handle additional waste. As a result, high in-stream bacteria numbers were documented at the boat ramp (see Figures 14 and 15). Ohio EPA is currently working with the City of McConnelsville to correct this situation. The public should be aware that there is a high potential of being exposed to bacteria at the McConnelsville boat ramp and they should take precautions to minimize exposure, especially for children, pregnant woman, the elderly, and anyone with a compromised immune system.

Morgan Jr and Sr High School (Ohio EPA # 0PT00058)
Morgan Jr. and Sr. High School is located at 800/820 S Riverside Dr, McConnelsville, Ohio in Morgan County and is a 0.01 MGD activated sludge package plant. Average flows for the plant were 0.006 MGD in 2006. Treatment includes trash trap, flow equalization, aeration, settling, fixed media, surface sand filters, and ultraviolet disinfection.

Morgan County Care Center (Ohio EPA # 0PR00145)
The Morgan County Care Center is located at 856 S Riverside Dr, McConnelsville, Ohio in Morgan County and is a privately owned facility that treats both sanitary waste and restaurant/cafeteria waste. The facility has a 0.02 MGD extended aeration WWTP and treatment which includes surface sand filters, chlorination and dechlorination. Average flows were 0.0053 MGD in 2006.

Stockport Wastewater Treatment Plant (Ohio EPA #0PA00005)
The Stockport WWTP is located at 830 East River Road, Stockport, Ohio in Morgan County and is a publicly owned treatment works providing wastewater treatment for the Village of Stockport. The treatment plant serves 507 residents within the Village of Stockport. The design flow of the plant is 0.09 MGD and the average flow for 2006 was 0.063 MGD. Treatment includes bar screen, aerated lagoon, secondary settling, and ultraviolet. The plant was built in 1974 and has not had a major modification or upgrade since that time.

Columbus Southern -formerly PSEG Waterford Energy LLC (Ohio EPA #0IB00027)
Columbus Southern is located at Township Road 32, Waterford, Ohio in Washington County and is an electrical generation plant. The plant consists of natural gas fired combustion turbines and HRSG steam turbines at a capacity of 850 megawatts. Cooling is provided by Muskingum River water and a cooling tower with multiple cycles. The average cooling water discharge for the plant was 0.605 MGD in 2006.

AEP Ohio Power Company - Muskingum River Plant (Ohio EPA # 0IB00003)
The AEP Ohio Power Company Muskingum River Plant is located at 1501 Sparling Road, Waterford, Ohio in Washington County and is a pulverized coal-fired steam electric generating facility consisting of five units, with a total generating capacity of 1425 megawatts. Outfall 001 is cooling water from units one through four, outfall 002 is bottom ash from unit five, outfall 003 is bottom ash from units one through four, and outfall 007 is the fly ash pond and seepage collection pond. The average discharge for the Ohio Power Company outfalls was 753.9 MGD for 2006.

Due to the large volume of flow from outfall 001, temperature levels from the AEP Muskingum River Plant have the potential to significantly increase the temperature of the Muskingum River. This is especially the case during the summer when river levels are low and the normal water temperature is elevated. During

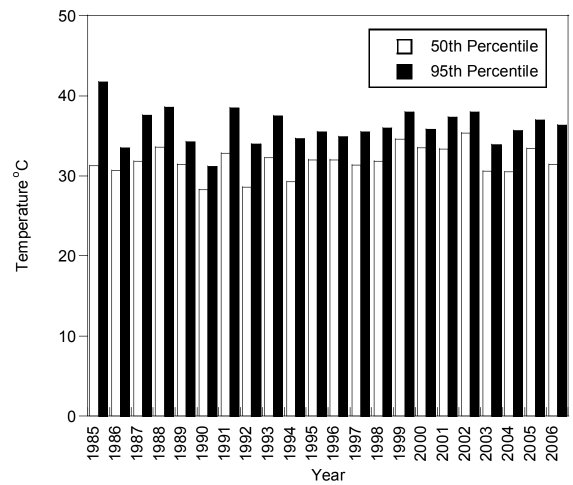


Figure 23. 3rd quarter (July, August, September) median and 95th percetile temperature from the AEP-Muskingum River Plant, (outfall 001)1985-2006. Outfall 001 is cooling water from units 1-4.

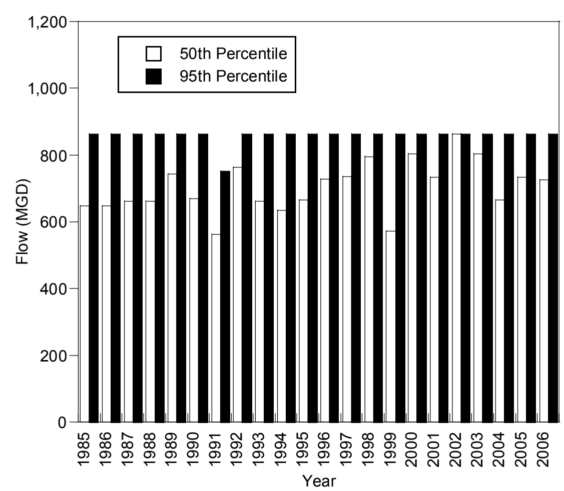


Figure 24. Annual median and 95th percentile conduit flow from the AEP-Conesville Plant (outfall 001) 1985-2006.

the 2006 survey, water temperatures were significantly higher downstream from the facility and often exceeded the Ohio WQS average criterion (Figures 11 and 13). Median and 95th percentile temperature data from outfall 001 in the summers have typically been between 30-40 °C from 1985 to 2006 (Figure 23). Median and 95th percentile flows from outfall 001 have typically been between 600 to 864 MGD from 1985 to 2006 (Figure 24).

Globe Metallurgical, Inc. - Beverly Plant (Ohio EPA # 0ID00005)
Globe Metallurgical, Inc. is located at County Road 32, Beverly, Ohio in Washington County and is a producer of ferroalloys as well as silicon and manganese metals. Outfall 001 is a combination of non-contact cooling water, sanitary wastewater, and storm water runoff. The average discharge in 2006 was 0.034 MGD.

CG & E - Beverly (Duke Energy Washington LLC) (Ohio EPA # 0IB00028)
Cincinnati Gas & Electric (formerly Duke Energy) is located at Route 1, Box 29B, State Route 83, Beverly, Ohio in Washington County. The CG & E Facility is an advanced, natural gas fueled, combined cycle electric power plant with a nominal capacity of 620 megawatts. The facility generates electricity for distribution and sale in commerce. Outfall 001 discharges non-contact cooling water and had an average flow of 0.037 MGD in 2006.

BP Oil Company Beverly Bulk Plant (Ohio EPA #0IN00134)
The BP Oil Company Beverly Bulk Plant is located in Beverly Ohio, Washington County. This bulk plant receives refined petroleum products by transport truck from a BP owned terminal. The products are stored in above-ground or under-ground tanks and distributed to consumers via smaller tank trucks. Discharge from the facility is insignificant and consists of storm water runoff from the load-rack.

Village of Beverly Wastewater Treatment Plant (Ohio EPA #0PB00002)
The Beverly WWTP is located at 609 Mitchell Ave, Beverly, Ohio in Washington County and is a publicly owned treatment works providing wastewater treatment for the Village of Beverly, Beverly Hills Subdivision, and Waterford. The total population served by the treatment plant is approximately 2,140. Treatment includes communition, activated sludge-contact stabilization, chlorination and dechlorination. The design flow of the treatment plant is 0.3 MGD and the average flow for 2006 was 0.172 MGD.

Lowell Wastewater Treatment Plant (Ohio EPA # 0PB00022)
The Lowell WWTP is located at State Route 60 North, Lowell, Ohio in Washington County and is a publicly owned treatment works providing wastewater treatment for the Village of Lowell. The population served by the Lowell WWTP is 611. Treatment includes influent pumping, bar screen, grit removal, chlorination and dechlorination. The plant was constructed in 1987 and the last modification occurred in 2000. The design flow of the plant is 0.108 MGD and the average discharge for 2006 was 0.065 MGD.

Devola Wastewater Treatment Plant (Ohio EPA # 0PG00019)
The Devola WWTP is located on State Route 60, Marietta, Ohio in Washington County and is a publicly owned treatment works providing wastewater treatment for Muskingum Township and Devola. The population served by the treatment plant is 334. The treatment plant was constructed in 1974 and last modified in 1991. Treatment includes bar screen, flow equalization, pre-aeration, activated sludge-extended aeration, sand filter, chlorination and dechlorination. The design flow of the plant is 0.09 MGD and the average flow for 2006 was 0.077 MGD.

RJF International Corporation (Ohio EPA # 0IQ00020)
The RJF Int. Corp is located at 700 BF Goodrich Road, Marietta, Ohio in Washington County. The plant manufactures a variety of vinyl plastic products from purchased resins. Products include flexible and rigid thermoplastic pellets, calendared film, matting and wallcovering. The discharge to the Muskingum River is process water, sanitary water, and non-contact cooling water. Average flow from the plant was 0.77 MGD in 2006.

City of Marietta Water Treatment Plant (Ohio EPA # 0IW00080)
The Marietta Water Treatment Plant is located at 2000 Fourth Street, Marietta, Ohio in Washington County. This facility is a municipal water treatment plant utilizing wells (ground water supply) for its public water supply. Outfall 001 is discharge from the wastewater return tank, outfall 002 is discharge from interceptor well #1, and outfall 003 is discharge from interceptor well #6 after the aerator unit. The average flow from the outfalls was 0.346 in 2006.

River Physical Habitat
Physical habitat was evaluated in the Muskingum River at each biological sampling location. Physical habitat was assessed using the Qualitative Habitat Evaluation Index (QHEI). QHEI scores are detailed in Table 9.

The Muskingum River was predominated by substrates of gravel, cobble, and sand, with lesser amounts of boulders. These conditions were consistent across both free-flowing and impounded sections of river. Bottom embeddedness, the degree to which cobble, gravel and boulder substrates are surrounded or covered by fine materials, was evaluated at each site. Results indicated distinct differences between free-flowing and impounded sites, where normal and moderate embeddedness prevailed, respectively. Instream cover at most locations was considered moderate, reflective of adequate levels for supporting warmwater fish communities. Most free-flowing sections of river were represented by well developed pool, run, and riffle areas. Impounded sections of river lacked riffle and run habitat.

QHEI scores for free-flowing sites of the Muskingum River ranged from 71.0 to 86.0, with a mean value of 82.3 (Figure 25). These scores are indicative of excellent river habitat, and are adequate for supporting Warmwater or Exceptional Warmwater Habitat biological communities. QHEI scores from impounded Muskingum River sites ranged between 54.0 and 64.5, with a mean value of 60.9. Impounded QHEI scores are marginally adequate for supporting warmwater fish communities, particularly in light of the lack of riffle and run habitats. Average QHEI scores for free-flowing sites were 21 points higher than impounded locations.

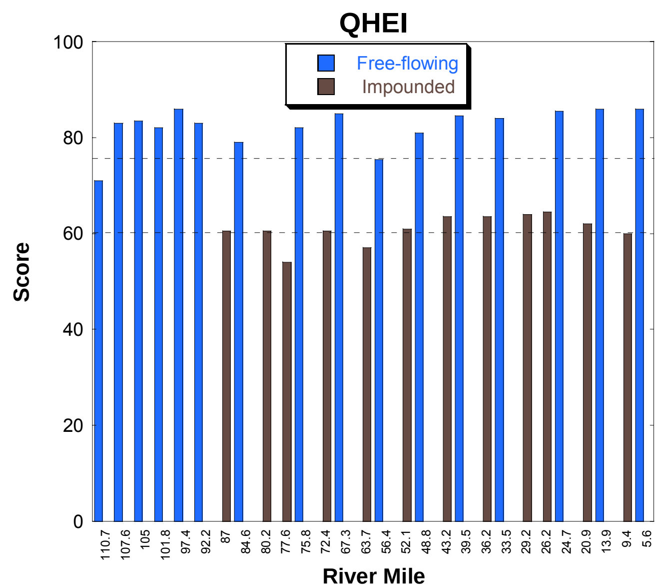


Figure 25. Qualitative Habitat Evaluation Index (QHEI) scores for free flowing and impounded sites in the Muskingum River, 2006. Dashed lines indicate scores generally conducive to the establishment of warmwater faunas (60) and exceptional faunas (75) .

Table 9. Qualitative Habitat Evaluation Index (QHEI) scores and physical attributes for fish sampling sites on the Muskingum River, 2006.

Key QHEI Components

WWH Attributes: columns 4–14. MWH Attributes: High Influence, columns 15–20; Moderate Influence, columns 21–33.

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
(17-001) Muskingum River																																		
Year: 2006																																		
110.7	**71.0**	1.73	■	■		■		■		■	■		6						0				●	●	●			●			●	5	0.14	0.86
107.6	**83.0**	1.73	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
105.0	**83.5**	1.73	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
101.8	**82.0**	1.96	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
97.4	**86.0**	1.96	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
92.2	**83.0**	1.40	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
87.0	**60.5**	0.10	■	■		■		■			■		5				♦		1		●			●	●			●	●		●	6	0.33	1.33
84.6	**79.0**	1.32	■	■		■		■	■	■	■	■	8						0						●							1	0.11	0.22
80.2	**60.5**	0.10	■	■				■		■	■		5				♦		1					●	●			●	●		●	5	0.33	1.17
77.6	**54.0**	0.10	■					■			■		3				♦		1					●	●			●	●		●	5	0.50	1.75
75.8	**82.0**	1.11	■	■		■		■	■	■	■	■	8						0						●							1	0.11	0.22
72.4	**60.5**	0.10	■	■				■			■		4				♦		1					●	●			●	●		●	5	0.40	1.40
67.3	**85.0**	2.27	■	■		■		■	■	■	■	■	8						0						●							1	0.11	0.22
63.7	**57.0**	0.10	■	■				■			■		4				♦		1					●	●			●	●		●	5	0.40	1.40
56.4	**75.5**	0.60	■	■		■		■	■	■	■	■	8				♦		1					●	●							2	0.22	0.44
52.1	**61.0**	0.10	■	■				■			■		4						0					●	●			●	●		●	5	0.20	1.20
48.8	**81.0**	0.54	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
43.2	**63.5**	0.10	■	■				■			■		4						0					●	●			●	●		●	5	0.20	1.20
39.5	**84.5**	2.52	■	■		■		■	■	■	■	■	8						0						●							1	0.11	0.22
36.2	**63.5**	0.10	■	■				■			■		4						0		●			●	●			●	●		●	6	0.20	1.40
33.5	**84.0**	3.77	■	■		■		■	■	■	■	■	8						0						●							1	0.11	0.22
29.2	**64.0**	0.10	■	■				■			■		4						0					●	●			●	●		●	5	0.20	1.20
26.2	**64.5**	0.10	■	■				■			■		4						0		●			●	●			●	●		●	6	0.20	1.40
24.7	**85.5**	1.30	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20
20.9	**62.0**	0.10	■	■				■			■		4						0		●			●	●			●	●		●	6	0.20	1.40
13.9	**86.0**	1.10	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
9.4	**60.0**	0.10	■	■				■			■		4				♦		1		●			●	●			●	●		●	6	0.40	1.60
5.6	**86.0**	1.06	■	■		■	■	■	■	■	■	■	9						0						●							1	0.10	0.20

Fish Community

A total of 16,113 fish representing 65 species were collected from the Muskingum River between August and October, 2006. Relative numbers and species collected per location are presented in Appendix Table 9, and IBI and MIwb scores are presented in Appendix Table 8. Sampling locations were evaluated using Warmwater Habitat biocriteria.

Table 10. Average IBI and MIwb scores for the upper free-flowing section, impounded sites, and tailwater sites of the Muskingum River for 2006, 1994, and 1988. NA = not available.

IBI			
	2006	1994	1988
Free-flowing	45.5	40.1	37.4
Tailwaters	45.0	NA	44.2
Impounded	43.0	NA	38.7
MIwb			
	2006	1994	1988
Free-flowing	9.3	8.5	8.2
Tailwaters	9.7	NA	9.9
Impounded	9.2	NA	9.2

Muskingum River fish communities at 26 of 28 sampling locations achieved the WWH biocriterion. IBI scores for these 26 sites ranged from 38 to 50, and MIwb scores ranged from 8.5 to 10.3, all within the marginally good to exceptional range (Table 11). Two locations, RMs 87.0 and 77.6, were not fully meeting applicable biocriteria. However, because of unsuitable sampling conditions at both locations, fish MIwb results were not used in the aquatic life use attainment determination. Both sites were located in impounded sections of river. At RM 87.0, the initial fish sample was collected during daylight hours. Nighttime electrofishing was planned for the second sampling pass, but due to elevated flow conditions, a second pass was not completed. All other impounded locations were sampled at night, which is the preferred method for assessing large river impounded segments (Ohio EPA 1989b, Simon and Sanders 1999). At RM 77.6, the fish sampling zone was located on the inside bend of the river, which resulted in reduced habitat diversity and extensive sedimentation of the river bottom. This site was chosen to assess potential influences from the AK Steel – Zanesville effluent discharge to the Muskingum River. The preferred sample approach is to sample the outside bends of large rivers (Ohio EPA 1989b); however, this would have required that the sampling site be established at least 1.5 miles downstream from the discharge and perilously close to the Zanesville dam.

An evaluation of fish communities by habitat type (free-flowing upper section, tailwaters, and impounded sections) is presented in Table 10. In addition, longitudinal profiles of IBI and MIwb results are noted in Figures 26 and 27. These results reveal that the free-flowing and tailwater sites were largely reflective of very good to exceptional conditions, and at or approaching EWH levels of biological integrity. Physical habitat features at the free-flowing and tailwater sections were adequate for supporting the EWH use. Sampling sites from these areas had an average QHEI score of 82.3.

Ohio endangered (E), threatened, or special concern fish species collected during this survey included blue sucker (E), river redhorse, mountain madtom (E), bluebreast darter, and eastern sand darter. Fish species collected which are intolerant of water pollution included mooneye, blue sucker, river redhorse, bigeye chub, streamline chub, silver shiner, rosyface shiner, mimic shiner, stonecat madtom, mountain madtom, slenderhead darter, eastern sand darter, banded darter, variegate darter, and bluebreast darter. River redhorse and mimic shiner, two species intolerant of water pollution, were recorded at a number of sampling sites on the Muskingum River. Mimic shiners were recorded from impounded and free-flowing (including tailwater) sites, with fish collected from 22 of 28 sampling locations. River redhorse, a fish species which prefers moderate to swift water habitat, were recorded from 15 of 16

blue sucker @ Lowell

free-flowing sites.

Historical trends in fish community results, represented by average IBI and MIwb scores per habitat type, are presented in Table 10. Additionally, longitudinal profiles of fish data from 1994 and 1988 are presented in Figures 26 and 27. Substantial improvement in fish communities in the upper free-flowing section of the Muskingum River occurred from 1988 to 2006. Improvement occurred in both IBI and MIwb scores; IBI values improved 8.1 points between 1988 and 2006 and MIwb values improved 1.1 points. Translated into narrative quality, fish communities improved from fair/marginally good in 1988 to very good in 2006. The condition of the tailwater fish communities was stable between 1988 and 2006, with results indicative of very good to exceptional quality. Impounded sections of the Muskingum River showed a small improvement between 1988 and 2006. Impoundment MIwb scores were similar during the two sampling years (both averaged 9.2), while the IBI scores improved from 38.7 to 43.0. Overall, fish communities of the Muskingum River have improved over the last 18 years of monitoring.

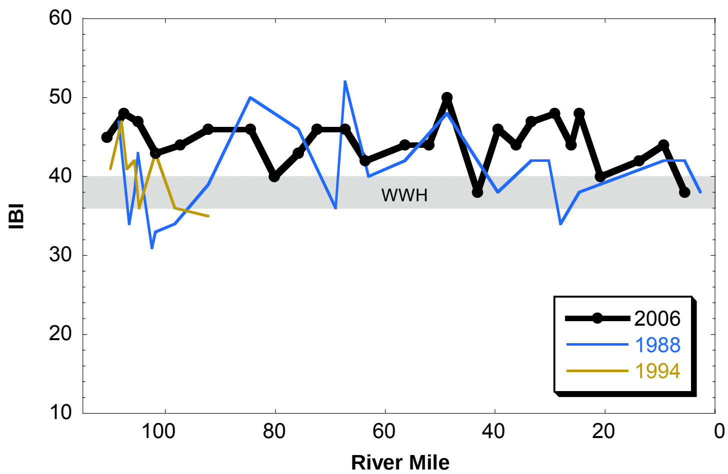


Figure 26. Longitudinal plot of Index of Biotic Integrity (IBI) scores for the Muskingum River from 1988, 1994, and 2006. Scores include impounded and free-flowing sites. Shaded areas represent biological criteria for Warmwater (WWH) habitat.

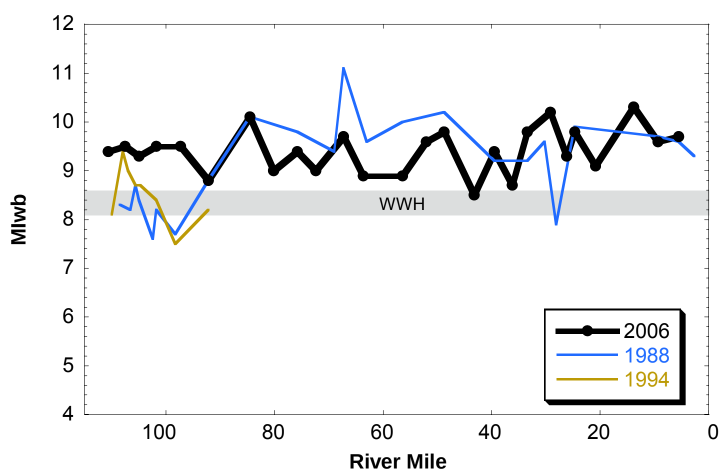


Figure 27. Longitudinal plot of Modified Index of Well-being(MIwb) scores for the Muskingum River from 1988, 1994, and 2006. Scores include impounded and free-flowing sites. Shaded areas represent biological criteria for Warmwater (WWH) habitat.

Table 11. Fish community summaries based on pulsed D.C. electrofishing sampling conducted by Ohio EPA in the Muskingum River from August – October, 2006. Relative numbers and weight are per 1.0 km. The applicable aquatic life use designation is WWH.

Stream River Mile	Sampling Method	Species (Mean)	Species (Total)	Relative Number	Relative Weight (kg)	QHEI	Modified Index of Well-Being	Index of Biotic Integrity	Narrative Evaluation
Muskingum River									
110.7	Boat-Day	21.5	26	398	228.7	71.0	9.4	45	Very Good
107.6	Boat-Day	26.5	33	563	153.8	83.0	9.5	48	Very Good - Exceptional
105.0	Boat-Day	23.0	29	576	107.2	83.5	9.3	47	Very Good
101.8	Boat-Day	29.0	38	737	125.2	82.0	9.5	43	Very Good
97.4	Boat-Day	25.5	36	624	143.5	86.0	9.5	44	Very Good
92.2	Boat-Day	24.5	33	687	198.1	83.0	8.8	46	Good - Very Good
87.0	Boat-Day	14	14	331	42.6	60.5	6.8[a]	36[ns]	Fair - Marginally Good
84.6	Boat-Day	28.0	34	931	168.4	79.0	10.1	46	Very Good - Exceptional
80.2	Boat-Night	23	23	1434	36.2	60.5	9.0	40	Good
77.6	Boat-Night	18	18	462	100.7	54.0	7.1[a]	40	Fair - Good
75.8	Boat-Day	23.5	29	804	187.0	82.0	9.4	43	Very Good
72.4	Boat-Night	23	23	680	119.6	60.5	9.0	46	Good - Very Good
67.3	Boat-Day	25.0	31	1174	195.7	85.0	9.7	46	Very Good - Exceptional
63.7	Boat-Night	24	24	2144	88.5	57.0	8.9	42	Good
56.4	Boat-Day	23.0	30	991	167.9	75.5	8.9	44	Good – Very Good
52.1	Boat-Night	22	22	1132	94.5	61.0	9.6	44	Very Good - Exceptional
48.8	Boat-Day	27.0	33	674	193.8	81.0	9.8	50	Exceptional
43.2	Boat-Night	20	20	784	44.2	63.5	8.5[ns]	38[ns]	Marginally Good
39.5	Boat-Day	25.0	35	695	227.2	84.5	9.4	46	Very Good
36.2	Boat-Night	17	17	474	100.6	63.5	8.7	44	Good - Very Good
33.5	Boat-Day	28.5	36	782	229.5	84.0	9.8	47	Very Good - Exceptional
29.2	Boat-Night	24	24	908	63.1	64.0	10.2	48	Exceptional
26.2	Boat-Night	17	17	568	30.5	64.5	9.3	44	Very Good
24.7	Boat-Day	28.0	33	558	175.1	85.5	9.8	48	Exceptional
20.9	Boat-Night	20	20	358	137.1	62.0	9.1	40	Good - Very Good
13.9	Boat-Day	25.5	33	389	222.4	86.0	10.3	42	Good - Exceptional
9.4	Boat-Night	22	22	592	101.2	60.0	9.6	44	Very Good - Exceptional
5.6	Boat-Day	20	27	410	245.4	86.0	9.7	38[ns]	Marginally Good - Exceptional

Ecoregion Biocriteria: Western Allegheny Plateau (WAP) (Ohio Administrative Code 3745-1-07, Table 7-15)		
INDEX	WWH	EWH
IBI: Boat	40	48
MIwb: Boat	8.6	9.6

* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from biocriterion (≤4 IBI units; ≤0.5 MIwb units).
[a] Due to unsuitable sample conditions, results were not used in the use attainment evaluation (see text).

Macroinvertebrate Community

The macroinvertebrate communities from 28 sampling locations on the Muskingum River were sampled in 2006. Qualitative samples were collected from all sampling locations. Quantitative samples were collected from all but three of the sampling locations. Artificial substrate samplers at RMs 110.7, 107.6, and 97.4 were not collected as declining flow levels left the samplers out of water. At two locations in impounded segments (RMs 77.6 and 43.2) the mid-channel artificial substrate samplers were lost or vandalized. A summary of the macroinvertebrate data are presented in Table 13. The ICI metrics and the raw data are presented in Appendix Tables 10 and 11.

Macroinvertebrate sampling results from 2006 indicate that all sampled sites were in full attainment of the WWH biocriterion (Figure 28). Macroinvertebrate community evaluations from RMs 110.7, 107.6 and 97.4 were based on the qualitative sample results. Although a quantitative sample from RM 92.2 was collected, the ICI score was not used due to low current velocity across the sampler. A narrative evaluation of an exceptional macroinvertebrate community based on the qualitative sample results was used for this site. The RM 77.6 site was in an impounded portion of the river on an inside bend downstream from the AK Steel- Zanesville facility. The mid-channel sampler from this site was lost and only the edge sampler and qualitative sample were available for site assessment. Based on low current velocity and poor habitat the edge quantitative sample was not used to assess this site. The similarity of the qualitative sample from RM 77.6 to other impounded sites where the mid-channel artificial substrate samplers were evaluated as good or better was the basis for evaluating this site as good for attainment purposes. The mid-channel artificial substrate sampler from RM 52.1 had low current velocity so the qualitative sample narrative evaluation of good was used for this site. Artificial substrate samplers from mid-channel locations in impounded areas were used for attainment assessment purposes.

Historical trends in macroinvertebrate community results are presented in Figure 29 and Table 12. The free-flowing sites show improvement in macroinvertebrate biology from 1988 (very good) to 2006 (exceptional). The dam tailwater sites improved, in general, from marginally good in 1988 to exceptional in 2006. The macroinvertebrate communities from impounded sites in the dam pools were, on average, fair in 1988 and very good in 2006. A portion of the improvement in the impounded sites was the result of changes in sampling method. The 2006 assessments were based on the mid-channel samples, while 1988 data is from near-shore edge samples.

Table 12. Average ICI scores for the upper free-flowing section, impounded sites (mid-channel), and tailwater sites of the Muskingum River for 2006, 1994, and 1988. NA = not available.

ICI			
	2006	1994	1988
Free-flowing	49.3	46.3	44.9
Tailwaters	46.0	NA	32.2
Impounded	42.7	NA	16.8

Sampling results using artificial substrate samplers in large rivers is very dependent on the current velocity and site specific habitat condition. Wading accessible sites from impounded portions of large rivers often have current velocities below the sampling method recommendation of 0.3 feet per second. Current velocities near the shore are sensitive to changes in river flow. Near shore areas (which make up a small percentage of the river surface area) are often sediment depositional zones with resulting poor macroinvertebrate habitat. In the 2006 sampling of the Muskingum River impoundments, an artificial substrate sampler was placed near mid-channel at each sampling location in addition to samplers on the edge, consistent with historical sampling methods. Current velocities at the mid-channel locations were higher than the nearshore sites and generally above 0.3 feet per second. Bottom substrates were predominantly cobble and gravel from the 8-14 feet deep mid-channel sites. Figure 28 shows 2006 ICI sampling results for free flowing, tailwater and impounded edge and mid-channel sites. Mid-channel ICI scores were consistently above edge ICI scores and in full attainment of the WWH biocriterion. Edge results were more variable and frequently below the WWH biocriterion. Edge locations where the ICI scores were similar to the mid-channel scores had current velocities similar to the mid-channel sites.

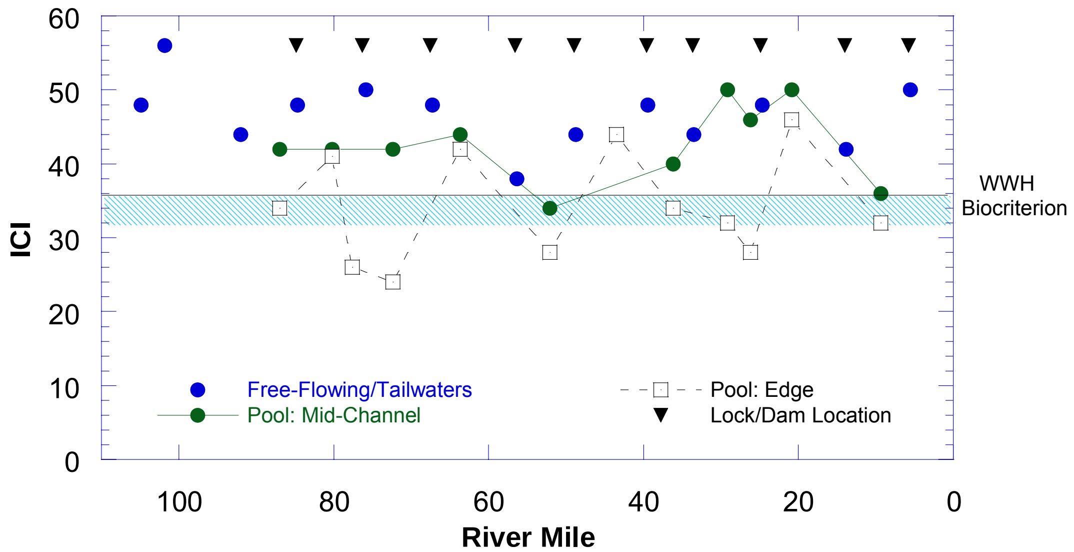


Figure 28. Longitudinal plot of Invertebrate Community Index (ICI) scores for the Muskingum River from 2006.

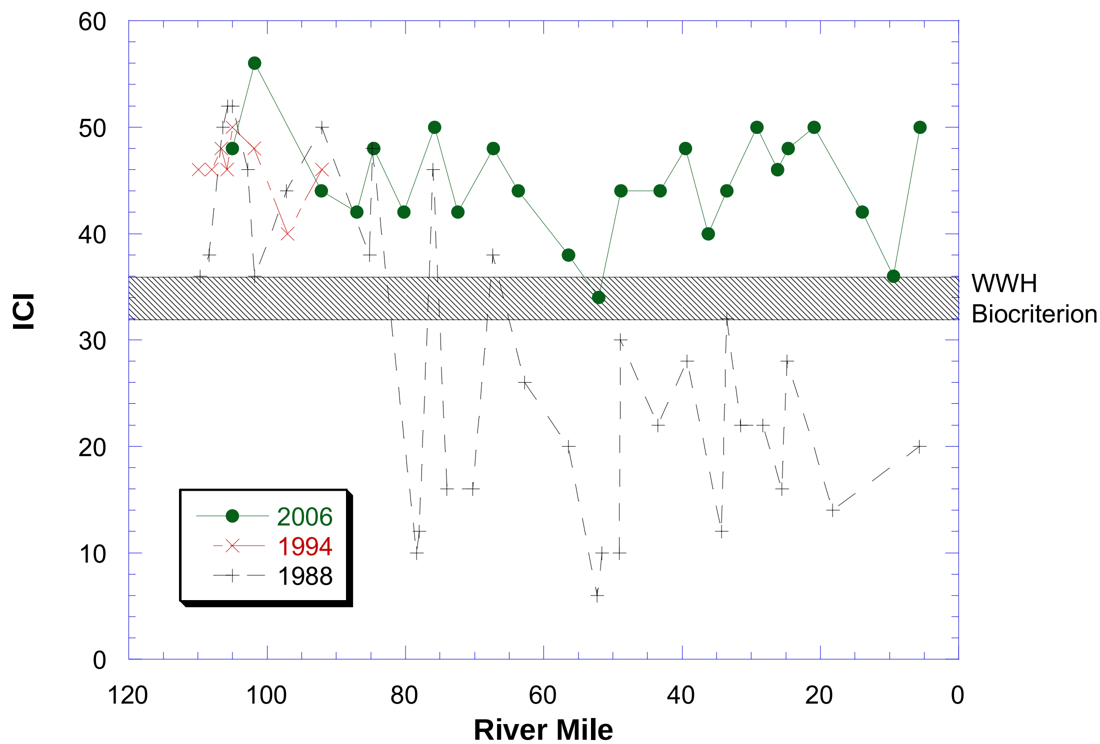


Figure 29. Longitudinal plot of Invertebrate Community Index(ICI) scores for the Muskingum River from 1988, 1994, and 2006. Scores include impounded and free -flowing sites.

Table 13. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Muskingum River, 2006. The applicable use designation is WWH.

Stream/ River Mile	Density Number/ft^2	Total Taxa	Quantitative Taxa	Qualitative Taxa	Qualitative EPT[a]	ICI	Evaluation
110.7	-	-	-	48	22	NA	Exceptional
107.6	-	-	-	56	21	NA	Exceptional
105.0	473	71	53	56	26	48	Exceptional
101.8	1807	66	40	56	27	56	Exceptional
97.4	-	-	-	51	22	NA	Exceptional
92.2	472	64	46	46	22	44[c]	Exceptional
87.0 – Mid	423	56	31	36	12	42	Very Good
87.0 – Edge	213	-	26	-	-	34[ns]	Marginally Good
84.6	1062	70	48	54	22	48	Exceptional
80.2 – Mid	799	45	31	25	7	42	Very Good
80.2 – Edge	603	-	31	-	-	42	Very Good
77.6 – Edge	266	41	36	15	4	26[c]	Fair[b]
75.8	1155	56	44	36	20	50	Exceptional
72.4 - Mid	331	49	39	20	4	42	Very Good
72.4 - Edge	208	-	42	-	-	24*	Fair
67.3	5951	61	38	47	23	48	Exceptional
63.7 – Mid	1673	52	38	22	4	44	Very Good
63.7 - Edge	465	-	36	-	-	42	Very Good
56.4	363	64	39	46	18	38	Good
52.1 - Mid	2145	42	38	13	3	34[c]	Good
52.1 - Edge	1847	-	23	-	-	28*	Fair
48.8	1481	56	37	44	21	44	Very Good
43.2 - Edge	2272	50	40	24	10	44	Very Good
39.5	943	62	40	48	17	48	Exceptional
36.2 - Mid	1886	46	34	20	3	40	Good
36.2 - Edge	1149	-	33	-	-	34	Marginally Good
33.5	3356	74	36	61	22	44	Very Good
29.2 - Mid	1970	43	24	26	5	50	Exceptional
29.2 - Edge	213	-	28	-	-	32[ns]	Marginally Good
26.2 - Mid	506	47	39	21	7	46	Exceptional
26.2 - Edge	546	-	34	-	-	28*	Fair
24.7	1088	52	38	39	16	48	Exceptional
20.9 - Mid	1657	40	30	27	8	50	Exceptional
20.9 - Edge	368	-	34	-	-	46	Exceptional
13.9	1592	52	39	29	11	42	Very Good
9.4 - Mid	452	46	34	22	5	36	Good
9.4 - Edge	387	-	35	-	-	32[ns]	Marginally Good
5.6	1414	60	40	41	16	50	Exceptional

Ecoregion Biocriteria: Western Allegheny Plateau (WAP) (Ohio Administrative Code 3745-1-07, Table 7-15)		
INDEX	WWH	EWH
ICI	36	46

[a] EPT=total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness, a measure of pollution sensitive organisms.
[b] Evaluation is based on a qualitative sample only.
[c] Due to unsuitable sample conditions, results were not used in the use attainment evaluation (see text).
* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from biocriterion (≤4 ICI units).
NA Not available. HD out of water during part of the 6 week placement period.

Fish Tissue

Fillet samples of 11 fish species (including two hybrids) were collected from 17 locations in the Muskingum River and tested for arsenic, cadmium, lead, mercury, selenium, PCBs, and organochlorinated pesticides. A total of 86 samples were collected from the 17 locations, with collections occurring in the upper free-flowing section, tailwaters below dams, and impounded reaches. Laboratory analytical results have not been completed for the tissue samples; however, the analyses of these samples will be completed by June, 2007. When the results are available, they will be evaluated with other samples collected from around Ohio as part of the Ohio Sport Fish Consumption Advisory Program. The fish tissue data generated from the Muskingum River will be used to update Ohio's Sport Fish Consumption advisories issued by the Ohio Department of Health, in cooperation with Ohio EPA and the Ohio Department of Natural Resources. The Ohio advisories are typically updated on a yearly basis for the entire state, with the last update occurring on February 28, 2007.

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