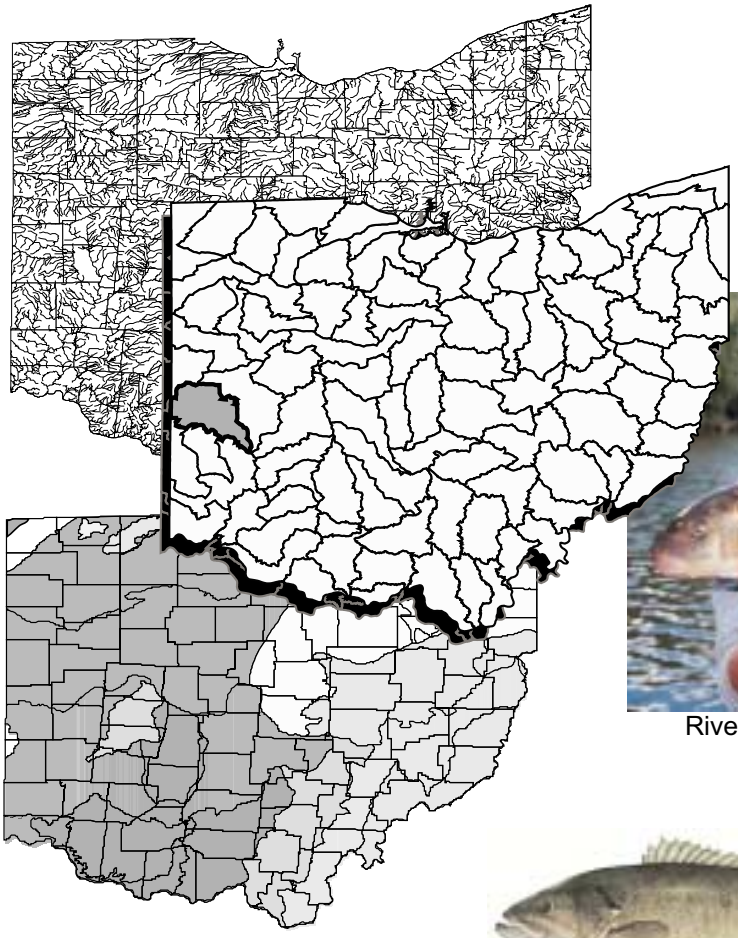
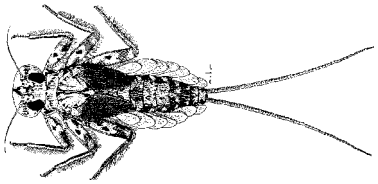
Division of Surface Water
Ecological Assessment Section

Biological and Water Quality Study of the Stillwater River Watershed

Darke, Miami and Montgomery Counties





Mayfly (*Eurylophella* sp.)

River Redhorse (*Moxostoma carinatum*)

Smallmouth Bass (*Micropterus dolomieui*)

November 6, 2001

P.O. Box 1049, 122 South Front Street, Columbus, Ohio 43216-1049

Biological and Water Quality Study of the Stillwater River Basin, 1999

Darke, Miami and Montgomery Counties

November 6, 2001

OEPA Technical Report
Number MAS/2001-12-8

Bob Taft, Governor
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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., Ecological Assessment Section, 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.

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

Since the publication of the preceding guidance documents new publications by Ohio EPA have

become available. The following publications should also be consulted as they represent the latest information and analyses used by 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.

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

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Acknowledgments

The authors who contributed to this report, and their respective contributions are:
MaryAnne Mahr - Pollutant Loadings and NPDES discharger facility descriptions (937-285-6196);
Louise Snyder - Water Column Chemistry and Trends (937-285-6475);
Greg Buthker - Sediment Chemistry, Spills, CSO information (937-285-6445);
Hugh Trimble - Nonpoint Sources of Pollution, Study Area (937-285-6444);
Michael Bolton - Biological Assessment: Macroinvertebrate Community (614-836-8781);
Bob Miltner - Introduction, Summary, Physical Habitat for Aquatic Life, and Biological Assessment: Fish Community (614-836-8796).

This report was reviewed in whole or in part by Jeff DeShon, Dale White, Chris Skalski, Marc Smith, Chris Yoder and Diana Zimmerman.

Water chemistry analysis was provided by the Ohio EPA Division of Environmental Services. Numerous college interns and district office staff assisted in the collection of field samples. Chad Meador, Zarin Kresge and Brian Pefly helped with the arduous task of collecting fish. Landowners who granted permission for site access are duly appreciated. Appreciation is also extended to the Stillwater Watershed Project, and other OEPA divisions for their assistance during the planning of this survey.

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 10-15 different study areas with an aggregate total of 250-300 sampling sites.

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]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] report).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised 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 is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. 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 declining species or bacterial levels which serve as surrogates for the recreational 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 Ohio Water Resource Inventory (305[b] report), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Uses

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.

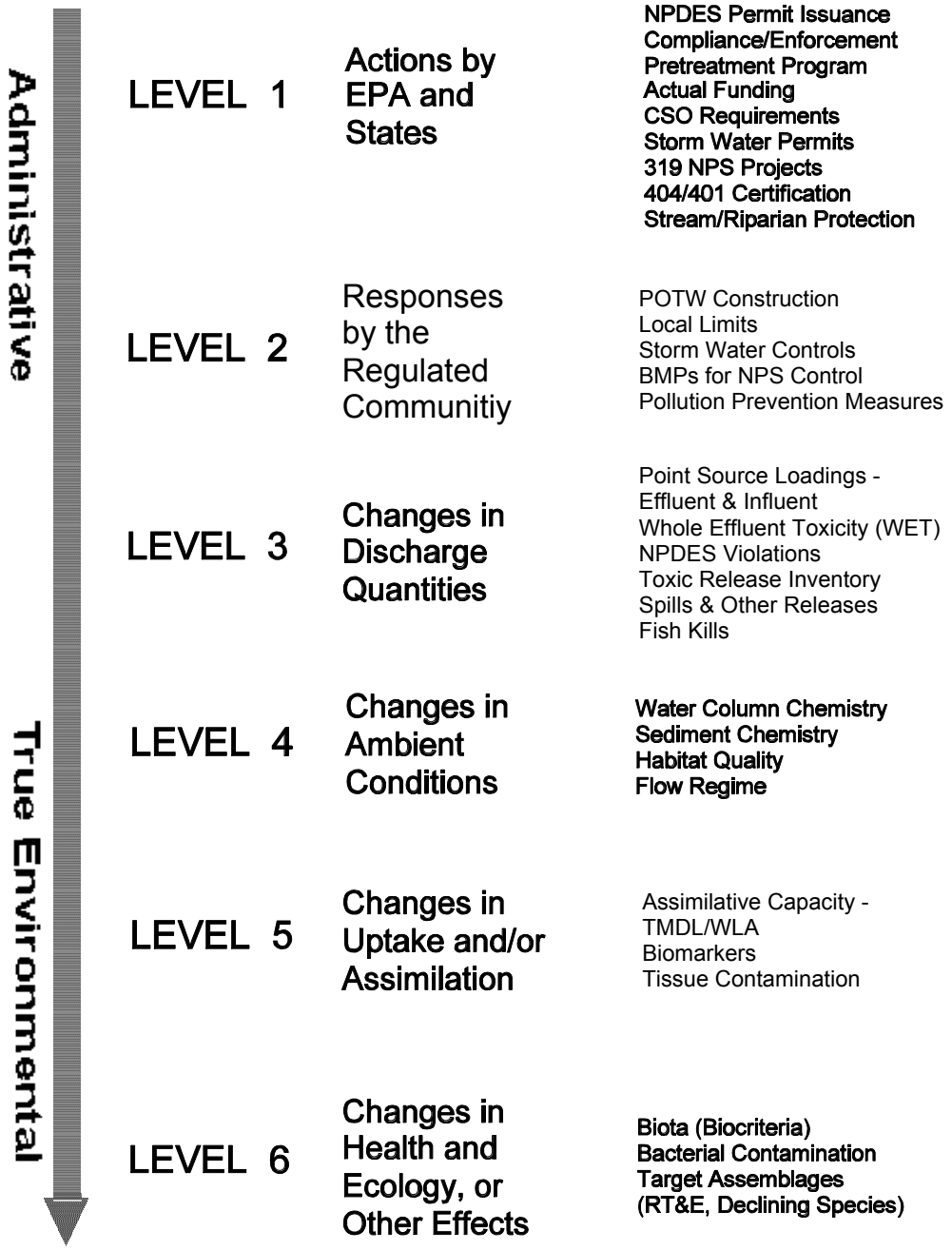

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995).

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 and permitted 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, NH_3-N, 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 is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliforms, *E. coli)* and the criteria for each are specified in the Ohio WQS.

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 Agricultural Water Supply (AWS) and Industrial Water Supply (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 are detailed in other documents.

INTRODUCTION

Biological, physical, surface water and sediment samples were collected from the Stillwater River basin in 1999. The information gathered from this survey evaluates ambient conditions, existing environmental impacts from both point source discharges and nonpoint sources of pollution, attainment of designated stream uses, and will be used, in part, to develop Water Quality Based Effluent Limits. Also, sources and causes of impairment identified in this study will help guide development of a Total Maximum Daily Load (TMDL) model for the basin. The primary areas sampled in this survey included the Stillwater River mainstem, Greenville Creek, Ludlow Creek, Painter Creek, Harris Run, Trotters Creek, Swamp Creek, and any tributary or ditch named in the Ohio Water Quality Standards. Also sampled were any unnamed tributaries with permanent flow or natural habitat features encountered during the survey.

Specific objectives of this study were to:

1) evaluate of impacts to water quality and aquatic life from the following point source dischargers:

   Englewood WWTP
   Union WWTP
   West Milton WWTP
   Village of Pleasant Hill
   Village of Covington WWTP
   Greenville WWTP
   Union City WWTP
   Versailles WWTP
   Ansonia WWTP and CSOs
   Arcanum WWTP and CSOs
   Bradford WWTP and CSOs

2) evaluate possible water quality and aquatic life use impacts associated with Animal Feeding Operations (AFOs) and the land application of manure centered mainly in the Swamp Creek basin, and the Stillwater watershed upstream from Ansonia;

3) evaluate possible water quality and aquatic life use impacts from unsewered communities, subdivisions, or residences including the subdivision upstream from Greenville (Daly Road), Wayne Lakes Park (Mud Creek subbasin), and Bradford;

4) evaluate possible water quality and aquatic life use impacts from small package plants on Bridge Creek (tributary to Greenville Creek);

5) assess the Stillwater River for potential aquatic contamination in the vicinity of the Garland Road landfill;

6) assess recovery of, or continued impact to, aquatic life in Mill Creek from deicing chemicals used at Cox Dayton Airport, and;

7) verify existing uses on designated streams and assign appropriate use designations to undesignated waters.

SUMMARY

Biological and water quality conditions vary widely in the Stillwater River basin from the best of the best to the worst of the worst measured within Ohio (Table 1). The stream segments with the highest biological and water quality are the lower Stillwater River mainstem from Covington to the confluence with the Great Miami River, and Greenville Creek and its tributaries originating from the Farmersville Moraine. The reason the lower Stillwater River is in such good condition is because the riparian forest is intact, development within the adjacent flood plain is largely agricultural, and the agriculture practiced there employs conservation measures. The Stillwater River has the largest population of river redhorse in Ohio. River redhorse are listed as Special Interest on the Ohio Division of Wildlife Endangered Species list because of their comparative rarity and declining abundance in Ohio. Water quality and reasonably intact biological communities are maintained in Greenville Creek and its tributaries by groundwater-augmented baseflow.

The stream segments having the poorest water quality and the most degraded biological communities are, in order of severity of impairment, Painter Creek, the North Fork Stillwater, Swamp Creek, Indian Creek, the Stillwater River mainstem upstream from Ansonia, Ballinger Run, and Mill Creek. Painter Creek is degraded by Arcanum's failed sewage collection and treatment system. Swamp Creek, the North Fork Stillwater and the Stillwater mainstem are impacted by habitat destruction and organic enrichment from land-applied manure, Indian Creek from the preceding factors plus failing septic systems, Ballinger Run by organic enrichment from combined sewer overflows (CSOs), and Mill Creek from deicing chemicals used at the Dayton-Cox International Airport.

The most pervasive problem facing streams in the basin is habitat destruction through channelization. Almost the entire stream network in Darke County has previously been channelized. Channelization is the removal of trees from stream banks coupled with deepening, and often straightening, the stream course. Channelization always results in long-term aquatic life use impairment, especially for sport fishing, is a direct cause of sedimentation, and greatly magnifies the effects of introduced nutrients. This latter problem is especially troublesome in the northern portion of the basin where large amounts of manure are applied to the land. Because the streams are maintained in a channelized state with little or no riparian buffer, organic matter and nutrients are able to enter unimpeded during storm events. The absence of a shading riparian canopy allows full sunlight to reach the stream and cause algal blooms. The algal blooms then result, either through decomposition or respiration, in dissolved oxygen depletion to below levels

needed to sustain higher aquatic life. Further complicating matters is the loss or diminution of sustained stream flow in channelized headwaters, especially those less than 10 mi^2, as the whole point of channelization is to expedite drainage. The upshot being, from a pollution loadings standpoint, that less flow for a given drainage area means less assimilative capacity.

The other pervasive problem facing the basin, as mentioned in the previous paragraph, is organic enrichment. Organic enrichment in the Stillwater basin comes primarily from land-applied animal manure and failing septic systems. That organic enrichment is a problem in the basin was evidenced by biological and water quality results (*e.g.*, high fecal coliform bacteria and *E. coli* counts, high biochemical oxygen demand, wide diel oxygen swings, poor to very poor biological scores, and fish kills occurring in streams with sustained flow). Although channelized streams are expected to have less biological and water quality integrity compared to natural streams, channelized streams are expected to be free from nuisance conditions (*e.g.*, mats of decaying algae), safe for recreational contact (*i.e.*, fecal matter should not be present), and should have sufficient water quality to harbor aquatic life. Swamp Creek and its tributaries, the North Fork, and the Stillwater River upstream from Ansonia were similarly impacted from excess organic enrichment from land-applied manure. Failing septic systems caused noticeable water quality impacts and biological impairment in Indian Creek, Greenville Creek downstream from Gettysburg, the Wayne Lakes area, and to Ludlow Creek or its tributaries near Phillipsburg and Pittsburgh.

The existing problems should not, however, overshadow successes. Most of the point source problems along the Stillwater mainstem have been abated and considerable recovery has occurred since 1982 (Figure 2). The existing threat from point sources is now population growth over-running treatment capacity (Table 2). Several treatment plants are now approaching their design capacity and so occasionally have flows exceeding treatment ability.

The other area of success has been in the implementation of agricultural best management practices. Conversion of farmed acres to no-till, filter strips, and conservation easements have collectively resulted in improved biological communities for the entire Stillwater mainstem downstream from Ansonia.

RECOMMENDATIONS

Stillwater River

Status of Aquatic Life Uses

Approximately sixty-six miles of the Stillwater River were assessed for the status of aquatic life uses and attainability of those uses. The Stillwater River is designated Warmwater Habitat (WWH) from its headwaters to Biesner Road (RM 57.0), and Exceptional Warmwater Habitat (EWH) from Biesner Road to the confluence with the Great Miami River. The WWH designation is not attainable upstream from Woodington Run/Ansonia (RM 61.8) as the river there is under active channel maintenance. Therefore, the appropriate and attainable aquatic life

use designation is Modified Warmwater Habitat (MWH). The WWH designated segment should be extended downstream to Shroeder Road (RM 52.0) as the stream between RMs 57 and 52 has been previously channelized and has not recovered enough warmwater habitat attributes, either over time or due to proximity to the actively maintained headwaters, to make EWH a realistic use. Based on these adjusted use recommendations, the attainment status for the sixty-six miles of Stillwater River mainstem are 3.3 miles not attaining, 8.2 miles partially attaining and 55.0 miles fully attaining aquatic life uses. Aquatic life use impairment in the headwaters upstream from Ansonia is being caused by organic enrichment from land applied manure combined with poor habitat. Impairment downstream from Ansonia is being caused by a combination of organic and nutrient enrichment from CSOs (Ansonia), wastewater loadings (Ansonia and Versailles) and manure (North Fork and Swamp Creek), and by the downstream footprint resulting from keeping the headwaters maintained in a channelized state. A small reach of partial attainment also exists downstream from the Englewood WWTP. The impairment there is caused by a combination of being immediately downstream from the Englewood Dam and wastewater loadings from the treatment plant.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreation use designation are appropriate for the Stillwater River. The Stillwater River is designated for Public Water Supply at RM 18.0.

Future Monitoring Concerns and Other Recommendations
Efforts to minimize the downstream impact of having the headwaters maintained in a channelized state are needed to safeguard existing biological communities and to affect further recovery. Such efforts should include increasing the width of filter strips, re-establishing wooded riparian corridors where practical, streambank stabilization, and widening floodplain channels where feasible. Also, existing conservation measures need to be maintained, and manure management plans need to be doggedly adhered to. Monitoring in the near-term should include sampling downstream from Ansonia and Swamp Creek to assess potential impacts to the mainstem from land-applied manure. Long-term sampling plans will be developed in support of the ongoing Total Maximum Daily Load (TMDL) project.

Greenville Creek
Status of Aquatic Life Uses
The entire thirty-four miles of Greenville Creek in Ohio are designated Exceptional Warmwater Habitat. That use designation is appropriate for all segments except for the reach flowing through Greenville, which has been channelized and is maintained *de facto* by hard urban surfaces. The appropriate aquatic life use designation for this reach, based on demonstrated biological performance and habitat quality is Warmwater Habitat. Adjusting for this recommendation, 11.1 miles fully attain, 20.2 miles partially attain, and 3.2 miles do not attain aquatic life uses. The single most important factor responsible for impairing the aquatic life uses in Greenville Creek is habitat degradation. Portions of the creek upstream from Greenville have

been recently channelized to accommodate development, most of the tributaries have been channelized and consequently are a source of sediment, and as previously mentioned, the creek in and downstream from Greenville has been altered. The collective effect of all this contributes to the impairment immediately downstream from the Greenville WWTP. Organic and nutrient enrichment from the Greenville WWTP and, more importantly, onsite sewage disposal (septic tanks) is the primary cause of impairment further downstream from Greenville.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply use designations, and the Primary Contact Recreation use designation are appropriate for Greenville Creek. A Public Water Supply designation exists at RM 22.3.

Future Monitoring Concerns and Other Recommendations
Obviously failing on-site systems need to be brought up to code as a first step. And, as with the Stillwater River, impacts from having the tributaries and portions of the creek maintained in a channelized state should be minimized. Again, such efforts should include, along with existing conservation measures, increasing the width of filter strips, re-establishing wooded riparian corridors where practical, streambank stabilization, and widening flood plain channels where feasible. All existing, expanding, or new animal feeding operations, whether requiring a permit or not, should develop and adhere to manure management plans. Follow-up monitoring plans will be developed with the TMDL.

Mill Creek
Status of Aquatic Life Uses
Mill Creek is designated WWH. This use was fully met in the lower 0.5 miles of the creek, and not met in the remaining 2.1 miles assessed. The biological communities remain impaired by releases of deicing chemicals used at the Cox-Dayton International Airport.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use designations are appropriate.

Future Monitoring Concerns and Other Recommendations
Stormwater plans at the Cox-Dayton Airport should be reviewed and amended as necessary to prevent discharges of deicing chemicals from their northwest retention basin.

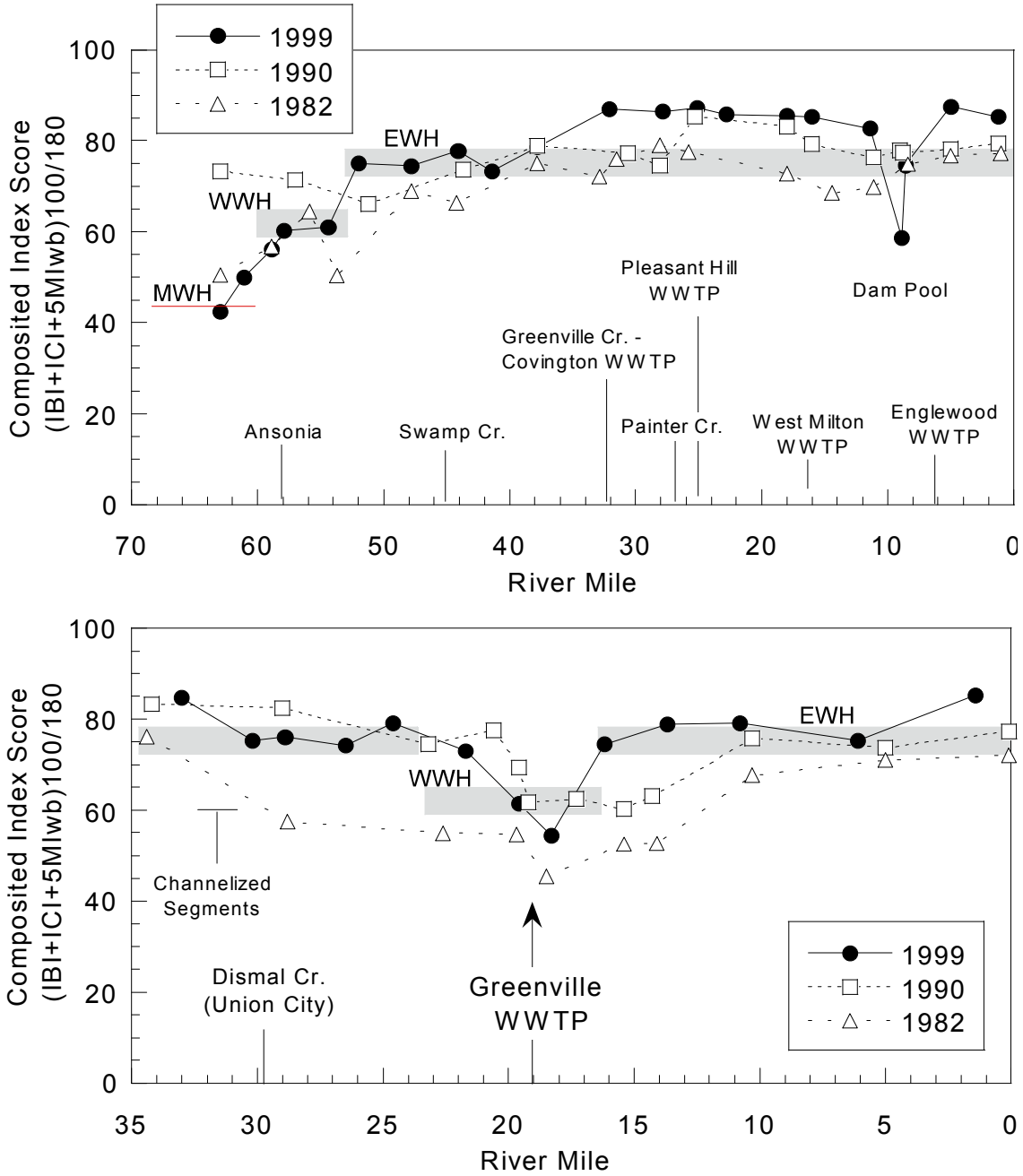

Figure 2. Trends in biological communities sampled in the Stillwater River (upper panel) and Greenville Creek (lower panel), 1982, 1990 and 1999 in relation to point source dischargers or major tributaries. Biological index scores were composited into a single score based on the formula IBI+ICI+5MIwb*100/180. Shaded bars on graph depict the lower boundaries of existing or proposed biological criteria based on composited scores.

Ludlow Creek

Status of Aquatic Life Uses

Ludlow Creek is designated WWH. That designation is appropriate except for the channelized and actively maintained headwaters where a Modified Warmwater Habitat (MWH) designation is appropriate. When MWH is considered for the headwaters upstream from the Darke County line, the aquatic life uses are fully met.

Status of Non-aquatic Life Uses

The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use designations are appropriate.

Future Monitoring Concerns and Other Recommendations.

Although the aquatic life uses in Ludlow Creek were fully met, the channelized headwaters impacted the lower 8.0 miles of natural stream by causing sedimentation. The MIwb scores showed nonsignificant departure from WWH at all four sites sampled in the natural reach due to the absence of pollution sensitive species, particularly redhorse suckers and cyprinids. Given that the habitat and water quality are otherwise sufficient to support these species, those species were likely extirpated by an episodic kill or a prior history of degraded water quality. Reintroduction of those species should be attempted.

Brush Creek

Status of Aquatic Life Uses

Brush Creek is designated WWH. That use designation was not met at RM 7.1 due to organic enrichment, presumably from on-site sewage disposal. The impact at RM 7.1 was likely exacerbated by the drought. The site sampled at RM 0.4 fully met WWH.

Status of Non-aquatic Life Uses

The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use designations are appropriate.

Future Monitoring Concerns and Other Recommendations.

Failing onsite systems as a source of organic enrichment should be confirmed and brought up to code as necessary.

Painter Creek

Status of Aquatic Life Uses

Painter Creek has an unconfirmed EWH use designation from its confluence with the Stillwater River to the Darke County line (RM 5.5), and a MWH designation upstream from there. The EWH use has not been demonstrated; therefore, the appropriate aquatic life use is WWH. Given these designations, of the approximately eighteen miles assessed, 1.5 miles were in full attainment, 8.0 miles did not attain, and 5.5 miles partially attained their respective aquatic life use designations. The eight mile reach of non-attainment was caused by gross organic

enrichment from the failing sewage collection and treatment system in Arcanum.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use designations are appropriate.

Future Monitoring Concerns and Other Recommendations.
The combined sewers should be separated, and the sewage treatment plant should be upgraded from a simple sewage lagoon to at least secondary treatment.

Harris Run and Ballinger Run
Status of Aquatic Life Uses
Harris Run and Ballinger Run are both designated WWH, and that designation has been confirmed for the portion of both streams in Miami County. However, both streams are actively maintained for drainage in Darke County where a MWH use designation is appropriate. The RM at the Darke-Miami county line for Harris Run is 5.2, and 1.7 for Ballinger Run. So designated, there were 4.2 miles of partial attainment and 1.0 mile of full attainment in Harris Run, and 3.0 miles of non-attainment in Ballinger Run. Bradford CSOs continued to be the main source of impairment to both Ballinger Run and Harris Creek.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use designations are appropriate.

Future Monitoring Concerns and Other Recommendations.
Obviously Bradford's CSOs should be addressed.

Trotters Creek and Tributaries
Status of Aquatic Life Uses
Trotters Creek has an unconfirmed WWH aquatic life use designation. The fish and macroinvertebrate community downstream from Rike Road (RM 1.7) met expectations for EWH and should be so designated. Upstream from Rike Road, WWH is the appropriate aquatic life use.

Of the tributaries to Trotters Creek assessed, a WWH aquatic life use is appropriate for Sigmon Ditch and Bennett Ditch. Orr Ditch, Apple Ditch and Rudy Ditch should be resampled during a non-drought year to be properly designated as the macroinvertebrate samples were collected during the height of the drought.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use

designations are appropriate for Trotters Creek, and should also apply to Sigmon Ditch, and Bennet Ditch.

Future Monitoring Concerns and Other Recommendations.
Resample Orr Ditch, Apple Ditch and Rudy Ditch after allowing for recovery from the drought.

Swamp Creek and Tributaries
Status of Aquatic Life Uses
Swamp Creek is designated MWH upstream from RM 6.5, and WWH downstream from that point. Of the 12.1 miles assessed, 5.6 miles fully attained, 4.2 miles partially attained, and 2.3 miles did not attain their respective use designations. The main cause of impairment was organic and nutrient enrichment, with conditions being so enriched as to result in critically low dissolved oxygen concentrations and fish kills. The source of the organic and nutrient enrichment is land applied manure.

Indian Creek is similarly impaired by organic and nutrient enrichment, but failing septic systems are an additional source of enrichment. Indian Creek is designated WWH and that designation has been confirmed for the lower 1.9 miles (Conover Road) of stream. Upstream, the creek is an actively maintained drainage ditch and therefore should be designated MWH. So designated, 4.1 miles - the entire assessed portion being proposed for MWH - were not attaining, and the lower 2.0 miles were partially attaining the WWH aquatic life use designation.

The tributary to Swamp Creek at RM 3.54 is actively maintained for drainage and should be designated as MWH. So designated, the 1.0 mile reach assessed was meeting its aquatic life use.

Grassy Fork is a maintained ditch and should be designated MWH. The MWH aquatic life use was not met due to drought related stresses.

Status of Non-aquatic Life Uses
The existing Agricultural and Industrial Water Supply and Primary Contact Recreation use designations are appropriate for Swamp Creek and Indian Creek, and should be applied to Grassy Fork and the unnamed Swamp Creek tributary at RM 3.54.

Future Monitoring Concerns and Other Recommendations.
Manure management plans, areas where manure is being applied, and whether plans are being adhered to should be reviewed. Also, measures to either decrease or filter the runoff entering Swamp Creek need to be implemented. Two simple measures include increasing filter strip widths and applying during the growing season. The failing septic systems discharging to Indian Creek at Wolf Road should be repaired.

Boyd Creek and Tributaries

Status of Aquatic Life Uses

The entire Boyd Creek drainage network is a series of maintained drainage ditches that should be designated MWH. Based on the MWH aquatic life use, Boyd Creek fully attained at RM 0.8, and partially attained at RM 3.5. The two tributaries to Boyd Creek (confluences at RM 2.46 and 2.67) did not attain due to very poor qualitative macroinvertebrate scores. The macroinvertebrate community from the tributary at RM 2.46 may have been limited by the drought, but the tributary at RM 2.67 was impaired by organic enrichment, most likely from failing onsite sewage disposal. On-site disposal was also the reason for partial attainment in Boyd Creek.

Status of Non-aquatic Life Uses

An Agricultural and Industrial Water Supply, and Primary Contact Recreation use designations are recommended for Boyd Creek and all its tributaries.

Future Monitoring Concerns and Other Recommendations.

Unsewered homes on the north side of Greenville should be inspected for properly maintained on-site systems.

North Fork Stillwater River and Sycamore Ditch

Status of Aquatic Life Uses

The North Fork is appropriately designated MWH. All eleven miles evaluated did not attain the MWH aquatic life use due to organic and nutrient enrichment from land-applied manure. Sycamore Ditch met MWH.

Status of Non-aquatic Life Uses

The existing Agricultural and Industrial Water Supply, and Primary Contact Recreation use designations are appropriate for the North Fork, and should be applied to Sycamore Ditch.

Future Monitoring Concerns and Other Recommendations.

Manure management plans, areas where manure is being applied, and whether plans are being adhered to should be reviewed. Also, measures to either decrease or filter the runoff entering the North Fork need to be implemented. Two simple measures include increasing filter strip widths and applying manure only during the growing season.

Woodington Run

Status of Aquatic Life Uses

Biological communities in Woodington Run met expectations for WWH at RM 4.9 and partially met expectations at RM 1.1. The limiting component at RM 1.1 was the bug community, which was evaluated as “fair” because of effects from nutrient enrichment. Because the fish community met WWH at both sites, the physical stream habitat has recovered some function since being channelized, and because the macroinvertebrate community was impaired beyond simply the effects of habitat, a WWH aquatic life use is recommended for Woodington Run.

Status of Non-aquatic Life Uses
The existing default Agricultural and Industrial Water Supply, and Primary Contact Recreation use designations are appropriate for Woodington Run.

Future Monitoring Concerns and Other Recommendations.
Riparian restoration would easily result in full attainment of WWH for Woodington Run.

South Fork Stillwater River
Status of Aquatic Life Uses
Biological communities in the South Fork met expectations for WWH at RM 0.4, did not meet based on one qualitative bug sample at RM 1.3, and partially met expectations at RM 3.0. Habitat function was admittedly worse than that for Woodington Run, but as the fish community met WWH, and the fish community is generally the more limiting component when habitat is the issue, a WWH aquatic life use is recommended for the South Fork.

Status of Non-aquatic Life Uses
The existing default Agricultural and Industrial Water Supply, and Primary Contact Recreation use designations are appropriate for the South Fork.

Future Monitoring Concerns and Other Recommendations.
Riparian restoration would easily result in full attainment of WWH for the South Fork.

Other Tributaries
Status of Aquatic Life Uses
Numerous other nameless and undesignated tributaries were assessed to determine the appropriate aquatic life use designation, more than can be conveniently discussed in the prior format; refer to Tables 1 and 3 for those recommendations. The rational for assigning a designation in all cases was based on demonstrated biological performance unconfounded by water quality impacts, or potential biological performance based on habitat quality in the absences of a direct water quality problem where such a problem existed.

Status of Non-aquatic Life Uses
Agricultural and Industrial Water Supply, and Primary Contact Recreation use designations are appropriate across the board.

Future Monitoring Concerns and Other Recommendations.
As most of the streams in question are treeless, maintained ditches draining tiled agricultural land, set-backs, filter strips, woody buffers, judicious fertilizer use, and conservation tillage practices are recommended for all.

Table 1. Aquatic life use attainment status for stations sampled in the Stillwater River basin July-September, 1999. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Stillwater River (14-200) *WWH/MWH proposed*						
65.8	30	NA	MG	31	Partial/Full	
65.0	18*	NA	F	31	NON/NON	Organic enrichment - AFOs
63.8	40	NA	MG	37	Full/Full	
63.0	34	5.3*	F*	38	NON/NON	Organic enrichment - AFOs.
61.1/61.8	25	7.0	30	34	NON/Full	
				WWH		
60.2	-	-	38		(Full)	
58.8	30*	7.8ns	32ns	43	Partial	Organic enrichment - CSOs
58.1	38	9.0	-	47	Full	
57.9	37ns	8.3	MGns	48	Full	
57.0	-	-	34ns	-	(Full)	
			EWH /WWH Proposed			
54.4	43	7.8ns	-	44	NON/Full	
				EWH		
52.0/51.2	46ns	9.0ns	44ns	73	Full	
47.8	48	9.6	38*	74	Partial	Sedimentation and nutrient enrichment
44.1	47	10.2	42ns	73	Full	
41.4	50	9.2ns	36*	75	Partial	Sedimentation and nutrient enrichment
37.7	51	9.3ns	44ns	82	Full	
33.5	-	-	48		(Full)	
32.1	54	10.1	52	81	Full	
27.9	58	9.9	E	81	Full	
25.1	59	10.4	46	86	Full	
22.8/21.2	58	9.7	48	73	Full	
18.0	57	9.8	E	75	Full	
16.0	59	10.1	44ns	81	Full	
11.4	52	9.8	48	77	Full	
8.9	28*	7.5	--	52	Partial	Hydromodification - impoundment
8.8	--	--	40*	--	(NON)	Hydromodification, organic enrichment
8.6	53	10.3	MG*	88	Partial	Hydromodification, organic enrichment
5.0	59	10.5	46	86	Full	
1.2	55	10.5	46	86	Full	

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Pigeye Creek 14-201 WWH						
0.6	36[ns]	NA	F[*]	36	Partial	Organic enriched - septic/livestock
Mill Creek 14-202 WWH						
2.6	22[*]	NA	F[*]	47	NON	Toxics (deicers) - Dayton Airport
1.2	26[*]	NA	G	57	NON	Toxics (deicers) - Dayton Airport
0.3	44	NA	52	50	Full	
Brush Creek 14-203 EWH/WWH - Proposed						
0.1	41	NA	G	63	Full	
Jones Run 14-204 WWH						
0.4	28[*]	NA	G	57	Partial	Organic enrichment, sewer line leak
Rocky Run (14-205) WWH						
0.5	-	-	G	-	Full	
Opossum Run 14-206 WWH - EWH proposed						
0.8	46[ns]	NA	E	70	Full	
Painter Creek 14-208 MWH						
16.9/17.9	28	NA	F	28	Full	
16.2/15.5	16[*]	NA	10[*]	32	NON	Organic enrichment - CSOs.
14.7	12[*]	NA	4[*]	28	NON	Toxics (NH_4) - CSOs & sewage lagoon
9.7/8.9	24	5.6[*]	26	41	NON	Organic enrichment - CSOs
			EWH /WWH - proposed			
3.4/4.4	33[*]	6.8[*]	G	78	NON/Partial	Organic enrichment - CSOs
0.7/1.1	33[*]	6.3[*]	44	63	NON/Partial	Organic enrichment - CSOs
Little Painter Creek 14-209 MWH - proposed						
0.4	34	NA	F*	44	Partial	Organic enrichment - livestock
Ludlow Creek 14-210 MWH - Proposed						
12.6	34	NA	MG	51	Full	
				WWH		
6.4	36[ns]	7.9[ns]	VG	60	Full	
3.5	44	8.1[ns]	VG	77	Full	
2.9	42	8.1[ns]	-	78	Full	
2.3	40	7.9[ns]	40	76	Full	

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Brush Creek 14-211 WWH						
7.1	38[ns]	NA	VP[*]	41	NON	Organic enrichment - on-site sewerage
0.4	40	NA	VG	76	Full	
Hog Run 14-213 WWH						
0.2	48	NA	MG	70	Full	
Baker Ditch LRW - Proposed						
0.6	-	-	VP	-	NON	Dry ditch
Feitshams Ditch LRW - Proposed						
0.6	-	-	F	-	Full	
Brown Ditch LRW - Proposed						
0.4	-	-	F	-	Full	
Heller Ditch 14-217 MWH - proposed						
0.1	26	NA	MG	43	Full	
Harris Run 14-218 WWH						
3.8/5.2	35[*]	NA	44	31	Partial	Sedimentation
2.0	30[*]	NA	G	58	Partial	Organic enrichment - CSOs
0.9	42	NA	38	73	Full	
Ballinger Run 14-219 MWH - proposed						
2.8	20[*]	NA	-	30	(NON)	
				WWH		
1.4	25[*]	NA	0[*]	57	NON	Organic enrichment, toxics - CSOs
0.6	34[*]	NA	32[ns]	62	Partial	Organic enrichment - CSOs
Greenville Creek 14-220 EWH -						
33.0/34.3	52	NA	58	76	Full	
30.2	48[ns]	9.1[ns]	42[ns]	61	Full	
28.9	45[*]	8.4[*]	50	49	Partial	Hydromodification - channelization
26.5	48[ns]	7.9[*]	46	57	Partial	Hydromodification - channelization
24.6	50	8.5[*]	50	72	Partial	Hydromodification - channelization

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Greenville Creek - Continued EWH - /WWH-proposed						
23.2/22.6	37[ns]	8.2[ns]	-	49	NON/Full	Hydromodification - Impounded
21.7/22.3	47	8.5	42	72	Partial/Full	
19.6	39[ns]	7.5[*]	34[ns]	45	NON/Partial	Hydromod. - urban, org. enrich.
19.3	*34*	*7.4*	*F*	-		
19.2	-	-	30[*]	-	(NON)/(NON)	Hydromod., org. enrich. - sewer line
18.3	36[ns]	7.2[*]	F[*]	53	NON/Partial	Hydromod, org. enrich., WWTP
				EWH -		
16.2	37[*]	8.6[*]	54	71	Partial	organic enrichment - WWTP
13.7	46[ns]	9.6	E	81	Full	
10.8	48[ns]	8.9[*]	50	86	Partial	Organic enrichment - on-site sewerage
6.1	46[ns]	9.1[ns]	44[ns]	84	Full	
3.7	38[*]	8.2[*]	-	75	NON	Organic enrichment - on-site sewerage
1.4	55	10.5	46	76	Full	
0.1	-	-	50	-	(Full)	
McQuay Ditch 14-221 WWH						
1.6/0.5	36[ns]	NA	VG	56	Full	
Poplar Ditch 14-222 WWH						
0.6	52	NA	G	61	Full	
Bolton Run 14-223 WWH						
0.6	50	NA	MG	45	Full	
Dividing Branch 14-224 WWH						
0.4	-	-	VG	-	Full	
2.4/3.1	48	NA	MG	41	Full	
Bridge Creek 14-225 WWH Existing						
1.4/0.2	38[ns]	NA	54	39	Full	
Mud Creek 14-226 WWH						
6.1	54	NA	40	58	Full	
4.7	51	NA	58	46	Full	
2.1/0.1	42	NA	54	35	Full	

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Prairie Outlet 14-227 WWH						
0.8	36[ns]	NA	28[*]	40	Partial	Organic enrich. - on site sewerage
W. Br. Greenville Cr 14-228 WWH						
10.2/10.7	42	NA	F[*]	37	Partial	Hydromodification
7.4	52	NA	G	43	Full	
5.3/5.8	56	NA	G	50	Full	
0.3	44	9.1	G	78	Full	
Spring Branch 14-229 WWH						
0.3	48	NA	MG	57	Full	
Kraut Creek 14-230 WWH						
5.9	54	NA	E	62	Full	
4.4	50	NA	-	52	Full	
0.6	42	8.8	VG	70	Full	
N. Fk. Kraut Creek 14-231 WWH						
2.1	42	NA	E	69	Full	
0.8	46	NA	G	56	Full	
Dismal Creek 14-232 WWH						
3.8/4.7	27[*]	NA	42	44	NON	Hydromodification
2.2/1.8	35[*]	NA	MG	53	Partial	Org. enrich. - land application
0.1	36[ns]	NA	36	48	Full	
Trotters Creek 14-234 WWH						
0.3/0.9	48	9.4	VG	74	Full	
Swamp Creek 14-235 MWH						
12.1	-	-	F	-	(Full)	
8.9	27	NA	28	33	Full	
6.5	17[*]	4.8[*]	30	35	NON	Organic enrichment - AFOs
				WWH		
4.5	32[*]	6.5[*]	G	42	Partial	Organic enrichment - AFOs
2.9	27[*]	7.2[*]	42	40	Partial	Organic enrichment - AFOs; hydromod
2.3	34[*]	7.1[*]	26[*]	34	NON	Organic enrichment - AFOs; hydromod
2.0/1.6	32[*]	6.4[*]	34[ns]	43	Partial	Organic enrichment - AFOs; hydromod
0.3	42	6.7[*]	42	49	Partial	Organic enrichment - AFOs; hydromod

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Indian Creek 14-236 MWH - proposed						
5.2/6.1	32	NA	P*	38	NON	Organic enrichment - AFOs; hydromod
3.1/2.0	20*	NA	32	30	NON	Organic enrichment - on-site sewerage
				WWH		
0.5	41	NA	F*	47	Partial	Organic enrichment - on-site sewerage
Boyd Creek 14-237 MWH - proposed						
3.5	34	NA	F*	45	Partial	
0.8	40	NA	F	55	Full	
N. Fk. Stillwater R. 14-238 MWH						
10.5	12*	NA	VP*	22	NON	Organic enrichment - AFOs
8.3	-	-	VP*	-	NON	Organic enrichment - AFOs
4.4	20*	NA	F	25	NON	Organic enrichment - AFOs
0.4	27	NA	12*	36	NON	Organic enrichment - AFOs
Woodington Run 14-239 WWH						
4.9	42	NA	G	52	Full	
1.1	44	NA	F*	51	Partial	Hydromod, enrichment
S. Fk. Stillwater R. 14-240 WWH						
5.5	36ns	NA	F*	30	Partial	Hydromod, enrichment
1.3	-	-	F*	-	(NON)	Hydromod, enrichment
0.4	38ns	NA	MG	40	Full	
Sycamore Ditch 14-241 MWH - proposed						
0.2	24	NA	F*	35	Full	
Trib. to Kraut Creek 14-245 WWH						
0.2	46	NA	F*	55	Partial	Unkown
Trib. to Ludlow Cr. 14-247 MWH - proposed						
0.4	26	NA	MG	42	Full	

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Trib Stillwater 32.6 14-250 WWH - proposed						
0.6	34*	NA	G	64	Partial	Organic enrichment - on-site sewerage
Bitch Run (trib to Mud Creek @ RM 2.1) 14-251 WWH - proposed						
0.1	42	NA	-	51	(Full)	
Lake Branch Ditch 14-252 WWH						
4.1	46	NA	P*	30	NON	Organic enrichment - on-site sewerage
0.7	54	NA	54	56	Full	
Trib. to Harris C. 14-253 WWH - proposed						
0.2	34*	NA	VP*	44	NON	Unkown
Sigmon Ditch 14-254 WWH - proposed						
1.2	40	NA	G	56	Full	
Bennett Ditch 14-256 WWH - proposed						
0.6	42	NA	P*	56	NON	Organic enrichment - livestock
Trib. to Swamp Creek 14-259 MWH - proposed						
0.6	28	NA	24	37	Full	
Grassy Fork 14-260 MWH - proposed						
0.9	-	-	P*	-	(NON)	Drought & habitat
Trib. to Stillwater @ RM 38.3 14-261 WWH - proposed						
0.7	28*	NA	P*	71	NON	Organic enrichment - livestock
Trib Stillwater 51.0 14-262 WWH - proposed						
1.3	42	NA	G	54	Full	
2.2	-	-	F*	-	(Partial)	Hydromodification - channelization
Trib to trib to Stillwater 51.0/2.4 WWH - proposed						
0.3	44	NA	-	44	(Full)	
Trib. to Boyd (2.67) 14-264 MWH - proposed						
0.5	30	NA	VP*	26	NON	Hydromodification - channelization

Table 1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Trib. to Boyd (2.46) 14-265 MWH - proposed						
1.2/1.7	30	NA	VP*	46	NON	Hydromodification - channelization
Trib to Stillwater 14-266 MWH - proposed						
0.4	-	-	F*	-	(NON)	Hydromodification - channelization
Trib Stillwater 55.4 14-267 MWH - proposed						
0.8	26	NA	P*	47	NON	Organic enrichment - on-site sewerage
Trib Stillwater 14-268 MWH - proposed						
0.3	-	-	F	-	(Full)	
Trib SF Stillwater 14-269 MWH - proposed						
1.6	32	NA	F*	29	Partial	Hydromodification - channelization
Trib Stillwater 64.9 14-270 MWH - proposed						
0.3	36	NA	-	42	(Full)	
1.1	30	NA	-	21	(Full)	

	Biological Criteria Eastern Corn Belt Plains (ECBP)		
Index-Site Type	EWH	WWH	MWH
IBI-Headwaters	50	40	24
IBI-Wading	50	40	24
IBI-Boat	48	42	30
MIwb-Wading	9.4	8.3	6.2
MIwb-Boat	9.6	8.5	6.6
ICI	46	36	22

a The Modified Index of Well-being is not applicable (NA) to headwater site types.
b A qualitative narrative evaluation used when quantitative data were not available or unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates (P = Poor, F = Fair, MG = Marginally Good, G = Good, VG = Very Good, E = Exceptional).
c Use attainment status based on one organism group is parenthetically expressed.
A Boat sampling method
D Wading method
* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
ns Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
d Modified Warmwater Habitat criteria for channel modified habitats.

Table 2. Summary of performance and impacts to receiving waters for NPDES dischargers evaluated in the 1999 survey of the Stillwater River Basin

NPDES Discharger	**Flow (mgd) Design /Median/ 95th**	**Toxicity Bioassay /Biosample**	**Receiving Water Impairment**
Ansonia (1PB00005)	0.35/0.12/0.27	NA/ND	Slight from CSOs
Arcanum (1PB00000)	0.40/0.36/0.94	Acute/Acute	Extreme from CSOs and WWTP
Bradford (1PB00008)	0.24/0.21/0.38	NA/Acute (CSOs)	Severe from CSOs; moderate organic enrichment from WWTP
Covington (1PB00013)	0.75/0.29/0.51	None/ND	None
Englewood (1PD00001)	2.50/1.31/3.14	Acute and chronic/ND	Slight due to organic enrichment
Greenville (1PD00005)	3.50/2.14/3.24	None/ND	Slight due to organic enrichment
Pleasant Hill (1PB00026)	0.20/0.10/0.16	NA/ND	None
Union (1PB00030)	1.00/0.58/1.19	Acute/ND	None
Versailles (1PB00033)	0.38/0.28/0.53	NA/ND	Slight impact to Stillwater due to organic enrichment
West Milton (1PC00011)	1.20/0.6*/1.6*	None/ND	Minimal - small decrease in macroinvertebrate scores

* 1999 data were not available for West Milton.

Table 3. Water Quality Use Designations.

SEGMENT	SRW	WWH	EWH	MWH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR
Stillwater River - headwaters to Woodington Run (RM 59.13)	+	+		•			+	+			+	
Stillwater River - Woodington Run to Steffen Road (RM 52.36)	+	•					+	+	+		+	
Stillwater River - Shroeder Road to GMR	+		+				+	+	+		+	
- at RM 18	+		+				+	+	+		+	
- all other segments	+		+				+	+			+	
Unnamed tributary (Stillwater River mile 6.4)		+					+	+				
Pigeye Creek		*/+					*/+	*/+			*/+	
Mill Creek		*/+					*/+	*/+			*/+	
Brush Creek		•	*				*/+	*/+			*/+	
Unnamed tributaries			*				*	*			*	
Jones Run		*/+					*/+	*/+			*/+	
Ludlow Creek		+					+	+			*/+	
Brush Creek - River Mile 0.5 to the mouth	*	+					+	+			*/+	
- all other segments		+					+	+			*/+	
Shank Ditch		*				•	*/+	*/+			*/+	
Hog Run		*/+					*/+	*/+			*/+	
Baker Ditch		*				•	*/+	*/+			*/+	
Feitshams Ditch		*				•	*/+	*/+			*/+	
Browns Ditch		*				•	*/+	*/+			*/+	
Unnamed tributary (Ludlow Creek at RM 11.8)				•			•	•			•	
Rocky Run		*/+					*/+	*/+			*/+	
Opossum Run		*/+					*/+	*/+			*/+	
Canyon Run		*					*/+	*/+			*/+	
Painter Creek - headwaters to Darke County												
line (RM 5.5)				+			*/+	*/+			*/+	
- Darke County line to mouth		•	*				*/+	*/+			*/+	
Little Painter Creek		*		•			*/+	*/+			*/+	
Heller Ditch		*		•			*/+	*/+			*/+	
Greenville Creek - at RM 22.3	+		+				+	+	+		+	

Table 3. Water Quality Use Designations.

SEGMENT	SRW	WWH	EWH	MWH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR
Greenville Creek - Wildcat Road (RM 24.6) to Bridge Creek (RM 17.8)	+	•	+				+	+			+	
Greenville Creek - all other segments	+		+				+	+			+	
McQuay Ditch		*/+					*/+	*/+			*/+	
Poplar Ditch		*/+					*/+	*/+			*/+	
Bolton Run		*/+					*/+	*/+			*/+	
Dividing Branch		*/+					*/+	*/+			*/+	
Bridge Creek		*/+					*/+	*/+			*/+	
Mud Creek - at RM 0.3		*/+					*/+	*/+	+		*/+	
- all other segments		*/+					*/+	*/+			*/+	
Bitch Run		•					•	•			•	
Prairie Outlet		*/+					*/+	*/+			*/+	
Lake Branch Ditch		•					•	•			•	
West Branch		*/+					*/+	*/+			*/+	
Spring Branch		*/+					*/+	*/+			*/+	
Kraut Creek		*/+					*/+	*/+			*/+	
North Fork		*/+					*/+	*/+			*/+	
Unnamed tributary (Kraut Creek at RM 7.25)		•					•	•			•	
Dismal Creek		*/+					*/+	*/+			*/+	
Elson Ditch		*					*	*			*	
Harris Run -confluence with Stillwater to Darke Co. line (RM 5.2)		+					+	+			*/+	
Harris Run - Headwaters to Darke Co. line (RM 5.2)		+		•			+	+			*/+	
Ballinger Run - Darke Co. line (RM 1.7) to Harris Run		+					+	+			*/+	
Ballinger Run - Headwater to Darke Co. line				•			•	•			•	
Unamed Tributary (Harris Run at RM 8.05)		•					•	•			•	
Trotters Creek - Headwaters to Rike Road (RM 1.7)		*/+					*/+	*/+			*/+	
Trotters Creek - Rike Road to Stillwater River			•									
Sigmon Ditch		•					•	•			•	
Bennet Ditch		•					•	•			•	
Swamp Creek - headwaters to Pittsenbanger												

Table 3. Water Quality Use Designations.

SEGMENT	SRW	WWH	EWH	MWH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR
Road (RM 6.5)				+			+	+			*/+	
- Pittsenbanger Road to mouth		+					+	+			*/+	
Indian Creek - Conover Road to Swamp Creek		+					+	+			*/+	
Indian Creek - headwaters to Conover Road (RM 1.94)				•			•	•			•	
Unnamed tributary (Swamp Creek at RM 3.54)				•			•	•			•	
Grassy Fork				•			•	•			•	
Boyd Creek		*		•			*/+	*/+			*/+	
Unnamed tributary (Boyd Creek at RM 2.46)				•			•	•			•	
Unnamed tributary (Boyd Creek at RM 2.67)				•			•	•			•	
North Fork				+			+	+			*/+	
Sycamore Ditch (Trib to North Fork at RM 0.67)				•			•	•			•	
Woodington Run		*/+					*/+	*/+			*/+	
South Fork		*/+					*/+	*/+			*/+	
Unnamed tributary (South Fork at RM 0.94)				•			•	•			•	
Unnamed tributary (Stillwater River at RM 32.6)		•					•	•			•	
Unnamed tributary (Stillwater River at RM 38.3)		•					•	•			•	
Unnamed tributary (Stillwater River at RM 51.0)		•					•	•			•	
Tributary at RM 2.5 to Stillwater trib. at RM 51.0		•					•	•			•	
Unnamed tributary (Stillwater River at RM 55.45)				•			•	•			•	
Unnamed tributary (Stillwater River at RM 57.2)				•			•	•			•	
Unnamed tributary (Stillwater River at RM 60.2)				•			•	•			•	
Unnamed tributary (Stillwater River at RM 64.9)				•			•	•			•	

Study Area Description

The Stillwater River flows 67 miles from its headwaters in Indiana and northern Darke County to a confluence with the Great Miami River in Dayton. The Stillwater River flows in a generally eastward direction through Darke County into western Miami County where it turns southward to Montgomery County. The watershed covers approximately 673 square miles with about 32 square miles in Randolph County Indiana. Along its course the river drops from an elevation of 1037 feet to 753 feet above sea level with an average gradient of 4.2 feet per mile. The Stillwater River watershed is drained by 280 miles of streams, but many of those stream miles suffer from modifications designed to maintain the field drainage system (Table 4). At one time almost one-third of the watershed may have been wetlands, but the field drainage system has reduced this to one-half of one percent. Major tributaries include: Greenville Creek, Ludlow Creek, Painter Creek, Swamp Creek and North Fork Stillwater River. There are no major impoundments in the watershed but there are several lowhead dams that have been established for various purposes, including power for mills. One dam, in the retarding basin for the Englewood Dam, creates an impoundment for recreation in the park area. This impoundment has become unusable due to sedimentation. The Englewood Dam is part of the flood protection system of the Miami Conservancy District and retains water only during times of high flow.

The topography of the Stillwater River watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. This aquifer was designated as a Sole Source Aquifer by U.S. EPA. Designation requires extra review for any federally funded projects proposed for the surface above the aquifer. The watershed lies completely with in the Eastern Cornbelt Plains ecoregion which is characterized by level to gently sloping land and relatively low gradient streams. Most of the upland area is covered with a glacial drift of varying thicknesses over limestone bedrock**.** Downstream from West Milton the valley narrows and deepens until reaching the Englewood Dam. The limestone bedrock is closer to the surface in this area and becomes the anchor for the dam at either end. This lower part of the river downstream from West Milton lies above a highly productive sand and gravel aquifer. Smaller pockets of sand and gravel aquifers are found in isolated areas of the watershed. These aquifers do not reflect current surface water flow patterns but are apparently part of an ancient river system known as the Teays River which was eliminated by glaciation. Soils tend to be poorly drained due to high clay content especially in the upland areas. Many small streams have been straightened and deepened to augment drainage of crop fields.

Three-fourths of the watershed's population of 66,266 rely on groundwater resources for their water supply. The Stillwater River watershed is an important recharge for the Buried Miami Valley Aquifer System that provides an abundant supply of groundwater to its residents. The City of Greenville uses Greenville Creek to supplement its well field and the Village of West Milton uses the Stillwater River as the major source of drinking water for its residents. West Milton maintains a lowhead dam on the river to ensure an adequate supply at its intake. Past problems with nitrate contamination of the drinking water in West Milton have led to plans to

connect to another city for supply from the buried valley aquifer.

Land uses in the watershed are dominated by agriculture with about 80% of the area dedicated to cropland, primarily corn, soybeans and wheat. Other land uses include pasture, woodland and urban (approximately 11%). The most densely populated portion of the watershed is in Montgomery County and the City of Dayton. There is some development pressure in the vicinity of Greenville and south of West Milton. Most of this development is not adjacent to the river but still can have an impact, particularly in the development stage when sedimentation rates are very high. Much of the mainstem of the Stillwater River and Greenville Creek have good forested riparian cover. Smaller streams generally have less desirable riparian zones.

Most industry in the watershed is light manufacturing with Greenville having the highest concentration of industry. Approximately 25 point source facilities exist in the watershed. The larger point source discharges are sewage treatment plants for the cities and villages in the watershed. Greenville and Englewood have the largest discharges, with the smaller communities of West Milton, Covington, Bradford, Versailles, Ansonia, Arcanum, Pleasant Hill, Laura, and Union also having treatment plants.

The northern portion of the watershed, especially the Swamp Creek and North Fork Stillwater River watersheds, have seen tremendous growth in livestock/poultry operations in the last ten years. In 1997, 218 livestock-poultry operations were inventoried with a total of 128,134 Animal Units (A.U.), located in the Darke County portion of the watershed. The 19 chicken operations account for only 15% of the total operations but house 54% (69,439) of the total A.U.. Swine operations are most prevalent at 41% (90 facilities) of the operations and account for 30% (38,301) of the A.U.. Dairies comprise 29% (63 facilities) of the operations and 7% (8,551) of the A.U., while beef operations account for 15% (33 facilities) of the inventory and only 2% (3,008) of the A.U. Turkey operations account for the remaining 6% (13 facilities) and house 7% (8,475) of the A.U.

The 218 livestock/poultry operations in the watershed produce more than 121,258 tons of solid manure annually. Based on the number of various animal types inventoried in the watershed, this waste produces about 2220 tons N/yr, 1665 tons P_2O_5/yr, and 1480 tons K_2O/yr, with a total annual value of $2.5 million[1]. With a P_2O_5 application rate of 60 lbs./acre, nearly 150,000 acres are needed to utilize the yearly phosphorus production. Although twice this much cropland exists in the watershed, considerations of time of year, crop type, distance to streams and dwellings, availability of non-owned land for spreading, and hauling distance from the livestock/poultry facility, all combine to reduce the actual amount of useable acreage.

[1]"Ohio Livestock Waste Management Guide, Table 1" Ohio Cooperative Extension Service, 1980

Table 4. Stream characteristics and significant identified pollution sources in the Stillwater River study area.

Stream Name	Length (Miles)	Average Fall (Ft/Mile)	Drainage Area (Mi^2)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Stillwater River	67.2	4.2	673.2	Agriculture Land Disposal Urban Hydromodification	Englewood WWTP West Milton WWTP Union WWTP Covington WWTP Pleasant Hill WWTP
South Fork Stillwater River	3.5	3.7	16.72	Agriculture	
Woodington Run	3.4	7.4	10.28	Agriculture	
North Fork Stillwater River	7.7	5.4	18.3	Agriculture Urban	Ansonia WWTP
Boyd Creek	3.3	6.1	14.84	Agriculture Urban	
Swamp Creek	13.8	7.0	63.9	Agriculture Hydromodification	Versailles WWTP
Indian Creek	5.2	7.5	20.38	Agriculture Hydromodification	
Trotters Creek	4.8	13.9	17.64	Agriculture	
Harris Run	9.1	10.8	18.08	Agriculture Hydromodification	
Ballinger Run	1.7	14.1	6.12	Agriculture Urban Land Disposal	Bradford WWTP

Table 4. Continued.

Stream Name	Length (Miles)	Average Fall (Ft/Mile)	Drainage Area (Mi^2)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Greenville Creek	40.5	5.9	201.0	Agriculture Land Disposal Urban Hydromodification	Greenville WWTP
Dismal Creek	9.5	7.2	19.2	Agriculture	
Kraut Creek	7.0	10.0	22.82	Agriculture	
N. F. Kraut Cr.	2.7	17.8	7.46	Agriculture	
West Branch	11.4	6.5	25.6	Agriculture	
Spring Branch	0.5	12.0	4.58	Agriculture	
Mud Creek	8.0	6.6	7.92	Agriculture Hydromodification	
Prairie Outlet	2.0	23.0	37.2	Agriculture Land Disposal	
Bridge Creek	4.6	8.7	11.38	Agriculture	
Dividing Branch	2.5	15.6	11.3	Agriculture	
Bolton Run	3.5	9.4	6.06	Agriculture	
Poplar Ditch	2.4	16.3	4.82	Agriculture	
McQuay Ditch	3.2	14.7	2.86	Agriculture	
Painter Creek	13.5	11.9	48.0	Agriculture Urban Hydromodification Land Disposal	

Table 4. Continued.

Stream Name	Length (Miles)	Average Fall (Ft/Mile)	Drainage Area (Mi^2)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Sycamore Ditch					Arcanum WWTP
Little Painter Creek	5.2	8.7	11.78	Agriculture	
Heller Ditch	4.1	8.1	2.68	Agriculture	
Canyon Run	1.6	70.7	5.04	Agriculture	
Opossum Run	2.0	54.0	2.6	Agriculture	
Rocky Run	2.2	49.6	3.12	Agriculture	
Ludlow Creek	13.5	14.7	63.5	Agriculture Land Disposal	
Feitshams Ditch	0.5	106.0	1.56	Agriculture	
Baker Ditch	2.5	22.8	1.38	Agriculture	
Hog Run	2.3	11.3	9.36	Agriculture	Laura WWTP
Brush Creek (trib to Ludlow Creek)	8.0	15.1	23.72	Agriculture Land Disposal	
Jones Run	0.6	175.2	2.58	Agriculture	
Brush Creek (trib to Stillwater)	6.0	30.0	17.36	Agriculture	
Mill Creek	5.7	36.5	6.0	Agriculture Land Dispoal	
Pigeye Creek	1.9	76.4	6.04	Agriculture	

The 121,258 tons, moreover, only accounts for the solid portion of the manure. When the liquid portion is added to the manure total, the figure increases to nearly 277,500 tons yearly. For the watershed as a whole, this amounts to 757 tons of manure per square mile, with individual drainage areas ranging from as little as 63 tons/mi^2 to more then 1250 tons/mile^2. This amounts to an average of about 222 gallons of manure per acre per year.

The Garland Road Landfill is located in Miami County adjacent to the Stillwater River (~RMs 15.05-13.60) and consists of 15 acres. This landfill was used for municipal and industrial waste disposal from the early 1960s through 1970. Ohio EPA investigations conducted in 1991 and 1992 discovered numerous drums scattered about the landfill's surface and partially buried. In 1993 the U.S. EPA conducted a removal assessment of the site and determined that it was necessary to conduct a time-critical removal action of the drums. U.S. EPA issued a unilateral order to General Motors Corporation (GMC) and the landowner. In September of 1994, the first phase of the removal action began by locating and digging up a total of 13, 486 drums and 24,541 tons of contaminated soils. Phase 2 of the removal action involved the on-site treatment of the contaminated soils using a low temperature thermal desorption process. This removed the majority of the volatile organic compounds (VOCs) and the polynuclear aromatic hydrocarbons (PAHs) from the soils and was followed by stabilization treatment to immobilize any remaining heavy metal contamination. The on-site soil treatment was completed in September of 1997.

Concurrent with the time-critical removal activities described above, U.S. EPA and GMC entered into an Administrative Order of Consent (AOC) on July 7, 1995, to study methods for dealing with the remainder of the landfill once the drums had been removed and the soils were treated. As part of this Order, GMC performed an Engineering Evaluation/Cost Analysis (EE/CA) to investigate any ground-water, surface soil or surface water/sediment contamination remaining and analyzed methods for dealing with that contamination. As part of the EE/CA, a Streamlined Risk Evaluation was prepared by a U.S. EPA contractor and included in the final EE/CA report. U.S. EPA is currently evaluating whether the final EE/CA Report meets the requirements of the AOC. Following final approval or modification and approval of the EE/CA Report, U.S. EPA will issue a Removal Action Recommendation describing the preferred remedy for the site. Key issues which may impact the remedy decision include the potential for off-site migration of contaminated ground water and the future of the riparian vegetation along the bank of the Stillwater River in the vicinity of the site.

Most of the streams in the watershed have Warmwater Habitat (WWH) aquatic life use designations. All of Greenville Creek and portions of the Stillwater River, Brush Creek and Painter Creek are designated Exceptional Warmwater Habitat (EWH). These streams are capable of supporting exceptional populations of fish and macroinvertebrates. Greenville Creek and the mainstem of the Stillwater River to river mile 57.0 are also designated State Scenic Rivers by the Ohio Dept. of Natural Resources (ODNR). This also adds a designation of State Resource Water (SRW) to these streams. Streams designated as Modified Warmwater Habitat (MWH) include: headwaters of Painter Creek, Brush Creek, Swamp Creek, and all of the North Fork Stillwater

River. All of the streams are designated for Agriculture and Industrial water supply. Greenville Creek and Stillwater River are also designated Public Water Supplies. All streams are designated Primary Contact Recreation.

The Stillwater Watershed Project[2] is a locally controlled effort to restore and protect the water quality in the watershed. Since 1993 a joint board of supervisors has raised funds and directed the efforts of a coordinator to work with landowners in the Darke and Miami County regions of the watershed. A great deal of effort and money have been expended to encourage the use of best management practices to protect and restore riparian habitats, reduce sedimentation, and manage nutrients (including manure) wisely. A local association, Agriculture for a Clean Environment (ACE), has also been instrumental in helping educate other farmers to the benefits of using BMPs. To date $2,067,600.00 have been raised for this effort through grants and special funding from Ohio EPA, ODNR, and USDA. Of the $2,067,600.00 raised, approximately $1,432,890.00 (69%) is earmarked to go directly to landowners/farm operators as cost sharing or incentive payments for best management practices. The remaining 31% is being used for administrative costs and educational activities.

[2]Stillwater River Protection Project, Darke & Miami Counties, Ohio Revised 1995.

Table 5. Sampling locations and samples collected from the Stillwater River basin study area in 1999 (B - quantitative benthic macroinvertebrate (B_q - denotes a qualitative sample), C - conventional water chemistry, C_o - conventional and organic water chemistry, chl - chlorophyll, D - datasonde, E - effluent, F - fish, M - modeling (may include cross section, time of travel or water chemistry data), Q - flow (USGS), Q_M - flow (manual), S - sediment chemistry). *Italics denote effluent and mixing zone sampling locations.* (Latitude/longitude coordinates are provided in WGS84 datum.)

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Stillwater River				
65.00	B_q, F, C	40.2622062, 84.7287787	Ust Young Rd	Rossburg
63.83	B_q, F, D	40.2564000, 84.7096000	Coletown Lightsville Rd	Rossburg
62.97	B, F, C_o, D, Q_M, S, chl	40.2524787, 84.6950588	SR 49	Rossburg
61.80	C	40.2435333, 84.6800095	Zumbrum Rd	Ansonia
58.97	B, F, C	40.2156252, 84.6465087	@ Ansonia water treatment plant	Ansonia
58.1	B, F	40.2190000, 84.6313000	Ust N. Fk. Stillwater; Ust Ansonia WWTP	Ansonia
57.90	B, F, C_o, S	40.2200673, 84.6280492	Dst N. Fk. Stillwater; Dst Ansonia WWTP	Ansonia
56.97	B, F, C_o, D, S	40.2168705, 84.6121123	Beisner Rd	Dawn
50.20	B, F, C_o, S	40.1878287, 84.5499563	Union City Rd	Dawn
47.75	B, F, C_o, D, chl	40.1913432, 84.5238535	SR 121; Ust Swamp Creek	Dawn
44.17	B, F, C_o, D, S, chl	40.1864796, 84.4728526	Barnes Rd; Dst Swamp Creek	Versailles
41.3	B, F	40.1647000, 84.4416000	Versailles Southeastern Rd	Versailles
37.77	B, F, C, D, S	40.1601633, 84.4009824	SR 185	Versailles
33.50	B, F, C_o, D, S	40.1316887, 84.3576098	Covington Bradford Rd; Dst Harris Cr	Piqua West
32.55	C_o	40.1203400, 84.3589967	US 36; Ust Greenville Cr/Covington WWTP	Pleasant Hill
32.20	*E*	*40.1154764, 84.3570742*	*Covington WWTP effluent*	*Pleasant Hill*
32.10	B, F, C_o, D, S	40.1144419, 84.3569401	Bridge St; Dst Greenville Cr/Covington WWTP	Pleasant Hill
27.85	B, F, C, Q	40.0577048, 84.3559721	Lauver Rd; Ust Pleasant Hill WWTP	Pleasant Hill
25.12	B, F, C_o, D, S	40.0374294, 84.3528422	Penny Rd; Dst Pleasant Hill WWTP	Pleasant Hill
21.50	B, F, C_o	40.0086430, 84.3201072	Horseshoe Bend Rd	Pleasant Hill
18.20	B, F, C_o, D, chl	39.9759320, 84.3246686	Dst W. Milton Dam; Ust W. Milton WWTP	West Milton
16.57	*E*	*39.9522786, 84.3185601*	*West Milton WWTP effluent*	*West Milton*
16.50	B, F, C_o	39.9520031, 84.3181716	Dst West Milton WWTP	West Milton
15.05	C_o, S	39.9364693, 84.3008633	Frederick-Garland Rd; Ust Garland Rd landfill	West Milton
14.65	C_o, S	39.9312132, 84.2979581	Adj Garland Rd Landfill	West Milton
13.60	C_o, S	39.9265979, 84.3010354	Dst trib at RM 13.61	West Milton
11.40	B, F, C_o, D	39.8983741, 84.2931096	Martindale Rd; Dst Union WWTP	West Milton
9.10	B, F, C	39.8708270, 84.2867369	Ust Englewood Dam; Ust Englewood WWTP	Trotwood
8.82	Q	39.8685505, 84.2816560	Dst Englewood Dam; Ust Englewood WWTP	Trotwood
8.75	B, F, C_o	39.8687139, 84.2801090	Adj Allwood Rd; Dst Englewood WWTP	Trotwood
4.96	B, F, C_o, S, chl	39.8370579, 84.2324138	Philadelphia Rd	Dayton N.
1.92	B, F, C_o	39.8043538, 84.2057195	Deweese Park; Ust Siebenthaler Rd	Dayton N.
Tributary to Stillwater River @ RM 64.96				
0.33	B_q, F, C	40.2670990, 84.7281970	Brock Cosmos Rd	Rossburg
South Fork Stillwater River				
5.5	B_q, F		Young Rd	Ansonia
1.26	B_q, F, C	40.2397960, 84.7094538	Coletown-Lightsville Rd	Ansonia
0.40	B_q, F, C, Q_M	40.2504106, 84.7041506	Washington Rd	Rossburg
Tributary to South Fork Stillwater River @ RM 0.94				
1.56	B_q, F, C	40.2331808, 84.7283550	Young Rd	Ansonia

Table 5. continued.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Tributary to Stillwater River @ RM 60.22				
0.35	B_q, F	40.2251000 , 84.6666000	White Coppess Rd	Ansonia
Woodington Run				
3.36	B_q, F, C	40.1782541, 84.6814044	Hillgrove-Woodington Rd	Ansonia
0.72	B_q, F, C, Q_M	40.2073552, 84.6554822	Elroy-Ansonia Rd	Ansonia
North Fork Stillwater River				
8.90	B_q, F, C	40.2993017, 84.6752490	Riegel Bell Rd	Rossburg
7.12	B_q, F, C	40.2940939, 84.6505181	Hiestand Rd	Rossburg
4.16	B_q, F, C, D, chl	40.2650312, 84.6284310	Brock Cosmos Rd	Rossburg
0.40	B, F, C_o, D, Q_M	40.2202679, 84.6369501	SR 118; Ust Ansonia WWTP	Ansonia
Tributary to North Fork Stillwater River @ RM 2.63				
0.2	B_q, F	40.2441000, 84.6366000	SR 118	Ansonia
Tributary to Stillwater River @ RM 57.10				
0.2	B_q, F	40.2145000, 84.6154000	SR 47	Dawn
Boyd Creek				
3.5	B_q, F	40.1504000, 84.6272000	Horatio-Harris Creek Rd	Ansonia
0.81	B_q, F, C, Q_M	40.1788493, 84.6024455	Woodington Rd	Dawn
Tributary to Boyd Creek @ RM 2.67				
0.5	B_q, F	40.1507000, 84.6192000	Horatio-Harris Creek Rd	Dawn
Tributary to Boyd Creek @ RM 2.46				
1.1	B_q, F	40.1350000, 84.6364000	SR 118	Ansonia
Tributary to Stillwater River @ RM 51.02				
1.20	B_q, F, C	40.1655301, 84.5529574	Ust Oliver Rd	Dawn
Swamp Creek				
12.05	B_q, F, C	40.2898013, 84.5496737	Greenville St. Marys Rd	North Star
8.85	B, F, C	40.2813211, 84.5045139	Versailles Yorkshire Rd	North Star
6.51	B, F, C, D	40.2699360, 84.4673279	Pittsenbarger Rd; Dst confluence of tribs	Osgood
4.44	B, F, C	40.2407854, 84.4675954	Long Rd; Ust AFO trib	Versailles
2.85	B, F, C, D, chl	40.2249228, 84.4841623	Reed Rd; Ust Indian Cr; Dst AFO trib	Versailles
2.20	B, F, C_o	40.2205415, 84.4940645	Adj Jameson Rd; Ust Versailles WWTP	Versailles
1.59	B, F, C_o	40.2128511, 84.4984988	SR 121; Dst Versailles WWTP	Versailles
0.28	B, F, C_o, D, Q_M, S, chl	40.1961932, 84.4992797	Martz Rd	Versailles
Grassy Fork				
0.82	B_q, F, C	40.2912391, 84.4953138	Yorkshire-Osgood Rd	Osgood
Tributary to Swamp Creek @ RM 3.54				
0.45	B, F, C_o, S	40.2278005, 84.4650330	SR 47; AFO trib	Versailles
Indian Creek				
6.11	B_q, F, C	40.2441457, 84.5677189	Greenville-St. Marys Rd.	Dawn
1.93	B, F, C_o, D, Q_M, S	40.2334531, 84.5136316	Conover Rd	Dawn
0.48	B, F, C	40.2251415, 84.4989803	SR 47	Versailles

Table 5. continued.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Tributary to Stillwater River @ RM 38.30				
0.60	B_q, F, C	40.1725591, 84.4131560	Bradford Bloomer Rd	Versailles
Trotters Creek				
0.97	B_q, F, C_o, Q_M	40.1471844, 84.3458798	Piqua Clayton Rd	Piqua West
Bennett Ditch				
0.01	B_q, F	40.1618000, 84.3476000	SR 185	Piqua West
Sigmon Ditch				
1.4	B_q, F	40.1426000, 84.3366000	McMaken Rd	Piqua West
Harris Creek				
5.20	B, F, C	40.1514925, 84.4314444	SR 721; Ust Ballinger Run	Versailles
2.02	B, F, C_o, D, Q_M	40.1384934, 84.3932903	Greenville Falls- Clayton Rd; Dst Ballinger Run	Versailles
0.90	B, F	40.1405000, 84.3740000	Range Line Rd	Piqua West
Ballinger Run				
2.75	B_q, F, C	40.1340094, 84.4498639	Zerber Rd	Versailles
1.40	B, F, C	40.1377716, 84.4256283	Adj Klinger Rd; Ust Bradford WWTP; Dst CSO	Versailles
0.59	B, F, C_o, S	40.1347333, 84.4121283	Bradford Bloomer Rd; Dst WWTP/CSOs	Versailles
Tributary to Stillwater River @ RM 32.60				
0.75	B_q, F, C	40.1206087, 84.3735835	Range Line Rd N of US 36	Pleasant Hill
Greenville Creek				
34.48	B, F, C	40.1273923, 84.8076254	Dst State Line Rd (Indiana/Ohio border)	Union City
30.23	B, F, C	40.1553698, 84.7507137	Palestine-Union City Rd; Ust Dismal Cr	Union City
26.60	B, F,C_o, D, S, chl	40.1344134, 84.7064439	Wagner Rd; Dst Dismal Cr; Dst Kraut Cr	Ansonia
24.60	B, F, C	40.1210905, 84.6793364	Wildcat Rd; Ust unsewered area	Greenville W.
23.08	B, F, C_o, D, S	40.1079600, 84.6610618	Dst Daly Rd; Dst unsewered/SWP	Greenville W.
19.55	B, F, C, S	40.1001377, 84.6181799	Ohio St; Ust Greenville WWTP	Greenville E.
19.35	*E*	*40.0994960, 84.6144024*	*Greenville WWTP effluent*	*Greenville E.*
19.3	*B, F*		*Greenville WWTP mixing zone*	*Greenville E.*
18.34	B, F, C_o, S	40.1044157, 84.5993119	Jaysville St Johns Rd; Dst Greenville WWTP	Greenville E.
16.22	B, F, C_o, D, chl	40.1029665, 84.5755188	Willis Rd; Dst Bridge Creek	Greenville E.
13.70	B, F, C, D, S	40.1079111, 84.5416741	Bears Mill Rd	Greenville E.
10.86	B, F, C_o	40.1083583, 84.5002952	Mill Rd; SWP/Dst ag ditches	Greenville E.
9.92	C_o	40.1124642, 84.4866957	Adj Old 36; Dst Gettysburg	Gettysburg
6.10	B, F, C_o, Q, S,chl	40.1025630, 84.4302483	SR 721	Gettysburg
1.45	B, F, C_o, Q_M	40.1082536, 84.3736726	Range Line Rd	Pleasant Hill
Dismal Creek				
4.70	B, F, C	40.1810592, 84.8064752	Dst State Line Rd (Indiana/Ohio border)	Union City
1.76	B, F, C	40.1749680, 84.7695983	Hill Grove-Southern Rd	Union City
0.10	B, F, C, Q_M	40.1562310, 84.7507137	Palestine-Union City Rd	Union City
Kraut Creek				
5.95	B_q, F, C_o	40.0772905, 84.7554762	Stingley Rd; Ust AFO	Spartanburg
0.60	B_q, F, C_o, Q_M	40.1430247, 84.7484863	Bickel Rd; Dst AFO	Ansonia

Table 5. continued.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
North Fork Kraut Creek				
0.84	B_q, F, C	40.1208346, 84.7529692	Wildcat Rd; Ust AFO	Spartanburg
West Branch				
7.36	B_q, F, C	40.0405471, 84.7233383	Byrket Rd; Ust Spring Branch	Greenville W.
5.78	B_q, F, C	40.0559013, 84.7074249	US 36; Dst Spring Branch	Greenville W.
0.30	B_q, F, C, Q_M	40.1168605, 84.6807678	Heller Rd	Greenville W.
Spring Branch				
0.25	B_q, F, C	40.0460719, 84.7247674	Clarks Station Rd	Greenville W.
Mud Creek				
7.50	C	40.0063777, 84.6739413	Vietor Rd	Greenville W.
5.87	B, F, C	40.0261765, 84.6674775	Weavers Ft. Jefferson Rd	Greenville W.
4.67	B, F, C, S	40.0411116, 84.6721469	Byrket Rd; Dst unsewered area	Greenville W.
0.09	B, F, C_o, Q_M	40.1016201, 84.6394697	SR 502	Greenville W.
Prairie Outlet				
0.80	B, F, C	40.0261420, 84.6582864	Weavers Ft. Jefferson Rd; Dst unsewered area	Greenville W.
Lake Branch Ditch				
0.40	B, F, C	40.0261762, 84.6732777	Weavers Ft. Jefferson Rd	Greenville W.
Bridge Creek				
0.28	B, F, C, Q_M	40.0959976, 84.5991373	Jaysville-St. Johns Rd	Greenville E.
Dividing Branch				
3.87	B_q, F, C	40.0443856, 84.5886143	SR 49	Greenville E.
3.51	C	40.0485945, 84.5838766	Hogpath Rd	Greenville E.
0.10	C, B_q, F	40.0943413, 84.5634102	near Riversedge Dr; near mouth	Greenville E.
Bolton Run				
0.60	B_q, F, C	40.1205614, 84.5222075	Horratio-New Harrison Rd	Greenville E.
Poplar Ditch				
0.50	B_q, F, C	40.1037243, 84.5255645	Spidel Rd	Greenville E.
McQuay Ditch				
0.50	B_q, F, C	40.1024483, 84.5137569	Spidel Rd	Greenville E.
Painter Creek				
17.90	C	39.9993645, 84.5766567	Littles Rd	Arcanum
16.20	B, F, C	39.9960580, 84.5588963	Ivester Park; Ust CSOs	Arcanum
15.48	B, F, C_o	39.9905454, 84.5485451	Pittsburgh Laura Rd; Dst CSOs; Ust WWTP trib	Arcanum
14.98	B, F, C_o, S	39.9903384, 84.5400663	Pittsburgh Laura Rd; Dst Arcanum WWTP trib	Arcanum
8.92	B, F, C, D, chl	40.0504475, 84.4753403	Hogpath Rd	Gettysburg
3.50	B, F, C	40.0807008, 84.4032147	Adj Harshbarger Rd; Ust Little Painter Cr	Gettysburg
0.80	B, F, C_o, Q_M, S	40.0789479, 84.3638343	Adj Sugar Grove Rd	Pleasant Hill
Tributary to Painter Creek @ RM 12.13				
1.07	B_q, F, C_o	40.0213943, 84.5169564	Gordon Landis Rd (Fourmans Corner)	Greenville E.

Table 5. continued.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Tributary to Painter Creek @ RM 10.81				
1.68	B_q, F, C_o	40.0337114, 84.5173595	Gordon Landis Rd	Greenville E.
Little Painter Creek				
1.18	B_q, F, C	40.0907035, 84.4155952	Patty Circle Rd	Gettysburg
Heller Ditch				
0.05	B_q, F, C	40.0768780, 84.4903434	Adj. Gettysburg Pittsburgh Rd	Gettysburg
Canyon Run				
1.00	B_q, F, C, Q_M	40.0433195, 84.3734692	Range Line Rd	Pleasant Hill
Opossum Run				
1.2	B_q, F, C	40.0194221, 84.3630412	Stitcher Rd	Pleasant Hill
Rocky Run				
0.50	B_q, F, C	40.0104553, 84.3395173	SR 48	Pleasant Hill
Ludlow Creek				
12.65	B_q, F, C_o	39.9953932, 84.4880885	Gettysburg Pittsburgh Rd	Laura
6.40	B, F, C_o	39.9830747, 84.4083534	Wright Rd; Ust Hog Run	Laura
3.49	B, F, C	39.9941508, 84.3710073	Range Line Rd; Ust Brush Cr; Dst Hog Run	West Milton
2.33	B, F, C_o, Q_M	39.9914563, 84.3512626	Davis Road; Dst Brush Cr	West Milton
0.65	C_o, S	40.0068096, 84.3331681	Adj Horseshoe Bend Rd; Dst Ludlow Falls	Pleasant Hill
Tributary to Ludlow Creek @ RM 11.80				
0.45	B_q, F, C	39.9838017, 84.4754843	Oakes Rd	Laura
Browns Ditch				
0.3	B_q, F, C	39.9774206, 84.4563529	Stocker Rd	Laura
Feitshams Ditch				
0.6	B_q, F, C	39.9690968, 84.4459331	West Grove Rd	Laura
Hog Run				
0.20	B_q, F, C_o	39.9892146, 84.4087240	Wright Rd	Laura
Brush Creek				
7.85	C_o	39.9128894, 84.4097385	SR 49	Laura
7.17	C	39.9199722, 84.4043345	County Line Rd	Laura
4.82	B_q, F		Emerick Rd	Laura
0.45	B_q, F, C_o, S	39.9867188, 84.3612489	Ellerman Rd	West Milton
Tributary to Brush Creek @ RM 5.92				
0.30	C	39.9345852, 84.4156833	Adj Frederick-Garland Rd	Laura
Jones Run				
0.40	B_q, F, C	39.9408484, 84.3186251	SR 48	West Milton
Brush Creek				
0.12	B, F, C_o, Q_M	39.9285075, 84.2907072	Frederick Garland Rd	West Milton

Table 5. continued.

Stream RM	Type of Sampling	Latitude/Longitude	Landmark	USGS Quad.Map
Mill Creek				
3.67	C_o	39.9107273, 84.2380644	Old Springfield Rd; Dst Dayton Airport	Tipp City
2.62	B_q, F, C_o, S	39.9220995, 84.2500948	County Line Rd; Dst Dayton Airport	West Milton
1.18	B_q, F, C	39.9225832, 84.2748327	Frederick Rd	West Milton
0.32	B, F, C_o, Q_M	39.9266129, 84.2888762	Karns Rd	West Milton
Pigeye Creek				
0.60	B_q, F, C	39.9226282, 84.3117570	SR 48	West Milton

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995). Chemical, physical and biological sampling locations are listed in Table 5.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-14). 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. Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. 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 (see 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 comments and observations for each sampling location.

The attainment status of aquatic life uses (*i.e.,* full, partial, and non-attainment) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-17). The biological community performance measures used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al*. (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al*. 1981).

Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater

Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al*. 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of the aquatic life use is full if all three indices (or those available) meet the applicable biocriteria, partial if at least one of the indices does not attain and performance is fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS.

Habitat Assessment

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

Macroinvertebrate Community Assessment

Macroinvertebrates were sampled quantitatively using multiple-plate, artificial substrate samplers (modified Hester/Dendy) in conjunction with a qualitative multi-habitat assessment of the available natural substrates**.**

Macroinvertebrates were sampled at 143 locations (Table 5) in the Stillwater River basin. Artificial (quantitative) and natural substrate (qualitative) samples were collected at 60 locations, and natural substrate only samples were collected at the remaining 83 sites. Lists of macroinvertebrate taxa and ICI metric scores from each site in the study area are available electronically on the Ohio EPA Division of Surface Water home page at http://chagrin.epa.ohio.gov/.

Fish Community Assessment

Fish communities were sampled twice at the same location 4 to 5 weeks apart in the Stillwater

River mainstem, and in tributaries receiving wastewater from a permitted discharger. Otherwise only one fish sample was collected. All samples were collected using either the longline or wading electrofishing methodology. Lists of fish species and their relative abundance and IBI metric scores from each site in the study area are available electronically on the Ohio EPA Division of Surface Water home page at http://chagrin.epa.ohio.gov/.

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Figure 3). The “magnitude” of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are expressed as ADV/mile to normalize comparisons between segments, sampling years, and other streams and rivers. The ADV was simplified to an average percent deviation from respective criterion for the IBI, ICI and MIwb in Figure 2.

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.

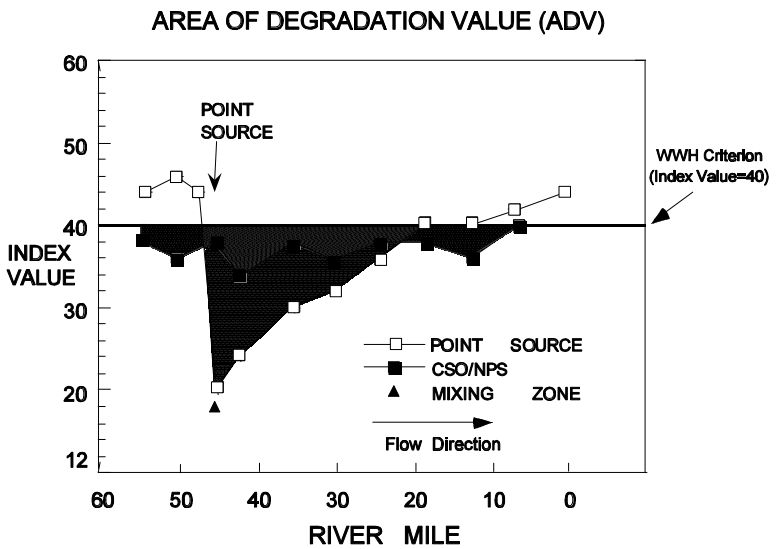

Figure 3. Conceptual illustration of how the Area of Degradation Value (ADV) is calculated based on the ecoregion biocriterion (WWH = 40 in this example). Hypothetical biological index scores for two scenarios are plotted as unfilled boxes and solid boxes. The unfilled boxes represent a typical response to a point source impact (the mixing zone appears as a solid triangle), and the solid shading shows the associated area of departure; the filled boxes represent a typical response to a nonpoint source or combined sewer overflow impact with the dashed shading showing its associated area of departure. The blended shading represents the overlapping impact of the point and nonpoint sources. The ADV in either example is calculated from the area bounded by the criterion line, in this case 40, and the line created by joining the plotted scores.

Pollutant Loadings and NPDES Discharger Descriptions

Ansonia WWTP-North Fork Stillwater River
Lat.:$40^0$13' 11"; Long:84^0 38' 02'
Permit #: 1PB00005

Constructed in May of 1970 and modified in 1986 (aeration added) and 1989, the Ansonia WWTP is a secondary treatment plant utilizing a continuous release Waste Stabilization Lagoons System. The treatment train design consists of two 8 feet deep waste stabilization ponds, approximately 5 acres each, which discharge through outfall 001 to the North Fork of the Stillwater River (RM 0.240). Annual average flows for outfall 001 were 0.160 MGD in 2000, 0.250 MGD in 1999 and 0.175 MGD in 1998 (Figure 4). The design capacity for outfall 001 is 0.350 MGD, with a daily maximum of 0.650 MGD, remaining unchanged since the inception of the wastewater treatment plant. The entire collection system is directed to the North Lift Station which sends flow to the wastewater plant through a ten-inch force main (estimated at an 8" currently a reduction of 2 inches over 30 years of use). Modifications to the facility occurred in 1986 and 1989, which included installation of two aerators on each lagoon. In 1993, a new lift station was installed on the village's south end, serving Master's Industry and residents of the area. All of the service area is served by sewers, with 95% of the system combined and 5% separate. Currently there are no alarms on the lift station or stand-by power for backup. The population served by the facility is currently an estimated 1,279.

The current estimated inflow and infiltration (I/I) value to the sewer system reported by Ansonia personnel is at 1.0 gallon per day (gpd). However, inaccurate flow measurements at Ansonia WWTP have been a problem historically as the actual flow is not measured. Flow is calculated from influent flow and then flow is metered on the lagoon and upon discharge to the waterway. Weak influent waste strength and clear water connections in the sewer system suggest infiltration problems.

The collection system is composed of 95 % combined sewers that have two permitted overflows, both which discharge to the Stillwater River mainstream. The collection system includes grouted clay tiles and old field tiles, with reported overflows of one or two occurrences per year. The combined sewer overflows (CSOs), outfall 003 and 005, are both located near the North Lift Station and downstream from a large portion of the collection system. Outfall 003 is a 24" pipe located approximately 300 feet east of the North Lift Station and east of St. Rt. 118. The outfall 005 overflow is located approximately 1,000 feet east of outfall 003. Facility records at the Ohio EPA suggest that both diversion structures have fixed bolted diversion plates which could be modified to reduce overflows. Combined Sewer Overflow 003 has a design flaw that aligns a large sewer pipe to join a diversion structure which is composed of a small, 8"pipe outlet that sends flow to the pump station near the outfall. Backups in this 8" line are common and overflows are reported as occurring during heavy rains. All of the sewers send flow to the North Pump Station which directs flow through a 10" force main to the wastewater plant. Outfall 002

was eliminated in 1998.

Combined Sewer Overflow Long Term Control Plans include modifying diversion structures to reduce overflows, eliminating an unused overflow pipe near the facility lift station and expanding storage capabilities at the facility.

Recent sewer additions include the placement of storm sewers in North Ansonia from Elroy-Ansonia Rd north to the North Fork of the Stillwater River. Storm sewers were necessary to relieve low lying flooding and reduce storm flows through the combined sewers. The additional storm sewers contain laterals that feed into catch basins for added storage capabilities. With the addition of a portable flow meter, the village should be able to predict the volume of precipitation which triggers overflows from the combined sewers. This will facilitate planning for future diversions of precipitation and reductions in overflow events. Currently, there are no plans to expand the plant through 2005 or remove the two existing CSO structures.

Industrial input to the collection system consists of non-contact cooling water discharged by two minor industries-Masters Industries Inc. (plastics) and Lambert Manufacturing. The total contribution of industrial wastewater from these two facilities equates to an estimated 2% of the influent at the Ansonia WWTP.

Currently the upstream and downstream monitoring stations (801 and 901) are situated on the Stillwater River, providing background information for the CSO structures as well as downstream from the overflows. Monitoring upstream and downstream from outfall 001 on the N. Fork of the Stillwater is not required by the permit. The upstream monitoring station (801) is located on the Stillwater River at the bridge on St. Rt. 118. The downstream monitoring station (901) is located on the Stillwater River just upstream from the confluence with the North Fork Stillwater.

In 1997, an18-lot residential subdivision (Carriage Way Subdivision) was connected to the combined sewer system upstream from the CSO at SR 118. Storm sewers were upgraded at the time of the project, eliminating approximately 125,000 gallons of storm water from the collection system.

In1992, the Southeast Lift Station and Sanitary Sewer Improvements Project provided sanitary sewers for the Master's Industries expansion and for future development in the southern portion of Ansonia. To accommodate the additional industry and residential flow, approximately 1,665' of 15" sanitary sewer line (including one lift station) was installed. The force main is connected to a combined sewer manhole south of the water tower tract.

Recent connections to Ansonia WWTP include an approval in 1999 for First Church of God which included gravity sanitary sewers with a force main and one pump station. This project qualified for the 1:1 tradeoff as a result of an upgrade to the North Lift Station that increased its

capacity from180 gpm to 400 gpm. This resulted in utilizing 25% of the available flow credit.

A minimum of fifteen violations of the NPDES permit were reported to the Ohio EPA between 1995-2000 from outfall 001. The annual number of permit violations ranged from five violations in 1995 to one in 2000. The violations, in declining order of frequency, were limited to fecal coliform, pH and $cBOD_5$. Fecal coliform accounted for 33 % of the total violations, the majority of these occurring in 1995 and 1998.

Percentile flows have remained fairly constant over time except during 1991 through 1994 when some variances became more evident and exceeded daily maximum limits. These steadily increasing flows observed during those four years were likely the result of operational practices, as flow characteristics inversely correlated with lower precipitation years. Other typical constituents of wastewater mimicked peak-flows, as represented by the 95th percentile particularly from 1991 to 1994 exhibiting variability in subsequent years. Ammonia-N remained variable throughout the remainder of the period of record however Ansonia WWTP has generally been able to meet the permitted effluent limits for ammonia. Upstream and downstream (801/901) monitoring does not reflect conditions in the area of the final outfall (outfall 001 to North Fork Stillwater River) because monitoring for these stations is conducted to bracket combined sewer overflows (CSO).

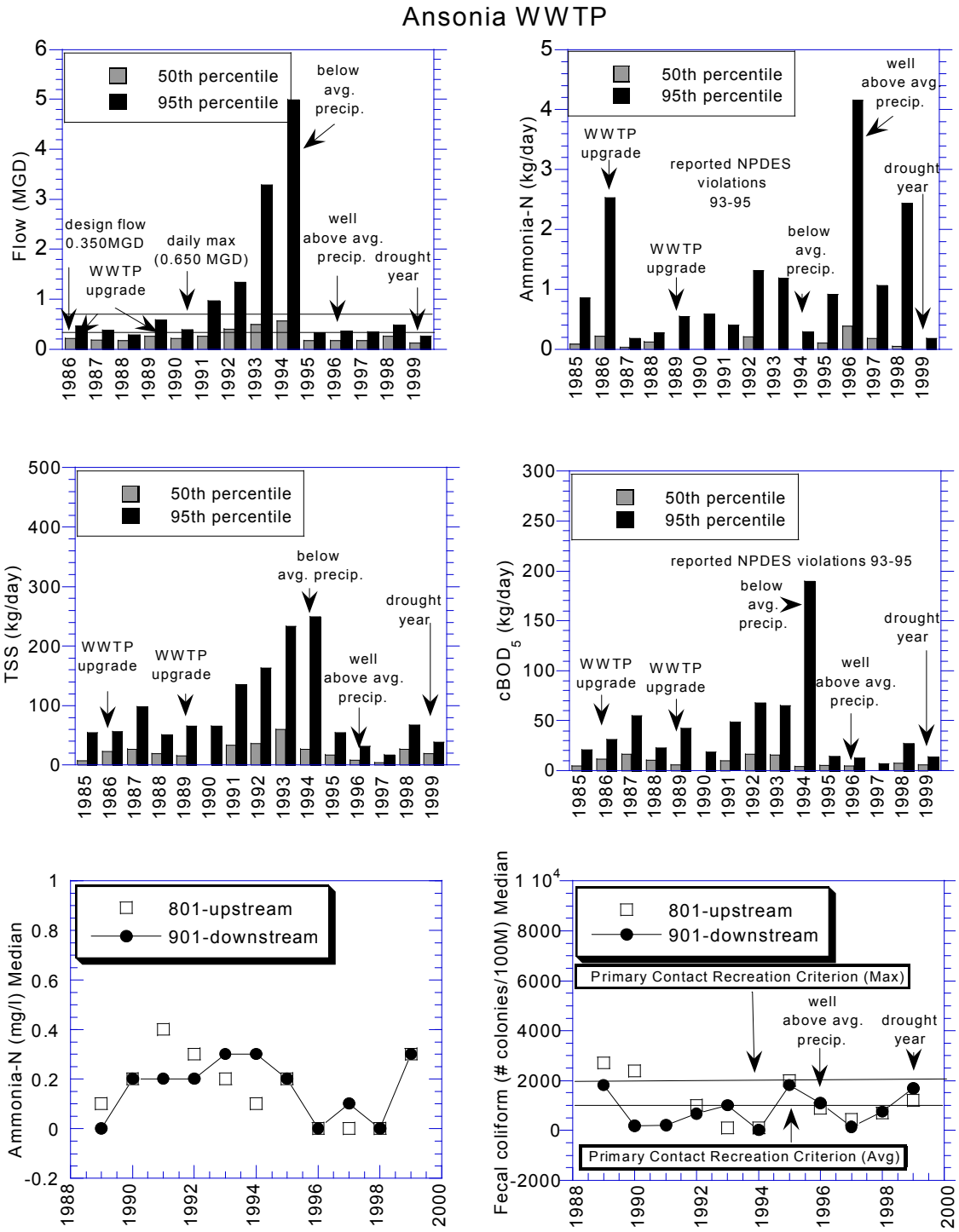

Figure 4. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from Ansonia WWTP for the period of record indicated.

Arcanum WWTP-Sycamore Ditch to Painter Creek
Lat:39^0 58' 36"; Long:84^0 32' 33"
Permit #:1PB00000

The Village of Arcanum WWTP was constructed in 1964 with modifications in 1986, which included an additional lift station as a wet weather backup. Wastewater treatment consists of two, 10-acre (5' depth) facultative lagoons in a series, with a design capacity of 0.400 MGD and a daily maximum of 1.163 MGD (combined detention time of 90-120 days). Roughly all of the service area is sewered which consist of 90% combined sewers and 10% separate sewers. The population in the village is estimated at 2,002 with stable growth predicted for the area. All sewers are gravity sewers using lift stations to pump flows to the wastewater treatment plant. The Village of Arcanum WWTP final outfall (001) discharges to Sycamore Ditch (RM 0.58) which flows into Painter Creek at RM 15.05. Fifteen (fourteen diversion points) CSO structures discharge to Painter Creek at various locations within the village residential boundaries. All diversion structures currently have fixed, bolted v-notch weirs in an attempt to minimize wet weather flows. There are no known separate sewer overflows (SSOs) in the sewer system. Upstream and downstream monitoring locations (801/901) are within Sycamore Ditch, bracketing the final outfall 001. The Village of Arcanum does not have any industries that are known to release pollutants into the sewer system. All industries in the village that produce a waste streams are handled by private hauling companies.

Sanitary sewers constructed in the late 1960s consisted of grouted clay tiles and old farm field tiles. In 1969, Arcanum removed septic tanks and connected house waste collection laterals to existing farm field tiles which became the collection system for wastewater and storm water in Arcanum. These field tiles still collect residential sewage for Arcanum which joins a 24" field tile in northwest Arcanum draining surrounding agricultural fields later linking to an 18" trunk line in the collection system. The collective discharge is transported to the wastewater treatment plant during dry weather or overflows to Painter Creek during storm events. Agricultural flow continues to infiltrate the combined sewer system which contributes to the elevation of nutrient levels instream.

In 1989, the Village of Arcanum modified their CSO structures in an attempt to divert a significant amount of flow to the wastewater plant for treatment. This resulted in doubling of the annual average flow from 0.477 MGD to 0.855 MGD (Figure 5). Annual average flow from outfall 001 for 2000 was estimated at 0.350 MGD. This documents a gradual reduction in average flow over eleven years, possibly demonstrating failure of CSO modifications over time.

Currently there are 15 Combined Sewer Overflow (CSO) structures that discharge from 14 overflow locations in Painter Creek. The diversion structures are divided equally across the meridian of Main Street, adjacent to Painter Creek.

Dry weather overflows in Arcanum have been suspected, however the village has described the

erroneous readings as meter default flows and malfunctioning meters recording unrealistic flows. Overflow data in 1997 recorded 44 events, occurring between May and September, with 32% of those events occurring between Friday and Sunday. Overflow data from1998-1999 document 14 overflows incidents. Arcanum estimates that a minimum rainfall of roughly 0.40 inches (average) is the action quantity for sewer overflows depending on previous ground saturation. A Long Term CSO Control Plan has been in development by Mote and Associates and was targeted for submittal at the end of 1998, however that deadline has passed.

In 1995, an 11-lot subdivision, Gray's First Addition, was connected to the collection system and was designed for a 0.004 MGD average flow. In 1996, the Village of Arcanum connected a 26-lot residential subdivision referred to as Northmoor Subdivision (designed for 0.01 MGD average flow).

Recent field observations by OEPA personnel in 1999 noted a peculiar "greenish" color in Arcanum's final effluent. A persistent algal bloom was described as the reason for the unique color and resultant suspended solids NPDES violations. A Notice Of Violation (N.O.V) of the Ohio Administrative Code (OAC) 3745-1-04 (Water Quality Standards) was drafted by Ohio EPA in response to the site visit.

Currently the Village of Arcanum has applied for "Issue 2" Grant Money and low interest loan money to complete a project that will address the separation of combined storm and sanitary sewers in the section of the system carrying farm runoff. As of 2000, approximately 20% of the village sewers were separated in this area referred to as Sugarfoot. A recently developed subdivision consisting of eight to ten streets in North Arcanum was developed utilizing separate sewers.

At a minimum fifty-five violations of the NPDES permit were reported to the Ohio EPA between 1995-2000. The annual number of permit violations ranged from 24 violations in 1995 to two in 1997. The violations, in declining order of frequency, were limited to four parameters: TSS, $cBOD_5$, ammonia-N and pH. Total suspended solids and $cBOD_5$ accounted for 44 % of the total violations with the majority of violations occurring from 1999-2000. The pattern of annual violations was roughly correspondent of annual TSS and $cBOD_5$ median loads. Additionally, the majority of these violations occurred during a period when conduit flows were approaching the daily maximum.

Two acute bioassay events were conducted by the Ohio EPA in spring and summer of 1995 using *C. dubia* and *P. promelas*. Mild toxicity occurred in the March 6, 1995 effluent sample with *P. promelas*, exhibiting 25 % adverse acute effects and 15% mortality after 24-hours and 48-hours. No mortality or adverse affects occurred with the test conducted in August, 1995.

Annual median and peak-flows consistently exceeded the design flow of 0.40 MGD throughout the period of record with peak-flows exceeding the daily maximum for two years.

Monthly operating reports submitted by the Village of Arcanum indicate that the current wastewater treatment plant cannot consistently meet NPDES effluent limits. Violations have occurred frequently for NH_3-N, TSS and $cBOD_5$, with occasional violations for pH. Graphically, variability between percentiles and years was evident for most parameters in the period of record evaluated. Inflow and infiltration in the sewer system, and operational and maintenance approaches have all contributed to the chronic inability of the wastewater facility to consistently meet permit limits. Monitoring results from fixed stations 801 and 901, which bracket outfall 001, demonstrate downstream concentrations of ammonia-N consistently more elevated than upstream for all years evaluated. Upstream values remained fairly consistent throughout the record inversely true of downstream values.

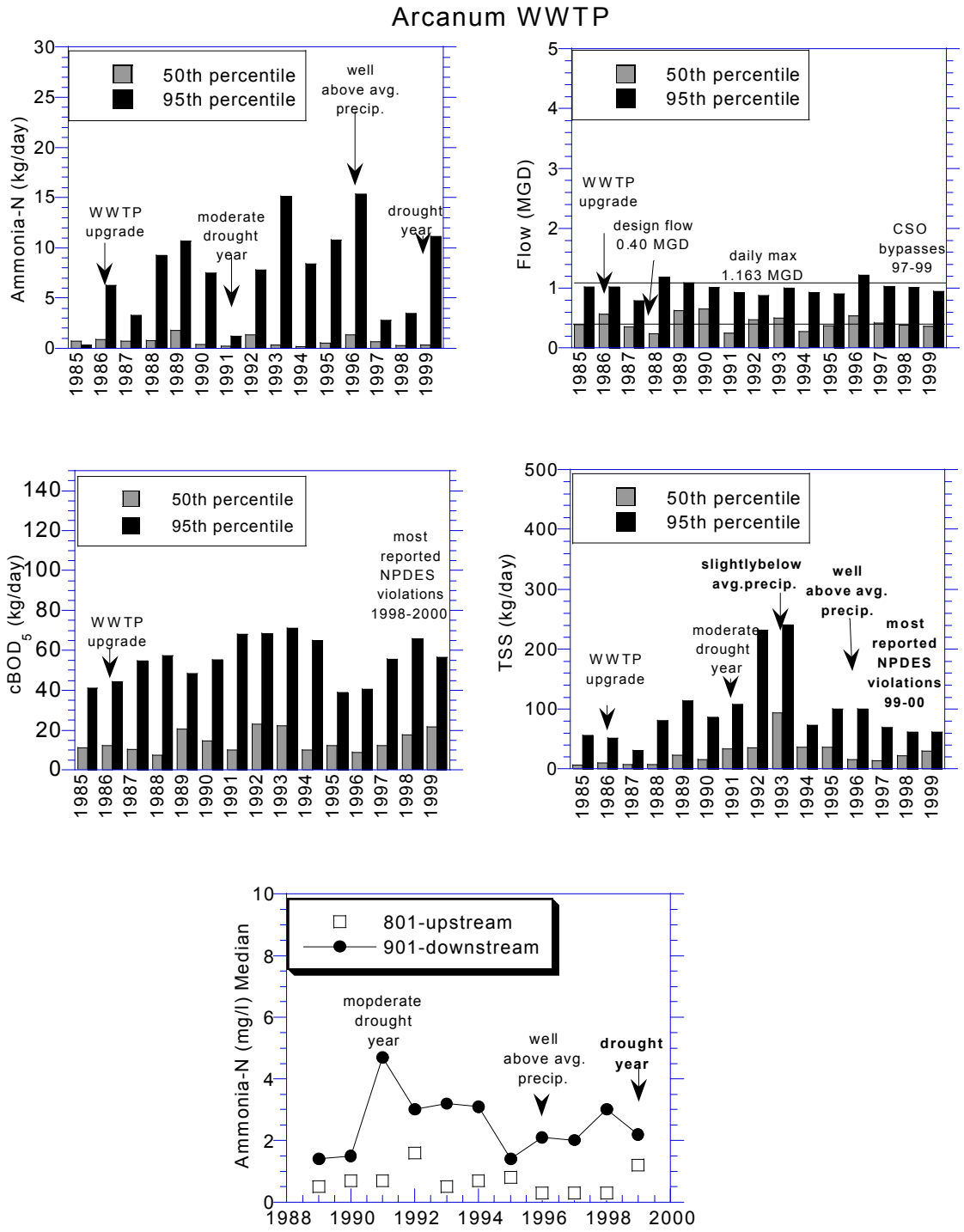

Figure 5. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from Arcanum WWTP for the period of record indicated.

Bradford WWTP-Ballinger Run
Lat:40^0 08' 16"; Long:84^0 25' 26"
Permit #:1PB00008

Constructed in the 1960's (connecting existing clay field tiles to new sewers), with a modification in 1998, the Bradford WWTP is a secondary treatment plant with a final effluent discharge (001) to Ballinger Run at RM 1.30. The collection system consists of 70% combined sewers and 30% separate sewers. Nine CSO diversion structures discharge to Ballinger Run and a tributary of Ballinger Run. Many of the home septic tanks were connected to original farm field tile systems which discharged directly to Ballinger Run. Two, five-acre, ponds (6' depth) in sequence comprise the newer mechanical wastewater plant. Additions to the wastewater plant in 1998 include an oxidation ditch, two aerobic digesters, two final clarifiers, chlorine building, cascade aerator, and chlorine contact tanks, in addition to new lines. In October 2000 dechlorination by sodium bisulfite was added to the treatment train at a dosing rate of 1.92 mg/l. The design capacity (0.24 MGD) for the new facility has remained the same as the old wastewater plant. Bradford WWTP has been able to operate at peak flows up to 1.0 MGD for a limited time without overflows. There are no known or suspected SSOs in the system or bypasses at the wastewater facility. The community of Bradford has a population of 2,000 people and currently no industrial discharge contribution to the sewer system exists. Upstream monitoring (801) is located on Ballinger Run upstream from all CSOs. Downstream monitoring is located on Bradford-Bloomer Rd. downstream from all Bradford discharges including CSOs and final effluent.

The restricted flow of an aging eight-inch force main may be limiting the amount of flow that can be carried to the wastewater treatment plant. An Ohio EPA site inspection in 1997 ascertained the underutilization of the first lagoon for storage capabilities and surmised that with a modification in standard operation of the lagoons the additional pond retention time could reduce incidents of overflows through the CSOs. Collection system upgrades occurred around 1996 for some areas of Bradford, providing new plastic storm sewers to relieve flooding and basement backup and to prevent or reduce CSO overflows.

Seven of the nine CSO overflow points discharge to Ballinger Run between just upstream from S.R 721 to just upstream from the Outfall 001. Ballinger Run headwaters are upstream from the village, with runoff and field underdrains contributing the majority of flow.

Two overflow structures, CSO 007 (#4) and CSO 008 (#5) merge and discharge to Ballinger Run at a single point southeast of the village adjacent Main Street (Covington-Bradford Rd-C.R 88) located directly between the distance to Liberty Street and Bradford-Bloomer Road. All diversion structures have adjustable diversion plates designed to minimize overflows. Combined Sewer Overflow Warning Signs are posted along Ballinger Run streambanks to warn the public of possible sewer overflows during storm events.

Outfall locations are as follows:
001-Lat:40^0 08' 16"; Long: $84^0$25' 26"-to Ballinger Run
004-Lat: 40^0 08' 12"; Long: 84^0 25' 55"-to Ballinger Run-located approx. 200 feet west of the intersection of Wise St. and Miami Ave (CSO #1)
005-Lat: 40^0 08' 13"; Long: 84^0 25' 54"-to Ballinger Run-located approx. 150 feet west of the intersection of Wise St. and Miami Ave. (CSO #2)
006-005-Lat: 40^0 08' 12"; Long: 84^0 25' 51"-to Ballinger Run-located approx. 25 feet northeast of station 012 (CSO #3).
007-005-Lat: 40^0 08' 08"; Long: 84^0 25' 46"-to Ballinger Run Intersection of Kellar St. and Clay St. (CSO #4).
008-005-Lat: 40^0 08' 08"; Long: 84^0 25' 42"-to Ballinger Run-Intersection of Kellar Rd. and Liberty St. (CSO #5)
009-005-Lat: 40^0 08' 00"; Long: 84^0 25' 33"-to Ballinger Run-Approx. 600 feet east of the intersection of Oakwood St. and Liberty St. (CSO #6).
010-005-Lat: 40^0 07' 51"; Long: 84^0 25' 13"–to unnamed tributary of Ballinger Run-Approx. 500 feet east of the intersection of Main St. and Locust St. (CSO #7)
011-005-Lat: 40^0 07' 49"; Long: 84^0 25' 13"-to unnamed tributary of Ballinger Run-Approx. 150 feet south of station 010 (CSO#7A)
012-005-Lat: 40^0 08' 12"; Long: 84^0 25' 52"-to Ballinger Run at the Intersection of Wise St. and Miami Ave (CSO#8).

In 1998, the Village of Bradford submitted the required Combined Sewer Overflow Operational Plan which identifies and includes pollution control measures, pollution prevention measures, monitoring schedules, operation procedures, maintenance schedules, sampling schedules and an example of the public health warning signs. In 1999, the Village of Bradford submitted the required CSO plan referred to as the "Characterization of the Combined Sewer System and The Combined Sewer Overflows." This plan addresses diversion structure locations, discharge characteristics, rainfall quantities during monitoring and various other information.

In 1997 Bradford implemented an inflow and infiltration (I/I) reduction program for the combined sewers by constructing storm sewers to reduce overflows. Concerning levels of influent demand parameters were the indicators of infiltration problems in the collection system. Combined Sewer Overflow discharges that occur in moderately wet weather appear to have a greater impact upon receiving water quality than CSO discharges associated with severe storms. This is attributable to dilution ratios of the given scenarios. There have been no documented dry weather releases from Bradford's collection system.

Sludge is hauled on a semiannual to annual basis and disposed of on a 200-acre farm in Adam Township. Sludge application rates are based on the needs of the crop grown, and the soil and sludge background information as well as the nutrient content of the sludge. The application rate is not to exceed 2.5 dry tons/acre (about 18,500 gallons/acre) in order to avoid excessive

application of sludge nitrogen to the site. Concerns are also associated with high levels of applied phosphorus and the overland flow reaching waterways. According to Bradford's Sludge Management Plan, wastewater sludge is currently land-applied at 8872 Horatio Harris Rd. near the intersection of Gettysburg-Webster Rd. An unnamed tributary of the Stillwater River appears to traverse the current application site and flows into the Stillwater River at RM 42.15.

In July of 2000, an undisclosed amount of hog lagoon waste spilled into Ballinger Run. Approximately three stream miles of Ballinger Run were impacted. The stream was dammed to capture the hog manure and pumped to Bradford's WWTP for treatment.

At a minimum eleven (11) violations of the NPDES permit were reported to the Ohio EPA between 1995-2000. The annual number of permit violations ranged from five violations in 1998 to two in 1999. The violations, in declining order of frequency, were limited to five parameters: TSS, mercury, ammonia-N, chlorine and D.O.. Total mercury accounted for 27% of reported violations, but concentrations remained below the Practical Quantification Level (PQL) for the facility and therefore were considered to be in compliance with the NPDES limit. Total suspended solids and mercury accounted for 64% of the total violations, the majority of all violations occurring from 1998-2000.

Percentile flows have remained fairly constant over time except for 1992 through 1994 where a percentile variances became more evident (Figure 6). Other typical constituents of wastewater evaluated, mimicked peak-flows from 1992 through 1994. However, these remained relatively constant in ensuing years, suggesting a limited period of inadequate degree of treatment. Treatment capabilities aided reduction of the number of overflows and backups in the system for volumes up to 1.0 MGD. Variability between percentiles remained low in the latter 1990s, reflective of efforts to reduce inflow and infiltration and thereupon backups in the collection system.

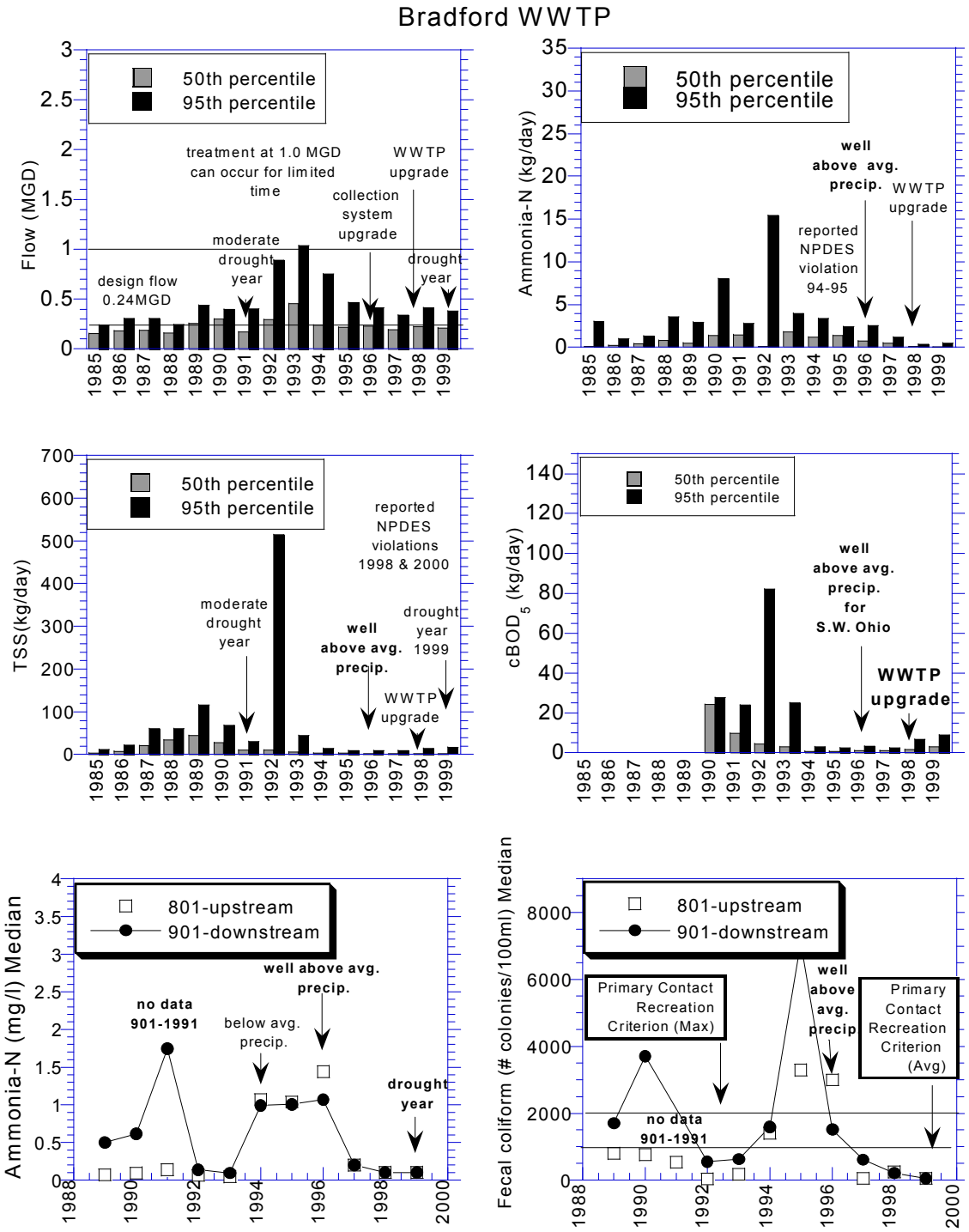

Figure 6. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and mean instream ammonia-nitrogen and fecal coliform concentrations from the Bradford WWTP for the period of record indicated.

Covington WWTP-Stillwater River
Lat.:40^0 06' 58", Long:84^0 21' 29"
Permit #:1PB00013

The Village of Covington WWTP was constructed in 1941 with modifications in 1982. Current treatment works at the facility are: a comminutor, grit removal, primary settling, trickling filters (roughing), intermediate settling, mechanical aeration, final settling, chlorination, dechlorination and post aeration. Biosolids are anaerobically digested and land applied in the Great Miami Watershed. Two shifts operate five days a week with a standby generator available. All of the service area is sewered separately and contains no known CSOs or SSOs. The current design capacity of the facility is 0.750 MGD, with a hydraulic capacity of 1.5 MGD. Annual average daily flow in 1999 was 0.241 MGD (Figure 7). In 1998, the annual average daily flow was 0.393 MGD and in 1997, 0.313 MGD. Reasons for reductions in average flow are not known other than suspected population reduction or improved flow metering accuracy. The village experiences stagnant and possibly reduced growth with a current population estimated at approximately 2,603, down from 1980 estimates of 3,197. Inflow and infiltration are estimated at 25,000 gpd with the last remediation project occurring in 1979.

Final effluent discharge from outfall 001 is to the west bank of the Stillwater River at RM 32.20 approximately 100 yards north of West Bridge Street and downstream of the confluence of Greenville Creek (RM 32.38). Upstream monitoring is conducted in the Stillwater River upstream from the low head dam near Covington's Water Plant. Downstream monitoring is at the West Bridge Street bridge. Ohio EPA record reviews note plant bypasses and overflows occurring back to 1985, reportedly related to mechanical failure or weather related incidences. Three lift stations exist in the collection system with historical bypass occurrences at the South High Street lift station in the 1980's into Rocky Branch. An overflow to the Stillwater River in 1999 occurred at a "Siphon Box" on West Wright and was related to heavy rainfall and a plugged siphon line. Total quantities of bypassed raw sewage for all years are beyond the scope of this report.

Industrial wastewater to the collection system is contributed by significant industrial user, Kerry Ingredients Inc. as of 1992 (formerly Beatreme Food Ingredients, Beatrice Foods and Westerville Creamery). Kerry Ingredients manufactures powdered food ingredients for the food service industry and currently contributes 5% of the total flow to Covington WWTP. Historical caustic (elevated pH) waste stream slugs from Kerry Ingredients Inc. have caused problems for the Covington WWTP, upsetting the biological treatment balance at the wastewater facility. The source of the caustic loads to the wastewater plant was linked to a process material reportedly overflowing a "day tank" attributable to a faulty valve. The faulty valve was reportedly remedied in April of 2000 by adding a valve timer. The latest incident happened over the weekend of April 15-16-2000.

Two Ohio EPA acute toxicity tests were conducted in the summer and fall of 1995. Both test endpoints indicated no acute toxicity to either *P. promelas* or *C. dubia*.

Between 1995 and 2000, seven NPDES permit violations were reported to Ohio EPA. Dissolved oxygen (DO) dominated the violations during 1998. Five-day Carbonaceous Biochemical Oxygen Demand ($cBOD_5$) and pH occurrences were also reported (listed in descending order of frequency). Reported violations were typical constituents of treated domestic wastewater. With two exceptions, annual median and peak-flows remained consistently below design flow throughout the period of record, with all years well below the hydraulic capacity of the facility.

All conventional parameter characteristics were commensurate with flow behavior, revealing notable variances in percentiles. This may have been indicative of unpredictable flow volumes, possibly attributable to inflow and infiltration influences or treatment process disruptions, or inadequacies. Unpredictable parameter load characteristics however did not result in significant permit violation totals during the six years evaluated. Final outfall (001) bracketing monitoring results of fixed stations 801 and 901 demonstrated that downstream concentrations of ammonia-N were commensurate with upstream values from 1994 to 1999. Precipitation data available for July through September1999 indicated that sampling at Covington was conducted in absence of rainfall influences in July and August and within a rainfall event in September. All ammonia-N concentrations were below detection in all weather conditions for both stations. Fecal coliform concentrations during wet weather sampling were slightly lower than dry weather in the upstream sample and more than three times lower in downstream samples.

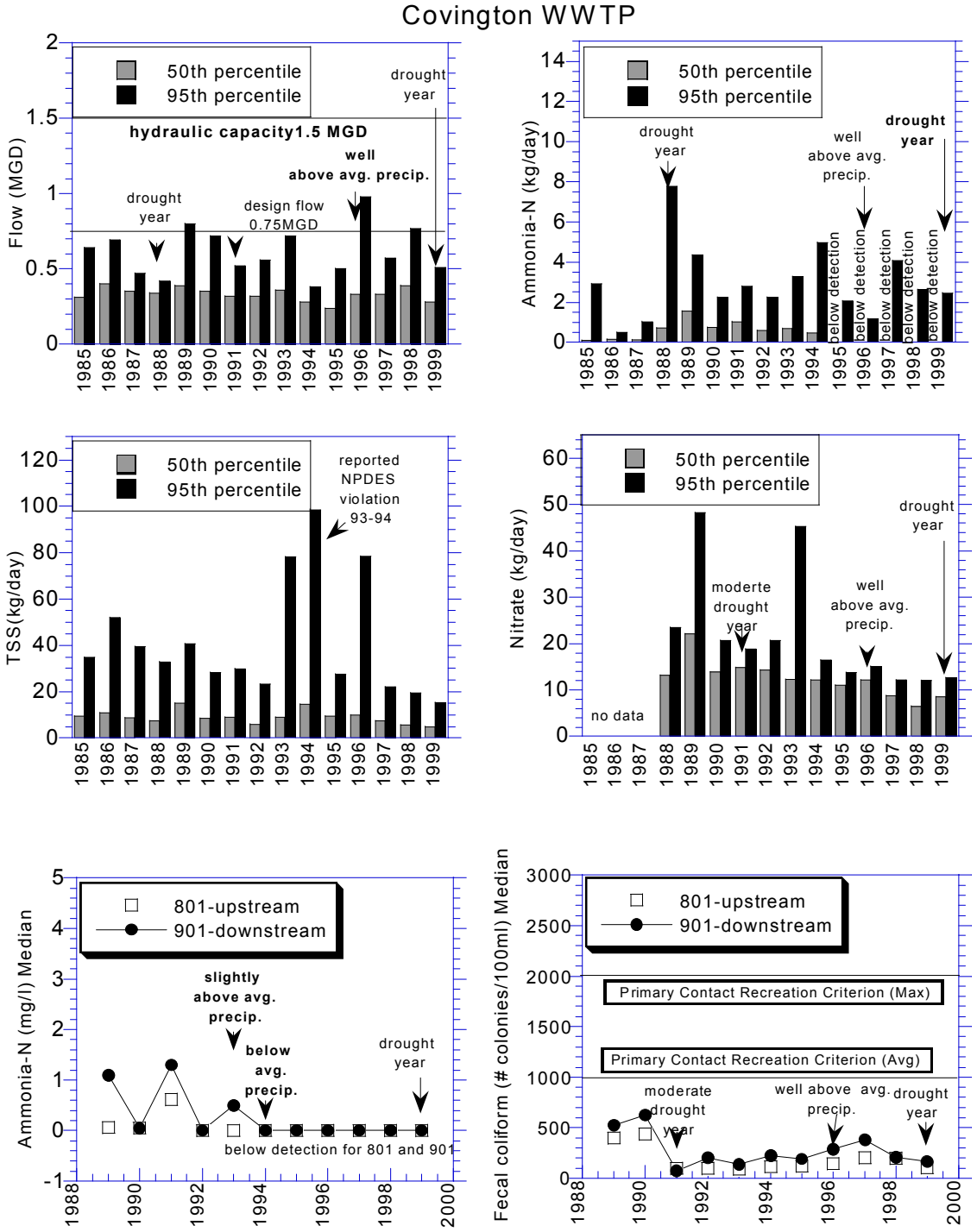

Figure 7. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from the Covington WWTP for the period of record indicated.

Englewood WWTP-Stillwater River
Lat:39^0 52' 06" Long:84^0 16' 55"
Permit #:1PD00001

The Englewood WWTP is an advanced secondary treatment facility constructed in May of 1939 (population 415) and modified numerous times, the latest modification completed in 1988. The current plant design flow is 2.5 MGD with a hydraulic capacity of 10.0 MGD. The treatment train consists of bar screening, course and fine screening, grit and grease removal, activated sludge aeration, final clarification, chlorination disinfection, dechlorination, aerobic digestion and land application of sludge. The Englewood WWTP discharges to Buttermilk Creek at RM 0.01, just upstream from the Stillwater River (the dam is upstream from the Buttermilk/Stillwater confluence) at RM 8.86. Upstream monitoring (801) is collected in the Stillwater River on the south side of the Englewood Dam. Downstream monitoring (901) is collected downstream from Heathcliff Rd.

All of the service area is sewered on separate sewers. The collection system contains four lift stations equipped with alarms for power outages, high water levels and burglaries. Standby power utilizing portable generators is available. Bypasses and overflows can occur during maintenance or extremely high flows, however consistent bypasses of treatment without extenuating circumstances have not been reported. Inflow and infiltration problems were addressed in the late 1980s using slip-lining which proved to be less expensive than replacement. This was a fairly extensive project that continued from 1986-1988. Industrial input is contributed by Plater's Service (electroplating facility) which currently contributes 10% of the industrial input to Englewood's collection system.

Instream flocculent and sewage fungus were documented coating the Buttermilk Creek streambed in the 1990s during Ohio EPA facility inspections and toxicity sampling events. Englewood has described the appearance of solids and sewage fungus was due to secondary settling tank overflows during heavy rain events. Another incident of stream impact believed to be associated with Englewood's final effluent occurred in May of 2000 which was described as a pesticide odor and fish kill, by a local fisherman. Dead fish with an associated sheen on the water were noted in the mixing zone and further downstream from the facility at the time of this complaint.

Sludge disposal volume is approximately four million gallons per year, composed of 1% solids. Sludge storage is limited to the capacity of the aerobic digesters which is an approximate 28-35 days). The City of Englewood installed a sludge dewatering facility in September 1998. Sludge is currently land applied to farm fields south of the City of Union near Rt. 40 and Union Rd. in the Great Miami River Watershed. The sludge application site doesn't appear to have a direct discharge to the watershed, however should runoff leave the site it would flow toward the North Fork of the Wolf Creek Watershed.

Between 1995 and 2000, six NPDES permit violations were reported to Ohio EPA. No particular constituent dominated the violations (TSS, fecal coliform, copper) during the period. Most violations were due to mechanical failures and scheduled maintenance, inducing interruptions of chlorination operations and resulted in inadequate treatment. All reported violations were typical constituents of treated domestic wastewater with the exception of copper in 1995.

Five acute bioassay events, were conducted by Ohio EPA in the winter and spring of 1989, 1990 and 1995. Acute toxicity was detected in only one test event in January 1990. The composite effluent was acutely toxic to *P. promelas* during the 48-hr evaluation (ammonia-N was 11.0 mg/l for this sample). Ammonia-N concentrations in November 1989 and December 1989 were 5.79 mg/l and 9.21 mg/l, respectively.

The entity conducted acute 48-hour Whole Effluent Toxicity (WET) bioassays (acute is measured in lethality) utilizing *C. dubia* and *P. promelas* in 11 events during 1992 through 1995. Results exhibited acute toxicity units exceeding the Allowable Effluent Toxicity (AET) of 1.0 for the 1993 test for *C. dubia* and *P. promelas* and for the 1994 test. Ninety-one percent (91%) of the 48-hour acute toxicity tests for Englewood WWTP were below the AET unit of 1.0 or below detection.

The entity conducted Whole Effluent Toxicity (WET) tests, for 7-day chronic bioassays (a chronic effect can be measured in lethality, growth or reduced reproduction) utilizing *P. promelas* and *C. dubia* in 11 events throughout 1992-1995. Both *C. dubia* and *P. promelas* populations exhibited some level of chronic effects in reproduction and survival, however neither test organism exhibited chronic toxicity units above the AET unit of 6.17.

Peak-flows, as represented by the 95th percentile, consistently exceeded design flow of 2.5 MGD from 1995 to 1999 (Figure 8). Flows were well below the hydraulic capacity of the facility for both 95th and 50th percentiles for all years in the record. The trend for all parameters, with the exception of ammonia-N, demonstrated increasing percentile variability from 1995 through the end of record. Graphically, ammonia-N percentile variances showed no discernable trend until 1995 when variability between median and peak loads reduced. Permit violation totals remain low for this facility and lack dominance of any particular constituent. A copper violation was likely due to loadings from pretreatment industries or copper leaching from water lines from homes. Monthly monitoring upstream and downstream from the final outfall indicates that downstream concentrations of ammonia-N are slightly higher than upstream for most of the years evaluated. Fecal coliform concentrations were commensurate and all values were below recreation criterion.

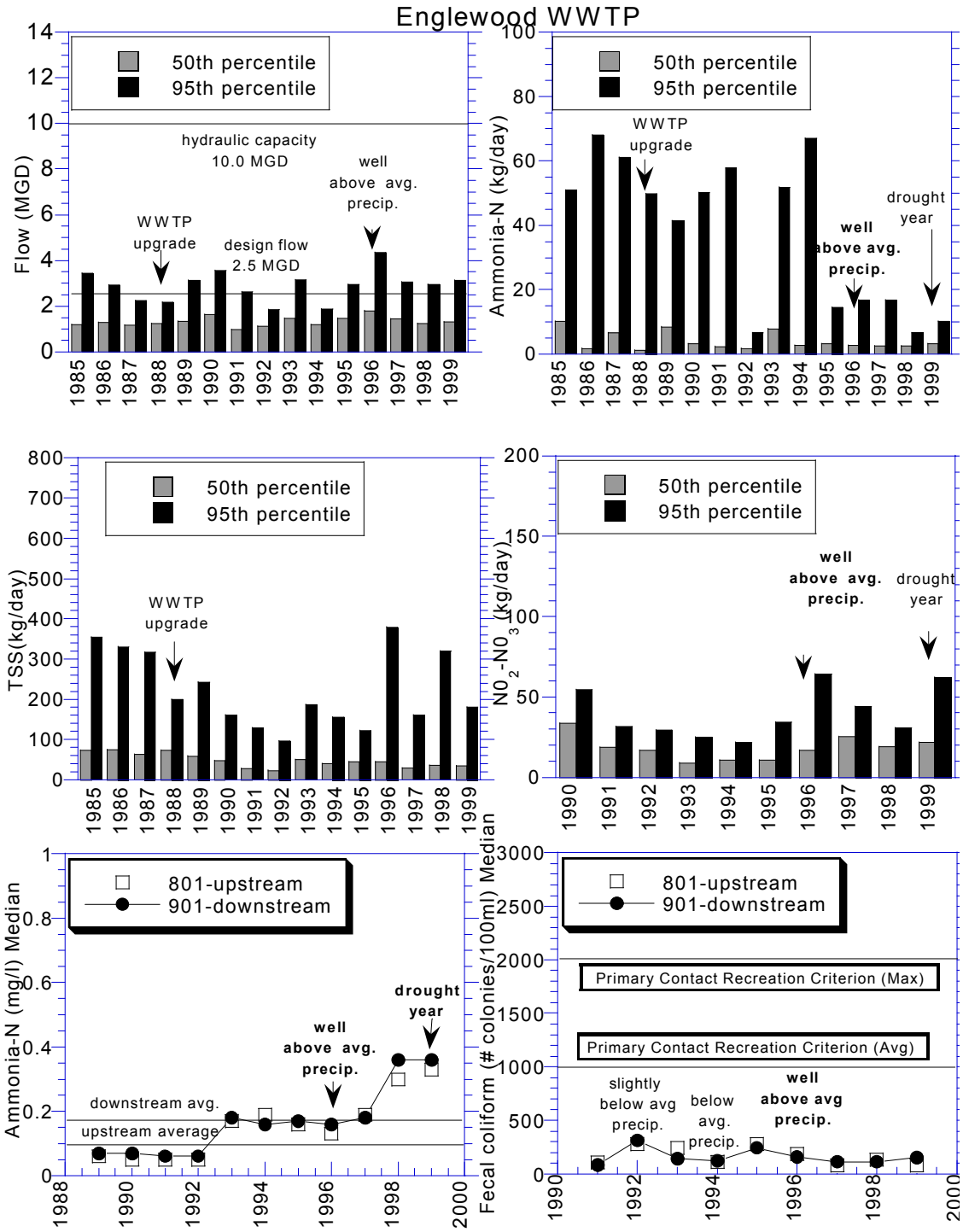

Figure 8. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from the Englewood WWTP for the period of record indicated.

Gettysburg Water Treatment Plant-Greenville Creek
Lat:40^0 06' 36"; Long:84^0 29' 37"
Permit#:1IX00043

The Village of Gettysburg Water Treatment Plant is located in Darke County on the corner of US 36 and Pittsburgh Rd. and discharges to Greenville Creek at RM 10.45. The facility softens and disinfects the water for the village, drawing groundwater through four wells in the vicinity of the plant. Final effluent discharge is filter backwash and softener regenerate. The average flow in 1999 and 2000 was 0.012 MGD, an increase from an original discharge in 1976 of 0.0006 MGD (Figure 9). Required parameters for monitoring final effluent (001) consist of Flow Rate, Total Suspended and Dissolved Solids, Chlorine (total residual), Iron (suspended), Manganese (suspended) and pH. National Pollutant Discharge Elimination System (NPDES) limits exist for all aforementioned parameters except for Flow Rate and Total Dissolved Residue.

Total residual chlorine averaged 14.6 mg/l during the Ohio EPA water quality survey. Average chloride for all of 2000 was 72.0 mg/l (omitting the outlier of 42,400 mg/l in October, 2000). Average chloride for 1998 was 12,354 mg/l. It has been documented that numerous species of fish were affected by chloride concentrations ranging from 2000 mg/l and greater (McKee, J. E. and Wolf, H.W., 1971). Currently Gettysburg is not required to monitor upstream and downstream from their final effluent discharge (801/901).

Median and peak-flows remained unchanged throughout the period of record as water demands remain constant for the area of Gettysburg. The chloride parameter showed little variance in percentile character throughout the record, reflecting consistent and predictable treatment of the waste stream.

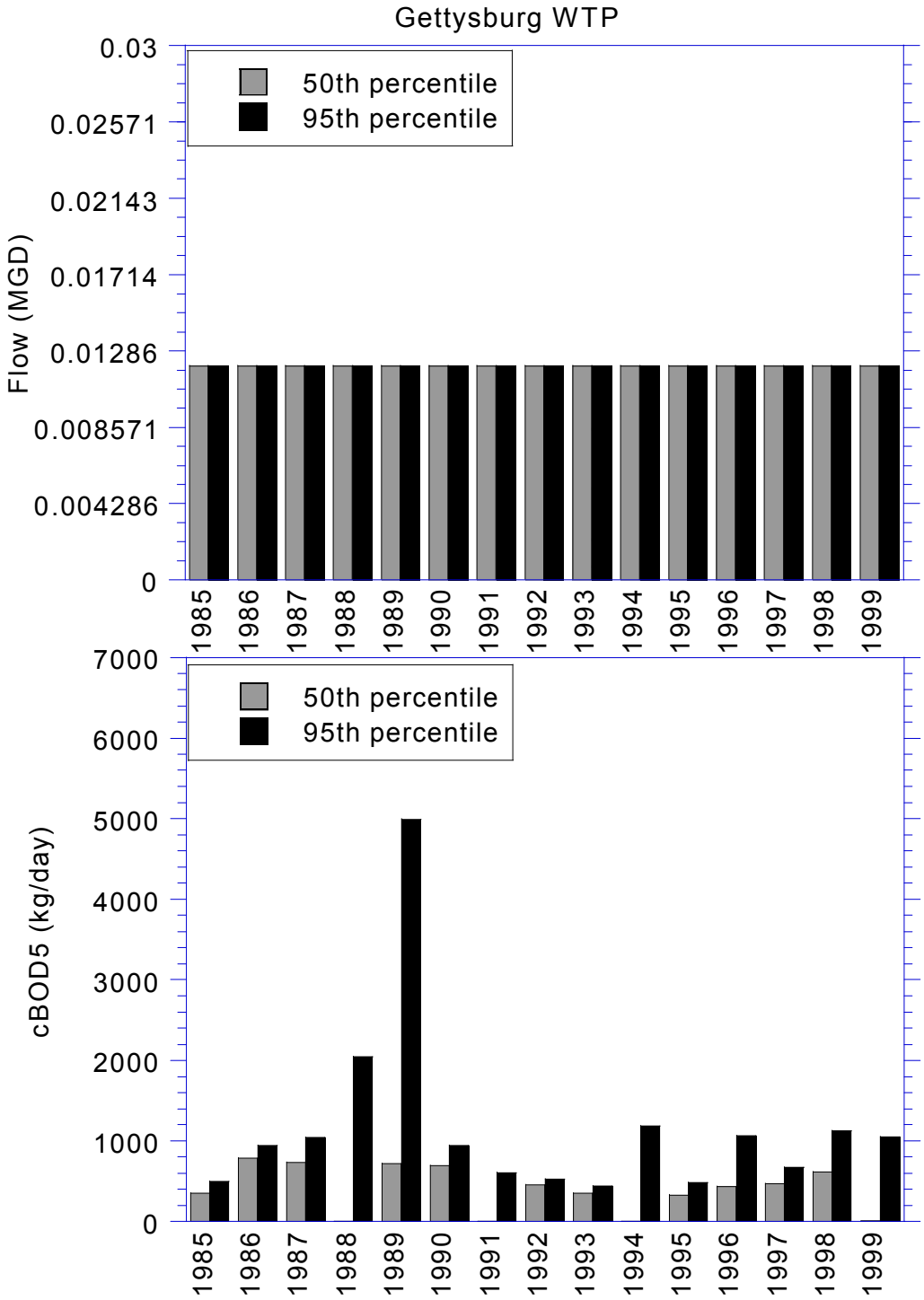

Figure 9. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand from Gettysburg WTP for the period of record indicated.

Greenville WWTP-Greenville Creek
Lat:40^0 05' 58" Long:84^0 36' 50"
Permit #:1PD00005

The City of Greenville WWTP was constructed in 1935 with modifications in 1967, 1986-1989, 1993 and 1996. Wastewater treatment is currently an advanced secondary treatment facility with an average design capacity of 3.50 MGD and hydraulic capacity of 6.0 MGD. The City of Greenville WWTP discharges to Greenville Creek at RM 19.35 which flows into the Stillwater River at RM 32.38. Approximately all of the service area is sewered with separate sewer systems. Treatment processes include bar screens, course and fine screening, flow equalization, activated sludge aeration, secondary clarification, disinfection by chlorination and dechlorination. The wastewater plant operates on one shift, seven days a week. The collection system is composed of gravity sewers that utilize seven lift stations to pump flows to facility. Overflows of lift stations were eliminated in 1987. The population in the city was estimated at 13,000 with moderate growth predicted for the area.

In December, 1999 the City of Greenville investigated the discharge of sewage into Greenville Creek overflowing through a storm sewer at the Ohio St. Bridge. Concurrent investigations correlating to this problematic overflow have revealed the need for sanitary sewer repairs at the Front and Gray Avenues and Fifth St. alley intersection. As of 2000 the crack in the clay tile was located, point patched and later slip lined to eliminate the discharge of raw sewage to Greenville Creek.

According to Ohio EPA files, hydraulic overloading of the wastewater facility due to heavy rains, occurred in 1997, with flows reaching 13.56 MGD and 13.91 MGD (Figure 10). Greenville was not able to determine how the excessive flows entered the collection system. This was the only reference to hydraulic overloading for Greenville noted.

A 1994 investigation by Ohio EPA documented a siphon overflow discharging raw sewage, midstream in Greenville Creek upstream from the WWTP. The biological impact instream was comparable to the impact noted in the mixing zone. Historically, this location has been referred to as a combined sewer area but has not been field verified as such. As of 2000 two siphon overflows were known to exist on the east and west side of the Ohio Street Bridge. The siphons are collection system pipes that cross Greenville Creek under the streambed. These pipes bring raw sewage in from the west and south ends of the city. The pipe located on the west side of the Ohio St. bridge is located approximately 300' west of the bridge. The pipe located on the east side of the bridge is located about 650' east of the bridge. Contributing dischargers downstream from Greenville WWTP are Corning Glass and BASF which enter Greenville Creek on the opposite bank from the WWTP and a reported abandoned dump site situated on Bridge Creek.

Four significant industrial contributors, classified as metal finishers, discharge to Greenville's WWTP. Significant Industrial Users (S.I.U.) include: Honeywell International Inc. (formerly

Allied Signal as of December 1999), Jafe Decorating, Whirlpool Corporation and Huhtamaki VanLeer Containers. In February 1999 Cadillac Gage Textron, Inc. was declassified from Significant to Non-Significant Industrial User (NSIU). In 1999 Allied Signal Inc. received an Ohio EPA Pretreatment Letter of Violation (LOV) for exceedences of molybdenum, phosphorus, and oil and grease. Honeywell International Inc. (East and West facilities) was in Significant Non-Compliance (SNC) in: 1995 for zinc and oil and grease; 1996 for phosphorus, oil and grease, zinc and suspended solids: and in 1997, 1998 and 1999 for phosphorus. Since January 2000, Honeywell's East and West facilities have contracted to have waste hauled off-site while deciding whether to upgrade their process lines and currently do not discharge to the Greenville WWTP collection system. Jafe Decorating was in SNC in 2000 for ammonia, copper and pH. Jafe is currently proposing to install a pH adjustment system to balance the acidity/alkalinity levels of their process water. Whirlpool Corporation was in SNC in 1994 and 1995 for zinc. Whirlpool implemented a variety of polymers to be able to process ample quantities of wastes under the existing treatment. Huhtamaki VanLeer Containers was in SNC in 1994 for phenol.

Between 1995 and 2000, four NPDES permit violations were reported to Ohio EPA from the Greenville WWTP. Total suspended solids (TSS) dominated the violations during the period 1998-1999, causing 75% of the total violations.

No acute toxicity to either test organisms, *P. promelas* or *C. dubia* was evident in eight acute bioassay events conducted by Ohio EPA from 1988-1995.

The entity conducted Whole Effluent Toxicity (WET) acute bioassays (acute tests are measured in lethality endpoints) utilizing *C. dubia* in one 48-hour testing event in 1994. Results of the test revealed no acute toxicity to *C. dubia*. The entity conducted Whole Effluent Toxicity (WET) acute bioassay in 1994, for the 96-hour test, using *P. promelas* as the indicator organism. This test also resulted in no acute toxicity endpoints.

Treatment improvements as a result of expansion of the plant completed in 1996 are well represented in most graphs. Loads of flow, ammonia, and results from outfall-bracketing monitoring all declined notably after the expansion went on line. A steadily increasing trend in median discharge rate is also indicated, likely due to sewer extensions sources. Suspended solids (TSS) trends exhibited no discernable patterns and were erratic before, with some reductions after, the upgrades. Percentile variances for TSS remained low for most of the record. Collection system overflows were reported around 1997-1998, although flow rates remained below the hydraulic capacity for the facility. Violations of the NPDES permit were reportedly low for this facility and were predominately suspended solids violations.

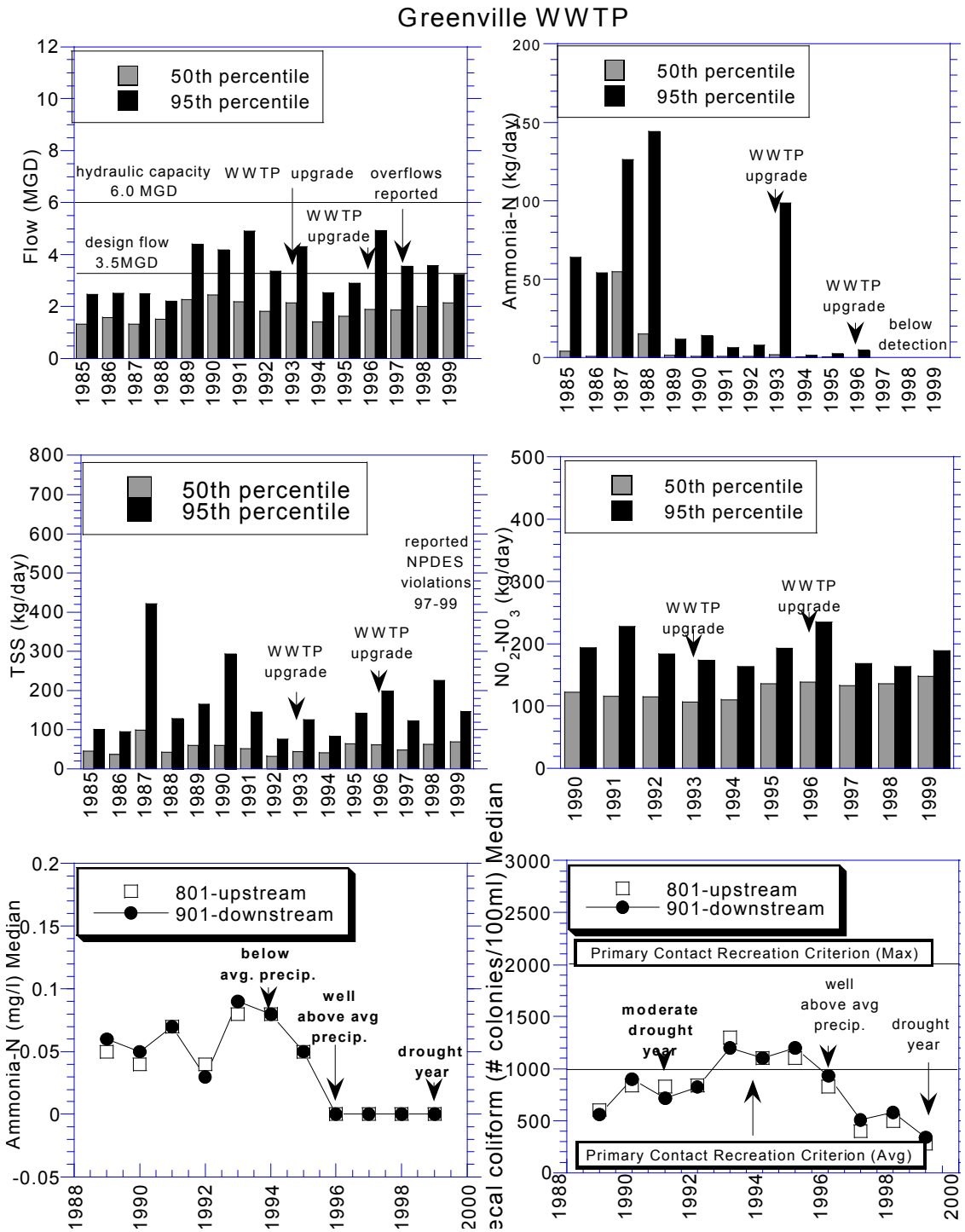

Figure 10. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from the Greenville WWTP for the period of record indicated.

Pleasant Hill WWTP-Stillwater River
Lat:40^0 02' 54"; Long:84^0 21' 59"
Permit #:1PB00026

The Pleasant Hill WWTP was constructed as a secondary treatment facility in 1977 by the Miami Conservancy District. Wastewater treatment at the facility consists of: a comminutor/barscreen (replaced in 2000), activated sludge, two primary oxidation ditches (one replaced in 2000-2001), secondary final clarifier, ultraviolet disinfection (1995) and an old Imhoff tank used an anaerobic sludge digester. The design capacity is 0.200 MGD with a daily maximum of 0.381 MGD (Figure 11). The final effluent discharges (001) to the Stillwater River (RM 26.88) mainstem, south of the S.R 718 bridge. The service area is 99% sewered with separate sewers containing no lift stations. The population in the Village of Pleasant Hill is estimated at 1,100, with a losing population projection for the village. There is no industrial contribution to the collection system. The upstream monitoring station (801) is located on the Stillwater River at the SR 718 Bridge. Downstream monitoring (901) is located at the Penny Road Bridge on the Stillwater River mainstem.

Due to large quantities of I/I during heavy rain events, the Pleasant Hill WWTP occasionally loses solids to the Stillwater River. A strategy for reduction of I/I influences has been designed, which proposes the inclusion of a second oxidation ditch. This will increase plant capacity and effluent detention time. The maximization of facility capacity should be online in 2000-2001. The Village of Pleasant Hill is also investigating various other approaches for reducing the quantity of I/I.

In June 2000 the shaft of the oxidation ditch failed, eliminating post aeration capabilities. Large quantities of sewage bypassed the majority of the treatment plant and received disinfection only (total quantity was unreported). The oxidation ditch unit was finally placed back into service on June 28, approximately two weeks later. As of July 2000, the wastewater plant performance was not fully operational due to required residency time to propagate bacteria. Suspended solids and demand constituent loads were not in compliance with NPDES limits during July of the same year.

Sludge is stored on site and land applied at agronomic rates. Sludge is land applied at two locations and referred to as the Johnston Farm and Brining Farm. The Johnston Farm lies within the Canyon Run Watershed. The sludge application site for this facility is located near the intersection of Rt. 718 and Shiloh Rd., perpendicular to Leonard Rd. No direct waterway appears to traverse the site. However, if runoff were to leave the site the approximate location on Canyon Run would be estimated at RM 1.7-1.5. The second sludge application site (Brining Farm) is just north from the intersection of S.R. 718 and Greenlee Rd.. No direct waterway appears to be on the site. However, should runoff leave the site it would enter the Stillwater mainstem via two unnamed tributaries between RM 24.00 to RM 22.5.

Between 1998 and 2000, twelve NPDES permit violations were reported to Ohio EPA. Fecal coliform and ammonia-N dominated the violations during those three years and all occurrences were reported in October of 1999. Reasons for the violations are related to heavy precipitation.

Treatment improvements as a result of an expansion completed in 1996 are graphically evident. Loads of $cBOD_5$, ammonia-N, and suspended solids (TSS) all notably decreased after the expansion, gradually increasing slightly in succeeding years. Flow trends have remained fairly constant over time and percentile variances remained insignificant. For all but one year, peak and median flows remained below design flow and never exceeded the daily maximum designed for the plant. Ammonia-N and fecal coliform dominated permit violations, reflecting the variability in ammonia loads exhibited throughout the period of record. Upstream and downstream (801/901) concentrations were commensurate throughout most of the years graphed, remaining below both recreational criterion for fecal coliform.

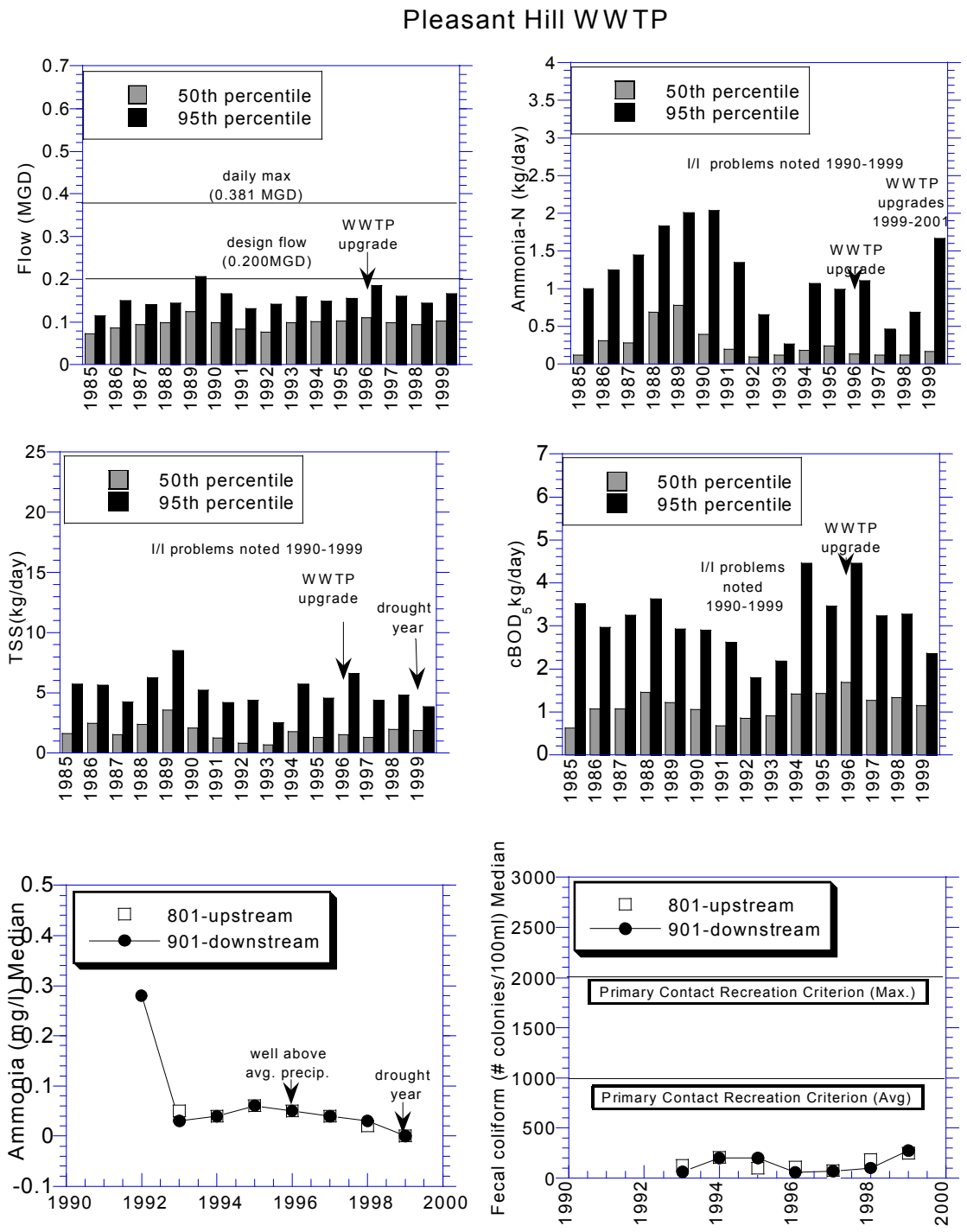

Figure 11. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and mean instream ammonia-nitrogen and fecal coliform concentrations from the Pleasant Hill WWTP for the period of record indicated.

Union WWTP-Unnamed tributary of the Stillwater River
Lat:39^0 54' 3.50" Long:84^0 18' 12'55"
Permit #:1PB00030

The City of Union WWTP was constructed in 1955, with modifications in 1966 and a major modification in 1983. Wastewater treatment currently consists of two lagoons in a series with a design capacity of 1.0 MGD and a hydraulic capacity of 3.0 MGD. The current chlorine contact tank has a volume of 34,165 gallons and provides a contact time of 29 minutes. The entire service area is sewered with separate sewers and has one lift station with no reported overflows or bypasses. The population of Union is currently estimated at 5,361 with slight to moderate growth predicted for the area. The City of Union WWTP discharges to the headwaters of an unnamed tributary that discharges to the Stillwater River at RM 11.74. The wastewater facility outfalls have been described as 001 and 002. However, discharge from outfall 002 is lagoon underdrain effluent and is reported as insignificant. Upstream monitoring (801) is conducted in the Stillwater River at Old Springfield Road Bridge (RM 12.2) and the downstream monitoring station (901) is located at Martindale Road Bridge at RM 11.4. An inflow and infiltration (I/I) analysis was conducted in the late 1970s and I/I was found to be insignificant at the time. Currently there are no plans to determine whether I/I is problematic at the wastewater treatment facility.

As of 1999, two sludge application sites were utilized near the wastewater treatment plant and located on farm land between Martindale Rd. and Old Springfield Rd. The farm land lies on either side of the wastewater treatment plant and directly adjacent to an unnamed tributary that parallels Old Springfield Rd. These sites have been accepting waste since the early 1990s. An additional site referenced in the Sludge Management Plan for 1992 lies east of the Stillwater River, approximately 0.5 mile northeast of the currently designated sites at Old Springfield Road. Historical sludge application sites were located at Haber, Phillipsburg-Union and Rinehart Roads in the mid-1980s. The annual sludge report for 1999 indicates a grassed waterway flows through the application site but is treated as an isolation area as part of sludge application guidelines. The current sludge application sites at Old Springfield and Martindale Roads are an estimated 0.5 mile from the mainstem of the Stillwater River.

Two acute bioassays, conducted by the Ohio EPA in July 1995, indicated final effluent was acutely toxic to *P. promelas*. In September 1995, toxicity in the final effluent affected *C. dubia* mobility yet was not acutely toxic (ammonia-N concentration at 0.22 mg/l). In the July 1995 toxicity test, ammonia-N was 16.5 mg/ls and phosphorus was 1.94 mg/l.

At a minimum 52 violations of the NPDES permit were reported to Ohio EPA between 1995 - 2000. The annual number of permit violations ranged from 13 violations in 1999 to zero violations in 2000. Violations, in order of decreasing frequency, were $cBOD_5$, ammonia-N, suspended solids (TSS), dissolved oxygen, fecal coliform, pH and chlorine. Ammonia-N and $cBOD_5$ accounted for 63% of the violations over six years with $cBOD_5$ violations occurring in all

years. Evaluated years reflecting ammonia-N violations of the NPDES roughly correlate to annual Union WWTP ammonia-N loads. Additionally, the majority of these violations occurred during a period when conduit flows were in excess of plant design capacity but not hydraulic capacity. An inflow and infiltration (I/I) analysis may be necessary to better characterize current conditions of the area serviced. In addition, flow metering equipment should be checked for accuracy and a plan implemented to waste sludge on a more frequent basis if violations reoccur. Violations in 1995 and 1996 were reported to Ohio EPA as relating to a change in water temperature at the facility, turnover and an emergence of an algal bloom onsite.

Treatment improvements as a result of the plant's expansion in 1986 were graphically evident. Loads of $cBOD_5$, ammonia-N, and suspended solids all notably decreased after the expansion, gradually increasing in loading in succeeding years. Median flows remained below design flow and never exceeded the hydraulic capacity (Figure 12). Peak-flows exceeded design flow for numerous years, remaining below the hydraulic capacity limit of 3.0 MGD from 1987-1999. Suspended solid (TSS), ammonia-N, and $cBOD_5$ loads demonstrated variability between median and 95th percentiles, with median loads nearly doubled for a majority of years. National Permit Discharge Elimination System (NPDES) violations indicate ammonia-N and $cBOD_5$ as predominant constituents in the 52 total violations during six years evaluated.

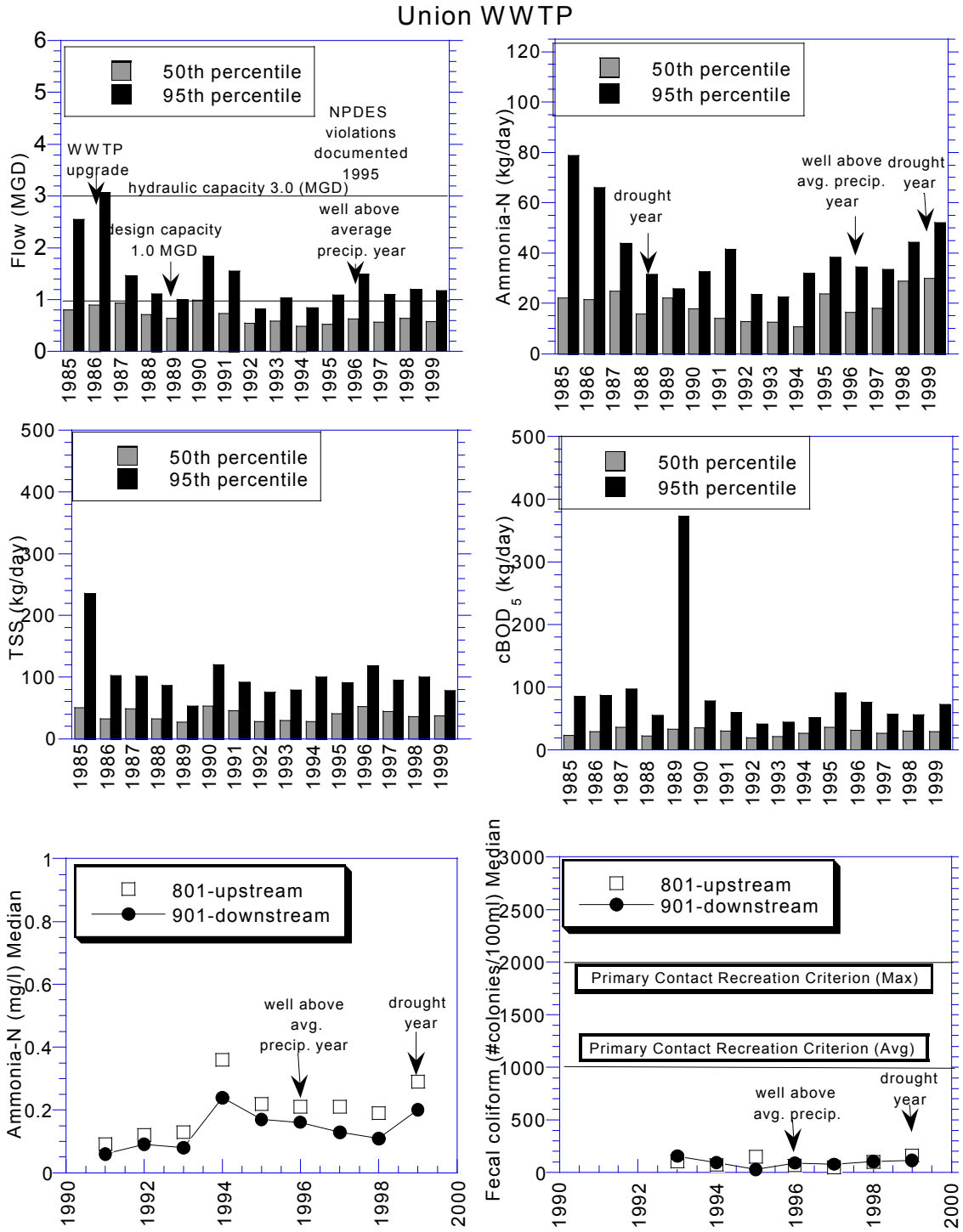

Figure 12. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and mean instream ammonia-nitrogen and fecal coliform concentrations from the Union WWTP for the period of record indicated.

Versailles WWTP-Swamp Creek
Lat:40^{0}13' 41"; Long:84^0 29' 44"
Permit #:1PB00033

The Village of Versailles WWTP was constructed in 1949 with modifications in 1964 and significant upgrades in 1992. Upgrades in 1992 included: additions of a new pumping facility, primary micro screening, oxidation ditch, two final clarifiers, ultraviolet disinfection, and two equalization basins (EQ) with a combined capacity of 256,000 gallons. Significant collection system upgrades occurred in 1996 when the village replaced 7,460 ft. of sanitary sewer main. All service laterals were replaced to the property lines in conjunction with the sewer main replacement project. Upstream monitoring (801) is located just upstream from the final outfall in Swamp Creek. Downstream monitoring (901) is located at the SR 121 bridge in Swamp Creek.

The Village of Versailles WWTP discharges through a 12" pipe that links to a drop manhole. This conduit leads to Swamp Creek and discharges at RM 2.12, just prior to the juncture with the Stillwater River at RM 45.88. The collection system contains four lift stations with reportedly no bypasses or overflows. The population in the village was recently estimated at 2,498 and stable growth is predicted for the area. Currently all of the service area is sewered separately with no overflow structures.

Wastewater treatment currently consists of: micro screening, two ring oxidation ditches, two secondary clarifiers, ultraviolet disinfection, aerobic digestion, and sludge drying beds. The two equalization basins (EQ) are diversion basins utilized during heavy rainfall events to increase storage capacity for influent. Overflows from the EQ basins are diverted to the existing chlorine contact tanks (holding areas) and then pumped to the disinfection chamber. The design capacity for the facility is 0.350 MGD with a current hydraulic capacity of 1.50 MGD. Industrial contribution accounts for 10% of the inflow to the sewer system and includes Midmark (metal fabrication), Acurite (plastic mold), Whitefords (frozen meat processing) and Weaver Brothers Eggs.

Historically, four Separate Sanitary Overflow (SSO) outfalls existed in the collection system and were referred to as outfalls 006-(Center St.), 007-(Reed Ave and Pearl St.), 008-(Reed Ave. and West St.) and 009 (Maple and Ward St.). Directors Findings and Orders (DFFO) issued in 1995 addressed unauthorized discharges (SSO's) that are considered in violation of the Ohio Revised Code (ORC) 6111.04 and 6111.07 and required all discharges ceased by August 1, 1997. Discharges from SSO outfalls have been illegal under the Clean Water Act since July 1, 1988. An extensive sewer rehabilitation project commenced in 1997, resulting in the elimination of the interconnection of the storm water discharges to the sanitary sewer system by 1998.

Sludge is stored at the facility and then land applied at agronomic rates. Sludge application occurs near Martz and Jamison Rd. intersection, on the north side of the Stillwater River and east of Swamp Creek. The sludge application site is directly adjacent to the mouth of (RM 0.28-0.10) Swamp Creek and the Stillwater River (RM 45.96).

At a minimum eight violations of the NPDES permit were reported to Ohio EPA between 1995-2000. Violations, listed in order of declining frequency, included: suspended solids (TSS), fecal coliform, $cBOD_5$ and oil and grease. Violations of suspended solids accounted for 50% of the total violations and occurred all years evaluated.

Peak-flows, as represented by the 95th percentile, consistently exceeded design flow for the majority of record during 1985 to1999 and were well below the hydraulic capacity of the facility for both percentiles (Figure 13). No discernable trend for flow was noted. Loads of ammonia declined significantly after the expansion went on line however, other typical constituents of wastewater were erratic with peak loads more than double median loads. Upstream and downstream fixed-station monitoring indicated ammonia-N concentrations with no discernable pattern, while downstream fecal coliform concentrations clearly exceeded upstream concentrations from 1995-1999. Violations of the NPDES permit indicated TSS and fecal coliform as primary constituents exceeding allowable limits, and was evident by downstream monitoring and TSS variability in loads. Separation of the sanitary sewers in 1998 reflected graphically as peak and median flows indicated a reduction in trends for 1998 to 1999.

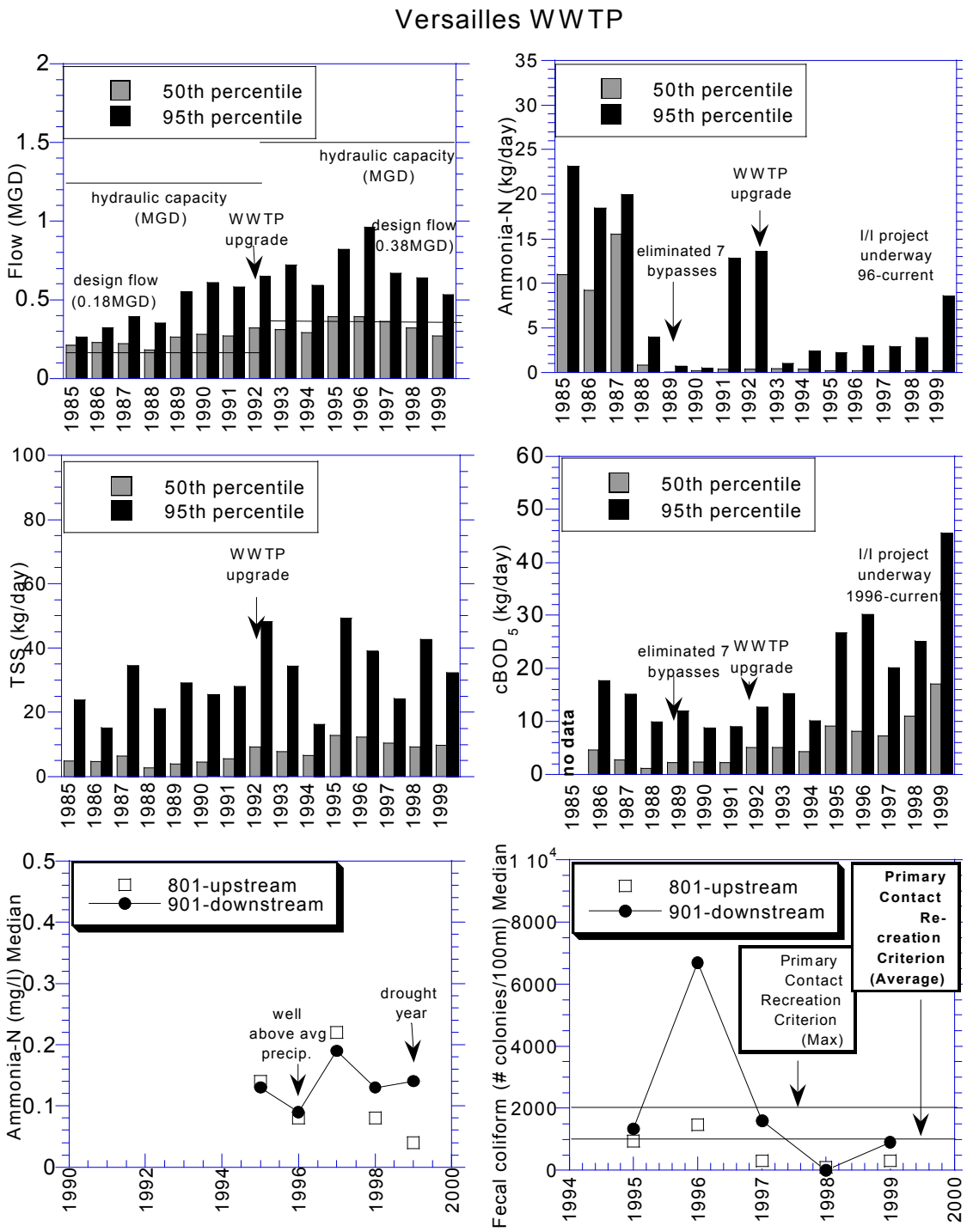

Figure 13. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from the Versailles WWTP for the period of record indicated.

West Milton WWTP-Unnamed tributary of the Stillwater River
Lat:39^{0}57'08"; Long:84^{0}19'18"
Permit #:1PC00011

The Village of West Milton WWTP was constructed in 1954, with modifications made in 1964, 1972 and 1993. The 1993 upgrade increased design capacity from 0.600 MGD to 1.2 MGD, with a current hydraulic capacity of 3.5 MGD. The treatment train consists of: an Imhoff tank (a primary settling and anaerobic digester), intermediate pumping station, nitrification towers (two), a 43' diameter secondary settling tank, ultraviolet disinfection, a 1.8 MG storm water overflow basin and a new control/laboratory building. The Village of West Milton WWTP technically discharges to an unnamed tributary of the Stillwater River at RM 0.2. The tributary starts as an underground spring on the west side of the Village of West Milton and meanders past the wastewater plant to the Stillwater River confluence at RM 16.57. Outfall 002 was referred to as a wet well overflow or secondary bypass in Ohio EPA files however this outfall was stated by wastewater personnel as having been eliminated in the early 1990's. Upstream monitoring (801) is conducted in the Stillwater River and is located at Calumet North St.. Downstream monitoring (901) is fixed at the Garland Rd. Bridge and is approximately 1.5 miles downstream of the final effluent discharge to the mainstem. Industrial contribution to the wastestream is less than 5% and is composed of two minor industries involved in plastic injection molding manufacturing.

In the 1980's, several manholes on the north trunk line would overflow routinely under heavy rain events. This problematic area was eliminated during the collection system upgrade process in the early 1990's which has eliminated all overflow and bypass events to the waterways. The extensive inflow and infiltration (I/I) project included replacement of the north trunk line interceptor which was completed in 1992. The Village of West Milton recently conducted smoke testing of down-spouts and cross-connections and is actively pursuing annual sewer televising to correct known I/I problems.

The City of West Milton has been applying biosolids to agricultural land for 11 years. Application occurs in fall and winter months and the majority of fields are located within a five-mile radius of the wastewater treatment plant. Sludge application rates are based on the needs of the crop, the soil and sludge background information, as well as the nutrient content of the sludge. The application rate is not to exceed 2.5 dry tons/acre (about 18,500 gallons/acre) in order to avoid excessive application of sludge nitrogen to the site. Concerns are also associated with high levels of land applied phosphorus and the overland flow vehicle for reaching waterways. Heavy metals in sludge are apparent in West Milton's sludge and typically consist of copper, zinc, arsenic, cadmium, lead, mercury, molybdenum, nickel and selenium. Soils in the West Milton area consist primarily of, Lewisburg-Brookston-Pyrmont and Milton-Miamian limestone substratum-Randolph. These soils are characterized by well drained to poorly drained soils that have a moderately fine textured subsoil, formed in thin loess (silt) and glacial till.

Sludge application sites include the Theis Farm south of Garland and north of County Line Rd. directly adjacent to the Stillwater River. An unnamed tributary of the Stillwater River meanders directly through the application field entering the Stillwater River near RM 13.60. The

Thompson Farm is an 80-acre farm in Union Township off SR 571 between Tippacanoe (571) and Shearer Rd. west of Brush Creek and is also utilized for sludge application. The Daum Farm which also accepts sludge from the West Milton WWTP is located near Emerick and RT 48 adjacent to local fish hatcheries. Another 50-acre tract of land also used for sludge application is located between SR 571 and Garland Rd. adjacent to the Stillwater River off Williams Drive North.

The Doat Farm has two sites available for land application of sludge. One site is located at the corner of Jay Rd. and Emerick Rd. (37 acres) and a 61-acre site is located at the corner of Diamond Mill and Phillipsburg-Union Rd. In 1999, these two farms received a total of 4.31 dry tons/acre of biosolids which is less than the five dry tons/acre/crop/year limit.

The Kleptz Farm (50 acres), an application site located at the corner of ST RT 48 and Calumet Rd., has been the site of historical odor complaints. Concerns about public drinking water have been filed relating to this site because of the shallow bedrock present at less than three feet beneath surface components. Another concern is the field tiles that have been installed to help improve the drainage of the farm field which can act as conduits for pollutants to the waterways. Isolation distance requirements are described in the Biosolid Application Guidelines that define application distances from roads, waterways, field tiles, knifing in the sludge to the soils, and several other guidelines. In 1996, Ohio EPA received a complaint describing the presence of raw sewage alongside a roadway at the application site. The cause of the sewage was determined to be leakage from the biosolid hauling truck.

Two acute bioassays, conducted by the Ohio EPA in the summer of 1995, revealed the absence of acute toxicity endpoints for both test organisms, *P. promelas* and *C. dubia*.

Thirteen violations of the NPDES permit were reported to Ohio EPA between 1995-2000. The annual number of permit violations ranged from seven violations in 1998 to zero violations in 2000. The violations, in declining order of frequency, were limited to four parameters: suspended solids (TSS), ammonia-N, fecal coliform and dissolved oxygen. Total suspended solids (TSS) accounted for 38% of the total violations with the majority occurring in 1998. The pattern of annual violations was roughly correspondent of annual suspended solids (TSS) and $cBOD_5$ median loads.

Reduction in median and peak flow trends and percentile variances were notable after the facility upgrade of 1993 however, variability in percentiles remained in unpredictable patterns (Figure 14). Ninety-fifth percentile flows were typically greater than the design flow but well below hydraulic capacity for the plant, indicating adequate treatment probably occurred the majority of the time. Variability persisted however, in peak and median loads for TSS and ammonia-N and were reflected in NPDES violations for these constituents. Upstream and downstream fixed station monitoring, bracketing the final outfall (001), indicated values mostly commensurate with each other for both ammonia-N and fecal coliform.

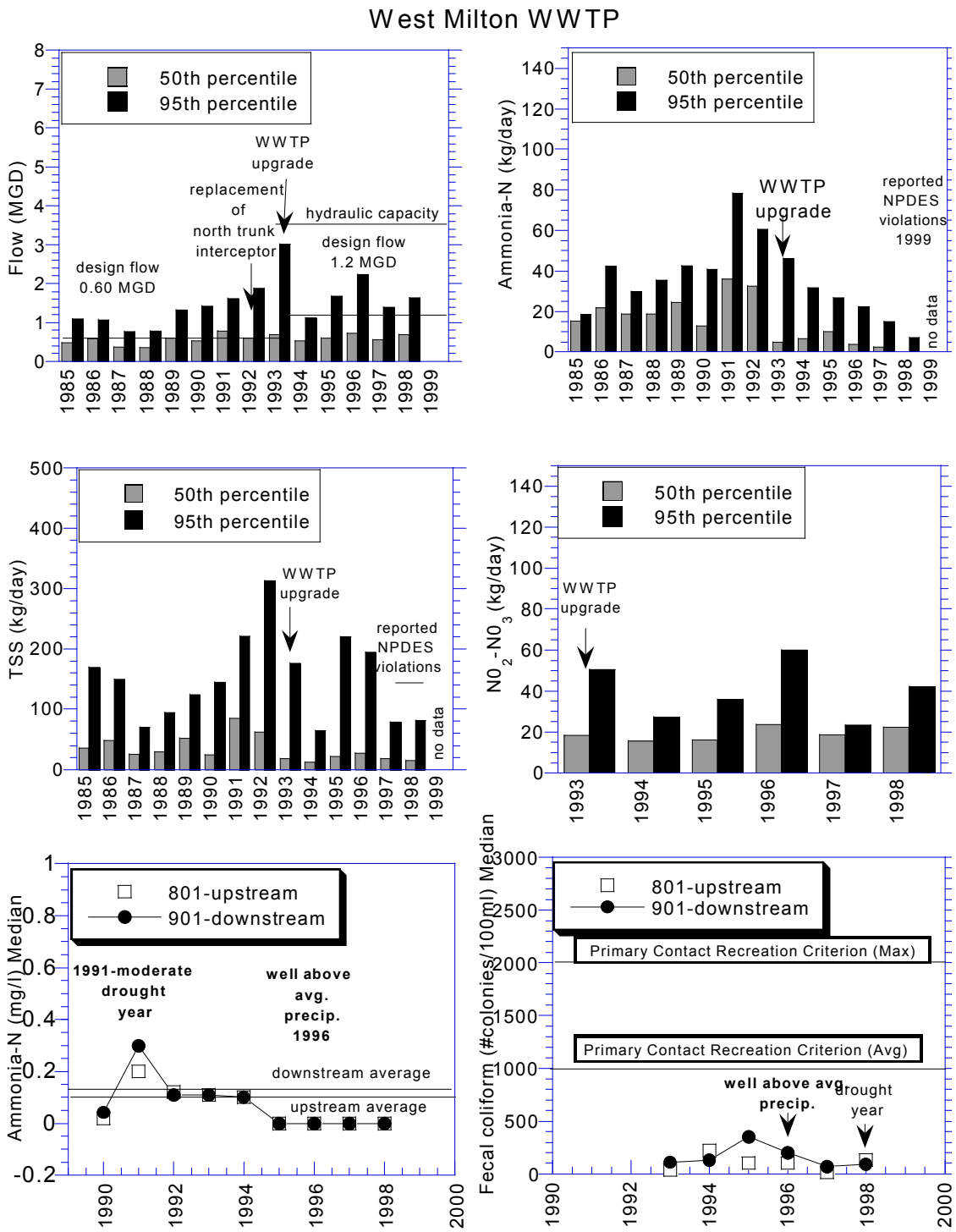

Figure 14. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen and median instream ammonia-nitrogen and fecal coliform concentrations from the West Milton WWTP for the period of record indicated.

Corning Glass Works-Greenville Creek
Outfalls 001-003
Lat:40º05'58"; Long:84º36'51"
Permit#:1IN00042

Corning Glass Works is located on Martin St. in Greenville and has been operating since at least 1980. Products developed at Corning Glass Works include glassware for replacement of sealed beam lamps, beam floodware, and clear consumer ware. Raw materials used at the facility are silica, borax, alumina, cullet (recycled glass), NACL and petroleum hydrocarbon oil. Total raw material consumption is estimated at 41,975 tons/year. Corning Glass operates with approximately 700 employees, 24 hours a day, with a production rate of roughly 29 million pieces a year. The manufacturing processes used for production of goods is machined press glass, glass forming and product packaging.

Corning's three outfalls (001-003) discharge non contact and contact cooling water, storm water, and filter backwash water to Greenville Creek through a drainage ditch which discharges to Greenville Creek at RM 17.77. Sanitary waste is directed to the Greenville WWTP. The outfalls (001-003) are located directly east of the City of Greenville, between 11th Ave. and the Pennsylvania R.R Line on Greenville Creek. From the south side of the property the outfalls are numbered from upstream to downstream as outfall 001, outfall 002 and outfall 003 (nearest confluence with Greenville Creek).

Outfalls descriptions:
Outfall 001 discharges contact cooling water and back wash water from water treatment and an oil and water separator. Sludge is disposed of at the local landfill in Greenville. Outfall wastewater volume in1999 averaged 0.429 MGD.

Outfall 002 discharges contact cooling water and stormwater from the sump pit for storm water. Outfall wastewater volume in 1999 averaged 0.0014 MGD.

Outfall 003 discharges stormwater to a manhole near the pump house to a discharge pipe on Greenville Creek. Outfall wastewater volume in 1999 averaged 0.013 MGD.

The upstream (801) fixed monitoring station is located in Greenville Creek upstream from the confluence of the drainage ditch to Greenville Creek. The downstream (901) fixed monitoring station is located in Greenville Creek downstream from the confluence of the drainage ditch to Greenville Creek

Twenty NPDES violations were reported between 1995 and 2000. Five NPDES violations occurred in 2000, all reported as weather induced. Total suspended solids (TSS) were the most frequent violations in 2000 and occurred at outfalls 002 and 003. One violation of oil and grease occurred at outfall 003. Bypassing of the clarifier for routine cleaning occurs quarterly. However, reportedly no violations of the NPDES permit occur during these cleanings. Sixty-six percent (66%) of violations in 1999 were oil and grease through outfall 003. Five (5) suspended

solids (TSS) violations in1998 were connected to outfalls 002 and 003. Two spills of 20-50 gallons of Houghto-Safe 620 (diethylethanolamine) hydraulic fluid from a pipe break, were reported in 1996 and again in 1998. Thousands of gallons of water were used for dilution and no discoloration was noted at the clarifier or downstream by OEPA officials. A follow-up inspection by Ohio EPA field personnel to the 1996 incident, scored the receiving waters as "marginal" due to the usually extensive algae growth and slight odors of the effluent. Four violations of the NPDES permit occurred in 1997, originating at outfall 002 and were divided equally between suspended solids (TSS) and $cBOD_5$. One NPDES violation at outfall 003 for pH, was reported in 1997. Continued suspended solids (TSS) violations of the NPDES permit occurred from 1996 to 2000. These were reported as originating from outfalls 002 and 003. Almost negligible NPDES violations were reported from outfall 001.

Percentile flows for outfall 001 demonstrated a steady decline over time where a percentile variances became less evident by 1998 to1999 (Figure 15). Contact cooling water without storm water influences allow for more predictable flow characteristics. Suspended solids at outfall 001 mimicked peak and median flows through the period of record, indicating fairly predictable loads by 1999. Percentile flows and subsequent TSS loads for outfalls 002 and 003 were more erratic, reflecting storm water characteristics of associated precipitation events.

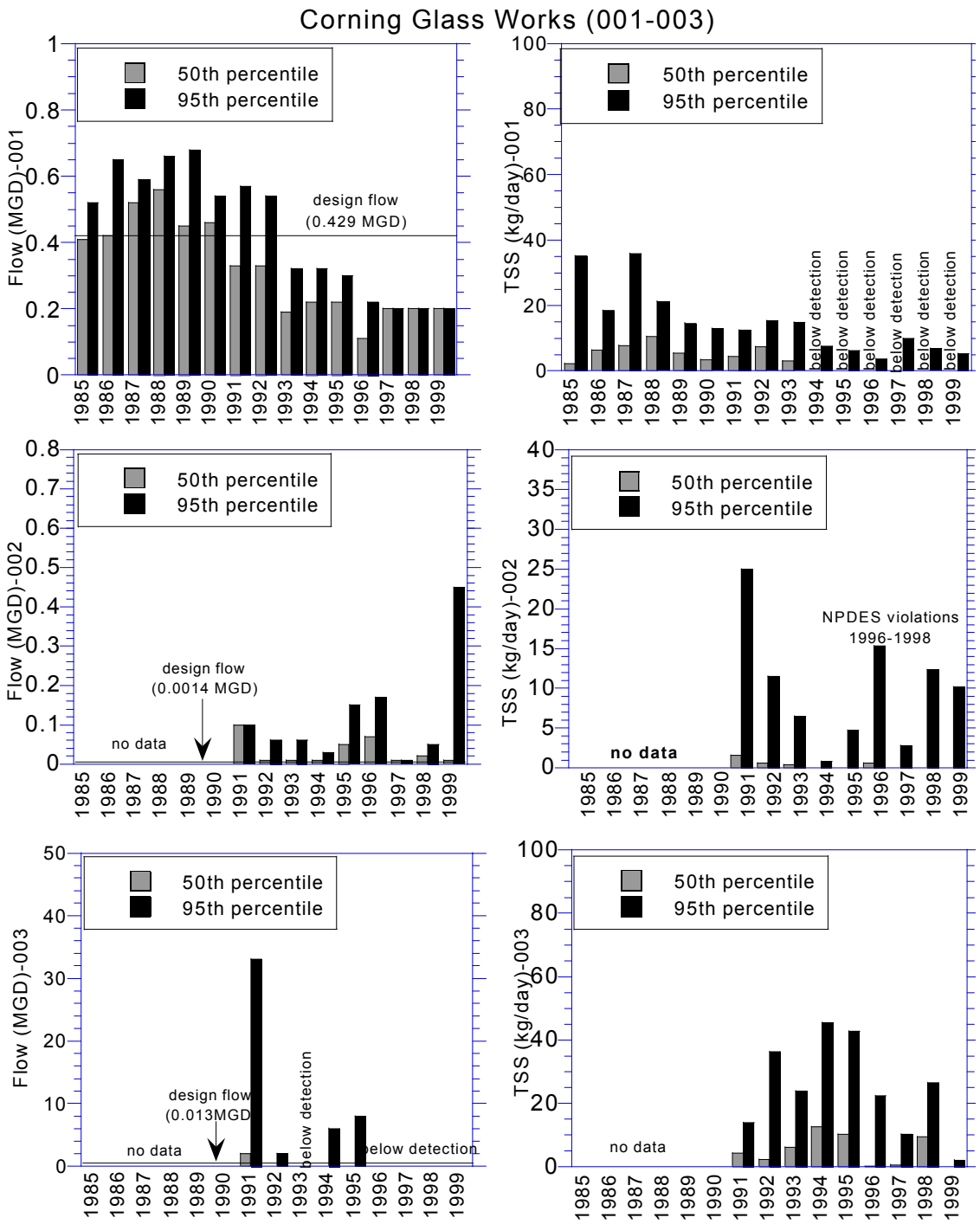

Figure 15. Median and 95th percentile effluent flows and loadings of total suspended solids from Corning Glass Works WWTP (001-003) for the period of record indicated.

Dayton International Airport (D.I.A)-Stillwater River and Mill Creek
Lat:39^0 53' 23" N; Long:84^0 15' 15"W- Outfall 001
Lat:39^0 53' 57" N; Long:84^0 13' 57"W- Outfall 002
Lat:39^0 53' 34" N; Long:84^0 14' 15"W- Outfall 003
Permit #:1II00029

The Dayton International Airport (DIA) is owned by the City of Dayton and located on U.S Route 40 near Vandalia, Ohio. Air traffic at DIA consist largely of commercial passenger and freight aircraft, of which there are currently 85 tenants at the airport. There are three major runways as well as fueling, maintenance and storage areas. There are estimated to be greater than 50,000 flight operations per year from the three runways. Stormwater related concerns (Stormwater Pollution Prevention BMP plan, October, 1994) include impervious areas such as buildings of operation, runways, taxiways, automotive parking areas and access roads. The remainder of the airport property is covered in grass, woodlands or croplands. Certain airport fields are leased to local farmers and soybeans are grown inside runway/taxiway areas and the surrounding grounds are planted in corn.

Outfalls discharging to the Stillwater Basin:
Outfall 001: discharges to two corrugated metal pipes that enters a ditch along the east side of Dog Leg Road. This outfall collects drainage from the field on the southwest side of the airport property.

Outfall 002: discharges to the drainage swale along the south side of the South Parallel Taxiway for Runway 6L-24R. The areas draining to this outfall: include car rental facilities along Valet Dr.; air cargo facilities along Cargo Rd., Freight Dr. and Concorde Dr.; a fuel farm; maintenance facilities; and airport parking lots. Petroleum products, surfactants, antifreeze, solvents, deicing chemicals, unleaded and leaded gasoline are all possible contaminants from this outfall. An oil/water separator treats runoff waters prior to discharge.

Outfall 003: discharges flow to Mill Creek from the Northwest Detention Basin through a valved outfall structure immediately south of Old Springfield Rd. The area draining to this outfall includes the Emery Worldwide Air Cargo Complex, aircraft deicing areas, the Emery apron, the passengers' terminal apron, and several taxiway and runway areas. Deicing chemicals, petroleum products, paint, transmission fluid, hydraulic fluid, and airplane lavatory waste are all possible contaminants from this outfall. There are two, oil/water separators located in major storm sewers at the entrance to the detention pond (Stormwater Pollution Prevention BMP plan, October, 1994).

A significant freight user of the airport is Emery Airfreight, who estimates 60-65 Emery Cargo Aircraft unload, refuel and receive maintenance (including deicing) after midnight each evening. Runway deicing is conducted only when other methods of snow and ice removal are ineffective which do not drain to the deicing fluid control system. In extreme weather conditions Emery applies deicing chemicals to their apron and taxiways for personnel and equipment safety which have the potential to drain to surrounding grassways of the runway.
Historical occurrences of pollutants reaching Waters of the State at DIA include numerous spills

of petroleum products reported in1974 migrating to an unnamed tributary of Mill Creek. Sources of petroleum product runoff originated from the loading pad and bulk storage facilities. Further investigations prompted by these reports unveiled airport grounds, north of the bulk storage facility, were soaked with spilled fuel in a gradient area that would migrate to Mill Creek. Consequently, airport operations drilled sump holes into the fuel soaked regions and residual fuels were collected and disposed of at a waste oil recycling facility. An oil/water separator was installed in 1976 with an upgrade to the oil/water separator in 1983.

Other problematic areas linked directly with the airport operations were the numerous overflows of pollutants from the retention basin to Mill Creek reported by citizens to the City of Dayton in the 1980's and early 1990's. When gross pollution in Mill Creek was documented, Ohio EPA conducted an intensive biological and water quality study of Mill Creek. Multimedia sampling was conducted in reaction to releases of contaminated retention basin water. The results of the study verified biological degradation and chemical impairment from the airport's retention basin.

Additional pollution collection systems installed at the airport, include spent deicing fluid recapture zones. The recapture zones allow deicing pad wastes to be collected and pumped to adjoining lagoons. These recapture zones were constructed between 1996 and 1997 and are reportedly 70-90% successful at recapturing deicing fluid runoff for either reuse or discharge to a sanitary sewer. The remaining 10-30% of uncaptured deicing fluid was attributable to "windblow-up" from the aprons or off of the aircrafts which travel to adjacent grassland.

Spills/Leaks

Spills at DIA are presently reported through the Airport Rescue and Fire Fighting (ARFF) Department, to the Dayton Regional Hazardous Materials Team (HAZMAT) and to the appropriate regulatory agencies. Information compiled from these spill reports from 1991-1998 indicated there were approximately 102 reported spills with potential for migration to the Stillwater River Watershed (Storm Water Pollution Prevention Best Management Practice Plan, CH2M Hill, 1997). Most of the spills were petroleum and occurred as refueling incidents from the Every ramps (41% of total spills). Most spills occurred in the spring and summer months, correlating with extensive travel seasons. Reasons given for the spills at Emery included mechanical or material failures of refueling hose, overfill of aircraft, or nozzle falling out during filling, valve failures, leaking tanks or loose connections.

The most common material spilled in declining order of frequency was Jet A-Fuel, which accounted for 62% of the listed materials and had an estimated spillage of 7,499 gallons over an eight-year period. Gasoline for vehicles accounted for 13% of the reported spills. Diesel fuel, hydraulic fluid, motor oil, deicing fluid (reported when the delivery system of the deicing applicator fails and not actual application runoff) and heating oil were reported less frequently. The largest estimated quantities spilled over the past eight years were Jet-A-Fuel (7,499 gallons), heating oil (5,500 gallons), diesel fuel (314 gallons), deicing fluid (175 gallons) and hydraulic fluid (143 gallons). An estimated 5,145 gallons of material were documented as migrating to storm sewers in the Stillwater Watershed during the eight years evaluated.

In 1996 Dayton International Airport installed a Deicing Fluid Control System (DFCS) which

consisted of: apron lagoons, inlets, storm sewers, diversion structures, Apron Pump Station, Central Lagoons, Central Pump Station, Force Main, N.E Deicing Apron, NW Deicing Apron, S.E Deicing Apron and S.W Deicing Apron. Aircraft at DIA must be deiced on the four aprons containing the DFCS System. Deicing at the gate and at other apron areas draining to the storm sewer system is prohibited. During the deicing season, ground traffic is minimized on the deicing aprons to minimize tracking of deicing fluid from the deicing aprons. Four deicing pads with lagoons, pump fluids to a series of lined, central storage lagoons (located in the S.W region of the airport near National Rd). These central storage lagoons pump fluids (propylene glycol) to the Montgomery County Sanitary Sewers which are situated south of the airport and south of I-70. Each deicing apron flows to a diversion manhole where the water passes through a glycol density measurement system capable of detecting glycol in storm water and diverting contaminated water to the central storage lagoon.

Violations of DIA's NPDES from 1998 to 1999 at outfall 003, occurred mostly in spring and winter and predominantly consisted of suspended solids (TSS) and $cBOD_5$. These occurences were reportedly caused by a construction project at the Taxiway Airfield and deicing overspray.

Two acute bioassay events, conducted by the Ohio EPA in winter and spring of 1995, both indicated acute toxicity in DIA's effluents. Toxicity from the NW retention basin spillway waters were acutely toxic in February, 1995 to *P. promelas* only. Ohio EPA testing conducted in April of 1995 from the same location exhibited acute toxicity to both test organisms, *P. promelas* and *C. dubia*.

Percentile flows for outfalls 002 and 003 reveal percentile variances apparent throughout the period of record (Figure 16). Median flows remained consistent however, peak flows reacted to events at the airport. Ammonia-N and TSS loads were variable until 1997 when deicing runoff recapture and treatment processes were improved. Percentile variability was reduced significantly, with occasional peak loads still evident. Upstream and downstream fixed monitoring locations documented deicing chemical overflow impacts to the watershed, as downstream ammonia-N concentrations exceed upstream, until improved controls were implemented in 1997-1998. Loadings for the glycols remained fairly predictable as propylene glycol was substituted for ethylene glycol in 1998 and 1999.

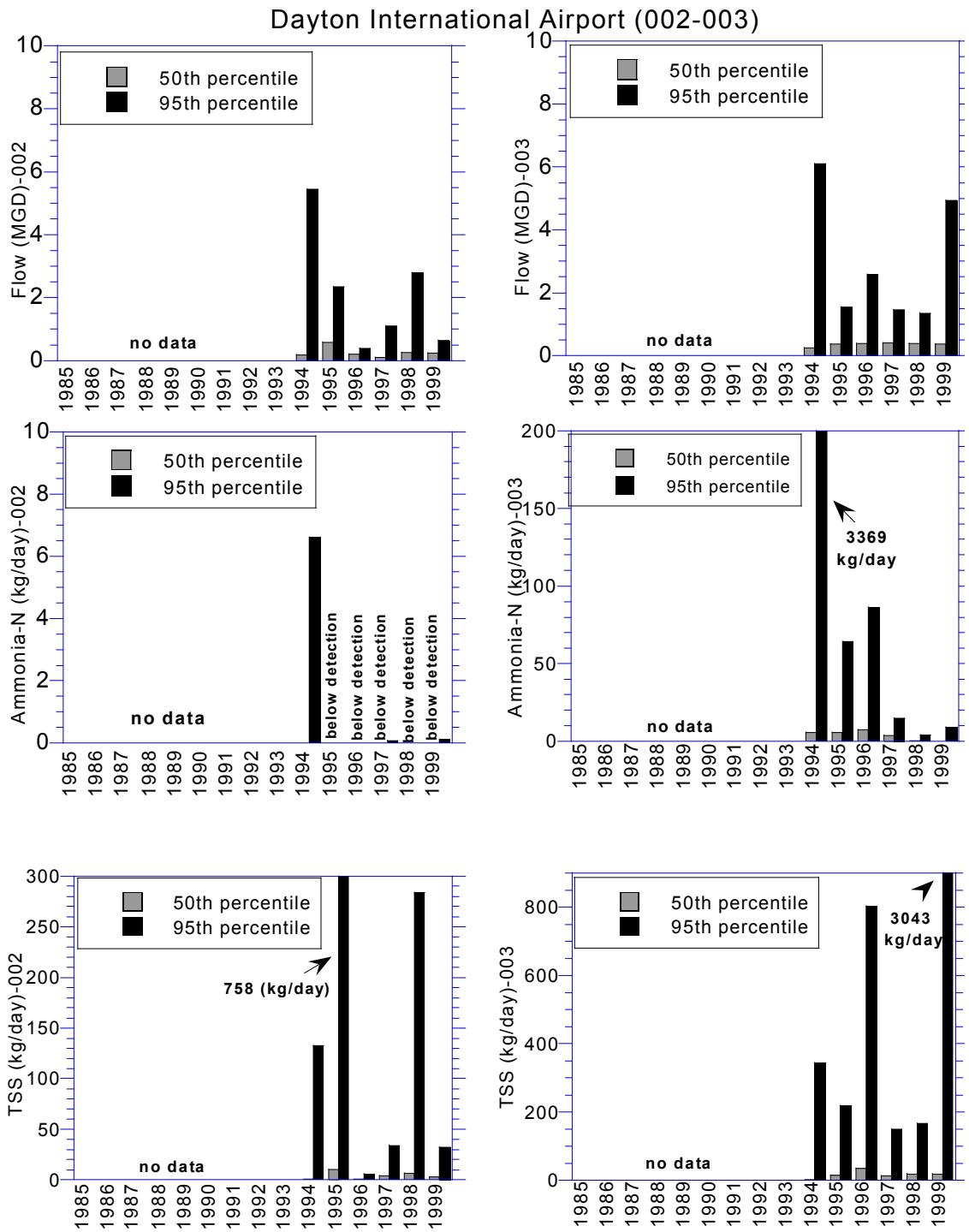

Figure 16. Median and 95th percentile effluent flows and loadings of total suspended solids, ammonia-nitrogen from Dayton International Airport (002-003) for the period of record indicated.

Laura WWTP- Hog Run
Lat:39^0 59' 20" Long:84^0 24' 35"
Permit#:1PB00045

Laura WWTP in Miami County was built in 1992 with a grant from U.S EPA and started receiving waste by 1993. The current population of Laura is estimated at 622 with an estimated growth to 958 by 2012. The construction grant included the collection system, which consists of a small diameter gravity sewer system collecting septic tank effluent for treatment at the wastewater plant. Laura WWTP has a design capacity of 0.060 MGD and a hydraulic capacity of 0.178 MGD. Treatment consists of activated sludge (two extended aeration tanks), fixed media clarifiers, two sand filters (gravity dosed), chlorination, dechlorination and post aeration. Facility modifications included a new chemical and equipment storage building, mufflers on blowers to reduce noise, and pulse damage to gauges and valves resulting in no hydraulic change to collection or treatment facilities.

The Village of Laura WWTP discharges to Hog Run at RM 0.22, a tributary of Ludlow Creek. The entire service area is sewered with a collection system that contains one lift station and has no reported overflow or bypass capabilities. Industrial contributions to the collection system include Kindex Company, a minor machine shop that conducts grinding, drilling, lathing, mill work and welding. Sludge from Laura WWTP is hauled off-site for disposal by a sludge hauling truck and disposed of at a local POTW's, incinerated and some landfilled.

Photos taken by Ohio EPA personnel in January of 1999, of notable amounts of sludge solids at clarifier weirs substantiate reported inflow and infiltration (I/I) problems that have plagued the system from 1993. The I/I problem appears to be extensive, allowing flows of 0.50 MGD into the plant which has a design of 0.060 MGD. Washouts of solids at the sand filters have occurred since the inception of the wastewater plant. Excessive inflow has resulted in the release of solids which clog sand filters. This has resulted in the need to purge the filters to an adjacent field. Review of design and specifications for the collection system reveal I/I problems are the result of poor workmanship and inadequate inspection during construction. Inflow and infiltration events occur when heavy precipitation traverse through septic tanks, clean outs and manholes, sometimes comprising approximately 75% of inflow. During one month in1997, approximately 600,000 gallons of wastewater bypassed sand filters, was disinfected and released to Hog Run. In April of 2000, a facility bypass incident occurred whereby 650,000 gallons of wastewater bypassed treatment. Only 37% of the bypassed wastestream received minimum treatment of disinfection. Overflows in the collection system have been documented occurring when incoming water to the facility is in excess of lift station capacity. These recent events have been noted to occur sometimes for four to six hours, with undocumented quantities of raw sewage being released to Hog Run (lift stations pump an approximate 245 gallons per minute).

The Ohio EPA, Division of Environmental and Financial Assistance (DEFA) has been collaborating with the Village of Laura since the conception of the facility to correct the I/I problems. Projects conducted to attempt to investigate and reduce inflow and infiltration include: sealed manholes, smoke testing on all collection lines, sealed clean outs, replacement of cracked septic tanks, and replacement of cracked fittings.

Between 1995 and 2000, eleven (11) NPDES permit violations were reported to Ohio EPA. Chlorine dominated the violations during the period 1995-1999. Suspended solids (TSS), dissolved oxygen, pH and $cBOD_5$ were additional parameters in violation status and are listed here in order of frequency. Sixty-four percent of the violations occurred between 1995 and 1997. Constituents were typical of facility washout and bypass occurrence.

With the exception of peak-flows, annual median flows remained consistently below design flow throughout the period of record, with both percentiles remaining below the hydraulic capacity of the facility. Percentile variability was graphically low (Figure 17), suggesting minor influences from precipitation. However, records indicated a different scenario, as bypassing occurred frequently at the plant. Conventional parameter load characteristics reacted inversely to graphed flow behavior. This revealed notable variances in percentiles and supporting records documented frequent bypassing and substantial inflow and infiltration problems.

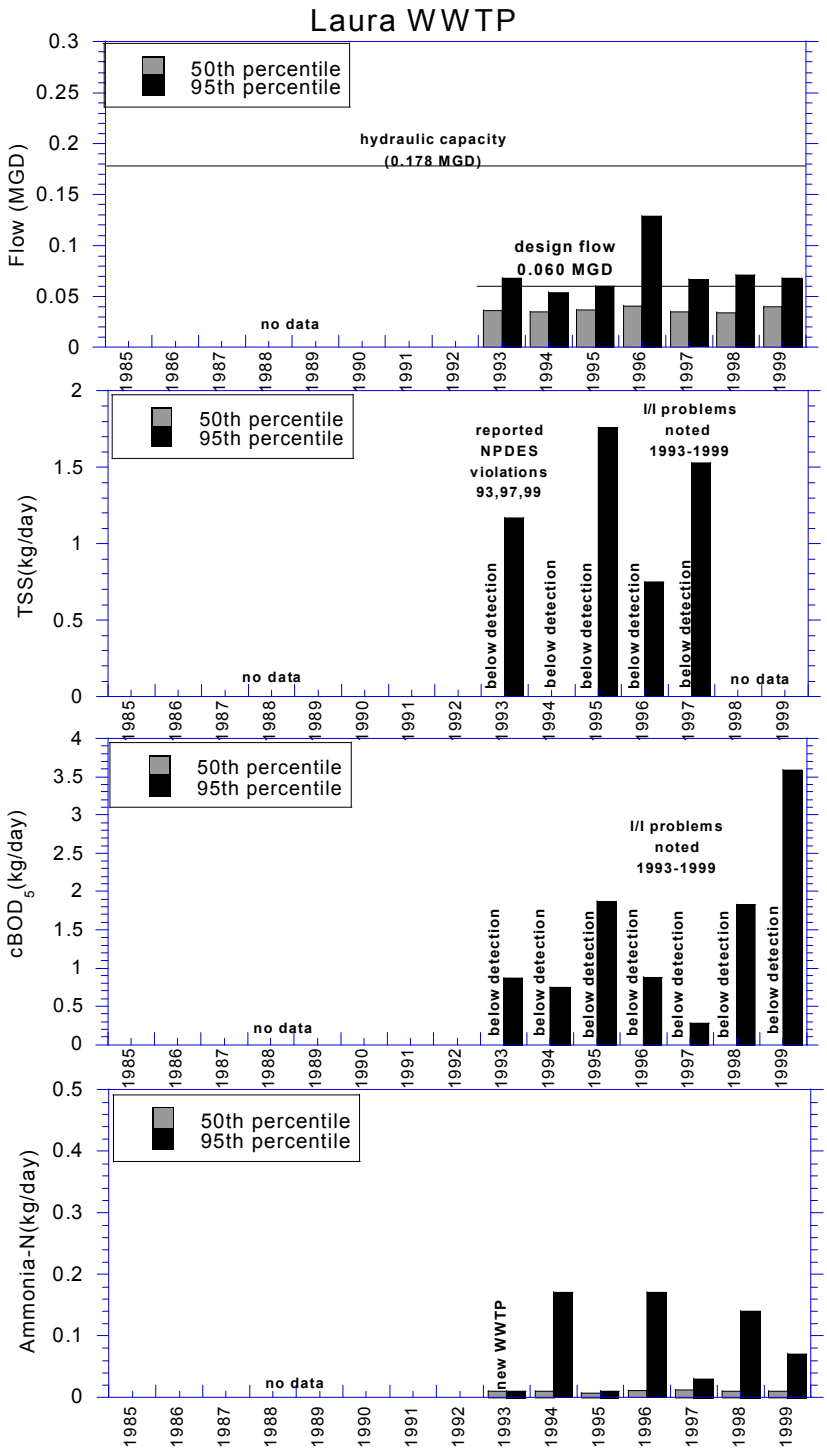

Figure 17. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen from the Laura WWTP for the period of record indicated.

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Norcold WWTP (formerly known as Arctek and Century Electric Co.)-unnamed tributary of Greenville Creek
Lat:40^0 6' 55"; Long:84^0 29' 55"
Permit#:1IS00131

Norcold is located in Darke County at 1 Century Drive in Gettysburg and manufactures absorption units for recreational vehicle refrigerators. The treatment plant was constructed to treat domestic waste from the original company, Century Electric. The waste water discharges through a 150' effluent pipe from the southwest corner of the property to an unnamed tributary of Greenville Creek, which joins with Greenville Creek at RM 10.88. (The outfall is located approximately 0.20/miles east of the convergence of Rt.36 and the abandoned Penn Central railroad. Only access appears to be along railroad track or from Norcold property off Rt. 36 approximately 0.20/mile west of Rt 36 and Penn Central Railway). Norcold WWTP was constructed in 1979 with modifications in 1991, 1992 and 1997. Norcold has a tertiary wastewater treatment consisting of an extended aeration package treatment plant with a Comminutor for grit removal, surge tank, foam control mechanisms, clarifier, dosing tank, sand filters, sludge holding tanks, chlorination and de chlorination (91.5%-Sodium sulfite, 8.5% Inert ingredients). Modifications included the installation of a 2700 gallon Trash Holding Tank (1991) which replaced the Comminutor, located at the front of the treatment plant. In 1992 Norcold modified their holding tank. The waste stream is composed of domestic sewage with no industrial contribution. The plant has a design capacity of 0.01 MGD with a 36-hour detention time and a maximum flow of 3.2 g.p.m. Sludge is removed from the treatment plant and taken to a local sanitation service treatment plant for further treatment.

Between 1995 and 2000, fourteen (14) NPDES permit violations were reported to Ohio EPA. Total Suspended solids (TSS) dominated the violations which occurred primarily between 1997 and 1999. Other reported violations, in descending order of frequency, were TSS, chlorine, oil and grease, and fecal coliform. Reasons for the violations were reported as primarily internal sampling errors and infrequent mechanical failures.

Percentile flow data was not available for association with conventional parameter loads (Figure 18). A facility upgrade in 1997 appeared to reduce ammonia-N loads, however TSS and $cBOD_5$ loads demonstrated increased variability before and after the upgrade. Violations of the NPDES permit were dominated by TSS for most years evaluated and appeared to occur when TSS loads attained 0.07 kg/day.

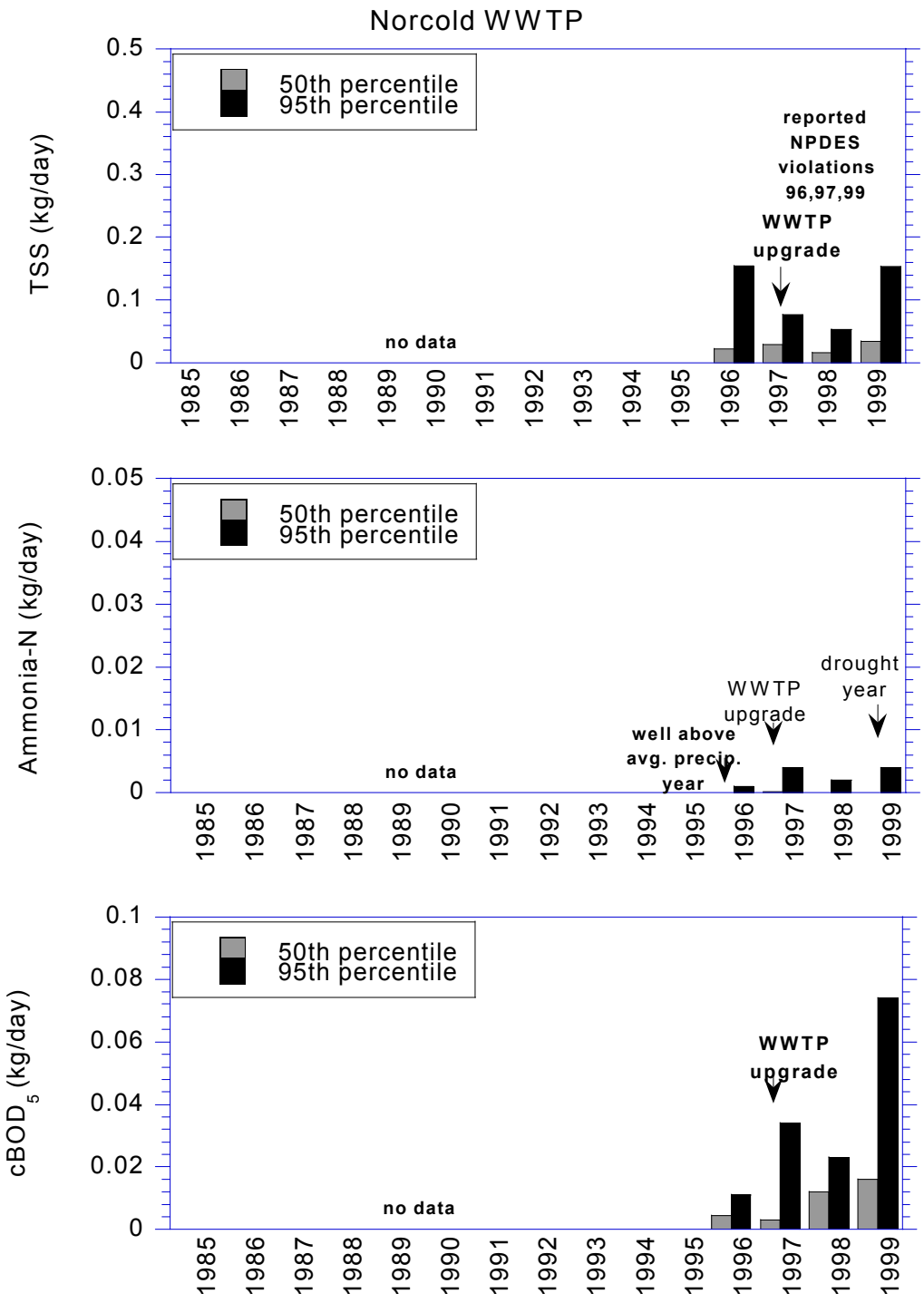

Figure 18. Median and 95th percentile loadings of five-day biochemical oxygen demand, total suspended solids and ammonia-nitrogen from Norcold WWTP for the period of record indicated.

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Rolin Acres Subdivision WWTP-Boyd Creek
Lat:$40^0$10' 20"; Long:84^0 36' 30"
Permit #:1PG00090

The Rolin Acres Subdivision WWTP is located in Darke County on U.S. Route 127 and Warvel Road near Greenville, Ohio. Rolin Acres has a discharge to Boyd Creek at RM 1.35, which joins with the Stillwater River at RM 54.23 near the Warvel Rd. bridge. The wastewater package plant has been overseen by the Darke County Board of Commissioners since the subdivision development in 1973. Rolin Acres WWTP has a design capacity of 0.024 MGD and has held an NPDES permit since 1984. The annual average daily flow rate in 2000 was 0.019 mgd. Current inflow and infiltration rates are estimated at 30,000 gpd. Treatment works at the facility include: a trash trap, five extended aeration tanks, three clarifiers (final clarifier did not have a skimmer at the time of a recent Ohio EPA inspection), slow surface sand filters, chlorination, dechlorination, and a sludge holding tank. Refurbishing the sand filters in 1995 was the only upgrade to the package plant since 1973. There is no industrial contribution to Rolin Acre's collection system.

Rolin Acres currently serves approximately 173 homes, an increase from 60 homes in 1973. Only minor sand filter-related modifications to the wastewater facility occurred in1995, however no expansion was made to increase capacity. The entire subdivision area is sewered with a separate sewer system and rapid growth is not expected for this area. There are no reported bypass or overflow locations in the collection system. However, an occasional bypass is reported at the facility when sand filters are offline for routine maintenance.

In 1993, Ohio EPA issued Director's Findings and Orders (DFFO) to the Darke County Commissioners to: enforce submission of Monthly Operating Reports (MOR), to obtain a Class 1 wastewater operator, to attain final effluent quality, and commence treatment plant improvements The order required the commissioners to attain compliance with the final effluent limitations of its effective permit within 12 months after the effective date of the DFFO.

In 1995, the collection system was investigated by the Darke County Commissioners by televising the two main sewer line collection routes. Video camera work, provided by the City of Greenville, was conducted to identify potential areas of collection system degradation. Televising findings resulted in notification to subdivision residents to disconnect downspout and sump pump connections to the sanitary system.

An Ohio EPA inspection in May 2000 reported the appearance of a heavy, dark solids in the aeration tanks and chlorine contact tank, and an infrequent "Solids Wasting"schedule. Diffusive infiltration of storm water routinely created washout conditions of the solids at Rolin Acres, resulting in a buildup in treatment tanks and the receiving stream. At the time of this inspection, a flexible hose was noted connecting the dosing chamber and the chlorine contact tank for purposes of bypassing the sand filters during heavy precipitation events. Such bypassing practices were documented as a violation of Rolin Acre's NPDES permit and upgrading of Rolin Acres treatment facility has been ordered. Upgrades to the wastewater treatment plant could include the addition of an equalization basin, additional aeration tanks and sand filters or an alternative approach to eliminate the problem of inflow and infiltration. As of May 2000,

bypasses of the sand filters were not being reported as required by Part III of Rolin Acre's NPDES permit.

Sixty-seven violations of the NPDES permit were reported to the Ohio EPA between 1995-2000. The annual number of permit violations ranged from 24 violations reported in 1995 to no violations reported in1999 and 2000. The violations, in declining order of frequency, were limited to four parameters: Total suspended solids (TSS), $cBOD_5$, ammonia-N and dissolved oxygen. Total suspended solids (TSS) and $cBOD_5$ accounted for 52% of the total violations and the majority of violations occurring from 1995-1997. The pattern of annual violations was roughly correspondent of annual TSS and ammonia-N median loads. Additionally, the majority of these violations occurred during a period when conduit flows were approaching the daily maximum.

Ninety-fifth percentile flows were typically greater than the design flow while median flows mostly remained under design flow of 0.024 MGD. Significant percentile variability showed itself in ammonia-N and TSS loads and coincide with the large percentage of NPDES violations noted for these two parameters. Inflow and infiltration problems have been noted throughout the history of this plant and are validated when the above-average precipitation year of 1996 appears to affect the normally predictable loads for $cBOD_5$.

Sherwood Forest Mobile Home Park-Unnamed tributary of Bridge Creek
Lat:40^0 3' 21"; Long:84^0 36' 32"
Permit #:1PV00094

Sherwood Forest Mobile Home Park (MHP) is located on S.R 49 near Hogpath Rd. in Greenville, Darke County. Sherwood Forest has been discharging at this location since 1970 (oversight by health department). In 1992, an Ohio EPA notification was served to Sherwood Forest MHP for failure to submit an application for an NPDES permit to discharge to Waters of the State. An NPDES permit was obtained in 1994. Sherwood Forest MHP final effluent discharges to the headwaters of an unnamed tributary of Bridge Creek, entering Bridge Creek at RM 0.9. Bridge Creek subsequently joins with Greenville Creek at RM 17.77. Wastewater treatment consists of a trash trap, plug flow activated sludge, upflow "Aero-Mod" clarifiers, radial flow filters "Aero-Mod" chlorination/dechlorination post aeration, a sludge holding tank, and flow measurement. An upgrade in 1997 was conducted to reduce significant inflow and infiltration and to increase the treatment capacity of the package plant.

The design of the plant is currently at 0.051 MGD (0.025MGD in 1993, 0.034 MGD in 1997). Final effluent sampling for Sherwood MHP is conducted by a consultant and analyzed by Belmonte Laboratory. Sherwood Forest MHP currently has 170 lots discharging 300 gpd per unit, falling short of the current design capacity and suggestive of the need for treatment of an additional 29,700 gpd to allow for residual I/I influence not remedied completely with the upgrade in 1997. Sludge is hauled off site and land applied at agronomic rates.

Sherwood Forest Mobile Home Park failed to comply with their NPDES discharge limits set by Ohio EPA in November 1995. In 1997, Ohio EPA initiated formal enforcement procedures

issuing a Director's Final Findings and Orders (DFFO). Three specific areas of the waste treatment operation were targeted by the DFFOs: continued upgrading of Sherwood Forest Wastewater Treatment Plant to meet capacity demands, compliance with its discharge permit, and payment of a civil penalty of $50,000 for historical violations to the required date of November 1, 1995. Additional violations of the NPDES permit were: the plant owners failed to submit a Sludge Management Plan, to hire a properly certified plant operator, and submit monthly operating reports (MOR) for approximately two years. Ohio EPA required Sherwood Forest to achieve consistent compliance with limits by November 1, 1997.

Construction of the upgrade to the wastewater treatment plant began in October 1997 which expanded the design flow to the current 0.051 MGD, with a peak daily flow of 0.124 MGD. Along with an improved treatment works in 1998, repair and replacement of sewer connections for individual mobile homes were initiated. A rehabilitation project that targeted all manholes throughout the park was also undertaken. An inspection in May, 2000 reported the treatment plant was being operated generally in a satisfactory manner with minor attention needed in a few areas. Suspected flow-monitoring problems were reported by Ohio EPA in 1994 and 1995 and again with the inspection conducted in 2000. Sherwood Forest has reported the flow monitoring equipment as inaccurate or inoperable for extended periods of time. The estimated cost of flow monitoring equipment upgrade was $150,000.

An unannounced sampling event was conducted by OEPA personnel in August 2000 of which background, final effluent and downstream samples were collected. Results indicate downstream outfall concentrations of phosphorus (3.14) at levels exceeding Ohio Water Quality Narrative Standards of 1.0 mg/l

Sixty violations of the NPDES permit were reported to Ohio EPA between 1995-2000. The annual number of permit violations ranged from 25 violations in 1995 to three in 2000. The violations, in declining order of frequency, were limited to five parameters: Total suspended solids (TSS), $cBOD_5$, ammonia-N and chlorine and dissolved oxygen. Total suspended solids and $cBOD_5$ accounted for 53% of the total violations, with the majority of these violations occurring from 1996-1997. Seventy-eight percent of all violations occurred from 1996-1998. The pattern of annual violations roughly corresponded to annual TSS and $cBOD_5$ median and 95th percentile loads.

Peak-flows, as represented by the 95th percentile, mostly exceed design flow from 1997 to 1999 however, percentile variability remained low. Suspended solids (TSS), ammonia-N, and $cBOD_5$ loads demonstrated variability between median and 95th percentiles with median loads nearly doubled by peak loads for a majority of years. Variability exhibited a decreasing trend over time for all constituents. However, 60 NPDES violations during the six years evaluated reached greatest frequency from 1996 to 1998. Records did indicate a reduction in the number of NPDES violations by 1999, correlating with facility upgrade implementation.

Stillwater Golf Estates WWTP-Unnamed tributary of the Stillwater River
Lat:$40^0$10' 24"; Long:84^0 27' 40"
Permit #:1PX00014

The Stillwater Golf Estates WWTP was constructed in 1976, to provide service for 19 homes and is located on S.R.185 (south of Versailles) approximately 0.220 miles south of the town of Webster. The Ohio EPA NPDES permit responsibility for the treatment facility was issued to the Darke County Commissioner in 1996. The wastewater treatment plant is an extended aeration facility composed of: a trash trap, aeration, clarifiers, aerated sludge holding, dosing chamber, slow surface sand filters, chlorine disinfection, dechlorination and post aeration. The design capacity of the plant is 0.0076 MGD. All of the homes in the subdivision are sewered with no combined sewers or separate sanitary sewers overflows in the system. The Stillwater Golf Estates WWTP's discharge travels approximately 100' before flowing into a headwater of an unnamed tributary of the Stillwater River. This tributary joins with the Stillwater River mainstem at RM 42.85. Inflow and infiltration has not been identified as a problem in the collection system.

During an unannounced inspection in 1994, an Ohio EPA field staff noted a structural crack in the sand filter bed which was allowing untreated effluent to seep through the bed wall and onto the ground. Also noted at this time was a defective diversion box responsible for diverting flow between sand filter beds. Upgrades to the facility treatment system and associated permitting ensued and were completed within a year.

At a minimum ten (10) violations of the NPDES permit were reported to the Ohio EPA between 1995-2000. The annual number of permit violations ranged from 5 violations in1995 to no violations reported in 2000. The violations, in declining order of frequency, were limited to three parameters: ammonia-N, $cBOD_5$ and TSS. Ammonia-N and $cBOD_5$ accounted for 90 % of the total violations, with the majority of all violations occurring from 1996-1999. The pattern of annual violations was roughly correspondent of annual ammonia-N and $cBOD_5$ median loads.

Annual median percentile flow rates showed little variability, suggesting low influence from precipitation events (Figure 19). A steadily increasing trend in discharge rates is also indicated, likely due to sewer extensions and population increases. Ammonia-N and TSS peak loads fluctuated intermittently however, median-flows remained stable even decreasing in loads from 1996 to 1999. Demand-parameter, $cBOD_5$, did not graphically indicate any discernable trend. Ammonia-N and $cBOD_5$ accounted for 90% of the NPDES violations for this facility.

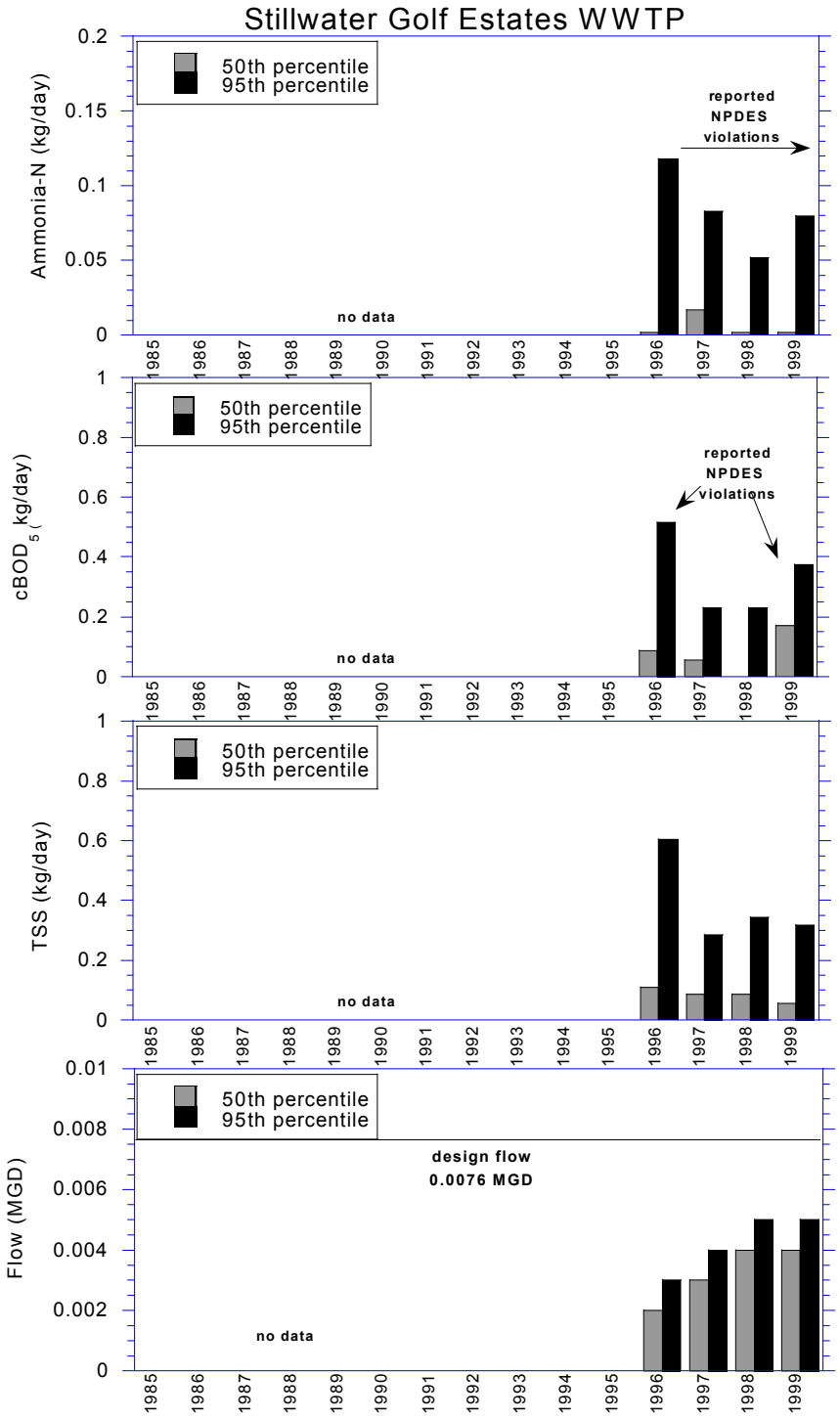


Figure 19. Median and 95th percentile effluent flows and loadings of five-day biochemical oxygen demand, total suspended solids, ammonia-nitrogen from the Stillwater Golf Estates WWTP for the period of record indicated.

Allied Aftermarket Division (formerly Fram Corporation)-Greenville Creek
Outfall 001-Lat: 40^0 05' 27"; Long: 84^0 37' 25"
Outfall 002-Lat: 40^0 05' 22"; Long: 84^0 37' 16"
Permit #:1IN00108

Allied Aftermarket Division is located in Darke County on the corner of Martz and Jackson Streets in Greenville. Allied Aftermarket manufactures gasoline, oil and air filters for motor vehicles at an approximate volume of 250,000 filters/day. Raw materials used in the filter production amount to 125,000 lbs. of steel per day, 25,000 lbs. of paper per day, 400 lbs. of paint per day and cardboard packaging materials. The processes Allied uses to produce filters are steel stamping presses, paper-cure ovens, paper making, adhesive curing, tapping, painting, metal cleaning (phosphate cleaner) and packaging. The total wastewater volume is an average effluent flow of 300,000 gallons per day non-contact cooling water.

Outfall 001 discharges non-contact cooling water from the "Old Building," the older of the facilities buildings used in production. Boiler blowdown and storm water discharge to this outfall prior to combining with the city storm sewer that is recorded as discharging near the Ohio Street Bridge. Boiler blowdown and process waters were reported as not containing chemical additives since 1989. Sanitary waste from the company is discharged to Greenville WWTP.

Outfall 002 discharges non-contact cooling water from the "New Building." This discharge flows to the city storm sewer through an open ditch along Katzenberger Rd. (just south of the first house on the property) to Bridge Creek and consequently to Greenville Creek. The sanitary waste generated from this location of the plant is discharged to Greenville WWTP.

Nine violations of the NPDES permit occurred from 1995-2000 and consisted of 1,1,1 trichloroethylene, benzene, temperature discharge limitations (1989 and1995), pH, TSS, and oil and grease in decreasing order of frequency.

Spills at the facility have occurred intermittently from 1988 to 1995, mostly associated with suppliers of raw materials (filling tanks) and unknown sources and materials. Interior and exterior spill containment areas were identified in 1990 through an industry spill plan and centered around the flammable liquid and hazardous waste storage areas, gasoline and kerosene tanks, latex storage area and transformer bank.

Barrett Paving Materials-Brush and Ludlow Creeks
Lat:39^0 59' 20"; Long: 84^0 21' 22"
Permit #:1IJ00048

Barrett Paving Materials, Inc (formerly Ludlow Quarry Plant #139) is located on Davis Rd in Ludlow Falls in Miami County. Barrett Paving Materials bought the Ludlow Stone Quarry in 1990. Barrett Paving Materials is a quarrying (mining) company, processing an estimated 2,000 tons/day and selling crushed limestone products for use in the construction industry. The quarry borders Brush and Ludlow Creeks and retained an NPDES permit in 1992 for a direct discharge to Brush Creek. A Storm water Permit was issued by OEPA in1999. Water generated onsite for

discharge results from de-watering the quarry working area of groundwater. Surface and groundwater flow to the north side of the quarry floor to a small, 12' deep hole containing a 4" pump where supernatant is decanted off through two quarry settling ponds. Decanted water is then pumped to a 6" PVC pipe extending up a quarry wall across a bound dike to an adjoining pipe. From this point water fans out of outfall 001 to the rip rap area adjacent to Brush Creek (total distance from quarry to stream is approximately 100'), at a metered flow rate of 0.20 MGD. Several flow channels have formed from ubiquitous discharges of the settling pond before its journey into Brush Creek. The renegade water from this pond flows into a ditch adjacent to and west of Davis Rd. which has eroded it's way over to Ludlow Creek.

During the Ohio EPA survey of 1999 field personnel documented a yellowish, brown material coming down Barrett Paving Materials' hillside into Ludlow Creek. The material had associated pockets of heavy algal growth which collected and were most visible where this material pooled or collected behind boulders. This material was later described by Barrett as a dust emission control substance, called Lignin Sulfonate or LS-50, is derived from tree sap. As a result of this, Ohio EPA issued a Notice of Violation (NOV) in 1999 for the Barrett Paving Materials resulting in the addition of an earthen berm adjacent to the creek to prevent further overland runoff. Monthly instream sampling was also required for three months and the company was required to prepare a Storm Water Pollution Prevention Plan (SWPPP) for the Davis Road Facility.

BP Oil Company-Greenville Bulk Plant-drainage swale to Greenville Creek
Lat.: 40^0 05' 59"; Long: 84^0 37' 40"
Permit #: 1IN00252

British Petroleum (BP) Oil Company is located in Darke County at 405 Wayne St. in Greenville. This site has intermittent storm water discharges, and treatment consists of a holding pond with an oil/water separator to treat storm water. Storm water discharge is contained on the property with rare events discharging to the railroad ditch (Outfall 001) that flows into Greenville Creek at approximately RM 21.94

When Outfall 001 discharges, it releases approximately 178 gal/day. All sites at any BP Bulk Plant are equipped with an 8,000 gallon oil/water separator, a load rack canopy to reduce storm water contact, a concrete pad to contain spills and a lined pond to prevent spills from migrating elsewhere. Contact and non-contact water from diked areas are routed through the oil/water separator. Factors such as pond size and evaporation from the pond limit the quantity and frequency of discharges from the pond. Pond releases that would reach surface waters are questionable as discharge is thought to evaporate or infiltrate to groundwater prior to reaching Greenville Creek. Parameters of concern are typical wastewater constituents along with organic compounds such as Benzene, Toluene, Ethyl benzene, Phenol and Naphthalene.

Village of Bradford WTP-Ballinger Run
Lat:40^0 08' 17"; Long:84^0 23' 04"
Permit #:1IZ00010

The Bradford Water Treatment Plant was built in 1910 and is located on West Klinger Rd. in Darke County. The Bradford WTP discharges to a tile that carries the flow to a swale along the north side of Klinger Road. The receiving swale flows east of the facility approximately 50' where it adjoins another tile flowing south. The flow is tiled under Klinger Road at this location when it emerges to confluence with Ballinger Run at RM 1.41.

Drinking water is extracted from two wells pumped at a daily production rate of 180,000-200,000 gpd. Water treatment of the well water includes aeration, iron filtration, sand filters, ion exchange, brine holding tanks and chlorination. The total waste volume is 9,000-12,000 gpd to the drainage swale, which eventually discharges to Ballinger Run. The waste stream consists of filter backwash and softener regeneration wastewater.

Between 1993 and 1995, a minimum of four NPDES permit violations were reported to Ohio EPA by Bradford Water Treatment Plant. All violations were limited to suspended solids (TSS) and total iron. Required NPDES parameters for monitoring final effluent (001) consist of Flow Rate, Total Suspended Solids, Chloride (total), Iron (suspended), Manganese (suspended) and pH. National Pollutant Discharge Elimination System (NPDES) limits exist for all aforementioned parameters except for Flow Rate and Total Chloride. Bradford is not required to conduct upstream and downstream monitoring (801/901) of the receiving stream. The wastewater Flow Rate in 1999, at outfall 001 was an average 0.012 MGD. Total chloride levels in final effluent, during the survey period of July-September, 1999, averaged 83 mg/l.

Green Villa Mobile Home Park-Unnamed tributary of Boyd Creek (Deubner Ditch #38)

Green Villa Mobile Home Park (MHP) is located in Darke County at 7833 Greenville-Celina Road in Greenville at the merger of the SR 127 bypass and Celina Rd. Green Villa MHP is currently owned and operated by American Builders Inc.. Currently there are 25 mobile homes in the park with an estimated population of 40.

The sewage system is comprised of a 1000 gallon septic tank containing 8 distribution lines (clay bleed off lines) and a leach field area of 18'x60'x30' with a line that discharges to a Deubners' Ditch #38. Sewage fungus has been observed in the bleed off line and beneath the rocks at the outfall to varying degrees. The mobile home park has been in existence since the 1970s and in1992 Green Villa filed an application with the Ohio EPA for exemption from the NPDES process. This application for exemption was denied. Currently Green Villa has applied for an NPDES permit for their discharge to the tributary of Boyd Creek also referred to as Deubner's Ditch #38 as referred to in correspondence files. A cost analysis conducted for Green Villa for connection to the city of Greenville's collection system was estimated at $190,000. In addition to the mobile homes, two homes exist within the mobile home park boundary with direct home aeration discharges to Boyd Creek. These discharges have been noted as having the appearance of inadaquately treated wastewater. Darke County Health Department has been notified of the

aeration system field inspections conducted by Ohio EPA.

Drinking water records for various months in the 1980 and 1990s (1980, 1993, 1996) indicated intermittent elevated counts of bacteria from Green Villa's two drinking water wells, which suggested questionable water quality. One of the wells, Well #2, is within 30 feet of the sewer lines of an adjacent building and therefore requires additional monitoring. Well #1 is used as a backup. In 1992, resident complaints of illnesses prompted a requirement to boil and filter water due to the presence of bacterial contamination.

In 1996, problematic tree roots plugging a bleed off line incited residents to file odor complaints. An ensuing field visit by Ohio EPA officials documented sewage emanating from a bleed off line and in the creek downstream from the tile.

Jafe Decorating Co. Inc.-Greenville Creek
Lat:40^0 06' 02"; Long:84^0 35' 12"

Established in 1978, Jafe Decorating Company is located on Martin St. in Greenville adjacent to Greenville Creek. Jafe manufactures decorated and colored glass items for auto and consumer industries. The two main processes at Jafe consist of drilling holes in glass lights for Corning Glass, coloring glass by ion exchange, and dipping it into a clay solution. Chemicals used in the ion exchange process are cuprous chloride and sulfur dioxide. Historically the auto lights were drilled by a diamond drill and placed in a "phosphorus wash." Both glass staining processes required rinse stages, of which the ion exchange process wastewater flowed through floor drains exiting the rear of the building to surrounding grass. The discharge of washwater to property grounds occurred for approximately six or seven years. The clay dipping process water was reclaimed to reinstitute captured clay pieces into the process. In 1998, the facility connected the floor drain rinse water to a drain tile which discharged to Greenville Creek at approximately RM 18.80. All facility drain connections that discharged to the creek were severed and ceased flowing on December 16, 1999 when Jafe connected to Greenville's sanitary sewer collection system. All discharges of process wastewater, non-contact cooling water and sanitary wastewater were connected to the Greenville WWTP for treatment as of January 2000. New installations to treat process wastewater include recycling and reusing the cooling water (phosphorus wash water) and a settling tank to remove process water solids.

Jafe entered Greenville's pretreatment program in January 2000 as a Significant Industrial User (S.I.U). It is presumed that the unpermitted discharge to and adjacent to Greenville Creek had occurred since the inception of the facility at the current location in approximately 1991. Constituents of concern in the wastestream are primarily copper, silver, ammonia, suspended solids (TSS) and oxygen demand parameters. The City of Greenville is currently taking enforcement against Jafe Decorating following Letters of Violations (LOV) issued from August 1999 through January 2000 due to Local Limits Violations of copper, ammonia and pH . Jafe failed to take corrective action regarding violations and treatment system process controls within an established time period.

EGI Inc-(formerly Derby Manufacturing and currently Markawith Tools Machining Co.)-Bridge Creek
Lat:40^0 04' 15"; Long:84^0 37' 44"
Permit #:1IN00240

EGI was located in Darke County at 5260 St. Rt. 49 in Greenville. EGI was classified as a Machine Shop and has manufactured Finished Weatherstrips and assembled Door Lock Modules for the automotive industry since 1984. EGI generated sanitary wastewater and discharged at RM 3.6 on Bridge Creek (100' north of the creek crossing at RT 49). Bridge Creek discharges to the Stillwater River at RM 17.77. Wastewater treatment consisted of pretreatment, extended aeration, clarification, filtration, chlorination and de- chlorination. EGI operated two shifts, from 6:30 a.m. until11:00 p.m., Monday through Friday.

In 1993, Ohio EPA received an NPDES permit application that was drafted and public noticed, yet never issued final due to issues related to Antidegradation. In 1997, EGI was finally issued an NPDES which expires in 2002. The NPDES permit contains limits for wastewater constituents and lists effluent sampling to be conducted. Upstream and downstream monitoring (801/901) from the final outfall is not required in the permit. In 1995, an inquiry by EGI referred to the need for an additional manufacturing process that would employ an additional 20 people. This process included the addition of a zinc/nickel phosphate coating that would be applied to the metal parts added in the process as a batch bath. Other steps to the addition include cleaners, a pickle bath and clear water rinse. Ohio EPA files do not indicate that EGI pursued the request for the addition of this manufacturing process.

At EGI cleaners, phosphate and pickling baths were skimmed once per day. The total consumption and discharge of water was 25,000 gallons per day. The discharged water was collected in an equalization tank and treated in a “hydroxide precipitation” process. The treated effluent was discharged to Bridge Creek.

EGI sold it’s business in September, 1998 to Markawith Tools, a machine shop located within the same building. Markwith Tools manufactures parts from raw materials for the printing industry and currently reports discharging only sanitary wastewater (no process wastewater is generated onsite).

Morris Mobile Home Park (MHP)
Permit #: PV00092

Morris Mobile Home Park is located at 503 Beamsville-Union City Road, Union City, Ohio. Complaints about the treatment facilities, cited the package plants in “poor” operating and discharging condition. Sewer backups created overflow conditions in the manholes, sending raw sewage onto the property. The sewage system consists of approximately 780' of 6" vitrified sewer pipe with premium rubber joints. Manholes are provided at changes of grade or direction and at the end of each sewer line. Each trailer lot is served by a 4" cast iron lateral and trapped riser. Sewage treatment consists of a trash trap, extended aeration and disinfection. Extended aeration is capable of treating 3,500 gallons per day. Disinfection of the effluent is achieved in a

2' prefab concrete chamber with a resulting capacity of 90 gallons and a retention period of approximately 38 minutes. Using a 5% free available chlorine solution the maximum dosing rate is near 74 mg/l. Discharge is to a 6" concrete storm sewer down State Route 571. The mobile home park is licensed for 41 lots and is near capacity at 300 g.p.d. per lot.

Two treatment facilities existed in the park and were referred to as the East and West Plants. The East Plant discharged to Dismal Creek which joins with Greenville Creek. The West Plant discharged to Gray Branch which into fed the Mississinawa River Watershed. Discharge from the East Plant ceased in November of 1999 when Morris MHP was connected to Union City WWTP. The West Plant was later connected to Union City on December 6, 1999. Although the mobile home park package plants discharged during the 1999 Biological and Water Quality Survey, they no longer have direct discharges to any stream.

Village of Wayne Lakes - Mud Creek and Prairie Outlet Watershed

Wayne Lakes was incorporated in 1980 with a population estimate in 1987 of 700. There are 17 spring-fed lakes comprising about 100 acres of surface area. The lakes within the village boundaries are owned by Wayne Lakes Park, Inc. and lies within the Mud Creek Basin. Wayne Lakes Park, Inc. controls the outlet dam spillway elevations and inlet diversion dams which control lake levels. This is an unsewered community with undersized lots.

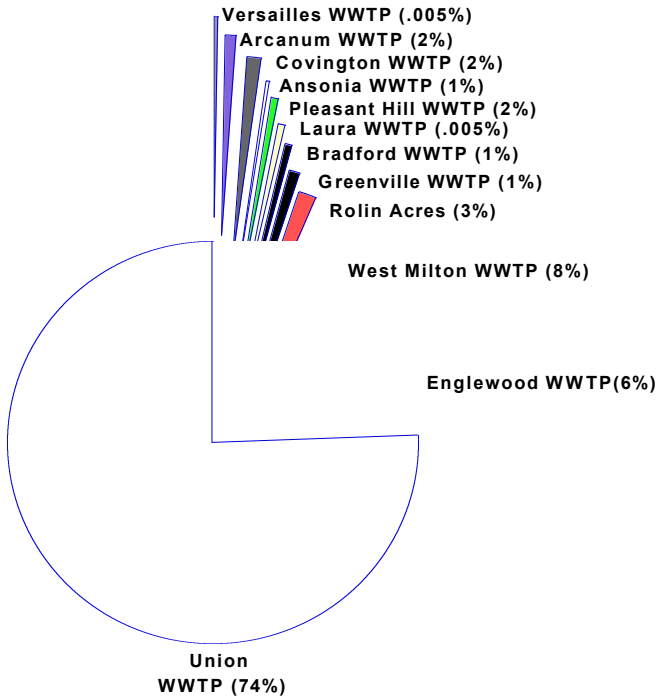
A verified complaint was filed in 1981 by the president of Wayne Lakes Park, Inc. alleging the pollution of lakes and groundwater at Wayne Lakes. Well logs near Wayne Lakes indicate the region is mostly dry gravel above clay and limestone. A random sampling evaluation of wells and surface waters of properties within the village was conducted Ohio EPA and the Darke County Health Department. An estimated 12 properties were noted as having sewage breakouts traversing to catch basins. This resulted in installation of holding tanks and additional leach lines for these properties. The investigation determined that although obvious individual sewage disposal problems existed in the area, wide pollution potential was not a risk.

More recent activities at Wayne Lakes include a citizen complaint in 1996 of a dark globule material observed floating on the surface of Iroquois Lake which discharges to Mud Creek. This investigation linked a direct discharge from a dairy farm on Rt. 503 to the manure noted in the lake.

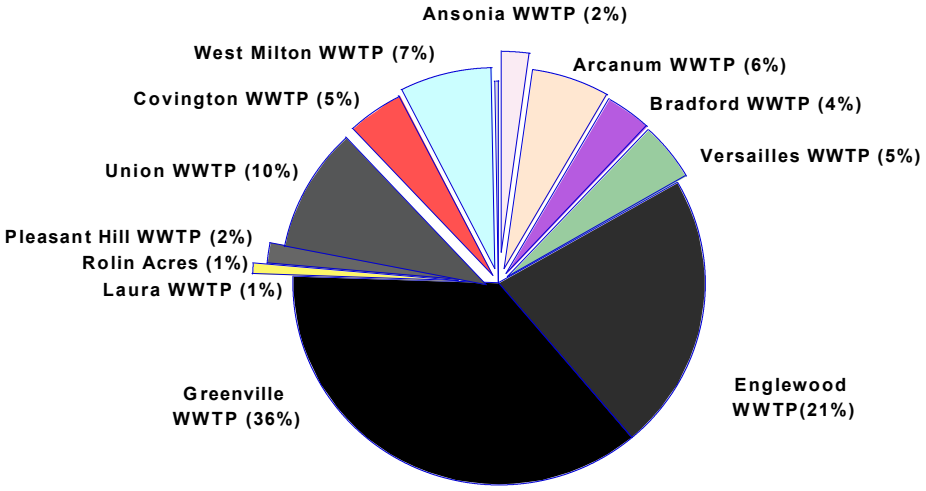
Another complaint reported to Ohio EPA in 1997 referred to a milky white residue in Prairie Outlet was found flowing into Wayne Lakes via Prairie Outlet near St. Rt. 121. Field investigations located a field tile discharging brown water with an obvious livestock manure odor. The investigation revealed a veal farm on St Rt. 121 was pumping manure lagoons onto adjacent farm land. The manure had percolated to field under-drains and discharged thru field tiles to Prairie Outlet.

Witt Plastics Inc.-Bridge Creek
Lat:40^0 05' 41"; Long:84^0 36' 0.9"
Permit #:1IQ00014

Witt Plastics Inc. in Darke County was established in 1972 and is located at 1671 Martindale Rd. in Greenville. Witt Plastics manufactures certified premium thin-gauge plastic sheet and roll extrusions for packaging industries. The manufacturing process extrudes plastic pellets into sheets used as packaging material for several industries (food, medical, automotive and plant markers). Bulk pellets are stored in enclosed silos located on site, while all other raw materials and products (plastic sheets) are stored in the facility building. Pellets that become ground debris are washed into catch basins during storm events and trapped by screen barriers installed in the basins. Witt Plastics discharges approximately 400 gallons per day of cooling water blowdown and 0.120 MGD per storm water event to Bridge Creek at RM 0.35 (Greenville Creek RM 17.77). Antimicrobial treatments using biocides C-2712 and WPC-30 are added into the cooling water tower for microbial growth control. The Ohio EPA issued Director's Findings and Orders (DFFO) in 1996 concerning the non permitted cooling water and boiler water treatment additives. Witt Plastics has obtained a General Storm water Permit and prepared a storm water pollution prevention plan.

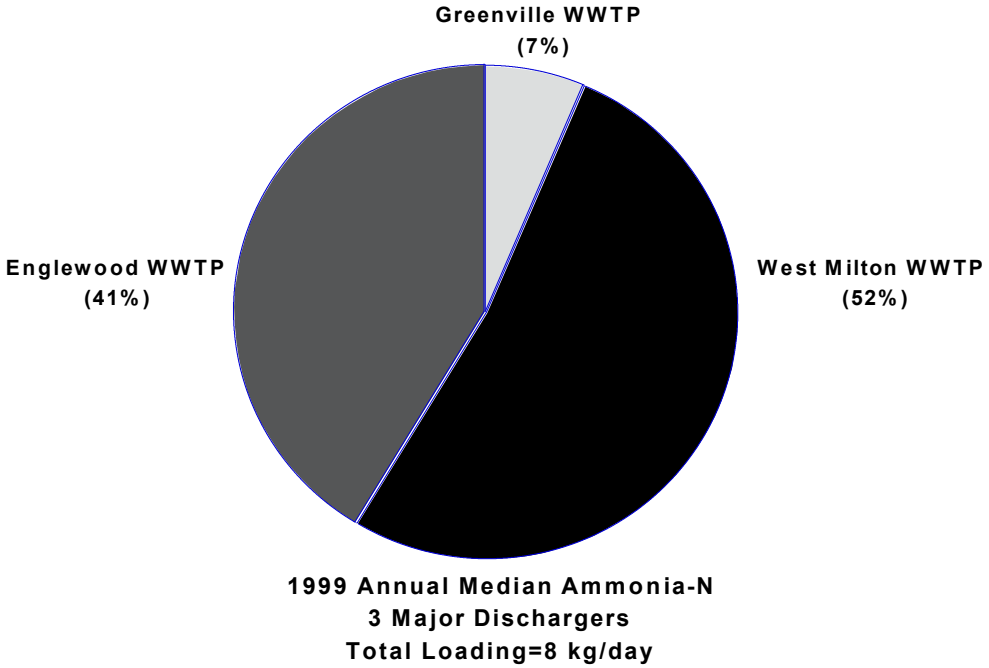


1999 Annual Median Ammonia-N
12 Dischargers
Total Loading= 40 kg/day



1999 Annual Median Flow
12 Dischargers
Total Loading= 5.83 MGD

Figure 20. Relative contribution to the aggregate flow (MGD) and ammonia-nitrogen (kg/day) loads from twelve entities discharging to the Stillwater River, 1999.



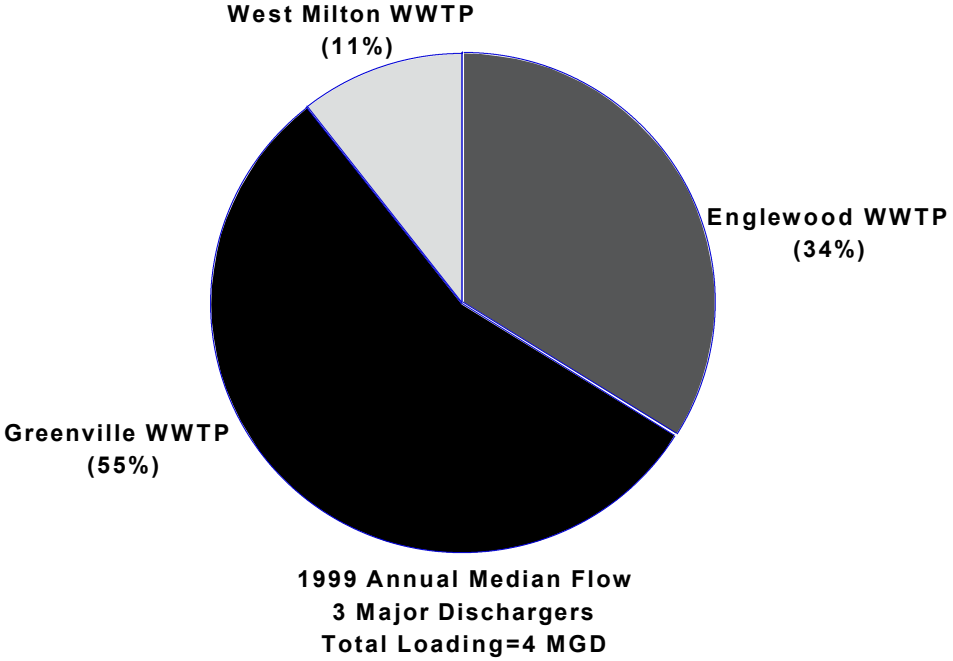
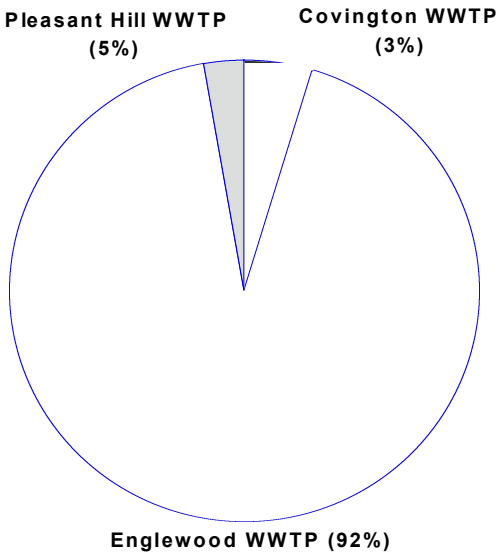
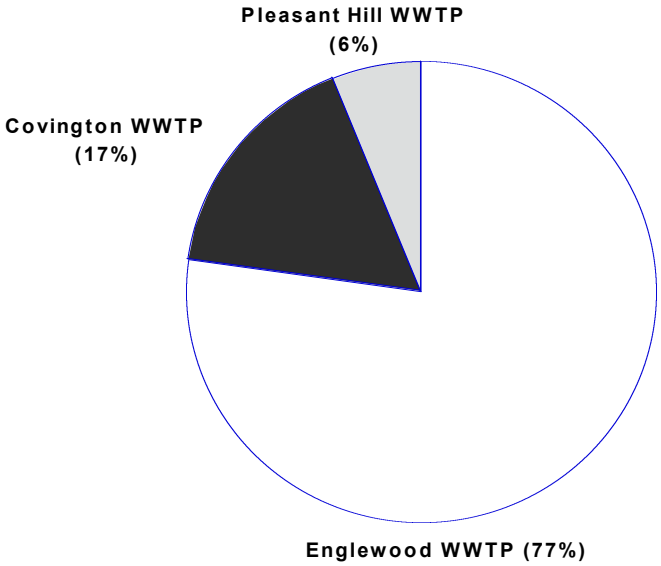


Figure 21. Relative contribution to the aggregate flow (MGD) and ammonia-nitrogen (kg/day) loads from three Major dischargers to the Stillwater River, 1999.

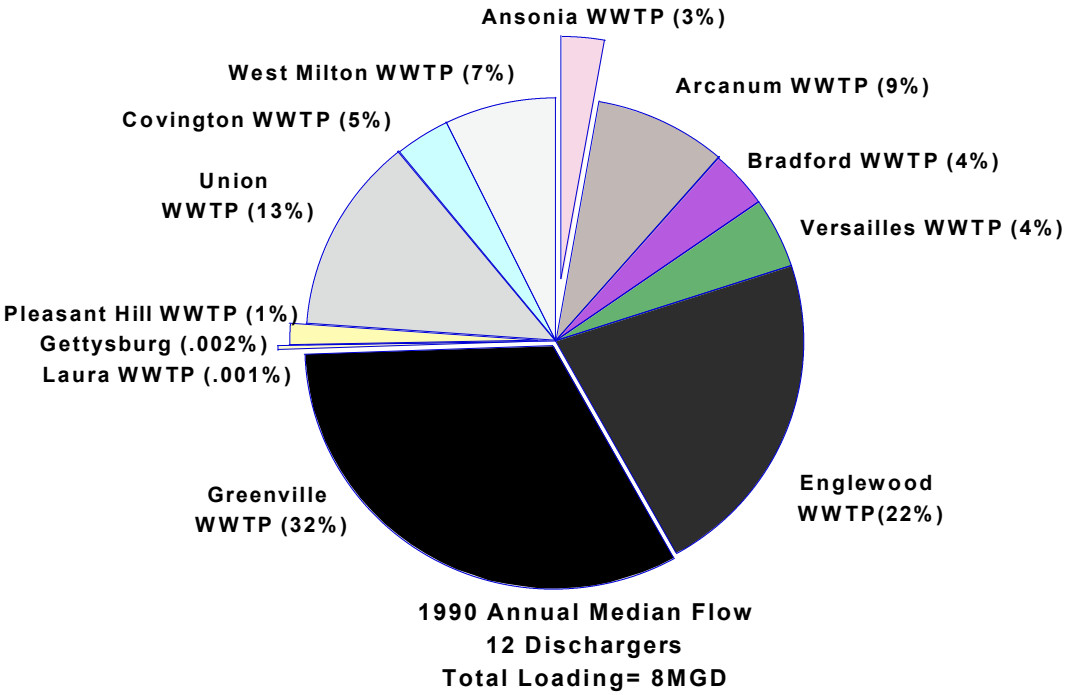


1999 Annual Median Ammonia-N
3 MainstemDischargers
Total Loading=3.44 kg/day



1999 Annual Median Flow
3 Mainstem Dischargers
Total Loading=1.7MGD

Figure 22. Relative contribution to the aggregate flow (MGD) and ammonia-nitrogen (kg/day) annual median loads from the entities discharging directly to the mainstem of the Stillwater River, 1999.



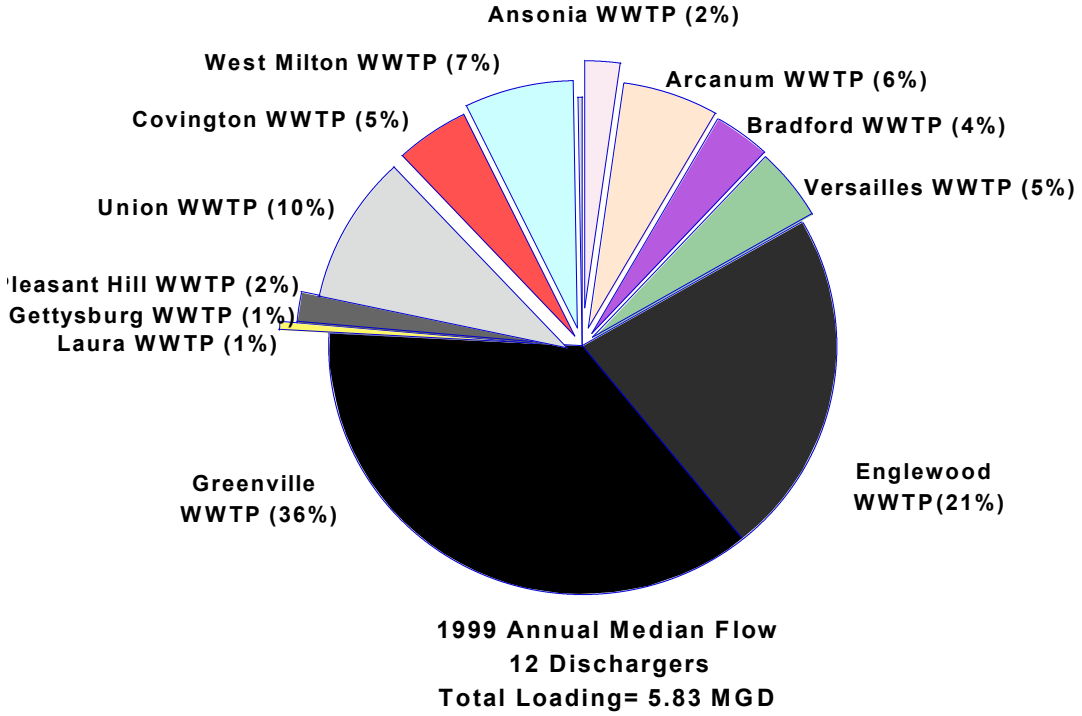
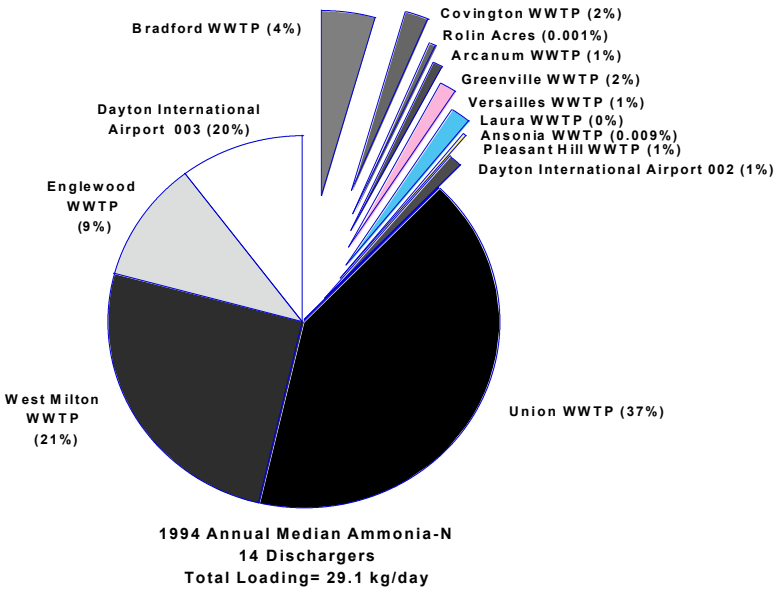


Figure 23. Relative contribution to the aggregate flow (MGD) from twelve entities discharging to the Stillwater River Watershed for 1990 and 1999.



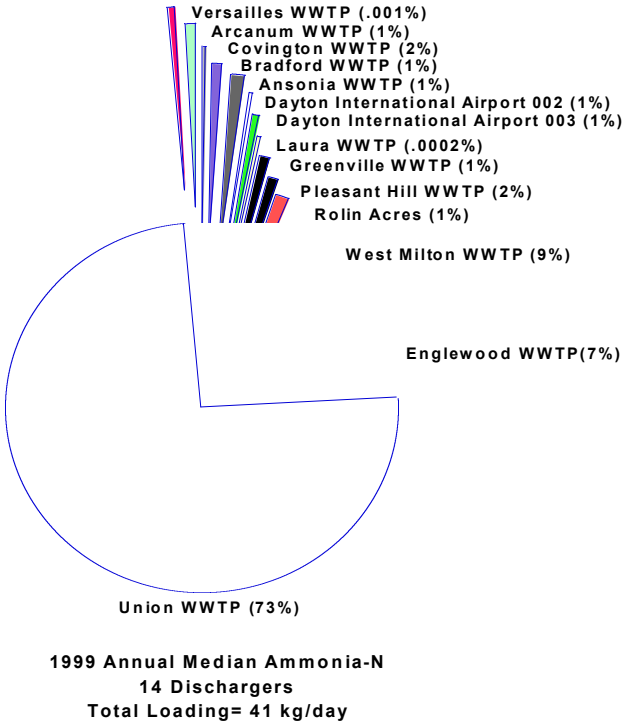
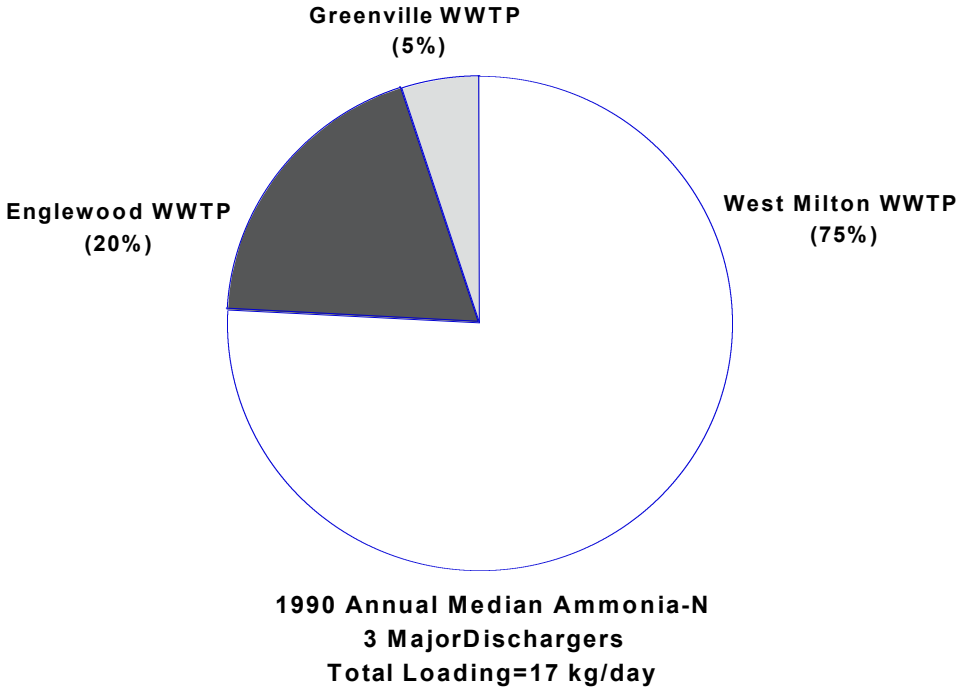


Figure 24. Relative contribution to the ammonia-nitrogen (kg/day) annual median loads from fourteen entities discharging to the Stillwater River Watershed for 1994 and 1999.



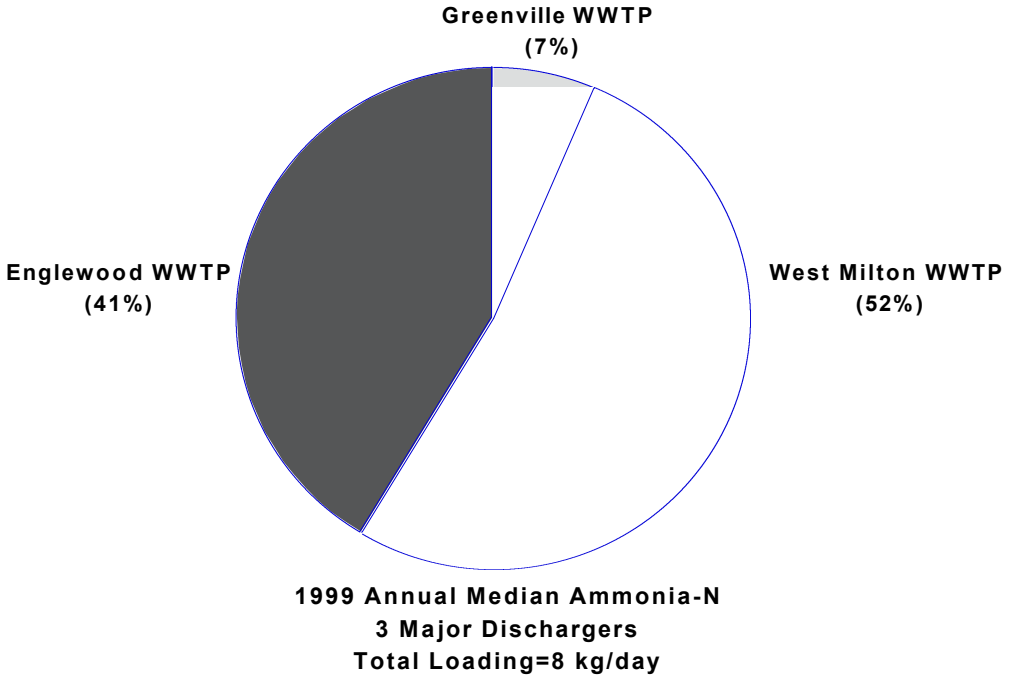
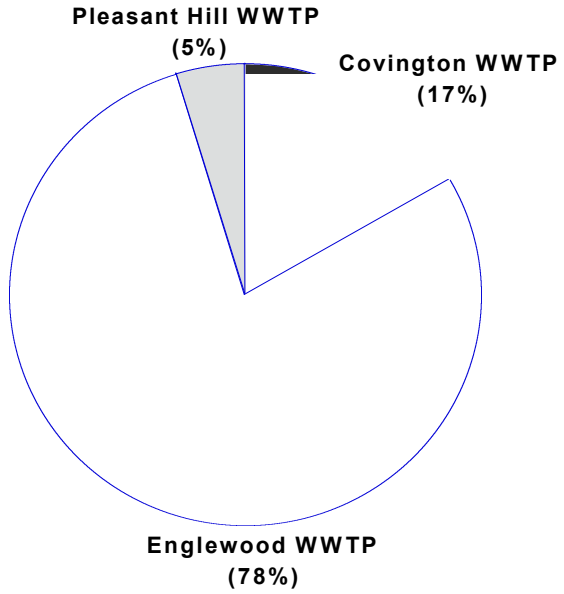
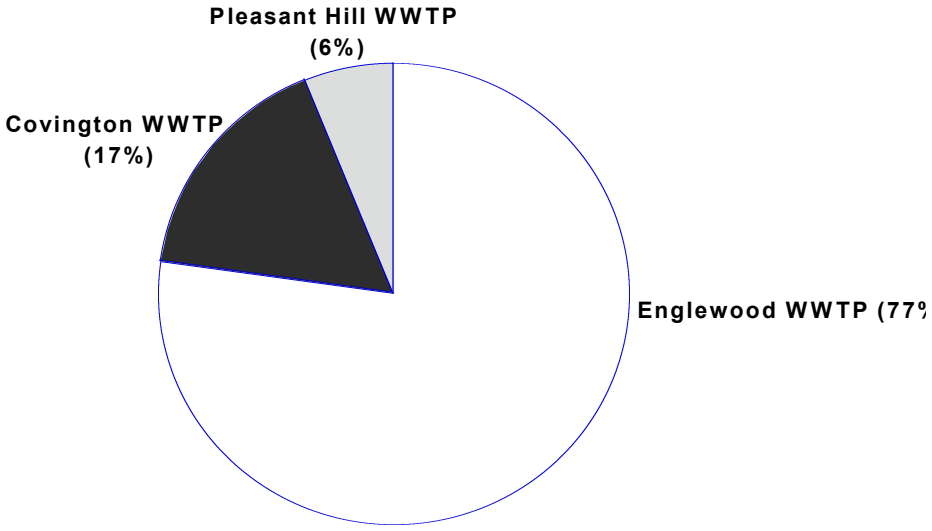


Figure 25. Relative contribution to the ammonia-nitrogen (kg/day) annual median loads from three Major entities discharging to the Stillwater River Watershed for 1990 and 1999.

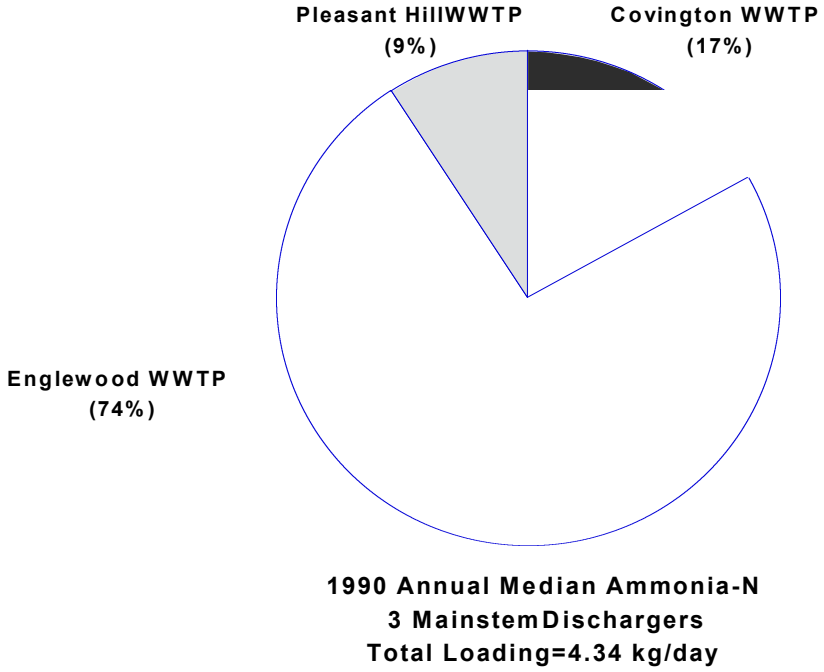


1990 Annual Median Flow
3 Mainstem Dischargers
Total Loading=2.1 MGD



1999 Annual Median Flow
3 Mainstem Dischargers
Total Loading=1.7 MGD

Figure 26. Relative contribution to aggregate flow (MGD) from three Mainstem entities discharging to the Stillwater River Watershed for 1990 and 1999.



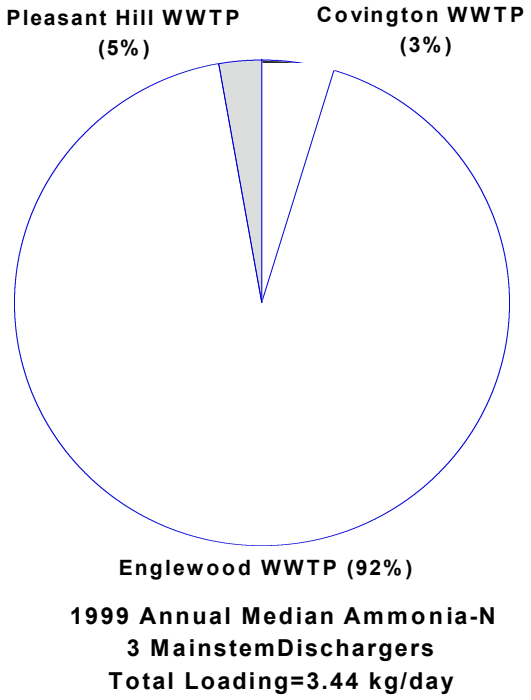
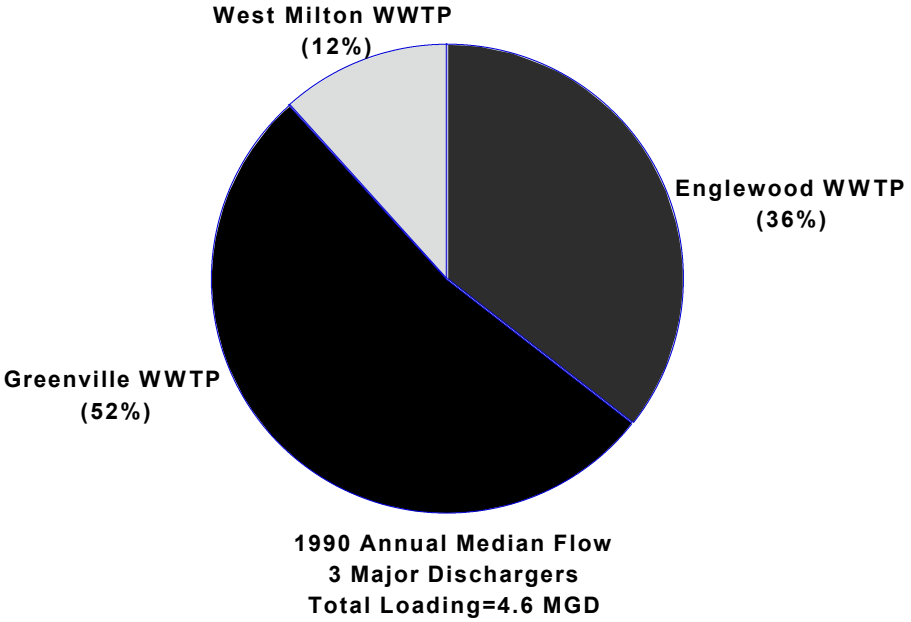


Figure 27. Relative contribution to ammonia-nitrogen (kg/day) annual median loads from three Mainstem entities discharging to the Stillwater River Watershed for 1990 and 1999.



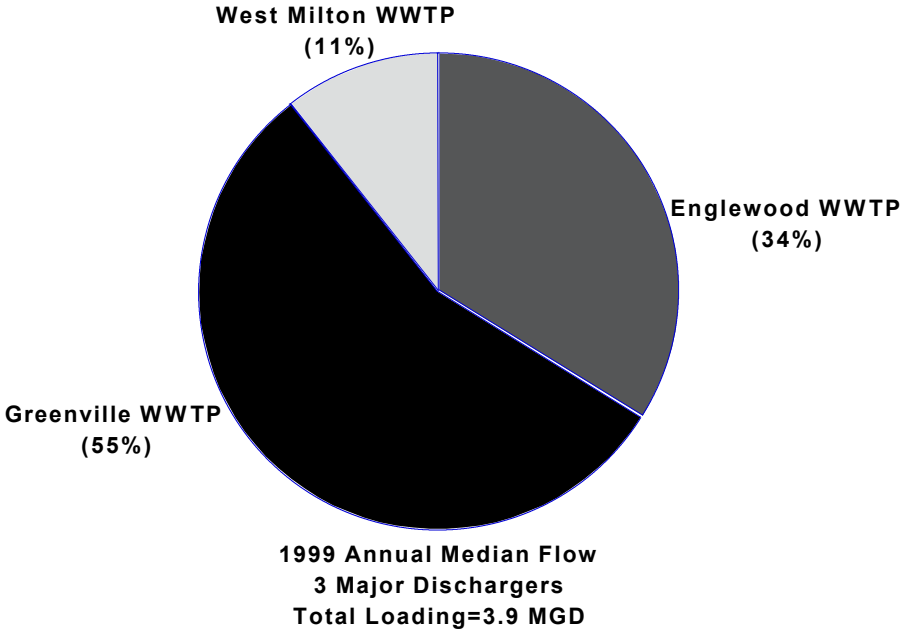


Figure 28. Relative contribution to the aggregate flow (MGD) from three Major entities discharging to the Stillwater River Watershed for 1990 and 1999.

Livestock Manure Land Application

Cal-Maine Farms, Inc-Historically headwaters of Stillwater River
(formerly Wayne Detling Farms, Union City Farm or S&W Farms)

Cal-Maine Farms Inc. currently operates two egg production facilities, the Union City Farm in Union City (Wabash River Watershed) and the Rossburg Farm in Rossburg (Stillwater River Watershed). The Union City Farm is 3 miles northeast of Union City on Zumbrum Rd and the Rossburg Farm is approximately 3.7 miles northwest of Ansonia on Washington Rd.

The Rossburg Farm has 563,000 laying hens housed in Hi-Rise Layer Barns and manure is managed as a solid in the storage pit areas underneath the cages. The concrete floors and walls are completely open to receive manure which has an anticipated moisture content of 65% or less. Periodically livestock manure is collected from the hen barns and historically has been land applied to area cropland residing in the Dismal Creek Watershed (Worth and Puckett Rd's), the headwaters of the Stillwater River on Tobin Road, the headwaters of Greenville Creek and numerous other application sites within the Stillwater Watershed. Manure application sites were cropped mainly in corn and soybean production with occasional hay and small grain plantings. Most unused nitrogen in these heavy clay soils is lost via denitrification which occurs during those times when soils are their wettest. As of 2000 all manure generated at the Rossburg farm is sold to neighboring farmers.

The soils of the Rossburg area include Pewamo silty clay loam and Blount silt loam. Depths to groundwater at wells nearest the Rossburg Farm site range from 91-165 feet all overlain with clay extending approximately 20-120 feet. A layer of an estimated 20 feet of sand and gravel is beneath the clay barrier where a clay layer appears again underlain by water bearing gravel or limestone.

Cherrystone Poultry Farm, Inc. (also known as Richard McGrath Farm)
Greenville Creek and N. Fk Kraut Creek

Cherrystone Poultry Farm is located at 1593 Wildcat Rd. at the intersection with Palestine-Union City Rd. in Washington Township, Darke County. The farm housed an estimated 672,000 pullets (chickens) in 1988 (current populations unavailable) producing a calculated 291,648 ft^3 of manure/yr with a minimum storage capacity of 12 months. Clean out of the pullet manure from the barns is approximately every five months. A little over 2,000 acres is available for land application of solid form, chicken manure where currently all application sites are available within a five mile radius of the facility at Wildcat Rd. Cropland receiving the solid form manure will be used for corn.and soybean rotation not to exceed an annual available nitrogen load of 200 lbs N/acre. Drainage occurring directly from the facilities west side would meander to a holding pond northwest of the facility near Wildcat Rd with resultant overflow traversing ~1500' to the Kraut Ck Watershed. There are 21 total manure application sites all within the Stillwater River Watershed.

Most well logs in Darke County indicate an initial clay layer with an average depth in the Greenville area of 24'. Geologic striation patterns taken from the well logs indicate typically a repeating pattern of clay, sand, clay, limestone and clay. Fifty-seven percent (57%) of the application sites are situated in the N. Fk of Kraut Creek Watershed. Twenty-four percent (24%) of sites receiving livestock manure application are located in the Greenville Creek Watershed.

Four Star Dairy Livestock Inc.-Swamp Creek Watershed
Four Star Dairy Livestock Inc .is located two miles east of the Village of Yorkshire near the Village of Versailles on Willowdell Rd. Four Star Dairy produces milk for wholesale consumption by the public. An estimated 3,085 dairy cattle were housed at this facility in 1997 producing an estimated 6,179 dry tons of manure. The average minimal lagoon cleanout interval is four months and eight months maximum at the various locations where cattle are housed. Most of the manure generated by the dairy cattle is land applied to surrounding agricultural lands while some of the manure nutrients are sold to local farmers. The livestock facility has approximately 1,238 acres of its own land available for land application. Much of the acreage for land application, owned by Four Star Dairy, is also farmed by Four Star Dairy. Livestock manure is stored in two earthen holding ponds where it remains until extraction by truck tankers for land application. Livestock manure application sites are cropped mainly in corn and forage crops and are based on nitrogen loading rates to minimize leaching. At no time should a manure be applied at a rate resulting in more than 200 lbs of available nitrogen per acre per crop year.

Based on a typical liquid manure/wastewater nutrient analysis there are 81.2 lbs of nitrogen per dry ton of animal wastewater. A breakdown of the nitrogen is approximated at 45 lbs per dry ton of nitrogen as organic nitrogen of which 33% is estimated to be available the first year of application. The remaining 36 lbs per dry ton of the nitrogen is ammonia nitrogen of which 50% is estimated to be available for immediate crop use. This yields 33 lbs of estimated available nitrogen per year per dry ton of manure.

It is estimated that 911 acres are required for land application of generated manure for this facility. Solid manure should not be applied within 50 feet of ponds, lakes, streams, ditches, grass waterways, or inlets to field tiles lines or roadways. Liquid manure should not be applied within 200 feet of private wells or springs.

Frozen ground application of manure greater than 20% solids have different requirements. Isolation distances are 200 feet from private wells or springs and not within 100 feet of ponds, lakes, streams, ditches or grass waterways or inlets to field tiles. Manure will be incorporated as soon as is physically possible unless fields are in no-till production management. Consideration is given to weather conditions, wind direction and velocity, time of day, week or year in order to minimize nuisance potential.

Most nitrogen is lost in soil due to denitrification which occurs primarily when the soils are saturated with water. Parameters to be analyzed for at a minimum of once per year include ammonia-nitrogen, pH, total phosphorus, nitrate-nitrogen, calcium, total suspended solids, total nitrogen, magnesium, total solids and potassium. Most of the soils in the Yorkshire/Versailles area are composed of yellow, blue and red clay, sand and limestone (Well Logs and Drilling

Reports by ODNR-Div. Of Water-Columbus). The underlying geology in this general area indicated a clay layer exist to an average 113'.

Of 18 land application sites utilized by Four Star Dairy for livestock manure application 44% of the sites lie within the Stillwater Watershed. Four application sites lie within the unnamed tributary of Grassy Fork Watershed and three directly within the Swamp Creek basin. A number of land application sites, plotted on topographic maps within the Stillwater River Watershed, suggest tributary headwaters traverse directly through application sites that drain to the Grassy Fork and Swamp Creek Basins. Surrounding agricultural lands are not as adjacent to streams as these selected farm fields for manure application.

M@M Poultry Farms-South Fork of the Stillwater River

M@M Poultry Farms is located at 9315 Young Rd. in Jackson Township, Darke County. M@M Poultry Farm is engaged in raising pullets (chickens). Baby chicks are brought to the facility and mature pullets are shipped out of the facility. There are five Pullet Houses on site all with a Hi-Rise design where pullets are suspended above the manure storage area in wire cages arranged in stacked decks.

Some of the pullet manure is applied to acreage (65 acres) owned by M@M Poultry Farm while most of the generated manure is sold to local farmers for fertilizer. An estimated 457 acres is needed for the 200 lb of actual nitrogen per acre application rate. The M@M Poultry Farm produces 40 lbs of available nitrogen per dry ton. Soils in this area are composed on the average of a 96' clay layer before arriving at sand or limestone. The facility is located at the headwaters of an unnamed tributary of the South Fork Stillwater River Watershed with land application sites located nearby in the North Fork of the Kraut Creek Watershed. Some land application sites were noted as containing headwater tributaries within the boundaries of the application target areas.

Surface Water Quality

[Many of the graphs included with the following summaries include dotted lines representing the 90th percentile concentration from least impacted regional reference sites of similar size (Ohio EPA 1999). Statistical data were segregated by ecoregion and further stratified by four ranges of stream and river size for these analyses as follows: headwater streams (0-20 sq. mi.); wadeable streams (> 20-200 sq. mi.); and small rivers (> 200-1000 sq mi.).]

[Additionally, given that all bacteriological data (fecal coliform and E. coli) collected during the 1999 survey were not analyzed within the required holding time, it should be noted that discussions of bacteriological results in the following summaries are included only with the intent of gauging the potential for impacts on the receiving streams.]

Stillwater River

Stream flows from May through September 1999 (Figure 29) as measured by two USGS gage stations in the Stillwater River were well below normal, reflecting below average precipitation throughout the period. Levels fell below the 80% duration exceedence flows at both sites in early August and continued to decline throughout September with flows approaching or falling below 7 Q_{10} values (USGS 1981 and 2000). (The 80% duration exceedence flow represents the discharge which was equaled or exceeded 80% of the time over the period of record while the 7 Q_{10} represents the lowest mean discharge for seven consecutive days over ten years during the period of record.) Precipitation records (ODNR 1999) indicate the southwest portion of the state experienced the driest May through September of record (117 years) while the west central region of the state experienced the 8th driest of record. On specific water chemistry sampling days during the 1999 survey, the two gage stations (RMs 27.85 and 8.82) recorded lows on September 7 with respective mean daily flows of 12 cfs and 20 cfs. Corresponding highs of 75 cfs and 89 cfs, respectively, were recorded on July 29 and July 26.

Datasonde continuous monitors recorded hourly dissolved oxygen (D.O.) concentrations, D.O. percent saturation, temperature, pH and conductivity from July 7-9 at eleven sites (RMs 63.83-11.40) in the Stillwater River mainstem in 1999 (Figures 30 and 31, Table 7, Appendix Table A-2). The lowest D.O. concentrations in the mainstem occurred in the headwaters at RM 62.97 (SR 49) with 43% of recorded values below the WWH minimum criterion of 4.0 mg/l. Both headwater sites (RMs 63.83 and 62.97) experienced significant diurnal fluctuation with dissolved oxygen saturation ranging from 23% to 200% at RM 63.83 and from 24% to 296% at RM 62.97. Relative saturation, expressed as a percentage, is the relation of the existing oxygen solubility to the equilibrium content of the gas expected at the same temperature and partial pressure. These two sites also experienced much greater variation in diurnal pH with 8% of measured values minimally exceeding water quality criterion at RM 63.83. The wide fluctuations in D.O. and pH reflect the significant algal growth in the headwaters. Similarly, diurnal temperatures at both sites varied widely and exceeded the maximum temperature criterion in 25% of the measurements. This headwater reach of the mainstem is a narrow, channelized, agricultural ditch totally lacking in riparian cover. The lower flows exacerbate the impacts from habitat modification and agricultural runoff. D.O. concentrations were also depressed at RM 56.97, downstream from the Ansonia WWTP and combined sewer overflows (CSOs).

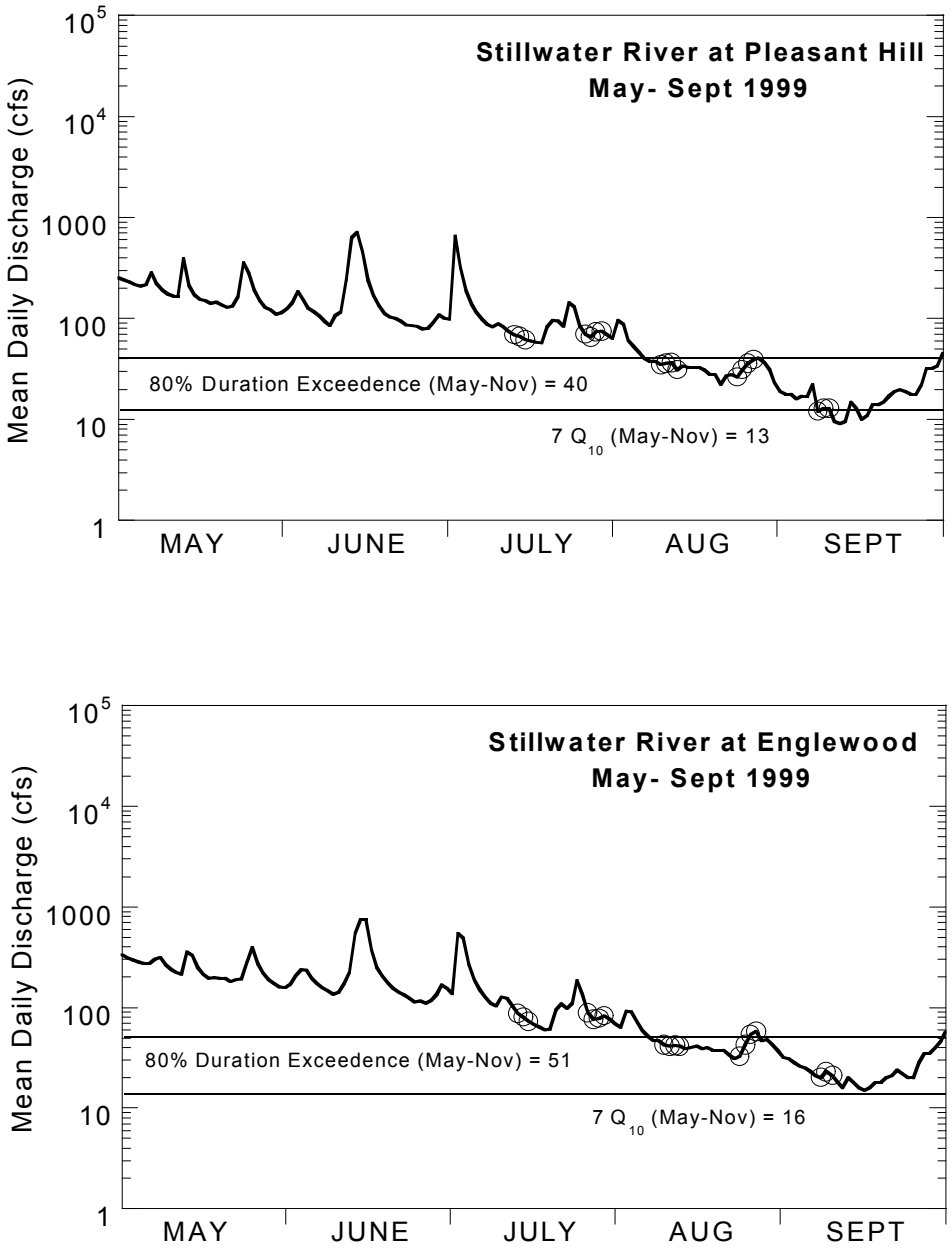


Figure 29. May through September, 1999 flow hydrographs for the Stillwater River at Pleasant Hill (Rm 27.85) and the Stillwater River at Englewood (Rm 8.82). Low flow conditions ($7Q_{10}$) and 80% duration exceedence flows for Pleasant Hill and Englewood are based on USGS stations #03265000 (period of record 1916-1928, 1934-1997) and #03266000 (period of record 1925-1997), respectively. Open circles indicate river discharge on water chemistry sampling days in the Stillwater River basin.

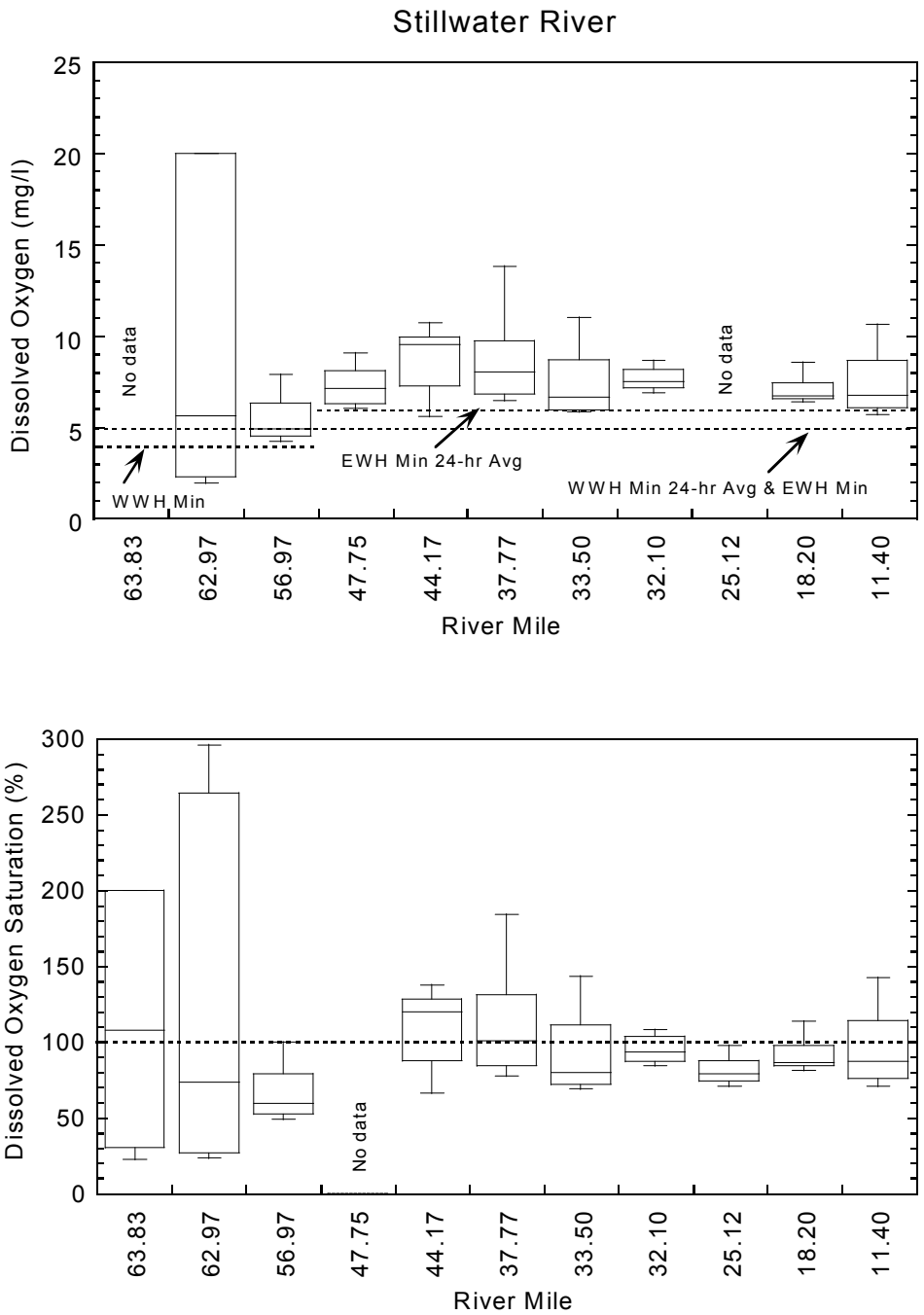


Figure 30. Distributions of dissolved oxygen concentration (upper figure) and percent dissolved oxygen saturation (lower figure) recorded hourly with Datasonde™ continuous monitors from July 7-9 in the Stillwater River, 1999.

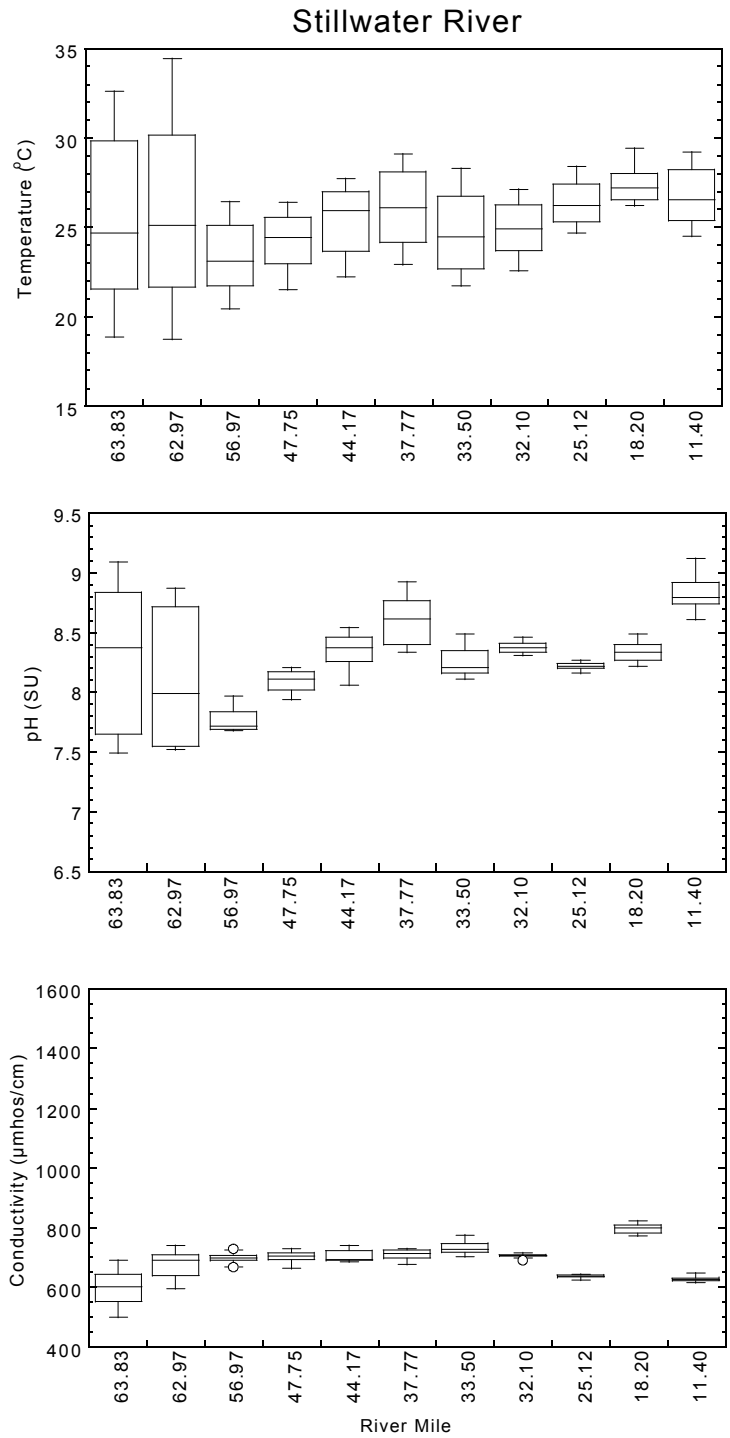


Figure 31. Distributions of temperature (upper figure), pH (middle figure) and conductivity (lower figure) recorded hourly with Datasonde™ continuous monitors from July 7-9 in the Stillwater River, 1999.

Median pH values increased longitudinally from RM 56.97 (7.72 SU) through RM 37.77 (8.62 SU) while corresponding median temperatures increased from 23.11°C to 26.08°C. The highest pH values of the survey as recorded by Datasondes® occurred downstream of the Union WWTP at RM 11.40 (median of 8.80 SU) with 14% of measured values exceeding water quality criterion. Conductivity remained relatively stable throughout the mainstem with medians ranging from 602 Fmhos/cm (RM 63.83) to 800 Fmhos/cm (RM 18.20).

Water chemistry grab samples were collected every other week (five times) at 26 sites in the Stillwater River mainstem and analyzed for a variety of parameters (Figures 32-35, Tables 6 and 7, Appendix Table A-1). Similar to Datasonde® results, numerous D.O. concentrations fell below water quality criteria in the upper reaches (RMs 65.00 - 56.97). The lowest values (respective median concentration and percent saturation of 3.4 mg/l and 39%) were recorded at RM 57.90 immediately downstream of the North Fork Stillwater River confluence. The Ansonia WWTP discharges to the North Fork Stillwater at RM 0.24 and there are also two active CSOs on the Stillwater mainstem within one-half mile of this site. Additionally, accelerated algal growth and excessive photosynthesis frequently pushed daytime dissolved oxygen concentrations to supersaturated levels at RMs 65.00 and 62.97. The highest dissolved oxygen saturation of the mainstem (257%) was recorded at RM 65.00 on July 13. Similarly, pH (9.04 SU) exceeded water quality criterion at the site on this day. Consistently lower D.O. values were recorded downstream at RMs 32.55 (located in an impounded area upstream of the Covington lowhead dam) and RM 11.40 (downstream of the Union WWTP). Additionally, concentrations dropped below the EWH minimum 24-hour average criterion of 6.0 mg/l on one occasion each at RMs 50.20, 33.50, 32.55, 27.85, 14.65, 13.60 and 11.40.

The majority (82%) of five-day biochemical oxygen demand (BOD_5) concentrations in the mainstem were less than or equal to the 90th percentile concentration for reference sites in the Eastern Corn Belt Plains (ECBP) ecoregion. Values downstream of the North Fork Stillwater River at RM 57.90, however, consistently exceeded the headwater reference concentration (3.4 mg/l). While less than the small river 90th percentile reference concentration (5.7 mg/l), higher values were also recorded upstream of Harris Creek at RM 37.77 (median 4.2 mg/l) and in the impounded area at RM 32.55 (median 4 mg/l). The highest concentrations were generally recorded in the lower reaches (RMs 15.05-1.92) with medians ranging from 3.7 mg/l (RM 9.10) to 5.5 mg/l (RM 1.92).

Ammonia-N levels were generally low in the mainstem with the majority (80%) of values less than or equal to applicable reference concentrations and 67% less than or equal to the minimum detection limit (MDL) of 0.05 mg/l. The highest concentrations occurred at RMs 57.90 and 56.97 (respective medians of 0.215 mg/l and 0.202 mg/l) downstream of the Ansonia WWTP and CSOs.

Levels of nitrate-nitrite-N were exceptionally low throughout the Stillwater mainstem with an overall median of 0.3 mg/l calculated for all concentrations. This compares to median concentrations recorded during prior surveys for other basins in Southwest Ohio ranging from 1.03 mg/l (upper Great Miami River mainstem) to 3.50 mg/l (Mad River mainstem). Lower

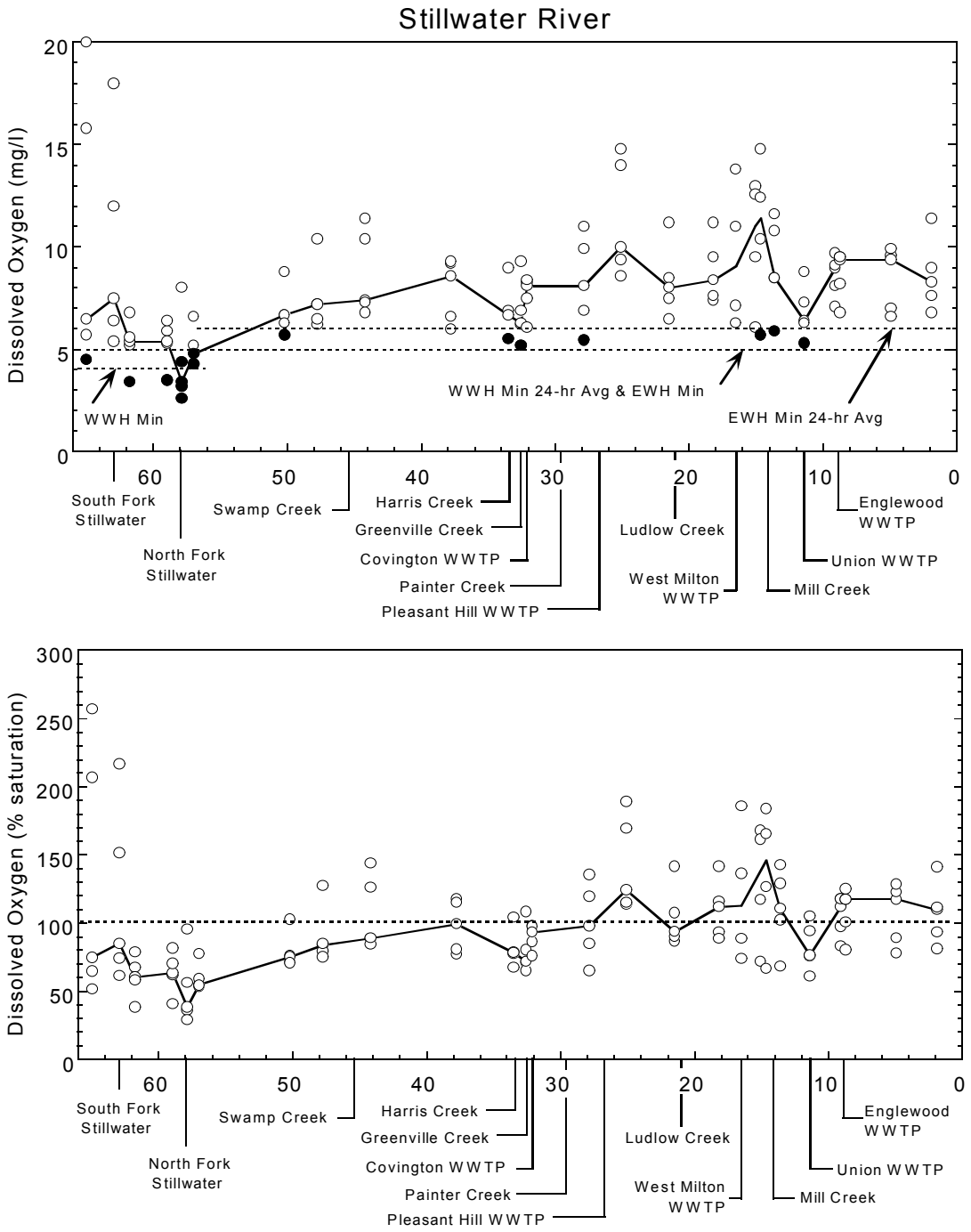


Figure 32 Longitudinal scatter plots (daytime grabs) of dissolved oxygen concentrations (upper figure) and percent dissolved oxygen saturations (lower figure) in the Stillwater River during the 1999 survey. The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the upper figure. Values below the water quality criteria are indicated by solid circles.

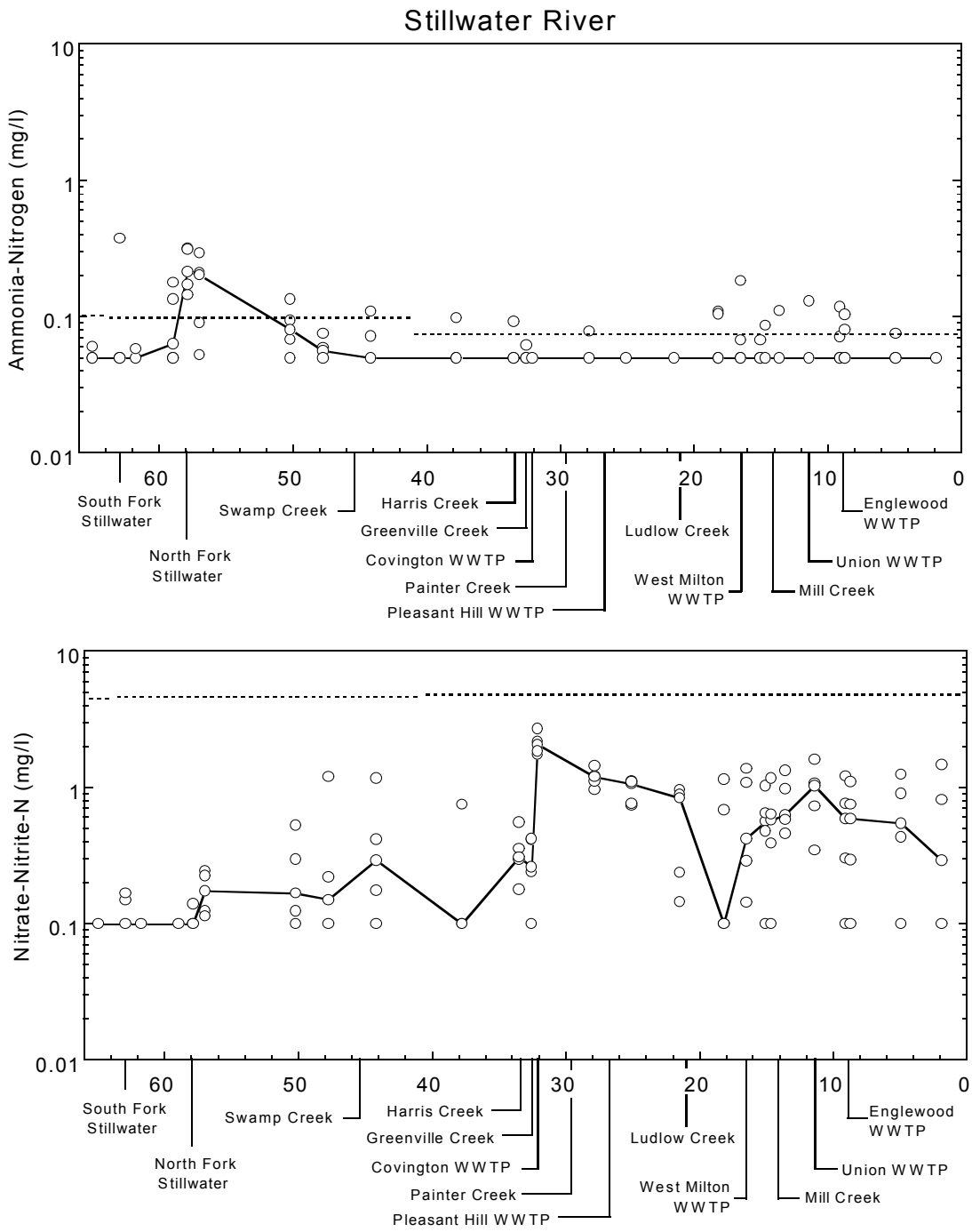


Figure 33 Longitudinal scatter plots (daytime grabs) of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in the Stillwater River during the 1999 survey (MDL is 0.05 mg/l for NH_3-N and 0.1 mg/l for NO_3-NO_2-N). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

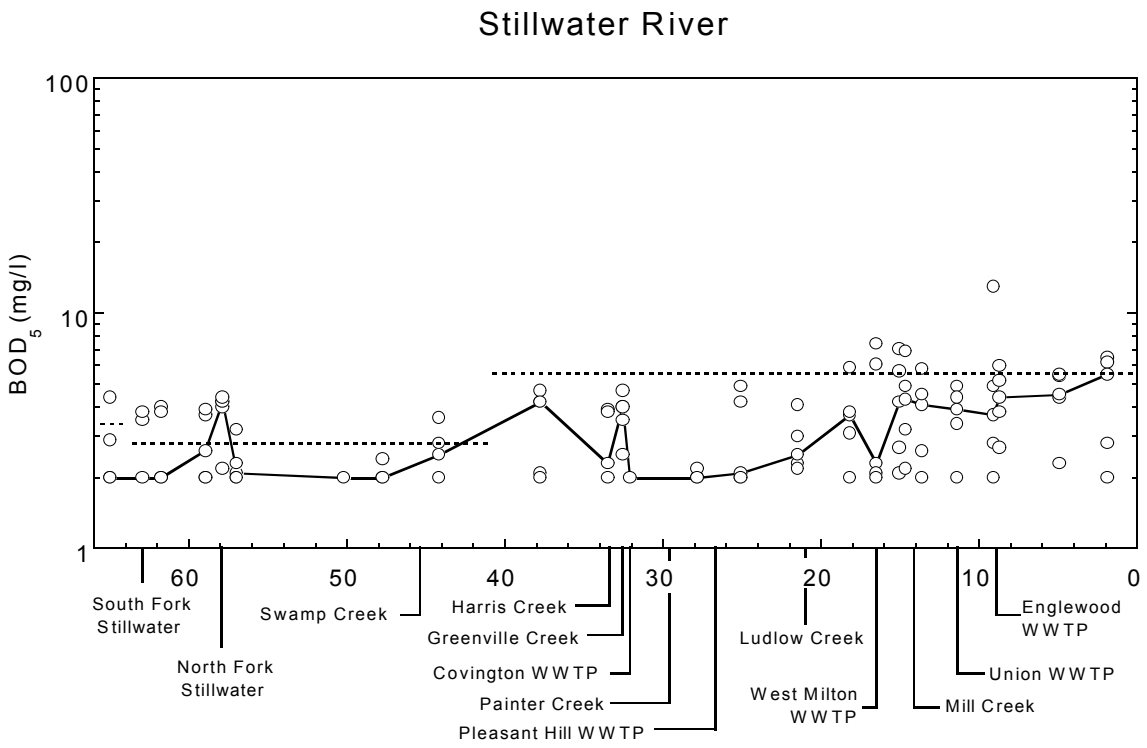


Figure 34. Longitudinal scatter plot (daytime grabs) of BOD_5 concentrations in the Stillwater River during the 1999 survey (MDL is 2 mg/l). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

levels may reflect the combined impact of the drought conditions observed throughout the survey and the relatively few point dischargers in the Stillwater compared to other Southwest Ohio rivers. Impacts attributable to non-point sources are typically more apparent during higher flows. Values measured in the mainstem were generally higher downstream of point sources with the highest median concentration (2.08 mg/l) recorded downstream of the Covington WWTP at RM 32.10.

Virtually all total phosphorus concentrations (97%) were greater than the MDL of 0.05 mg/l with a median concentration of 0.17 mg/l in the mainstem. Similar to nitrate-nitrite-N, phosphorus levels were also generally lower relative to prior surveys in other Southwest Ohio basins where medians ranged from 0.13 mg/l (Mad River mainstem) to 0.57 mg/l (Mill Creek mainstem). Values were again generally higher downstream of point sources. The highest concentrations occurred downstream of the Covington WWTP at RM 32.10 (median 0.77 mg/l) and downstream of Swamp Creek at RM 44.17 (median 0.53 mg/l). Additionally, elevated concentrations were observed in the headwaters at RM 65.00 (median 0.36 mg/l) reflecting the exacerbating impact of channelization and poor riparian habitat.

While concentrations of total suspended solids (TSS) at the uppermost headwater sites remained low, values increased sharply at RMs 58.97 and 57.90 (respective medians of 39.5 mg/l and 31 mg/l). Consistently elevated, the highest TSS concentrations in the mainstem were recorded in the dam pool at RM 32.55 (median 67 mg/l). Field notes indicate the water appeared somewhat murky on occasion and became more stagnant as the summer progressed creating a scum layer on the surface. Additionally, solids were frequently elevated in the unnamed tributary entering the Stillwater just upstream of the site at RM 32.60 (See Figure 71). Downstream concentrations increased longitudinally from RM 15.05 (median 25 mg/l) to RM 1.92 (median 58 mg/l). Most elevated values throughout the mainstem were recorded in July on higher flow days.

A minimal number of bacteriological samples were collected in the mainstem during the 1999 survey. The majority of concentrations (44 of 45 fecal coliform samples and 22 of 31 *E. coli* samples) were less than the applicable average recreation criteria. Fecal coliform exceeded the maximum recreation criteria at RM 33.50 on July 28 (3350 colonies/100ml). *E. coli* concentrations exceeded recreation criteria at numerous sites in the upper half of the mainstem (RMs 65.00-33.50) with the highest value (831 colonies/100 ml) measured at RM 56.97 downstream of Ansonia.

Manganese and iron concentrations were elevated above water quality criteria in 29% and 31%, respectively, of samples analyzed in the mainstem. Both metals are naturally occurring substances found in many types of rock and soils. Exceeding water quality criterion, the highest copper concentration (63 µg/l) of the survey was recorded downstream of Swamp Creek at RM 44.17 on August 24, a day of widespread precipitation. The Versaille WWTP on Swamp Creek is required to monitor copper and other metals only on a quarterly basis. Copper concentrations measured in Swamp Creek throughout the survey, however, were not elevated. Total suspended solids (114 mg/l) were also elevated at the site on this date. The majority (93%) of mercury concentrations

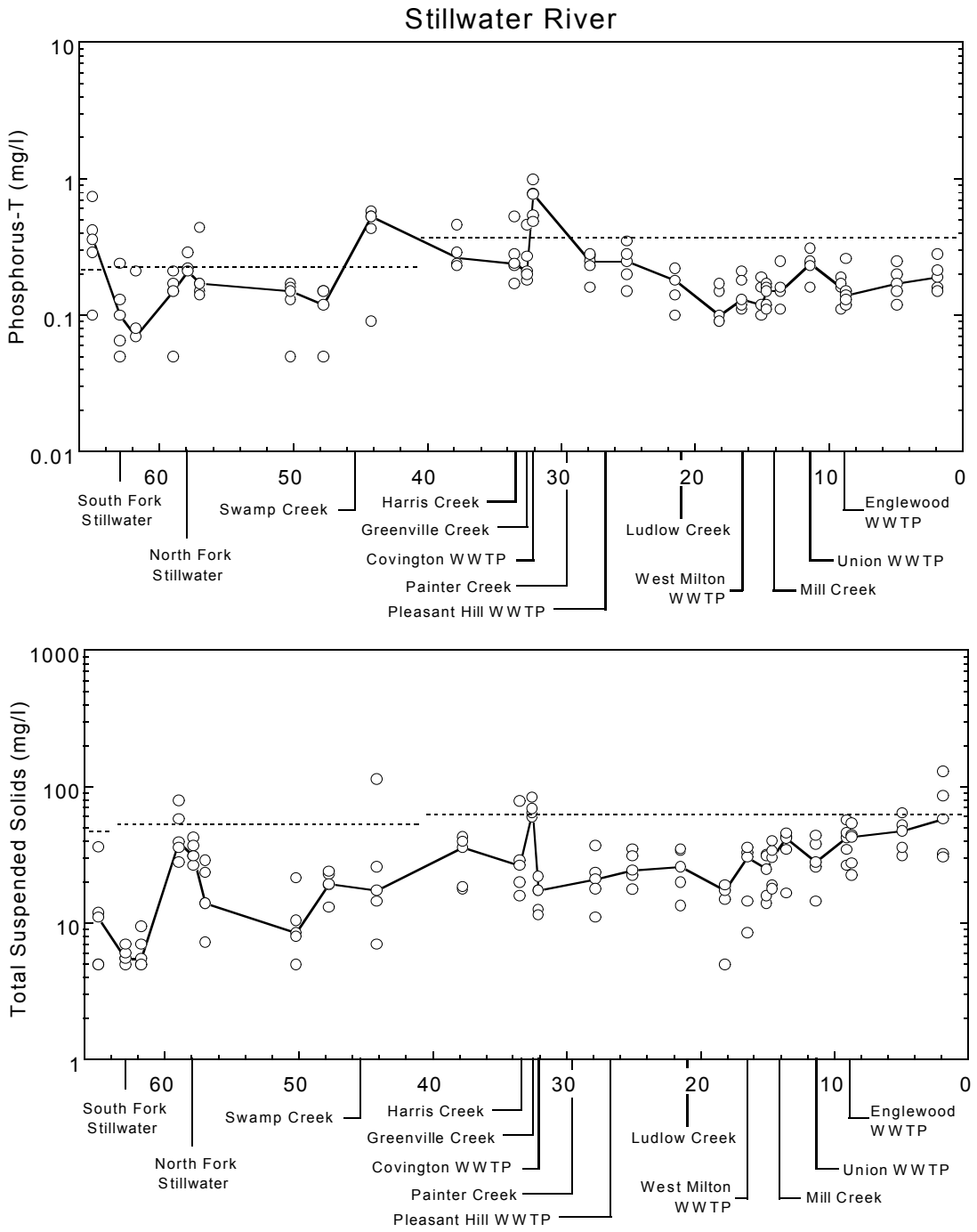


Figure 35. Longitudinal scatter plots (daytime grabs) of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in the Stillwater River during the 1999 survey (MDL is 0.05 mg/l for TP and 5 mg/l for TSS). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

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measured in the mainstem were less than the MDL of 0.2 µg/l. Mercury exceeded the non-drinking water human health water quality criterion of 0.012 µg/l on July 26 at RM 44.17 (0.3 µg/l). Values also exceeded criterion at eight of the nine sites (RMs 65.00-44.17) sampled on August 24. Excluding the July 26 sample noted above, the only samples which exceeded the MDL during the entire survey (mainstem or tributary) were collected on August 24 in the most upper reaches of the Stillwater basin. Precipitation records for Versailles indicate the area received 0.36 inches of rain during the 24-hour period beginning at 8 a.m. on this day and 0.23 inches for the preceding 24-hour period (MCD 1999). Mercury is readily removed from the atmosphere by precipitation. The majority of anthropogenic emissions of mercury are from combustion sources including waste and fossil fuel combustion. Additionally, past uses of mercury, such as fungicide application to crops can also be a component of the present mercury burden in the environment.

Additionally, while well within water quality criteria, the highest arsenic concentrations in the mainstem were recorded in the upper reaches (RMs 65.00-56.97) with values ranging from 4 to 17 µg/l and an overall median of 9 µg/l. Associated with outwash from glacial deposits high in celestite ($SrSO_4$), strontium concentrations were also highest in this reach ranging from 2620 µg/l to 10500 µg/l with an overall median of 4450 µg/l. Higher strontium levels were documented in much of the upper Stillwater basin and also appeared to be somewhat correlated to periods when groundwater recharge dominated stream flow.

Twenty of the 26 water chemistry sites in the mainstem were sampled for organic compounds volatiles, semivolatiles, pesticides, and polychlorinated biphenyls (PCBs)) twice during the 1999 survey (Table 8, Appendix Table A-3). Eleven of the fourteen organic compounds (and 109 of the 116 detections) found in the mainstem were pesticides. The most frequently detected compounds were atrazine (22% of detections), metolachlor (22% of detections) and gamma-hexachlorocyclohexane (15% of detections). Concentrations of aldrin, dieldrin, and heptachlor exceeded water quality criteria on several occasions. PCBs were not detected in the water column at any site (mainstem or tributary) during the 1999 survey.

South Fork Stillwater River and Tributary @ RM 0.94

The South Fork Stillwater River enters the Stillwater River at RM 63.10. There are seven animal feedlots located in this watershed (drainage area 13.9 mi^2) totaling over 4,000 animal units (77% poultry and 22% swine) and producing 3,900 tons of waste annually (MVRPC 1998). Water chemistry daytime grab samples were collected at two sites (RMs 1.26 and 0.40) on the South Fork Stillwater River and at one site (RM 1.56) on the tributary which enters the South Fork at RM 0.94 (Figure 36, Tables 6 and 7, Appendix Table A-1).

The daytime D.O. concentration (3.9 mg/l) dropped below the WWH minimum criterion at RM 1.26 on August 24 with a corresponding percent saturation of 44%. In contrast, supersaturated levels were measured at all sites on July 13 with D.O. saturations ranging from 113% in the tributary to 162% at RM 0.40 in the South Fork. Similar to the channelized headwaters of the Stillwater mainstem, riparians are narrow and bordered by rowcrops at all three sites. Open canopies and modified habitat accelerate algal growth and result in excessive photosynthesis.

BOD_5 concentrations remained low with 80% of values less than the MDL (2 mg/l). Concentrations of ammonia-N and nitrate-nitrite-N were also consistently low with only one ammonia-N value (0.251 mg/l at RM 0.40) above the ECBP 90th percentile headwater reference concentration and 93% of nitrate-nitrite-N values less than the 0.1 mg/l MDL. Phosphorus concentrations ranged from 0.06 mg/l to a high of 0.35 mg/l with a median for all values of 0.12 mg/l. While TSS concentrations remained low in both the tributary and at RM 1.26 in the South Fork, somewhat higher values were measured downstream at RM 0.40 where values ranged from 12 to 23 mg/l. *E. coli* concentrations measured on August 24 at RMs 1.26 and 0.40 exceeded the maximum recreation criteria.

Manganese exceeded water quality criteria at RM 0.40 on one occasion while mercury exceeded criteria at all three sites on August 24, a day of widespread precipitation (see Stillwater mainstem discussion above). Additionally, while well within water quality criteria, higher arsenic levels were measured at RM 1.56 in the tributary (median of 13 µg/l). Strontium concentrations were also elevated with medians ranging from 3060 µg/l at RM 1.26 to 7220 µg/l at RM 1.56 in the tributary.

Woodington Run

Three feedlot operations totaling 964 animal units (99% swine) and producing 915 tons of waste/year are located in the Woodington Run subbasin (drainage area of 11.4 mi^2) (MVRPC 1998). Daytime grab water chemistry samples were collected at RMs 3.36 and 0.72 in this tributary of the Stillwater River (confluence at RM 59.13) (Figure 37, Tables 6 and 7, Appendix Table A-1). Dissolved oxygen measurements were low at both sites (respective median saturations of 47% and 68%). Concentrations fell below WWH criteria in four of five measurements at RM 3.36 and once at RM 0.72. Lower values may be attributable to the combined impact of lower flows and algae observed in the stream. Both sites were sampled in the morning when algal respiration typically exceeds photosynthesis.

All concentrations of BOD_5 and nitrate-nitrite-N were less than MDLs. Ammonia-N and TSS concentrations also remained low with respective medians of 0.05 mg/l and 5 mg/l at both sites. Median phosphorus concentrations decreased longitudinally from 0.12 mg/l at RM 3.36 to 0.06 mg/l at RM 0.72 with respective maximums of 0.32 mg/l and 0.54 mg/l recorded at the sites. Manganese

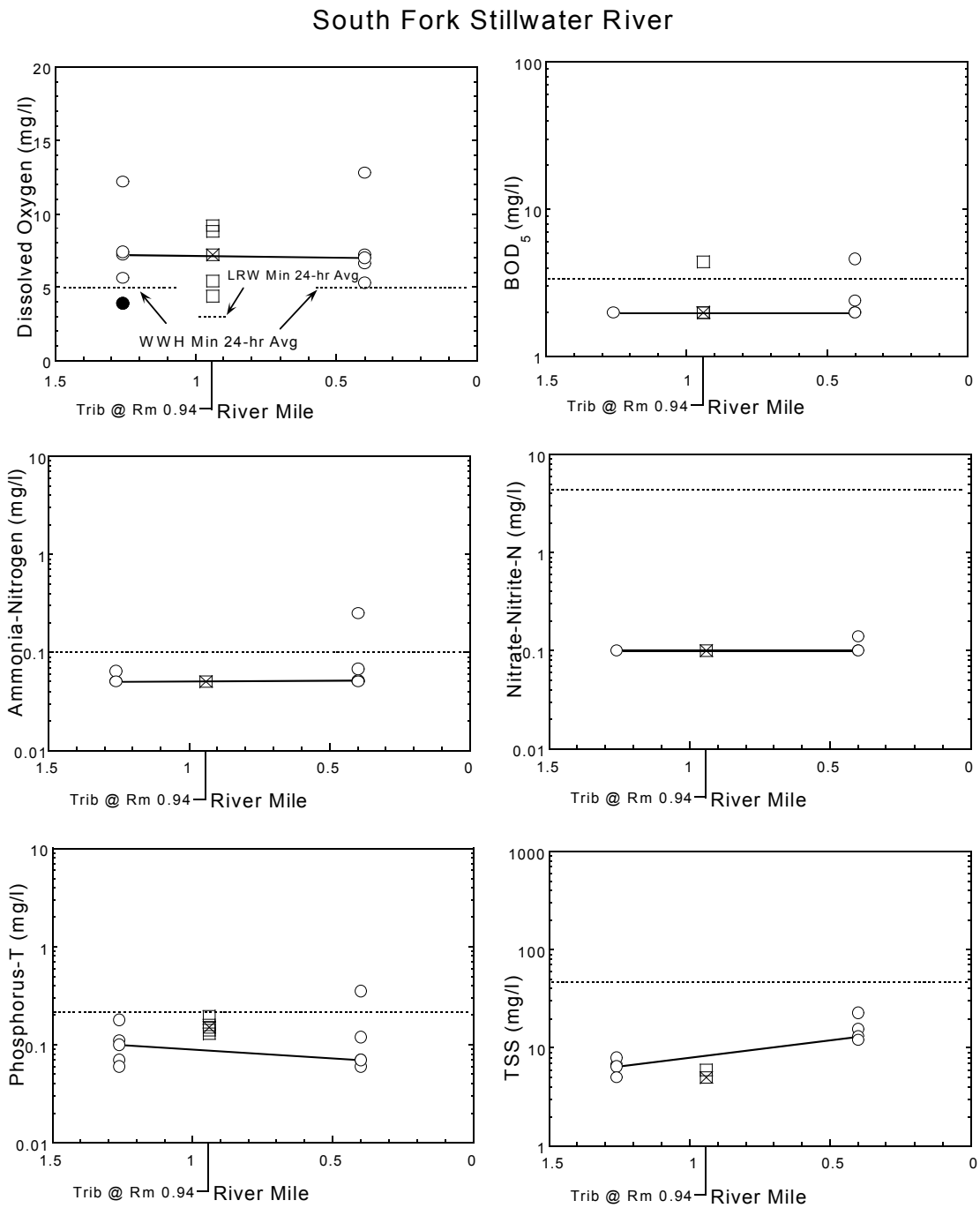


Figure 36. Longitudinal scatter plots of water chemistry results (daytime grabs) in the South Fork Stillwater River (circles) and the tributary @ RM 0.94 (squares) during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled in the South Fork while the 'X' depicts the median for the tributary. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid circles.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

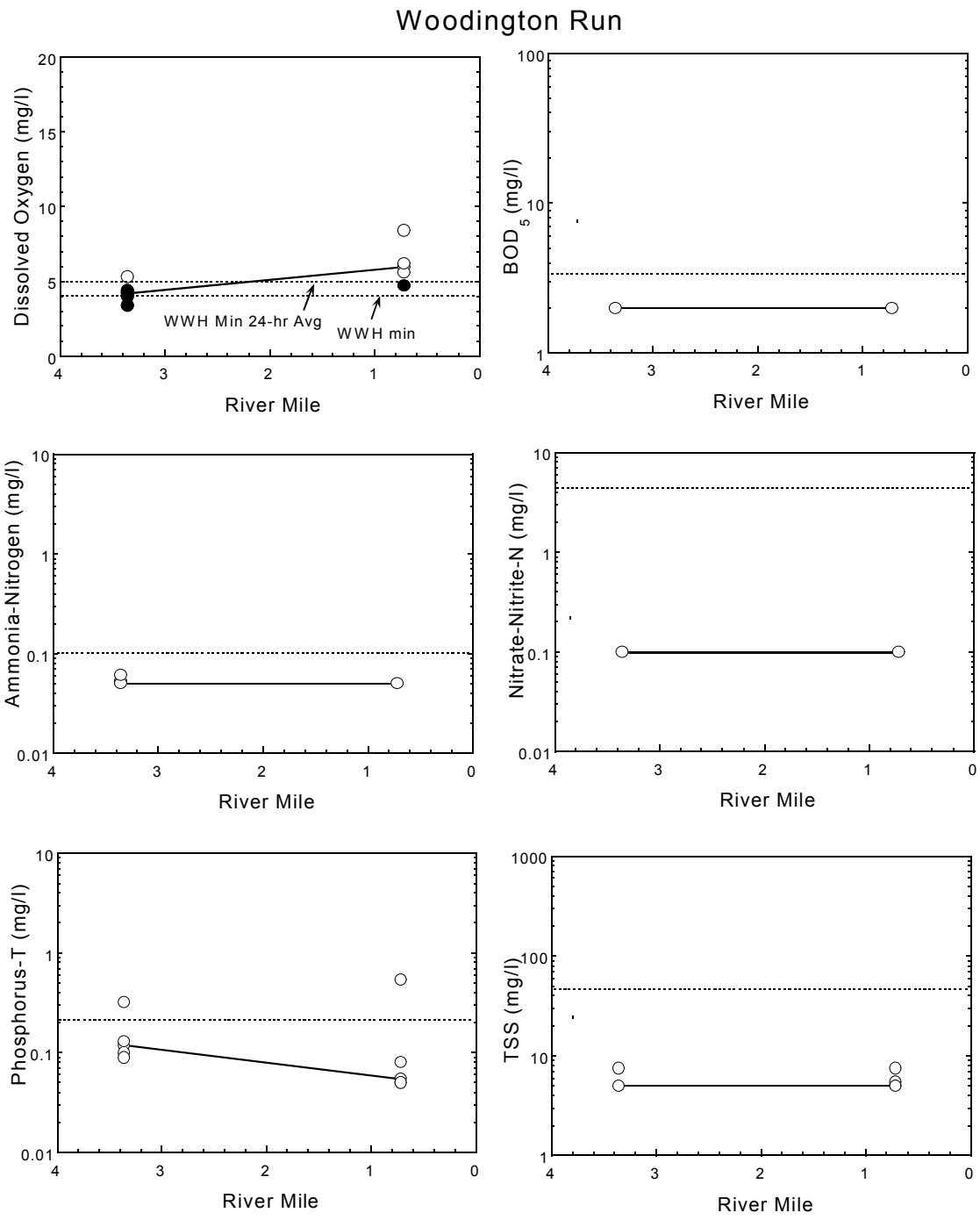


Figure 37. Longitudinal scatter plots of water chemistry results (daytime grabs) in Woodington Run during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid circles.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

exceeded water quality criteria on three occasions at the upstream site. Mercury exceeded criteria at both sites on August 24 (see Stillwater mainstem above for possible explanation). Minimal bacteriological sampling (two fecal coliform and one *E. coli* per site) revealed an exceedence of the *E. coli* recreation criterion at RM 3.36.

North Fork Stillwater River

The North Fork Stillwater River, entering the Stillwater River at RM 57.97, receives the discharge from the Ansonia WWTP at RM 0.24. This small subbasin (drainage area 18.9 mi^2) has 12 feedlot operations totaling over 18,000 animal units (86% poultry) and producing more than 17,000 tons of waste per year (MVRPC 1998). Characteristic of numerous tributaries in the upper Stillwater River watershed, the North Fork Stillwater River is a shallow, channelized stream with minimal riparian. The impact of nutrient loading is magnified by the poor stream habitat and extensive algal growth.

Hourly dissolved oxygen concentration and percent saturation, temperature, pH and conductivity were measured by Datasonde continuous monitors at two sites (RMs 4.16 and 0.40) from July 7-9 (Figure 38, Table 7, Appendix Table A-2). Both locations experienced significant diurnal fluctuation with D.O. percent saturations ranging from 21% to 207% at RM 4.16 and from 26% to 281% at RM 0.40. More than 25% of concentrations at both sites dropped below the modified warmwater habitat (MWH) minimum criterion of 3.0 mg/l. Higher temperatures were measured at the downstream site with 24% of measurements exceeding the maximum temperature criterion of 29.4EC.

Water chemistry daytime grab samples were collected at four sites (RMs 8.90, 7.12, 4.16, and 0.40) (Figure 39, Tables 6 and 7, Appendix Table A-1). Dissolved oxygen median percent saturations ranged from 42% (RM 7.12) to 83% (RM 4.16) with concentrations frequently falling below MWH criterion in the headwaters (RMs 8.90 and 7.12) and upstream of the Ansonia WWTP at RM 0.40. BOD_5 concentrations were elevated in the headwaters at RM 8.90 with values ranging from 5.5 mg/l to 22 mg/l (median 7.5 mg/l). Consistently elevated, ammonia-N at this site exceeded water quality criterion in three of the five samples collected. Ammonia-N levels decreased downstream with a median of 0.175 mg/l measured at RM 7.12 and 90% of values at RMs 4.16 and 0.40 less than the 0.05 mg/l MDL. Nitrate-nitrite-N in the North Fork remained below the 90th percentile headwater reference site concentration of 4.60 mg/l and an overall median of 0.1 mg/l. Phosphorus concentrations, however, were elevated at the upper three sites (RMs 8.90-4.16) with an overall median of 0.85 mg/l. Median phosphorus concentrations decreased longitudinally from 1.55 mg/l at RM 8.90 to 0.07 mg/l at RM 0.40. With the exception of RM 4.16 where all TSS concentrations were less than the MDL, values were relatively elevated with medians ranging from 18.5 mg/l at RM 7.12 to 30.5 mg/l at RM 8.90.

Limited bacteriological sampling (two fecal coliform and one *E. coli* per site) indicate fecal coliform concentrations above recreational criterion on one occasion at RMs 8.90 and 0.40. *E. coli* concentrations were above criterion at RMs 8.90, 7.12 and 0.40. Iron and manganese frequently exceeded water quality criteria at RMs 8.90, 7.12 and 0.40 while mercury exceeded water quality

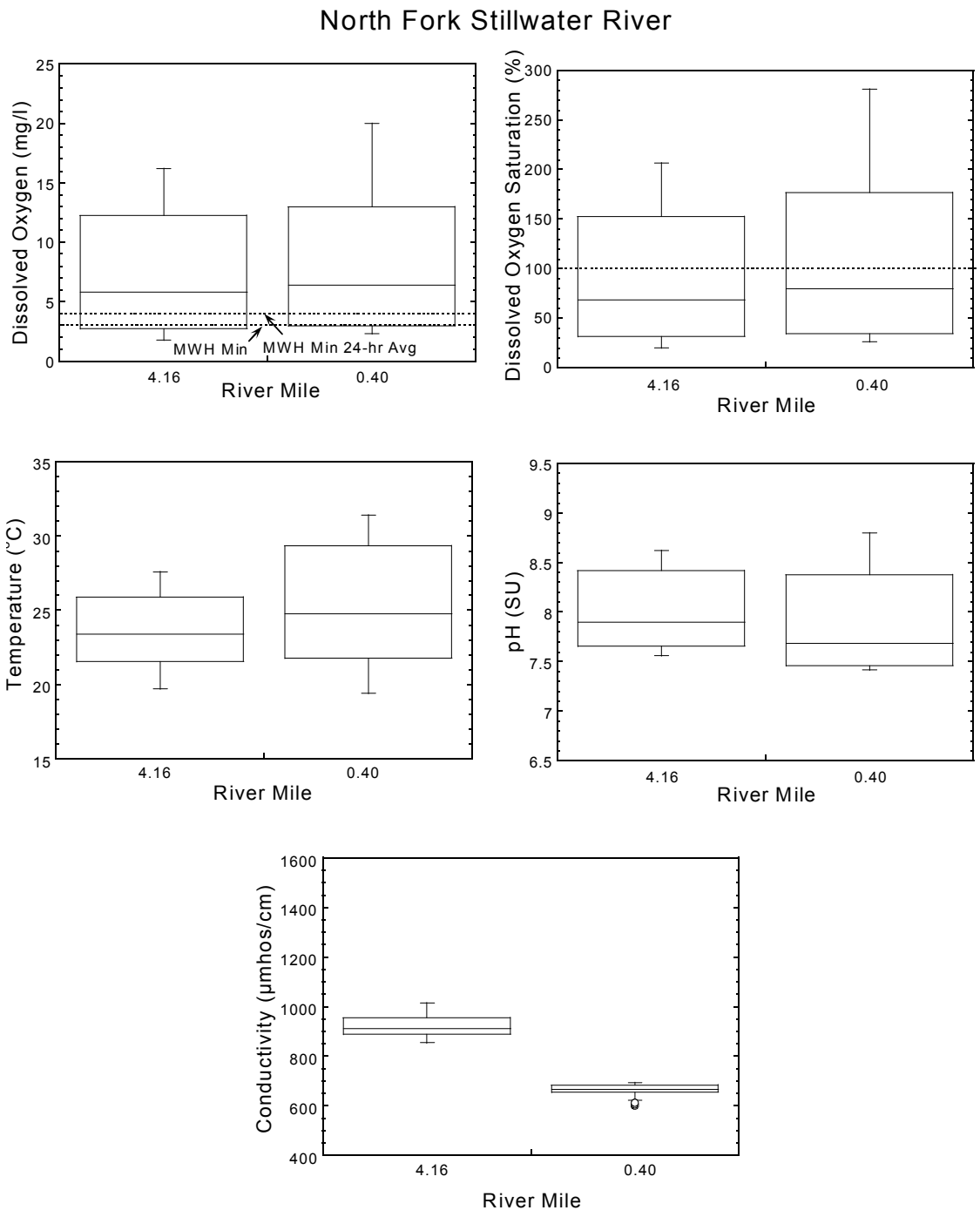


Figure 38. Left to right from the top: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, temperature, pH, and conductivity recorded hourly with Datasonde™ continuous monitors from July 7-9 in the North Fork Stillwater River, 1999.

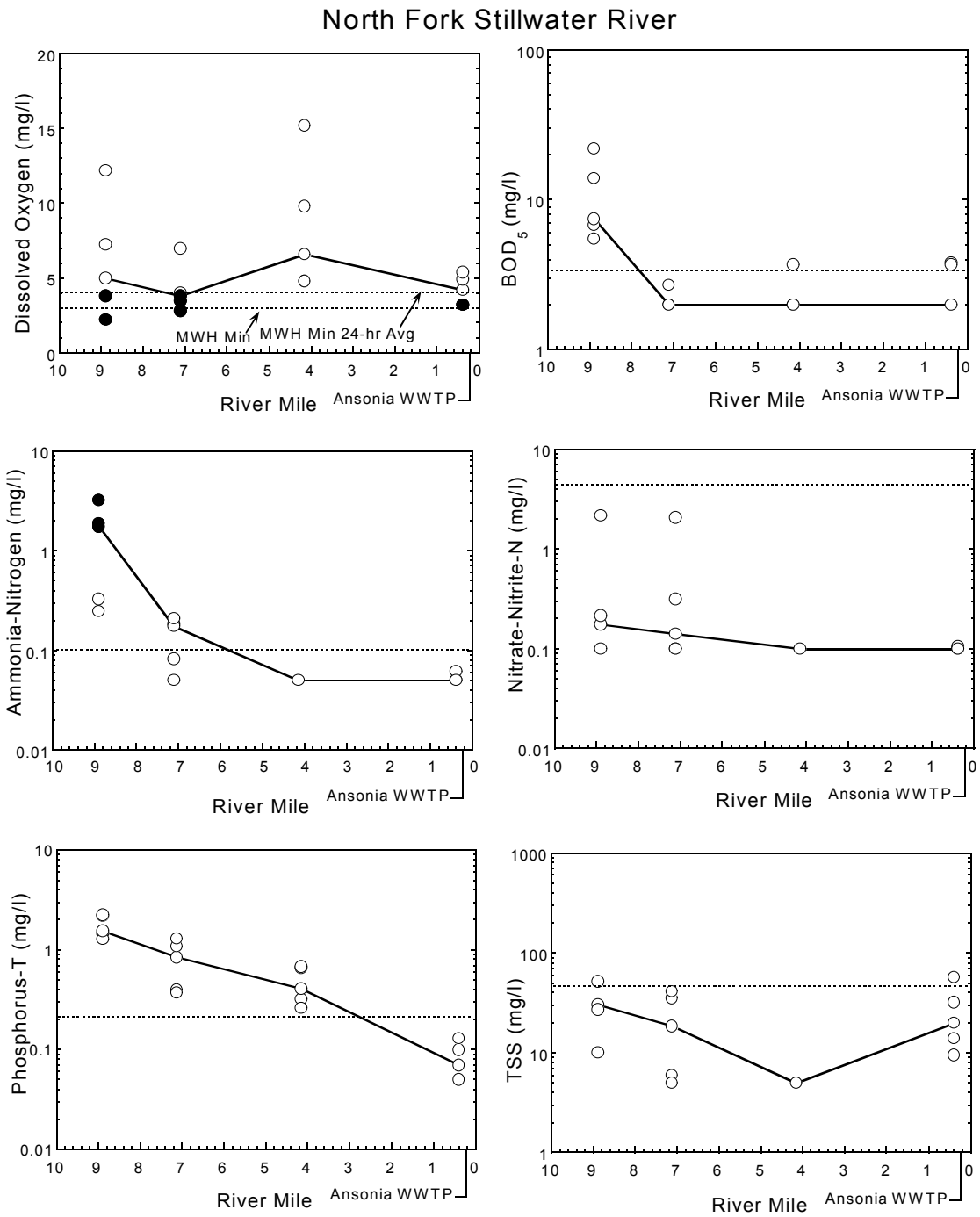


Figure 39. Longitudinal scatter plots of water chemistry results (daytime grabs) in the North Fork Stillwater River during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for dissolved oxygen and ammonia-nitrogen are shown as solid circles.)

criterion on August 24 at these sites (see Stillwater mainstem discussion). Chloride, sulfate, chemical oxygen demand (COD), and strontium were also somewhat elevated in the basin. Water samples from RM 0.40 were analyzed for organic compounds twice during the 1999 survey (Table 8, Appendix Table A-3), revealing various organochlorine pesticides. Dieldrin and gamma-hexachlorocyclohexane exceeded water quality criteria on July13.

Swamp Creek Subbasin (Swamp Creek, Grassy Fork, Tributary @ RM 3.54, and Indian Creek) Swamp Creek receives the discharge from the Versailles WWTP at RM 2.12 and enters the Stillwater River at RM 45.88. A suite of factors including poor habitat (minimal riparian, channelization), general agricultural runoff, and loadings from the Versaille WWTP impact Swamp Creek and its tributaries. Additionally, the Swamp Creek drainage area (63.2 mi^2) has 66 livestock and poultry feedlot operations which total over 49,000 animal units (67% poultry and 20% swine) and produce 47,000 tons of waste a year (MVRPC 1998). This accounts for 30% of the feedlots, 39% of the total animal units, and 39% of the waste inventoried in the entire Darke County portion of the Stillwater River watershed.

During the 1999 survey, the MWH aquatic life use designation and water quality criteria applied in Swamp Creek from the headwaters to RM 6.5 while the WWH aquatic life use designation applied from RM 6.5 to the mouth. The WWH use designation applied to Indian Creek also. Given that both Grassy Fork and the unnamed tributary did not have an aquatic life use designation during the 1999 survey, water quality criteria identified for the limited resource water (LRW) use designation applied (OAC rule 3745-1-07).

Datasondes®® monitored D.O., temperature, pH, and conductivity from July 7-9 at three sites in Swamp Creek (RMs 6.51, 2.85, and 0.28) and at one site (RM 1.93) in Indian Creek in 1999 (Figure 40, Table C, Appendix Table A-2). Dissolved oxygen at the three Swamp Creek sites generally remained above applicable water quality criteria with only 2 of the 47 measurements taken at RM 2.85 below the WWH minimum of 4.0 mg/l. D.O. percent saturations fluctuated widely from 42% to 184% at RM 6.51 and from 46% to 174% at RM 2.85. D.O. concentrations recorded at the Indian Creek site dropped below the WWH minimum criterion in 21% of the measurements. Percent saturations at the site ranged from 37% to 193%. Higher temperatures were measured in Swamp Creek at RM 6.51 (median 24.73EC) where 15% of the measurements exceeded the maximum criterion of 29.4EC. Temperatures were also elevated in Indian Creek (median 24.61EC), exceeding maximum criterion twice. Swamp Creek median pH values increased longitudinally from 7.71 SU at RM 6.51 to 8.01 SU at RM 0.28 while conductivity medians ranged from 783 µmhos/cm at RM 2.85 to 1001 µmhos/cm downstream at RM 0.28. The highest conductivities of the survey as measured by Datasondes®® occurred at the Indian Creek site with respective median and maximum values of 1422 µmhos/cm and 1447 µmhos/cm.

Water grab samples were collected from eight locations (RMs 12.05, 8.85, 6.51, 4.44, 2.85, 2.20, 1.59, and 0.28) in Swamp Creek. Indian Creek, entering Swamp Creek at RM 2.45, was sampled at three locations (RMs 6.11, 1.93, and 0.48). Additionally, RM 0.82 was sampled in Grassy Fork (a tributary to Swamp Creek at RM 8.04) and RM 0.45 was sampled in the unnamed tributary which enters Swamp Creek at RM 3.54 (Figs 13-17, Tables 6 and 7, App. A-1).

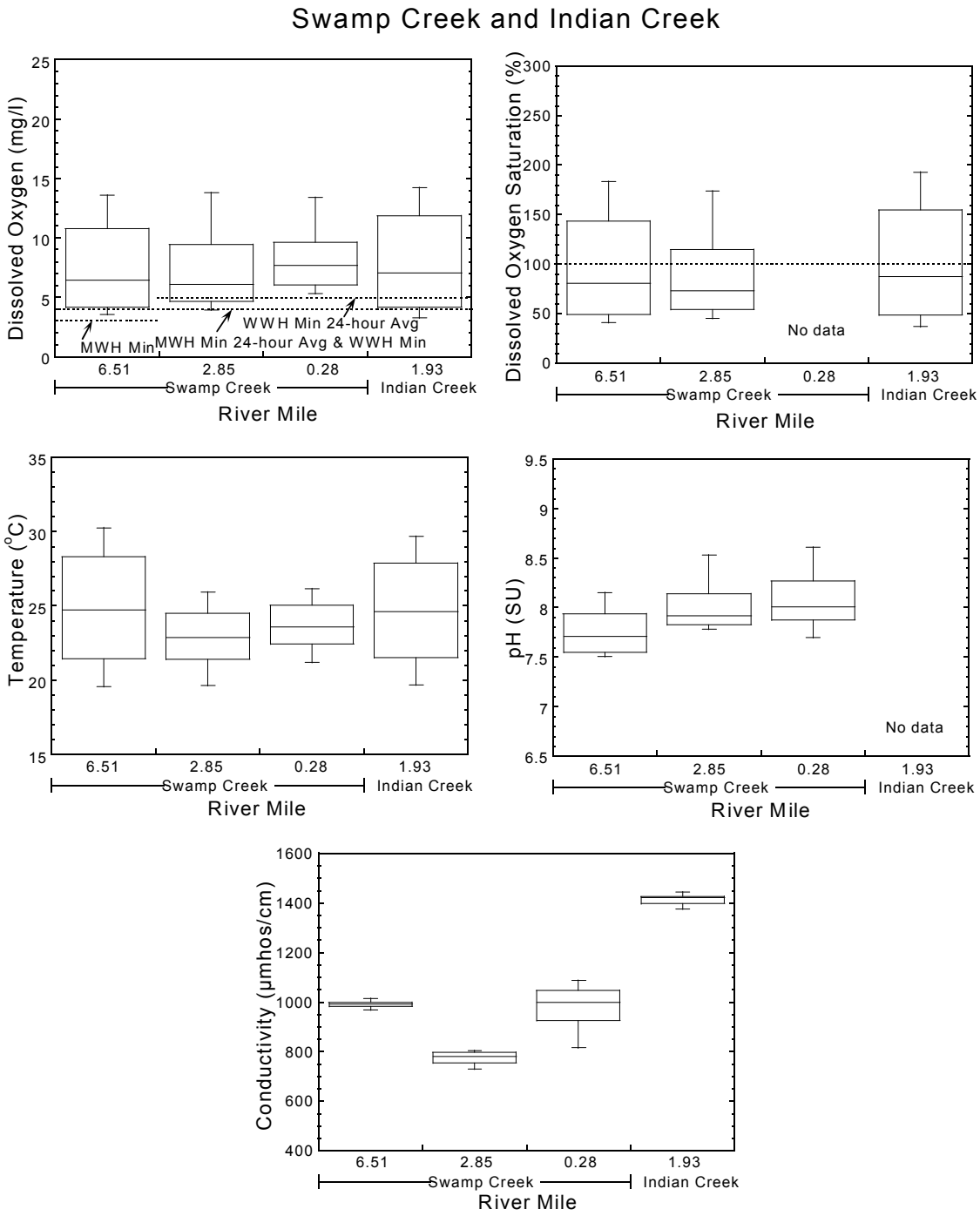


Figure 40. Left to right from the top: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, temperature, pH, and conductivity recorded hourly with Datasonde™ continuous monitors from July 7-9 in Swamp Creek and Indian Creek, 1999.

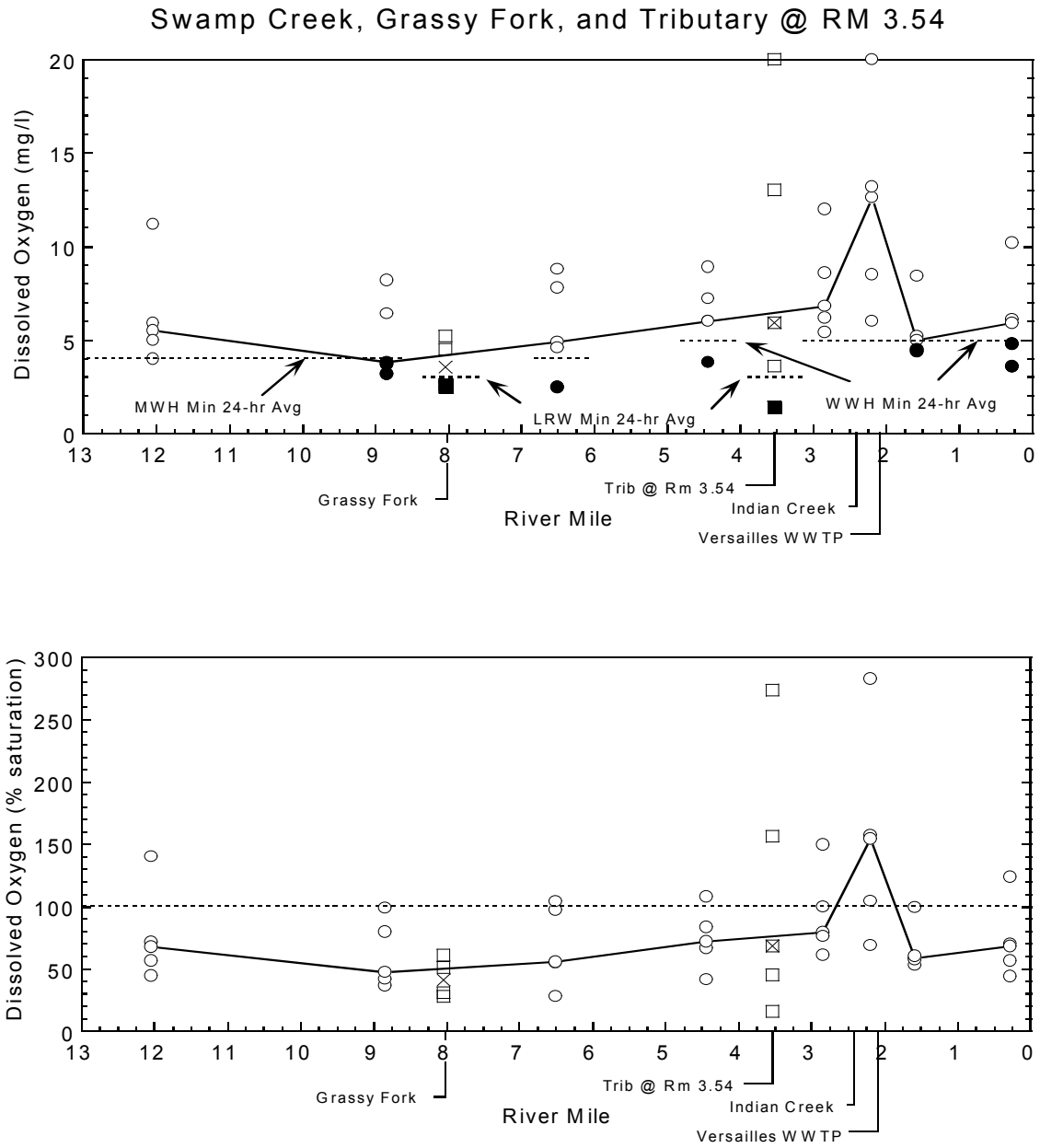


Figure 41. Longitudinal scatter plots (daytime grabs) of dissolved oxygen concentrations (upper figure) and percent dissolved oxygen saturations (lower figure) in Swamp Creek (circles), Grassy Fork, and a tributary to Swamp Creek @ RM 3.54 (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Swamp Creek while an 'X' depicts the medians for Grassy Fork and the tributary. Water quality criteria are shown in the upper figure. Values below the water quality criteria are indicated by solid circles or squares.

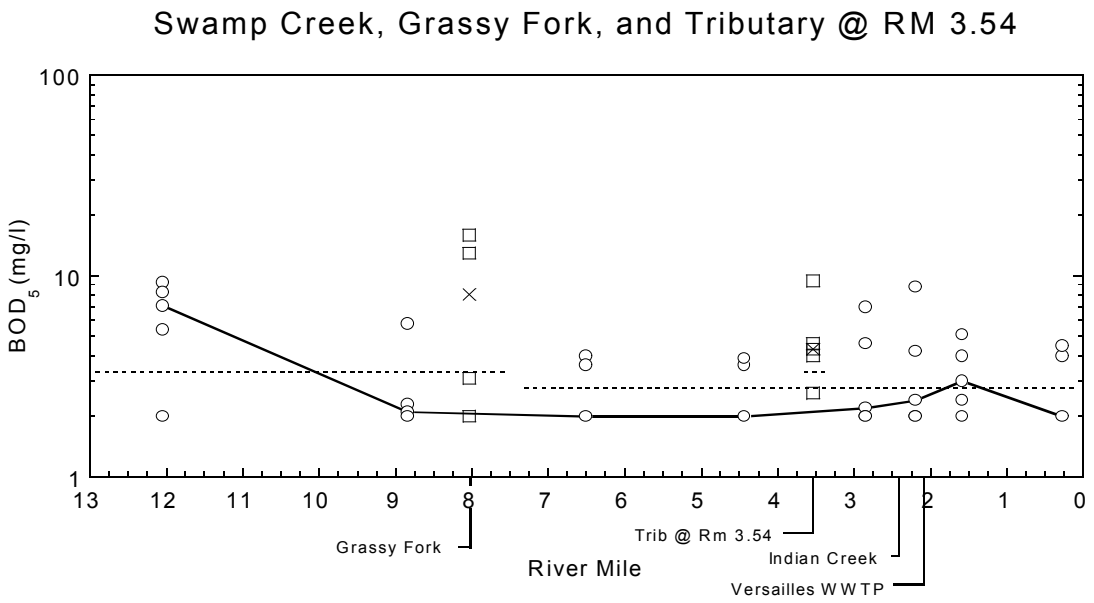


Figure 42. Longitudinal scatter plot (daytime grabs) of BOD_5 concentrations in Swamp Creek (circles), Grassy Fork, and a tributary to Swamp Creek @ RM 3.54 (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Swamp Creek while an 'X' depicts the medians for Grassy Fork and the tributary. The dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

With the exception of RM 2.20 where D.O. typically reached supersaturated levels (median percent saturation 155%), daytime dissolved oxygen values were depressed in Swamp Creek with median percent saturations ranging from 48% at RM 8.85 to 79% at RM 2.85. Numerous concentrations dropped below water quality criterion at RMs 8.85, 6.51, 4.44, 1.59, and 0.28. Concentrations below the LRW criterion were also recorded in Grassy Fork and the unnamed tributary where respective median percent saturations of 41% and 68% were documented. Additionally, the majority (64%) of D.O. concentrations measured in Indian Creek fell below WWH water quality criterion. Median percent saturations in Indian Creek ranged from 43% at RM 6.11 to 58% at RM 0.48.

BOD_5 concentrations were frequently elevated above the 90th percentile ECBP reference concentration in Swamp Creek at RM 12.05 (median 7.1 mg/l), in Grassy Fork (median 8.1 mg/l), and in the unnamed tributary (median 4.3 mg/l). The highest median BOD_5 concentration of the entire survey, however, was recorded at RM 6.11 in Indian Creek (13.2 mg/l).

Median ammonia-N concentrations in Swamp Creek ranged from less than the MDL at the upper three sites (RMs 12.05-6.51) to 0.157 mg/l downstream of the Versailles WWTP at RM 1.59. Values exceeded water quality criteria at RM 2.85 (0.452 mg/l) and RM 2.20 (0.39 mg/l) on August 24. Additionally, ammonia-N was consistently elevated in Grassy Fork with respective median and maximum concentrations of 0.52 mg/l and 7.22 mg/l. Values at the upstream site in Indian Creek (RM 6.11) were also elevated (median 0.63 mg/l) and exceeded water quality criterion on July 27.

Nitrate-nitrite-N remained low at most sites in Swamp Creek and all tributaries with an overall median of 0.1 mg/l for all values measured in the basin. The highest concentrations (median 4.42 mg/l) were recorded downstream of the Versailles WWTP at RM 1.59. An overall median of 0.24 mg/l was recorded for all phosphorus concentrations in Swamp Creek during the 1999 survey. Phosphorous medians ranged from 0.16 mg/l at the headwater site (RM 12.05) to a survey high of 2.33 mg/l downstream of the Versailles WWTP at RM 1.59. Phosphorus remained elevated downstream at RM 0.28 (median 1.56 mg/l). Phosphorus concentrations measured in both Grassy Fork and the unnamed tributary were typically elevated above the 90th percentile reference concentration with respective medians of 0.66 mg/l and 0.33 mg/l. Additionally, while phosphorus concentrations at downstream sites in Indian Creek remained low, consistently elevated values were recorded at RM 6.11 (respective median and maximum of 0.48 mg/l and 0.88 mg/l).

Median TSS concentrations in Swamp Creek ranged from 7.5 mg/l at RM 2.20 to 24.5 mg/l at RM 0.28. Values in Indian Creek were elevated with median values decreasing longitudinally from 65 mg/l at RM 6.11 to 17.5 mg/l at RM 0.48. Exceptionally high values were recorded in Grassy Fork (236 mg/l) and at RM 6.11 in Indian Creek (164 mg/l) on August 24 during a rain event.

Limited bacteriological sampling (two fecal coliform and one *E. coli* per site) reveals concentrations of fecal coliform above recreational criterion in Swamp Creek at RMs 6.51, 4.44,

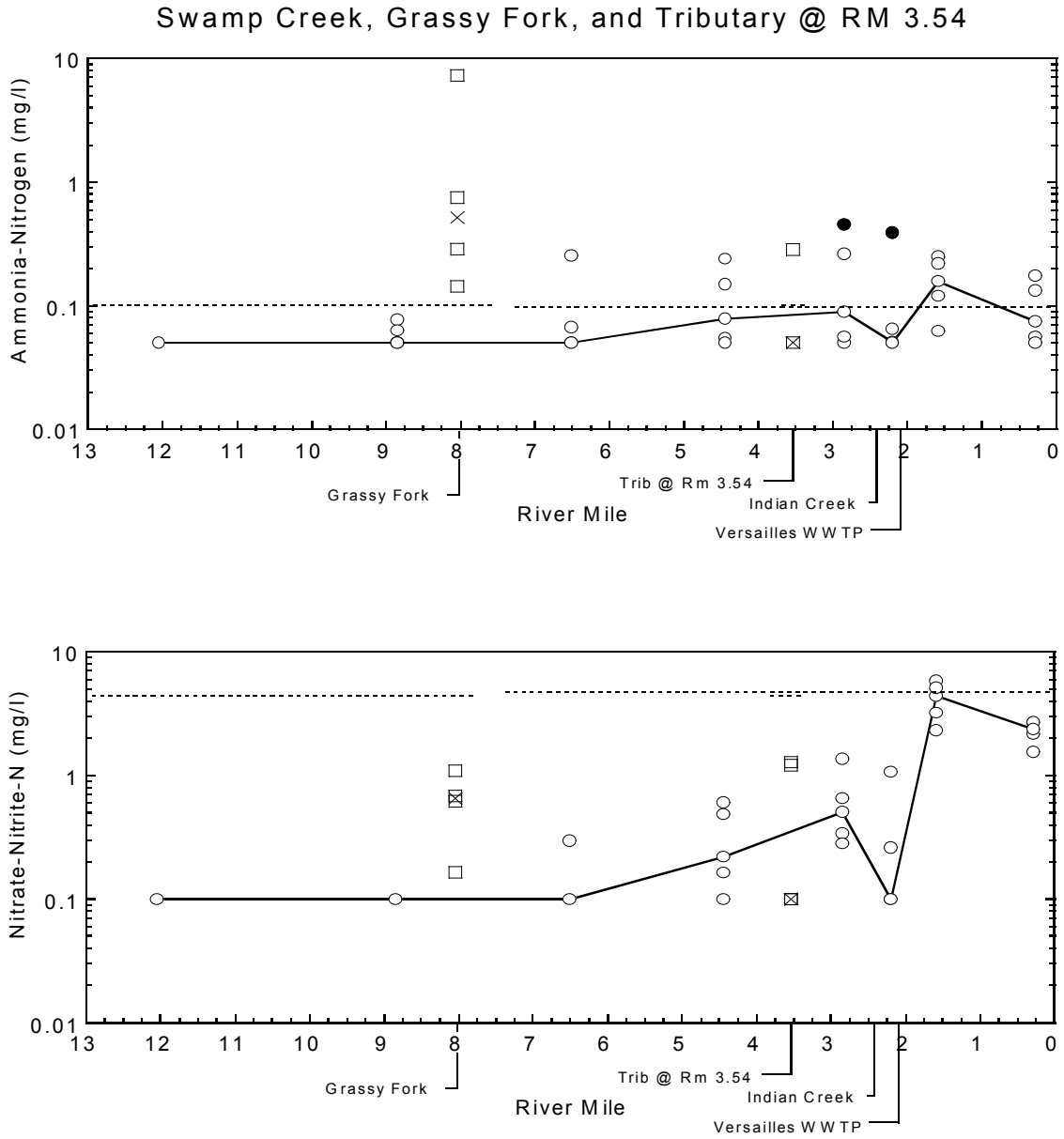


Figure 43. Longitudinal scatter plots (daytime grabs) of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in Swamp Creek (circles), Grassy Fork, and a tributary to Swamp Creek @ RM 3.54 (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Swamp Creek while an 'X' depicts the medians for Grassy Fork and the tributary. Dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for ammonia-nitrogen are shown as solid circles.)

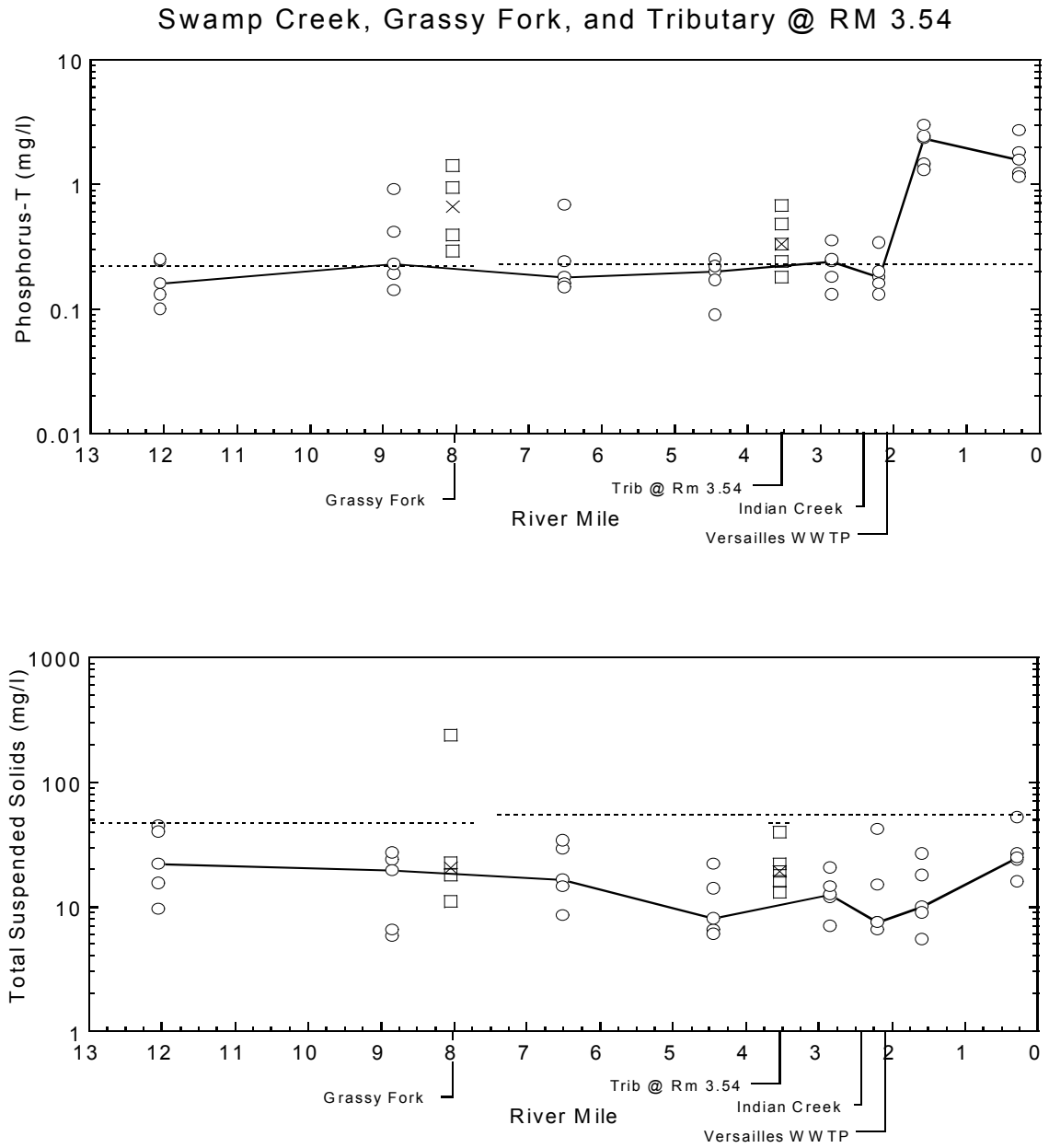


Figure 44. Longitudinal scatter plots (daytime grabs) of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in Swamp Creek (circles), Grassy Fork, and a tributary to Swamp Creek @ RM 3.54 (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Swamp Creek while an 'X' depicts the medians for Grassy Fork and the tributary. Dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

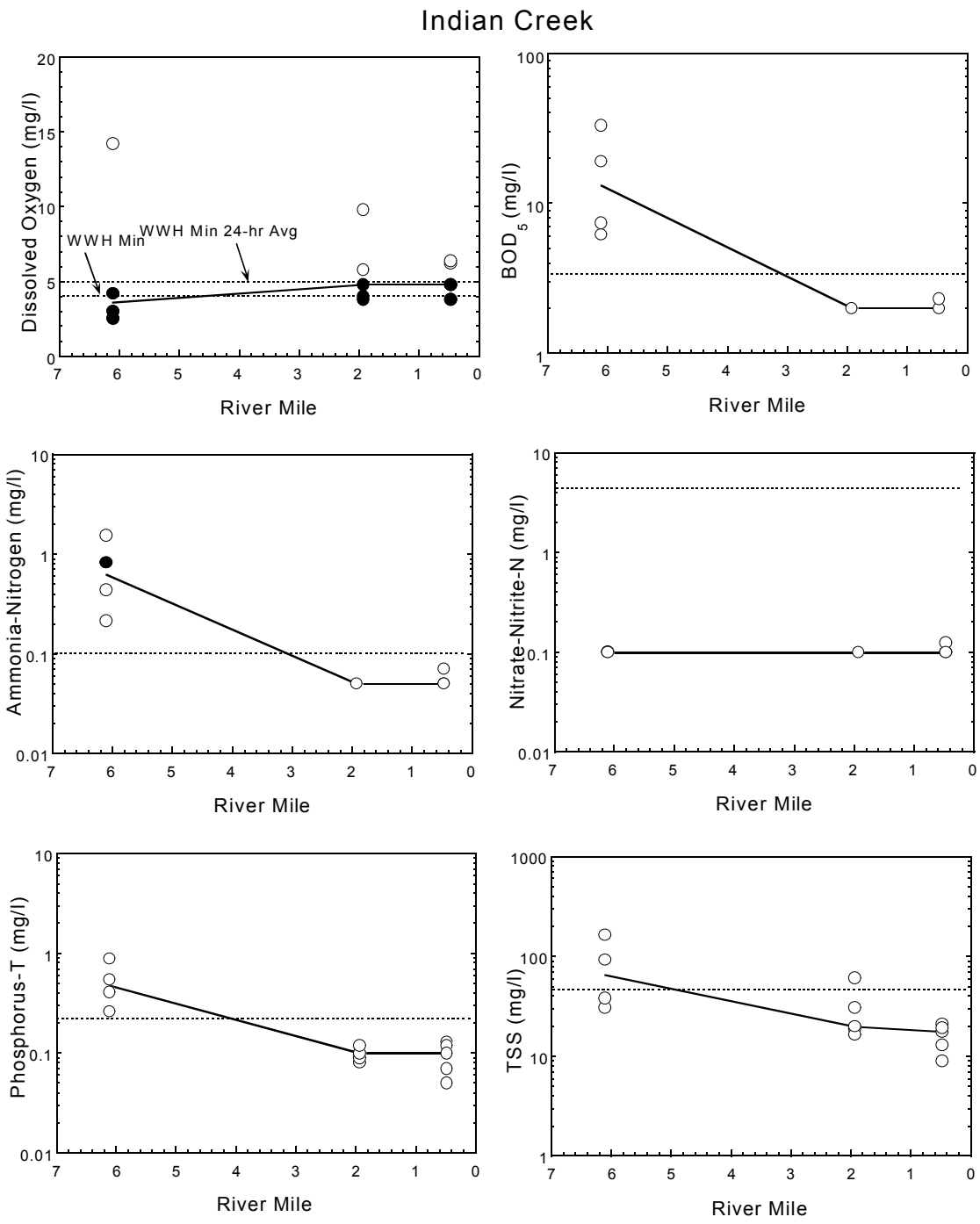


Figure 45. Longitudinal scatter plots of water chemistry results (daytime grabs) in Indian Creek during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for dissolved oxygen and ammonia-nitrogen are shown as solid circles.)

2.85, 2.20, and 1.59 with the highest value (45000 colonies/100 ml) recorded upstream of the Versaille WWTP at RM 2.20 on August 24. *E. coli* values above recreational criterion were also measured in Swamp Creek at RMs 6.51, 2.85, 2.20, 1.59, and 0.28, in the unnamed tributary, and at RMs 1.93 and 0.48 in Indian Creek. Most elevated values (93%) occurred on August 24. The rainfall station at Versailles recorded 0.36 inches of rain during the 24-hour period beginning at 8 a.m. on this day and 0.23 inches for the preceding 24-hour period (MCD 1999).

Temperature and pH were elevated above water quality criteria at RM 2.20 in Swamp Creek on separate occasions. Temperature also exceeded criterion in Indian Creek at RM 6.11 on July 27. Concentrations of manganese frequently exceeded water quality criterion throughout the basin with some of the highest values of the survey recorded in Grassy Fork (respective median and maximum values of 1158 µg/l and 2460 µg/l). While iron exceeded water quality criterion once at all Swamp Creek sites (except RM 2.85), concentrations at RMs 6.11 and 1.93 in Indian Creek frequently exceeded criterion. Mercury concentrations exceeded water quality criterion in Swamp Creek (RMs 12.05-2.85) and Grassy Fork on August 24 (see Stillwater mainstem discussion above). Additionally, elevated sulfate concentrations were common at RMs 8.85-0.28 in Swamp Creek (overall median 134 mg/l) and in Grassy Fork (median 145 mg/l). The highest sulfate concentrations of the survey, however, were measured in Indian Creek at RM 1.93 (median 307 mg/l) and RM 0.48 (median 275 mg/l).

COD, conductivity, arsenic, sodium, and aluminum were also elevated on occasion in Grassy Fork. While well within water quality criterion, higher arsenic and copper concentrations were recorded at RM 0.45 in the unnamed tributary on occasion (most notably on Sept 7 with respective values of 24 µg/l and 28 µg/l). Additionally, RM 6.11 in Indian Creek experienced consistently elevated concentrations of arsenic (median 20.5 µg/l), aluminum (median 1275 µg/l), and COD (median 79 mg/l). Strontium concentrations in Indian Creek were exceptionally elevated at the two downstream sites with the highest values of the survey measured at RM 1.93 (median and maximum values of 10300 µg/l and 13000 µg/l). Similar to Datasonde results, conductivities were also elevated at RMs 1.93 and 0.48 in Indian Creek (respective medians of 1180 µmhos/cm and 1090 µmhos/cm).

Water samples were analyzed for organic compounds twice at three sites in Swamp Creek (RMs 2.20, 1.59 and 0.28), at RM 0.45 in the unnamed tributary, and at RM 1.93 in Indian Creek (Table 8, Appendix Table A-3). Metolachlor and atrazine were the most frequently detected compounds in the basin with each accounting for 24% of detections. Concentrations of aldrin exceeded water quality criterion in Swamp Creek at RMs 2.20 and 1.59 on August 24 and gamma-hexachlorocyclohexane (Lindane) exceeded criterion at RM 0.28 on July 13. Additionally, dieldrin concentrations exceeded criteria in Swamp Creek at RM 0.28, in the unnamed tributary, and in Indian Creek on one occasion.

Harris Creek and Ballinger Run

Ballinger Run enters Harris Creek at RM 2.51 which in turn enters the Stillwater River at RM 33.80. Six animal feedlots are located in the 18.1 mi^2 drainage area of the Harris Creek subbasin totaling over 1,000 animal units (88% swine) and producing 1,000 tons of waste per year. In addition to the Village of Bradford WWTP discharge at RM 1.30, Ballinger Run also receives the discharges from the Village's nine CSOs between RMs 1.8 and 0.8. Water chemistry samples were collected at two sites (RMs 5.20 and 2.02) in Harris Creek and at three sites (RMs 2.75, 1.40, and 0.59) in Ballinger Run. Additionally, Datasondes®® monitored D.O., temperature, pH, and conductivity from July 7-9 at RM 2.02 in Harris Creek (Figures 46-48, Tables 6 and 7, Appendix Tables A-1 - A-2).

Datasonde D.O. concentrations measured at RM 2.02 in Harris Creek remained above water quality criterion with percent saturations ranging from 65% to 103%. While temperature and pH at the site remained relatively stable (respective medians of 22.18EC and 7.91 SU), conductivity fluctuated from 688 µmhos/cm to 1238 µmhos/cm. Daytime grab D.O. in Harris Creek also remained above water quality criterion with respective median concentrations and percent saturations approximately 6.0 mg/l and 70% at both sites. Ballinger Run concentrations, however, fell below WWH water quality criteria in all measurements at RM 2.75 and once at RM 1.40. (Flows at the headwater site (RM 2.75), low at the beginning of the survey, completely dried up during the last week of the survey.) Median D.O. percent saturation in Ballinger Run increased longitudinally from 42% at RM 2.75 to 104% at RM 0.59.

While BOD_5 concentrations remained low in Harris Creek, higher values were recorded in Ballinger Run at RMs 2.75 and 1.40 (respective medians of 3.65 mg/l and 4 mg/l). Median ammonia-N concentrations in Harris Creek decreased from 0.137 mg/l at RM 5.20 to 0.06 mg/l at RM 2.02. Ballinger Run ammonia-N concentrations were consistently elevated above the 90th percentile reference concentration with medians ranging from 0.134 mg/l at RM 0.59 to 0.516 mg/l at RM 1.40. Additionally, ammonia-N (3.06 mg/l) exceeded water quality criterion upstream of the Bradford WWTP at RM 1.40 on September 8, a day of minimal flow. (BOD_5 was also elevated at the site on this day (13 mg/l)).

Harris Creek nitrate-nitrite-N and total phosphorus concentrations increased downstream of the Ballinger Run confluence. Respective median concentrations of 0.338 mg/l and 0.15 mg/l were recorded upstream at RM 5.20 compared to medians of 1.94 mg/l and 0.64 mg/l downstream at RM 2.02. While nitrate-nitrite-N concentrations measured in Ballinger Run remained low upstream at RMs 2.75 and 1.40 (overall median of 0.28 mg/l), values increased downstream of the Bradford WWTP at RM 0.59 (median 4.95 mg/l). Phosphorus concentrations recorded in Ballinger Run also increased longitudinally with median values of 0.14 mg/l at RM 2.75, 0.34 mg/l at RM 1.40, and 2.08 mg/l at RM 0.59 downstream of the Bradford WWTP.

An overall median TSS concentration of 16.5 mg/l was measured for Harris Creek sites. While concentrations recorded in Ballinger Run at RMs 1.40 and 0.59 remained relatively low (overall median of 11 mg/l), concentrations were exceptionally elevated upstream at RM 2.75 (median and maximum values of 122 mg/l and 171 mg/l). It should be noted that as stream levels diminished over the summer, sampling became increasingly difficult, especially at headwater

sites. Some results may be somewhat compromised in that substrate may have inadvertently been disturbed, thus introducing sediments into the sample.

Fecal coliform and *E. coli* concentrations above the primary contact recreational criteria were documented at both Harris Creek sites. Exceptionally elevated fecal coliform concentrations were measured on July 27 in Ballinger Run at RM 1.40 (121000 colonies/100ml) and RM 0.59 (50000 colonies/100ml). (The Covington rainfall station recorded 0.46 inches of rain during the 24-hour period beginning at 8 a.m. on July 26 (MCD 1999)). Concentrations of fecal coliform at RM 1.40 and *E. coli* at RM 0.59 also exceeded criteria on September 8.

Concentrations of manganese frequently exceeded water quality criterion in Harris Creek at RM 5.20 and in Ballinger Run at RMs 2.75 and 1.40 while iron exceeded criterion at both Harris Creek sites and at RM 2.75 in Ballinger Run. Elevated aluminum (median 3745 µg/l) was also recorded at RM 2.75 in Ballinger Run. The highest median values of the entire survey for chloride (728 mg/l), sodium (319 mg/l), conductivity (2500 µmhos/cm), total dissolved solids (1990 mg/l), calcium (175 mg/l), magnesium (83 mg/l), and water hardness (779 mg/l $CaCO_3$) were recorded at RM 1.40 in Ballinger Run. Barium (median 222 µg/l) and strontium (median 3170 µg/l) were also elevated at the site. (This site is downstream of seven of the nine Bradford CSOs.) Chloride, sodium, conductivity, and TDS remained elevated at RM 0.59 in Ballinger Run and at RM 2.02 in Harris Creek downstream of the Ballinger Run confluence.

Water samples in Harris Creek at RM 2.02 and in Ballinger Run at RM 0.59 were analyzed for organic compounds twice during the 1999 survey (Table 8, Appendix Table A-3). Exceedences of water quality criteria were documented at the Harris Creek site for ã-hexachlorocyclohexane, Dieldrin and bis(2-ethylhexyl)phthalate. Heptachlor exceeded criterion in Ballinger Run on one occasion.

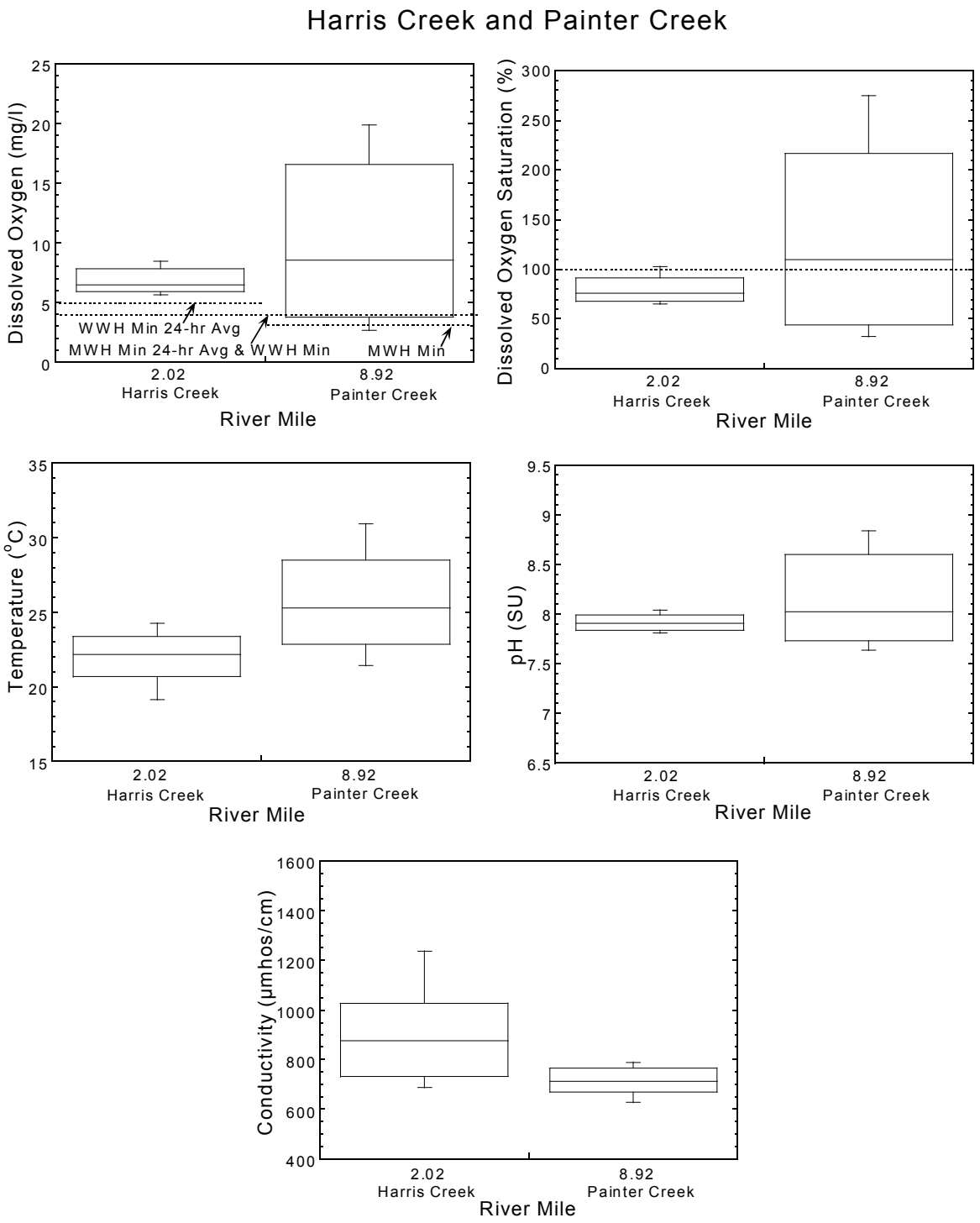


Figure 46. Left to right from the top: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, temperature, pH, and conductivity recorded hourly with Datasonde™ continuous monitors from July 7-9 in Harris Creek and Painter Creek, 1999.

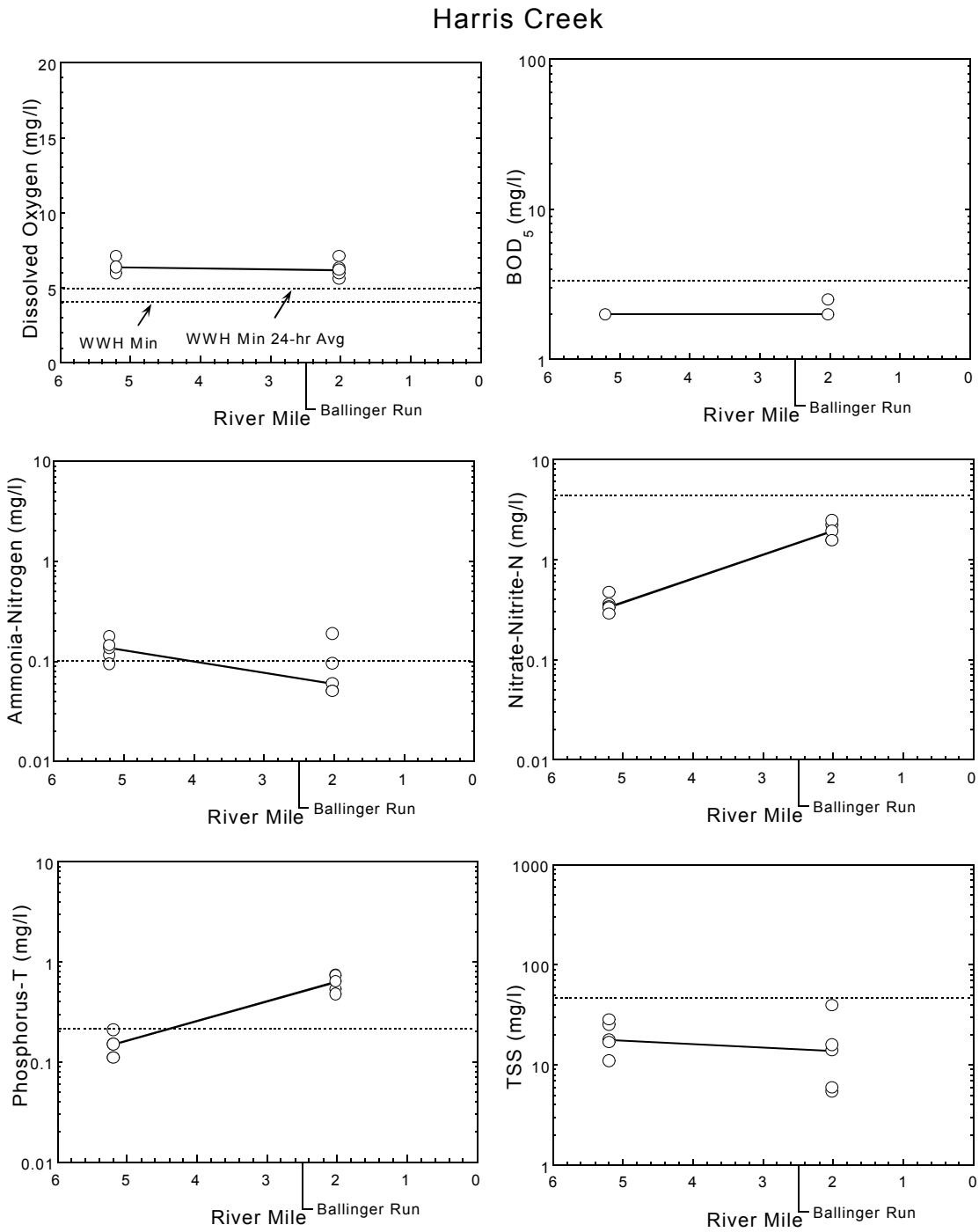


Figure 47. Longitudinal scatter plots of water chemistry results (daytime grabs) in Harris Creek during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

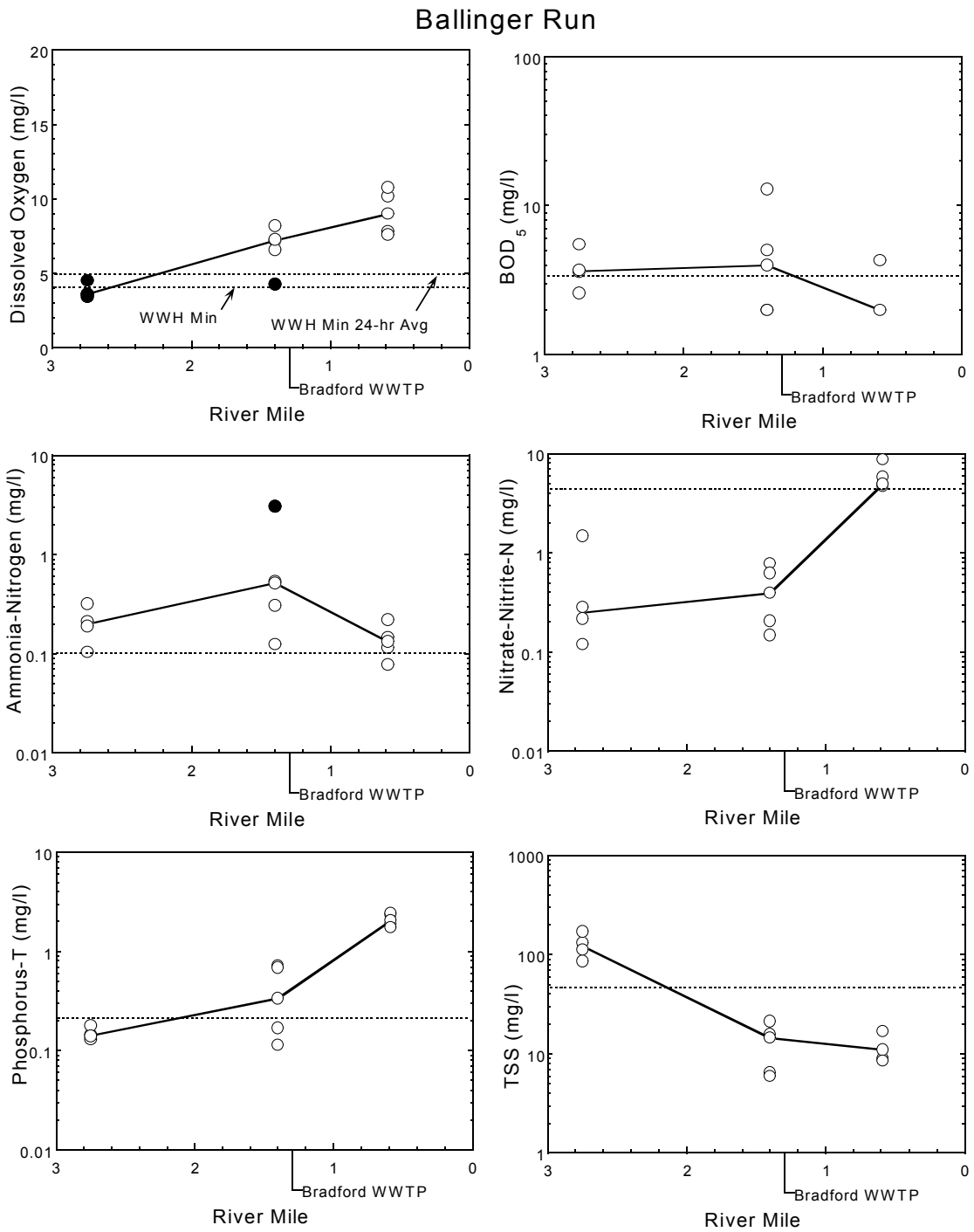


Figure 48. Longitudinal scatter plots of water chemistry results (daytime grabs) in Ballinger Run during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for dissolved oxygen and ammonia-nitrogen are shown as solid circles.)

Greenville Creek

Greenville Creek, draining approximately 200 mi^2 (167 mi^2 in Ohio and 33 mi^2 in Indiana), receives the discharges from the Greenville WWTP at RM 19.35 and the Gettysburg WTP at RM 10.45 before entering the Stillwater River mainstem at RM 32.38. The unsewered community of Gettysburg borders Greenville Creek in the vicinity of RM 10.5 to RM 10.0. Additionally, there are 55 animal feedlots in the Darke County portion of Greenville Creek subbasin totaling 13,738 animal units (59% swine and 21% poultry) and accounting for 13,037 tons of waste annually (MVRPC 1998).

Stream flow from May through September 1999 (Figure 49) was measured by the USGS gage station in Greenville Creek near Bradford (RM 6.10). Reflecting below average precipitation, flows fell below the 80% duration exceedence level in early August and continued to decline, falling below the 7 Q_{10} flow in September (USGS 1981 and 2000). The gage recorded the lowest September monthly mean (9.47 cfs) of record (1931-1999). On specific water chemistry sampling days in Greenville Creek during the 1999 survey, the gage recorded a mean daily high of 35 cfs on July 13 and a mean daily low on September 9 of 9.2 cfs.

Datasondes® monitored D.O., temperature, pH, and conductivity from July 7-9 at four sites in Greenville Creek (RMs 26.60, 23.08, 16.22, and 13.70) during the 1999 survey (Figure 50, Appendix Table A-2). Datasonde D.O. concentrations remained above EWH minimum water quality criterion (5.0 mg/l) at all four sites with minimal diurnal variation. Dissolved oxygen percent saturation medians ranged from 79% at RM 16.22 to 93% at RM 13.70. Temperatures and pH also exhibited nominal diurnal variation. Longitudinally, median temperatures increased from 23.29EC at RM 26.60 to 24.96EC at RM 13.70 while pH medians decreased minimally from 8.20 SU at RM 26.60 to 8.04 SU at RM 13.70. Median conductivities ranged from 644 µmhos/cm at RM 26.44 to 812 µmhos/cm at RM 16.22.

Daytime grab water chemistry samples were collected at 13 sites in Greenville Creek (Figures 51-26, Tables 6 and 7, Appendix Table A-1). D.O. concentrations dropped below EWH water quality criteria on one occasion each at RMs 24.60, 23.08, 16.22, and 9.92. Median percent saturations ranged from 76% at RMs 10.86 and 9.92 to 120% at RM 34.48. The majority (91%) of BOD_5 concentrations were less than the MDL (2 mg/l) with the highest value (5 mg/l) recorded at RM 18.34 downstream of the Greenville WWTP. Eighty-five percent of the ammonia-N concentrations were below the 90th percentile reference concentration. The highest concentrations were measured downstream of the Greenville WWTP at RM 18.34 (median and maximum of 0.123 mg/l and 0.749 mg/l). While all concentrations of nitrate-nitrite remained below the 90th percentile reference concentrations, values increased markedly in the reach downstream of the Greenville WWTP. Overall median and maximum concentrations of 0.45 mg/l and 0.813 mg/l were measured for the upper six sites (RMs 34.48 -19.55) compared to a median and maximum of 2.17 mg/l and 4.48 mg/l for the lower seven sites (RMs 18.34-1.45). Phosphorus followed a similar pattern with values increasing downstream of the Greenville WWTP and remaining elevated at sites downstream. Respective overall median and maximum phosphorus concentrations increased from 0.1 mg/l and 0.3 mg/l (RMs 34.48 -19.55) to 0.35 mg/l and 1.17 mg/l (RMs 18.34-1.45).

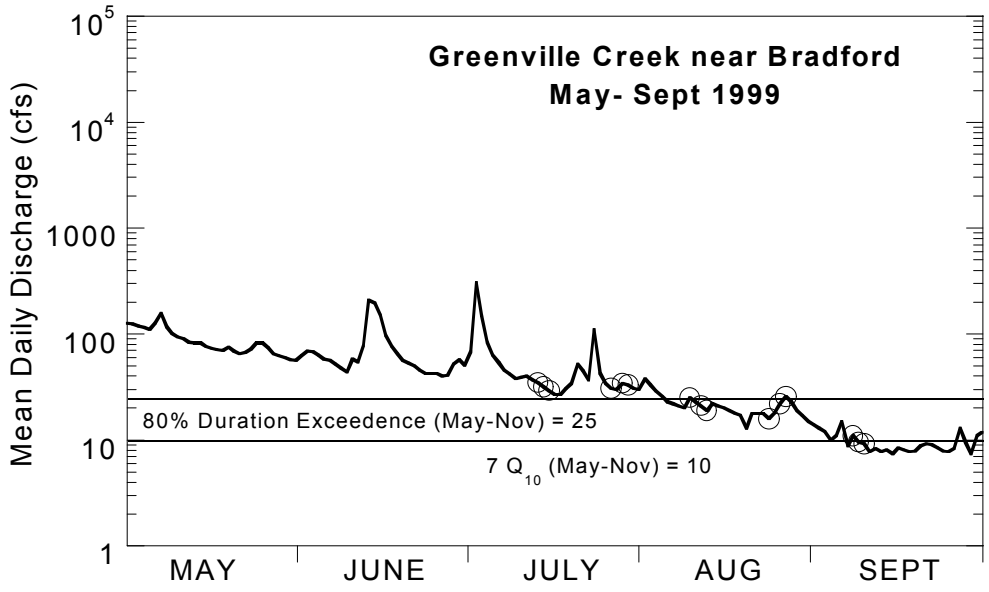


Figure 49. May through September, 1999 flow hydrograph for Greenville Creek near Bradford (Rm 6.10). Low flow conditions ($7Q_{10}$) and 80% duration exceedence flows are based on USGS station #03264000 (period of record 1930-1997). Open circles indicate river discharge on water chemistry sampling days in the Greenville Creek basin.

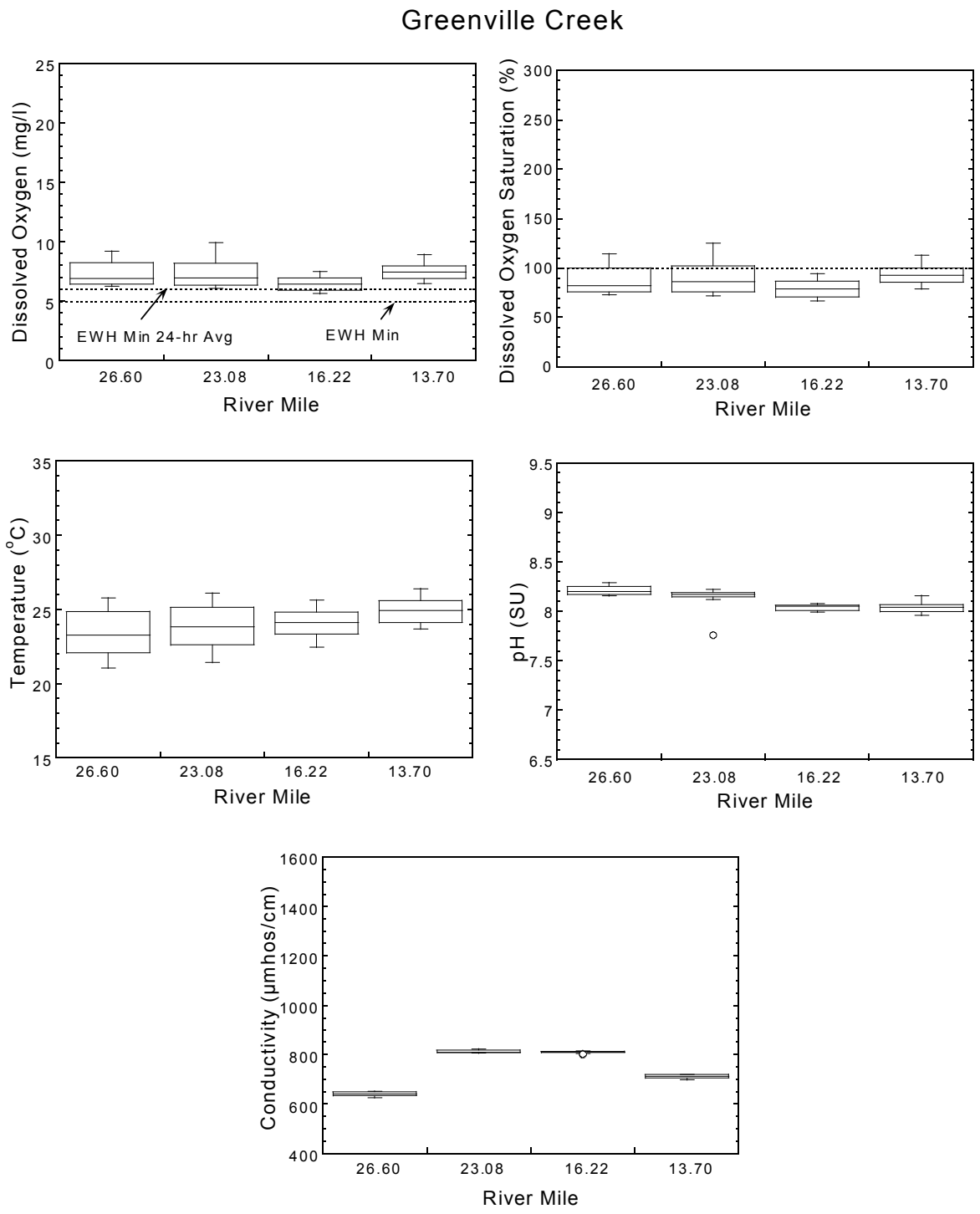


Figure 50. Left to right from the top: Distributions of dissolved oxygen concentration, percent dissolved oxygen saturation, temperature, pH, and conductivity recorded hourly with Datasonde™ continuous monitors from July 7-9 in Greenville Creek, 1999.

Total suspended solids generally remained low throughout Greenville Creek with an overall median of 12.5 mg/l. Site medians ranged from 5 mg/l at the two upstream sites (RMs 34.48 and 30.23) to 20 mg/l at RM 10.86. Bridge construction throughout the summer on SR 36 over Greenville Creek at RM 18.0 and over Bolton Run near its confluence with Greenville Creek (RM 12.81) may have contributed to TSS loadings at downstream sites. Maximum values of 69 mg/l (RM 18.34) and 67.5 mg/l (RM 19.55) were recorded on August 25 following a rain event.

Limited bacteriological sampling (typically two fecal coliform and one *E. coli* per site) during the survey indicated levels of *E. coli* above recreational criterion at RMs 26.60, 24.60, 23.08, 19.55, 18.34, 10.86, 9.92, and 6.10. Fecal coliform concentrations above recreational criterion were recorded at RMs 19.55, 18.34, and 9.92. Field investigators discovered raw sewage entering Greenville Creek via a large storm sewer located just downstream of the Ohio Street sampling site (RM 19.55). Subsequent repair of the sanitary sewers after the survey eliminated the inflow of sewage to the creek.

Concentrations of iron exceeded water quality criterion at RMs 19.55 and 18.34 on one occasion and manganese exceeded criterion once at RMs 18.34 and 13.70. Additionally, concentrations of aluminum were elevated on August 25 at RM 19.55 (2390 µg/l) and RM 18.34 (1340 µg/l) while COD was elevated at RM 1.45 (149 mg/l) on July 15.

While well within water quality criteria, higher concentrations of copper (15 µg/l and 14 µg/l), lead (9 µg/l), and zinc (60 µg/l) were recorded at RM 18.34 on occasion. Silver (0.4 µg/l) was also detected at the site. In addition to being downstream of the Greenville WWTP, this site was downstream of an unauthorized discharge from Jafe Decorating, a manufacturer of decorated and colored glass. In 1998 Jafe connected the floor drain rinse water to a tile which discharged to Greenville Creek in the vicinity of RM 18.80. Constituents of concern in the wastestream included copper, silver, ammonia-N, and TSS. This discharge was discontinued in December 1999 when Jafe was required to connect to the City of Greenville collection system.

Eight of the thirteen water chemistry sites in Greenville Creek were sampled for organic compounds twice during the 1999 survey (Table 8, Appendix Table A-3). The most frequently detected compound, gamma-hexachlorocyclohexane (31% of detections), exceeded water quality criterion at six of seven sites. Concentrations of aldrin (RMs 18.34 and 6.10), dieldrin (RMs 10.86 and 6.10), heptachlor (RM 6.10), and napthalene (RM 16.22) also exceeded water quality criteria on occasion.

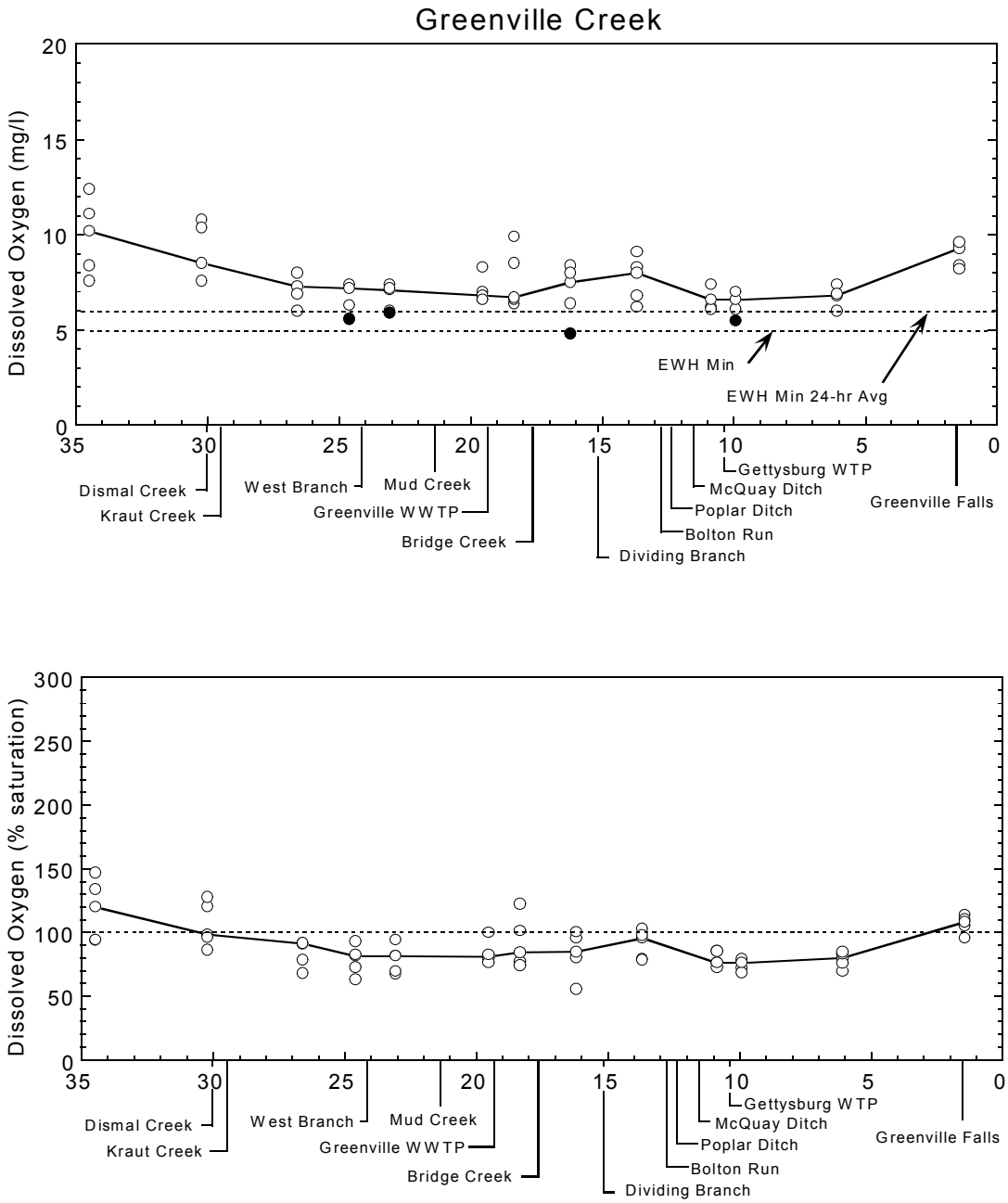


Figure 51. Longitudinal scatter plots (daytime grabs) of dissolved oxygen concentrations (upper figure) and percent dissolved oxygen saturations (lower figure) in Greenville Creek during the 1999 survey. The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the upper figure. Values below the water quality criteria are indicated by solid circles.

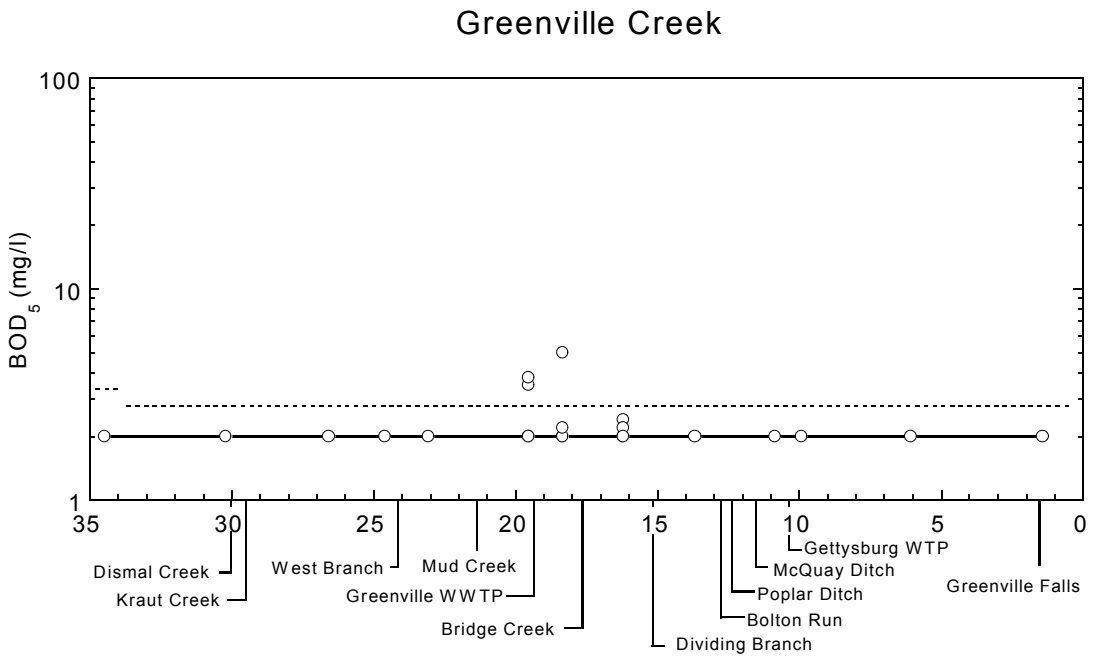


Figure 52. Longitudinal scatter plot (daytime grabs) of BOD_5 concentrations in Greenville Creek during the 1999 survey (MDL is 2 mg/l). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

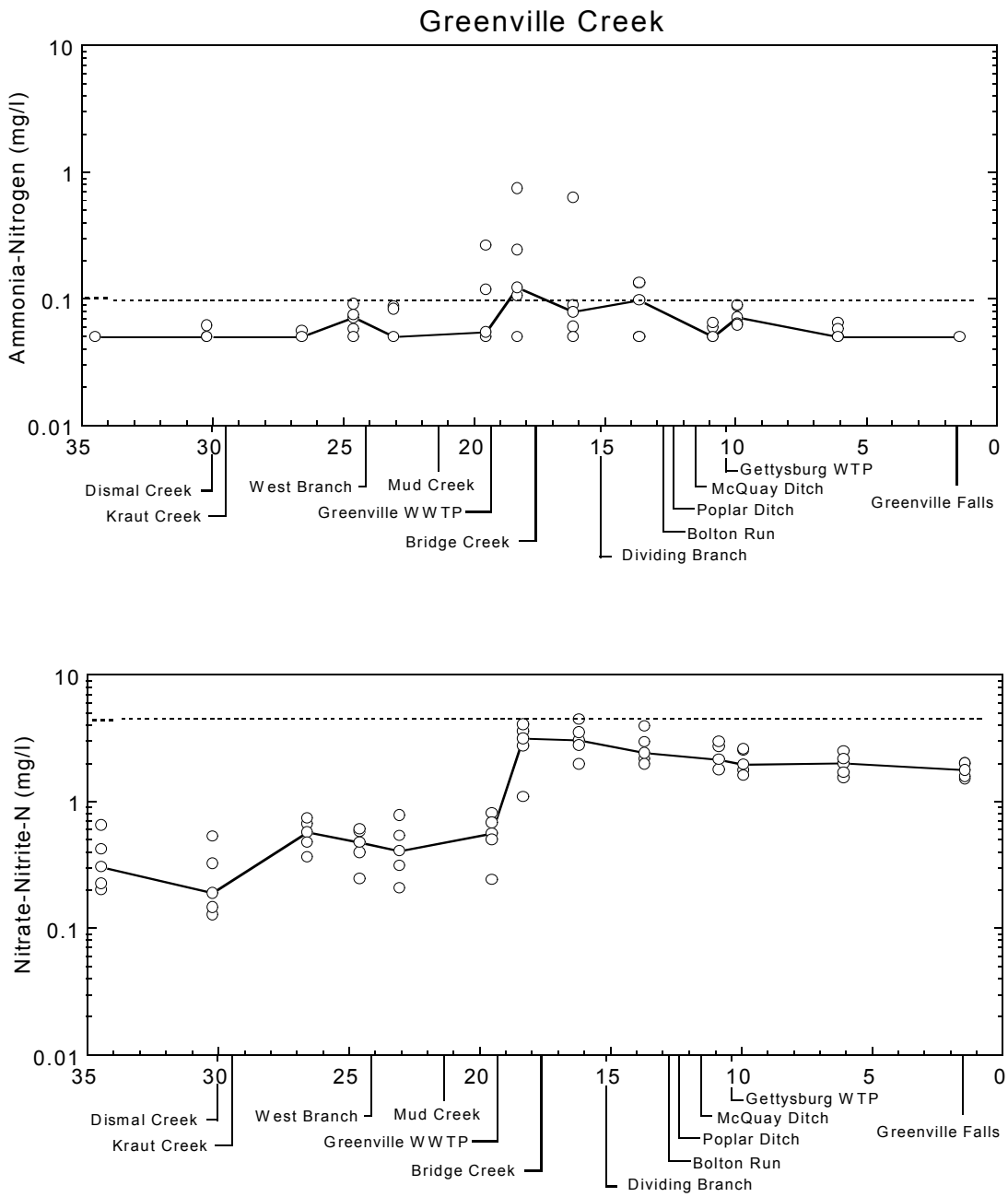


Figure 53. Longitudinal scatter plots (daytime grabs) of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in Greenville Creek during the 1999 survey (MDL is 0.05 mg/l for NH_3-N and 0.1 mg/l for NO_3-NO_2-N). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

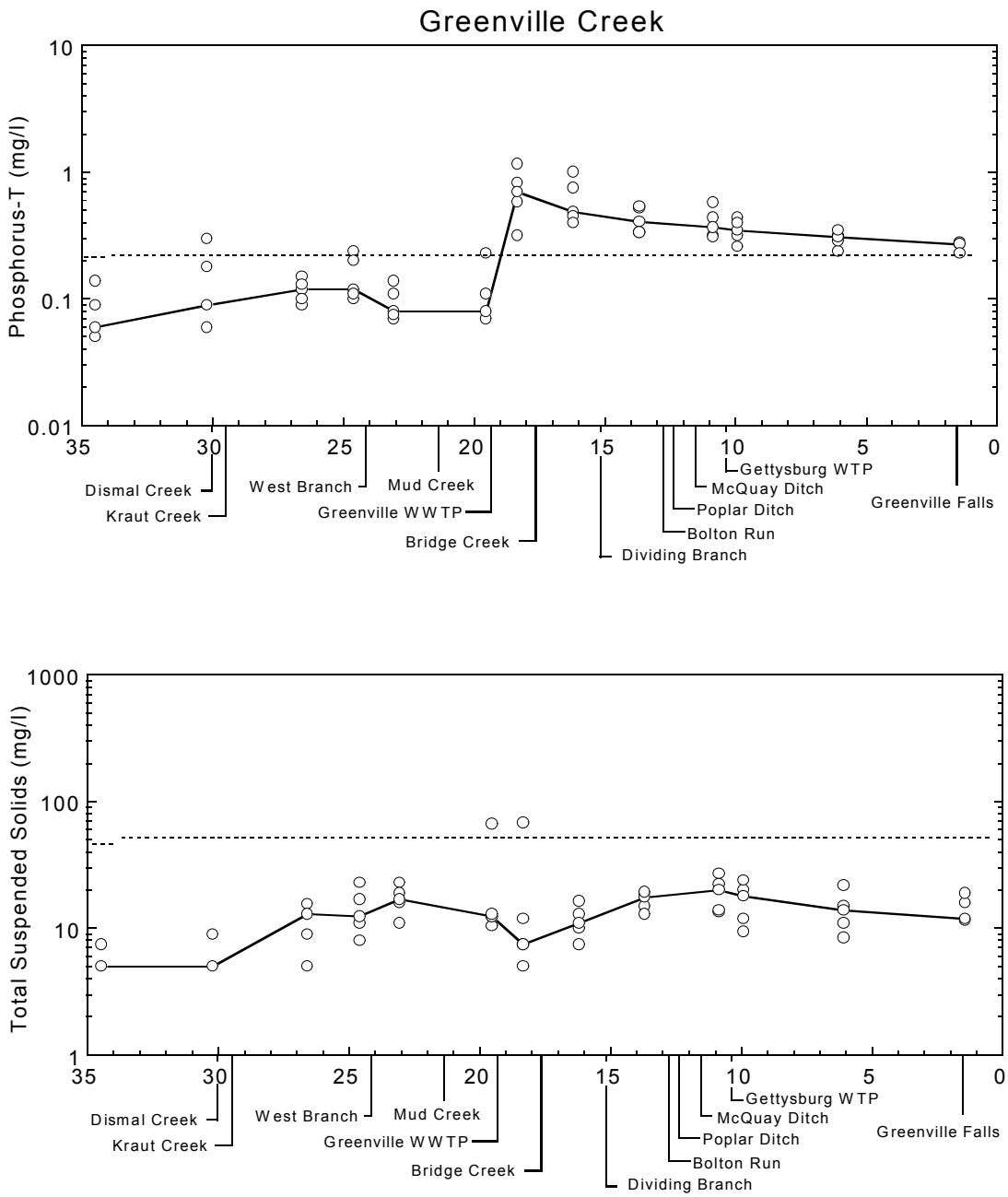


Figure 54. Longitudinal scatter plots (daytime grabs) of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in Greenville Creek during the 1999 survey (MDL is 0.05 mg/l for TP and 5 mg/l for TSS). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Dismal Creek
Dismal Creek, draining approximately 19.3 mi^2 (8.5 mi^2 in Ohio and 10.8 mi^2 in Indiana),enters Greenville Creek at RM 30.15. Water chemistry grab samples were collected from three locations in Dismal Creek (RMs 4.70, 1.76, and 0.10) during the 1999 survey (Figure 55, Tables 6 and 7, Appendix Table A-1).

Daytime grab D.O. concentrations frequently fell below WWH water quality criteria at RMs 1.76 and 0.10 while supersaturated values were recorded at the upstream site (RM 4.70). Median D.O. percent saturations decreased from 141% at RM 4.70 to 51% at RM 0.10. (Field crews noted abundant algae at the Indiana/Ohio border (RM 4.70)). All BOD_5 concentrations recorded were less than the MDL of 2 mg/l.

Ammonia-N concentrations frequently exceeded the 90th percentile reference concentration (53% of values) with the highest levels recorded at RM 1.76 (median and maximum of 0.158 mg/l and 0.315 mg/l). While nitrate-nitrite-N remained low with overall median and maximum values of 0.3 mg/l and 1.02 mg/l, phosphorus concentrations were elevated throughout with medians ranging from 0.25 mg/l at RM 4.70 to 0.42 mg/l at RM 1.76. Total suspended solids remained low with overall median and maximum concentrations of 6 mg/l and 24 mg/l.

Bacteriological testing (typically two fecal coliform and one *E. coli* per site) revealed fecal coliform above recreational criterion at RM 1.76 on one occasion and *E. coli* concentrations above criterion at RMs 1.76 and 0.10. Concentrations of manganese frequently exceeded criterion at all sites while iron exceeded criterion at RM 1.76. Additionally, while well within water quality criteria, higher arsenic levels were measured in Dismal Creek with overall median and maximum values of 10 µg/l and 16 µg/l.

During the 1999 survey, the Morris Mobile Home Park (MHP) located on Beamsville-Union City Road east of Union City discharged to Dismal Creek via a tributary upstream (within 1.5 miles) of the Hill Grove Southern Road sampling site (RM 1.76). In November of 1999, the MHP connected to the Union City WWTP (discharge to Gray Branch to Mississinewa River). Additionally, sites in Dismal Creek downstream of the confluence of O'Conner Ditch at RM 3.94 may also be impacted by discharges from Heartland Processing, a dairy located in Indiana. It was discovered that this facility historically discharged process water to the storm sewers leading to O'Conner Ditch and subsequently to Dismal Creek. In November of 1999 storm sewers were re-engineered to divert all Heartland flow to the sanitary sewers.

Kraut Creek and North Fork Kraut Creek
The North Fork Kraut Creek enters Kraut Creek at RM 1.65 which in turn enters Greenville Creek at RM 29.53. Water chemistry samples were collected at two sites (RMs 5.95 and 0.60) in Kraut Creek and at one site (RM 0.84) in the North Fork Kraut Creek (Figure 56, Tables 6 and 7, Appendix Table A-1). Daytime grab D.O. concentrations remained above WWH water quality criteria in both tributaries. Kraut Creek median percent saturations decreased from 114% at RM 5.95 to 82% at RM 0.60 while a median of 117% was recorded at RM 0.84 in the North Fork Kraut Creek. Inordinate algal growth was noted by field staff at supersaturated locations.

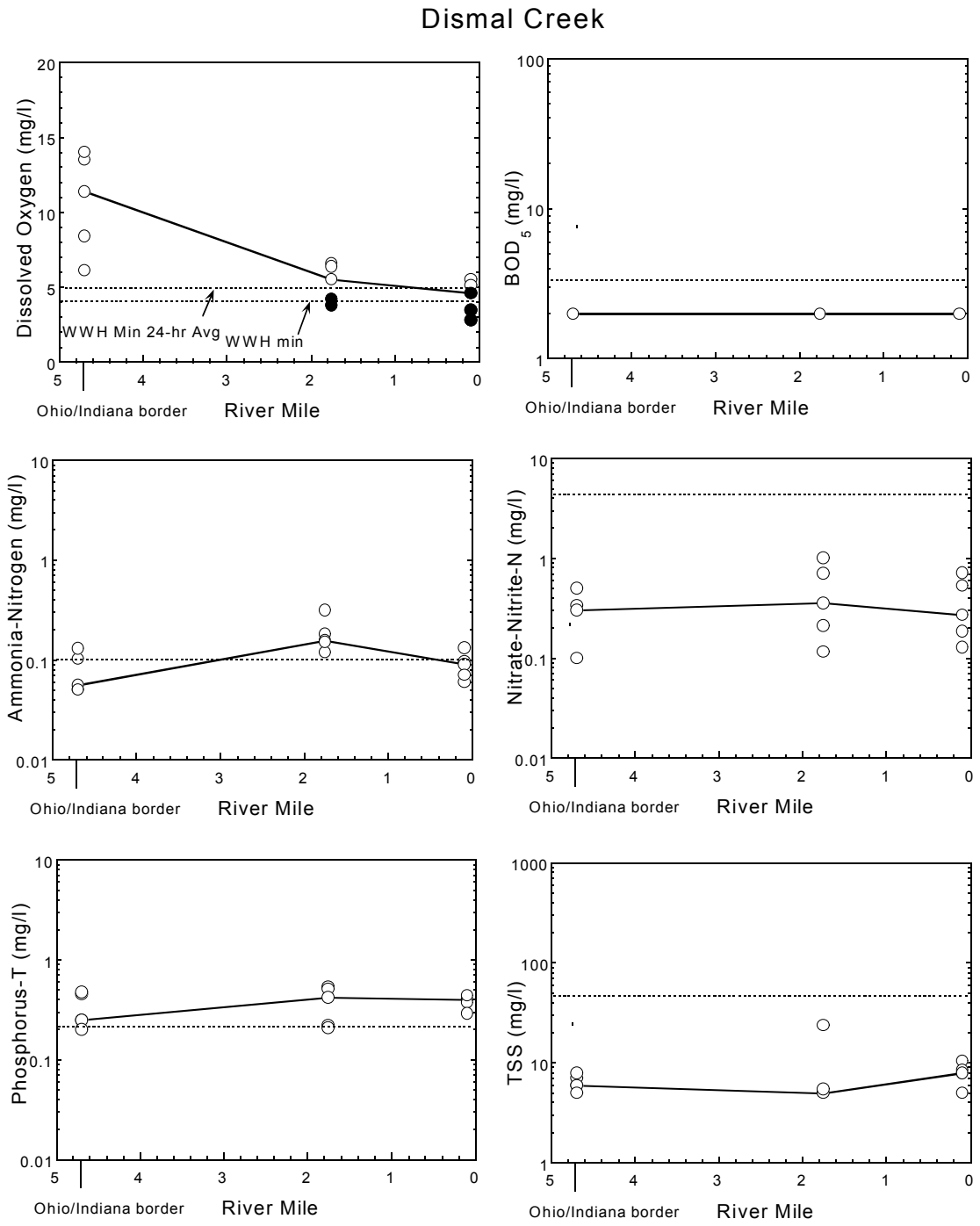


Figure 55. Longitudinal scatter plots of water chemistry results (daytime grabs) in Dismal Creek during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid circles.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

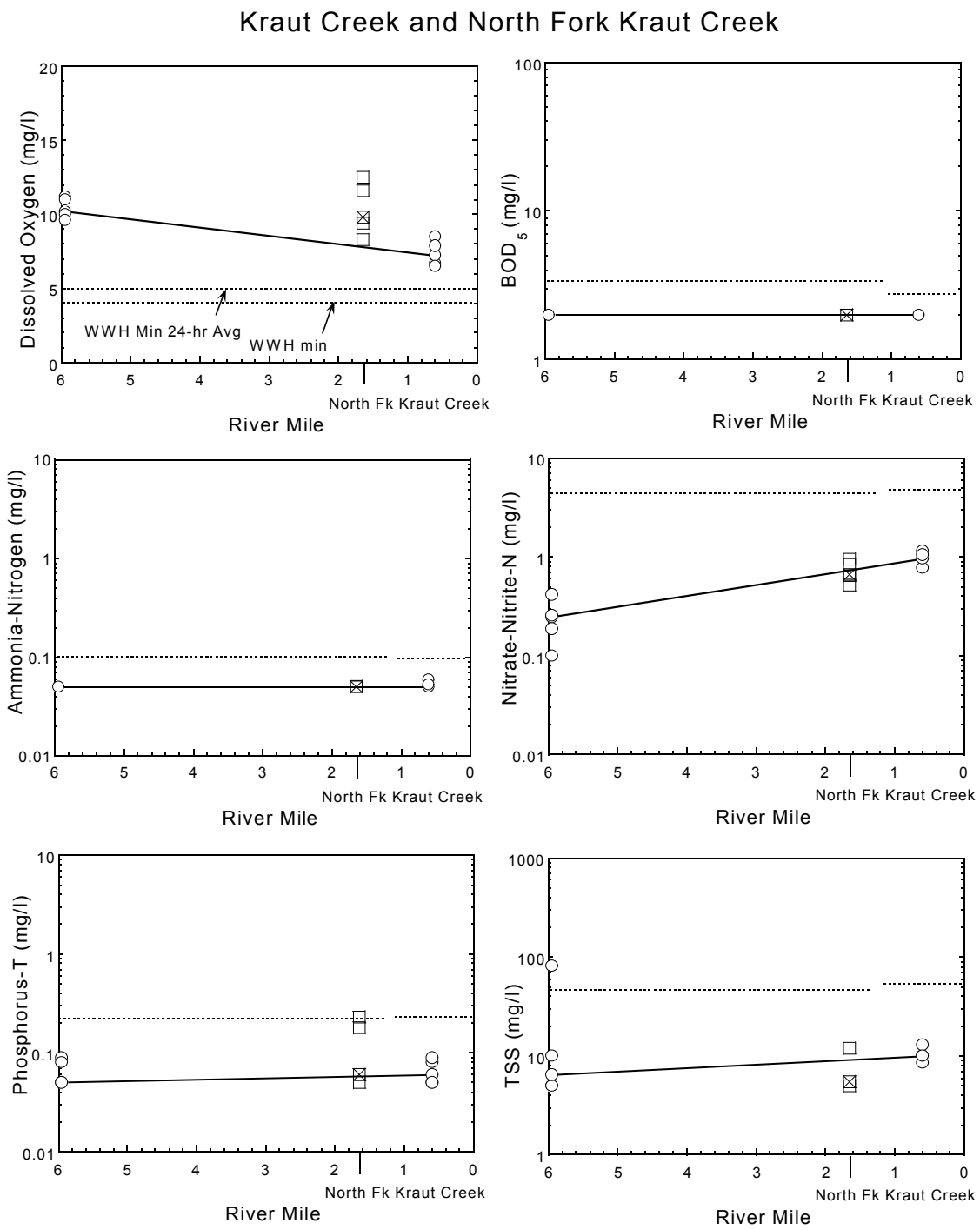


Figure 56. Longitudinal scatter plots of water chemistry results (daytime grabs) in Kraut Creek (circles) and the North Fork Kraut Creek (squares) during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled in Kraut Creek while an 'X' depicts the median for North Fork Kraut Creek. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

BOD_5 and ammonia-N concentrations remained low with all values less than or approaching applicable MDLs.

Kraut Creek median nitrate-nitrite-N increased longitudinally from 0.25 mg/l at RM 5.95 to 0.97 mg/l at RM 0.60 downstream of the North Fork Kraut Creek (RM 0.84 median 0.67 mg/l). Phosphorus concentrations also remained low in Kraut Creek with overall median and maximum values of 0.06 mg/l and 0.09 mg/l. Respective median and maximum phosphorus values of 0.06 mg/l and 0.23 mg/l were measured at the North Fork Kraut Creek site. TSS levels also generally remained low throughout the basin with an overall median value of 8.5 mg/l recorded for all sites. A maximum concentration of 82 mg/l was recorded at RM 5.95 in Kraut Creek on August 11.

Bacteriological sampling in Kraut Creek (two fecal coliform and one *E. coli* per site) indicate *E. coli* concentrations above primary contact recreational criterion at both sites (RMs 5.95 and 0.60). Concentrations of iron exceeded water quality criterion on one occasion at RM 5.95 in Kraut Creek.

Both sites in Kraut Creek (RMs 5.95 and 0.60) were sampled for organic compounds twice during the 1999 survey (Table 8, Appendix Table A-3). Low concentrations of alpha-hexachlorocyclohexane were detected at each location once while heptachlor epoxide was detected at RM 5.95.

West Branch Greenville Creek and Spring Branch

Draining 26 mi^2, West Branch Greenville Creek receives the flow from Spring Branch (confluence at RM 6.85) before entering Greenville Creek at RM 24.28. Water chemistry samples were collected from three sites (RMs 7.36, 5.78, and 0.30) in West Branch Greenville Creek and from one site (RM 0.25) in Spring Branch during the 1999 survey (Figure 57, Tables 6 and 7, Appendix Table A-1). Dissolved oxygen concentrations recorded in both tributaries remained above WWH water quality criteria. Median percent saturations in West Branch Greenville Creek decreased from 111% at RM 7.36 to 90% at RM 0.30 while a median of 87% was recorded in Spring Branch. All BOD_5 and ammonia-N concentrations were less than applicable MDLs (2 mg/l and 0.05 mg/l, respectively). An overall median of 0.662 mg/l was recorded for all nitrate-nitrite-N concentrations measured in the basin. Phosphorus concentrations in West Branch Greenville Creek also remained low with 67% of values less than or equal to the MDL of 0.05 mg/l and a maximum concentration of 0.21 mg/l recorded on July 28 at RM 5.78. Spring Branch phosphorus concentrations were somewhat higher with respective median and maximum values of 0.08 mg/l and 0.19 mg/l. While TSS concentrations in Spring Branch and in the upper reaches of West Branch Greenville Creek remained low, significantly higher values were recorded downstream at RM 0.30 (median and maximum values of 19 mg/l and 36 mg/l).

Limited bacteriological sampling (typically two fecal coliform and one *E. coli* per site) reveal fecal coliform above primary contact recreational criterion at RM 7.36 in West Branch Greenville Creek on one occasion and *E. coli* concentrations above criteria at RMs 7.36 and 5.78. Iron exceeded criterion on one occasion at RM 0.30 in the West Branch Greenville Creek.

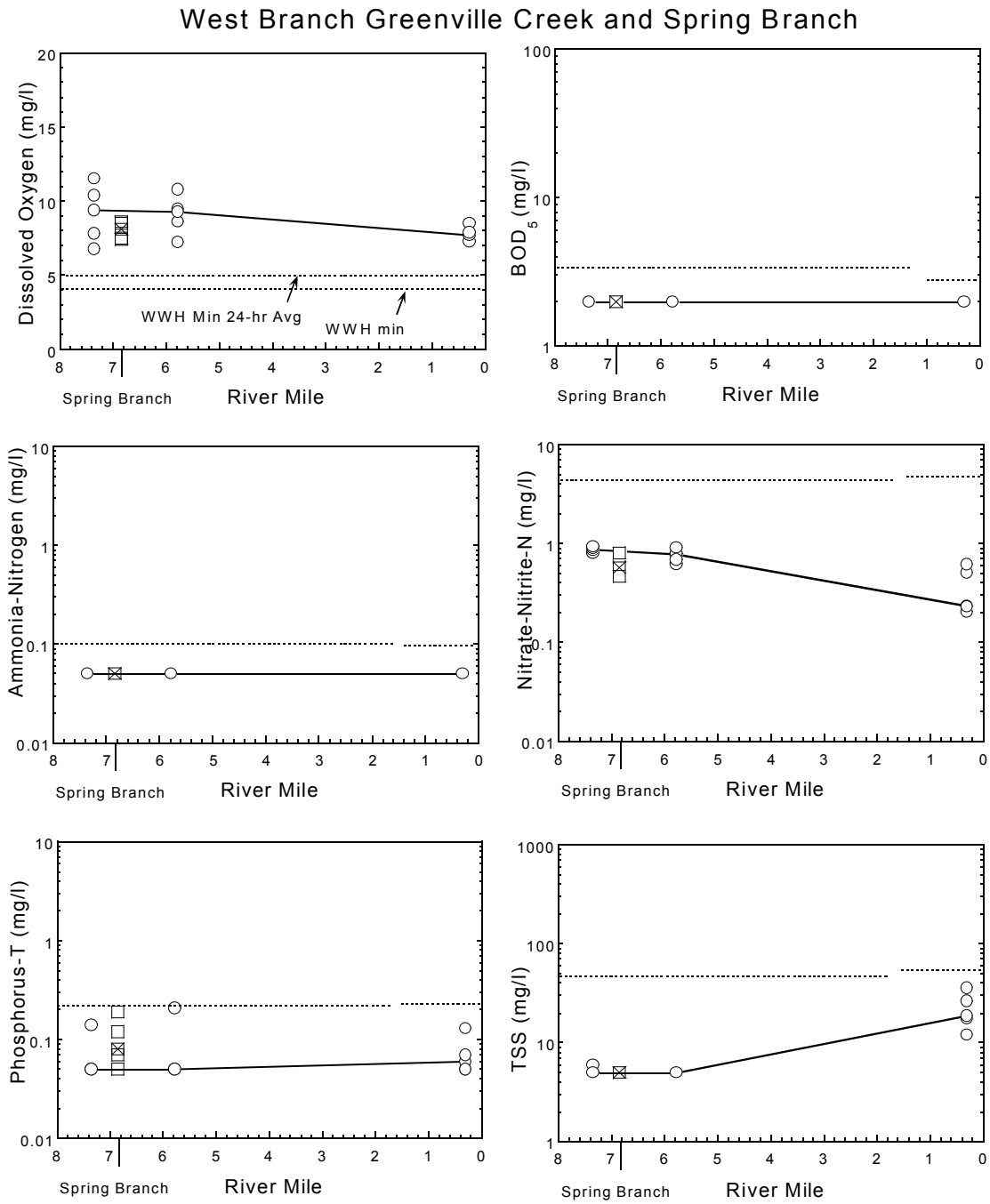


Figure 57. Longitudinal scatter plots of water chemistry results (daytime grabs) in West Branch Greenville Creek (circles) and Spring Branch (squares) during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled in West Branch Greenville Creek while an 'X' depicts the median for Spring Branch. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Mud Creek, Prairie Outlet, and Lake Branch Ditch

Prairie Outlet and Lake Branch Ditch enter Mud Creek at RMs 5.44 and 5.29, respectively. Draining 29.5 mi^2, Mud Creek then enters Greenville Creek at RM 21.31 near Greenville. The unsewered community of Wayne Lakes is bordered to the east by Prairie Outlet and to the west by Mud Creek. Additionally, Prairie Outlet has historically received occasional runoff from area veal farms. Daytime grab water chemistry samples were collected at four sites in Mud Creek (RMs 7.50, 5.87, 4.67, and 0.09), one site (RM 0.80) in Prairie Outlet and one site (RM 0.40) in Lake Branch Ditch (Figures 58-61, Tables 6 and 7, Appendix Table A-1). During the 1999 survey, the WWH aquatic life use designation and water quality criteria applied in Mud Creek and Prairie Outlet. Given that Lake Branch Ditch did not have an aquatic life use designation during the 1999 survey, water quality criteria identified for the limited resource water (LRW) use designation applied (OAC rule 3745-1-07).

Dissolved oxygen concentrations frequently fell below WWH criteria in Mud Creek at the headwater site (RM 7.50) and near the mouth (RM 0.09). Median percent saturations ranged from 43% at RM 7.50 to 94% at RM 4.67. Concentrations in both Prairie Outlet and Lake Branch Ditch remained above applicable criteria with median concentrations and percent saturations of 6.2 mg/l and 70% and 6.8 mg/l and 79%, respectively.

BOD_5 concentrations remained low throughout the basin with the majority (93%) of values less than the MDL (2 mg/l). While 72% of ammonia-N values recorded in the basin were less than the applicable 90th percentile reference concentrations, somewhat higher levels were measured in Mud Creek at RM 7.50 (median and maximum of 0.107 mg/l and 0.336 mg/l) and RM 0.09 (median and maximum of 0.096 mg/l and 0.232 mg/l).

Nitrate-nitrite-N remained low in Mud Creek and the two tributaries with an overall median of 0.56 mg/l for all values measured in the basin. The highest concentrations (median and maximum values of 1.32 mg/l and 1.42 mg/l) were recorded in Prairie Outlet. An overall median of 0.07 mg/l was recorded for all phosphorus concentrations in the Mud Creek basin during the 1999 survey. Site medians ranged from 0.05 mg/l at RM 5.87 in Mud Creek to 0.12 mg/l at RM 0.09. Maximum values ranging from 0.16 mg/l (RM 4.67) to 0.25 mg/l (RM 0.09) were recorded on July 28 after localized precipitation.

TSS medians of 5 mg/l were recorded at sites in Prairie Outlet and Lake Branch Ditch. Mud Creek median TSS concentrations increased longitudinally from 5 mg/l at the headwater sites (RMs 7.50 and 5.87) to 18 mg/l at RM 0.09. (A heavy silt and muck substrate was observed at RM 0.09 and field crews noted turbidity at the site throughout the survey.) A maximum of 88 mg/l was recorded in the headwaters at RM 7.50 on September 8, a day of exceptionally low flow. Additionally, concentrations of iron (11300 µg/l), manganese (628 µg/l), arsenic (7 µg/l), lead (8 µg/l), zinc (46 µg/l), and aluminum (7000 µg/l) recorded on this day at RM 7.50 were the highest measured in the Mud Creek basin during the survey. (It should be noted that as stream levels diminished over the summer, sampling became increasingly difficult, especially at headwater sites. Some results may be somewhat compromised in that substrate may have inadvertently been disturbed, thus introducing sediments into the sample.)

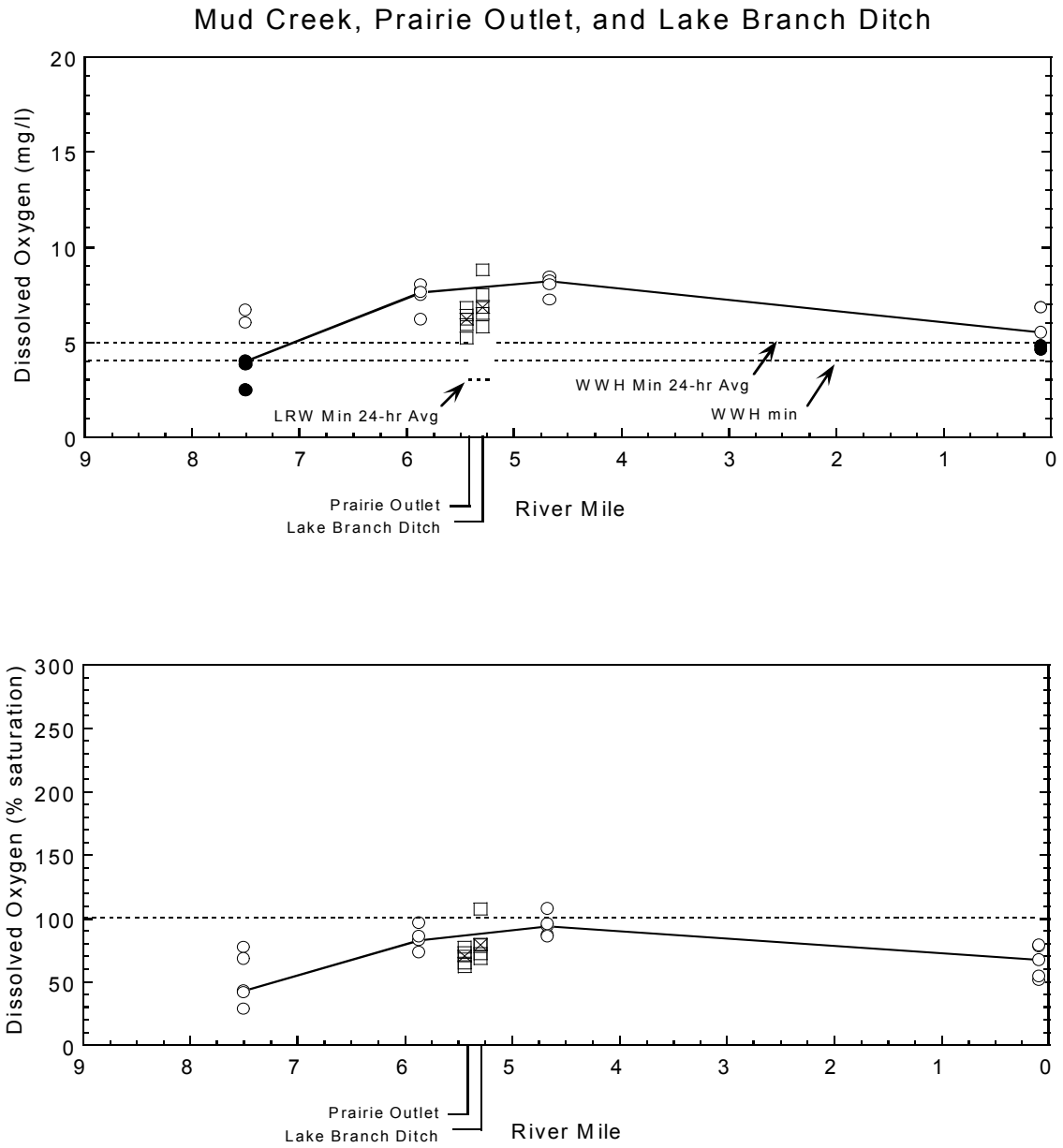


Figure 58. Longitudinal scatter plots (daytime grabs) of dissolved oxygen concentrations (upper figure) and percent dissolved oxygen saturations (lower figure) in Mud Creek (circles), Prairie Outlet, and Lake Branch Ditch (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Mud Creek while an 'X' depicts the medians for Prairie Outlet and Lake Branch Ditch. Water quality criteria are shown in the upper figure. Values below the water quality criteria are indicated by solid circles.

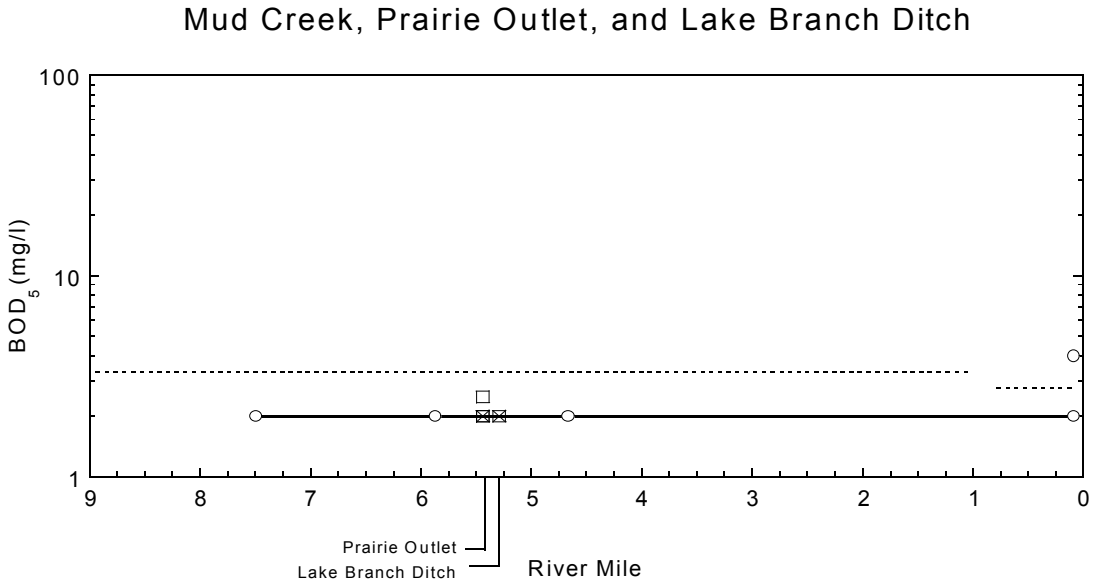


Figure 59. Longitudinal scatter plot (daytime grabs) of BOD_5 concentrations in Mud Creek (circles), Prairie Outlet, and Lake Branch Ditch (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Mud Creek while an 'X' depicts the medians for Prairie Outlet and Lake Branch Ditch. The dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

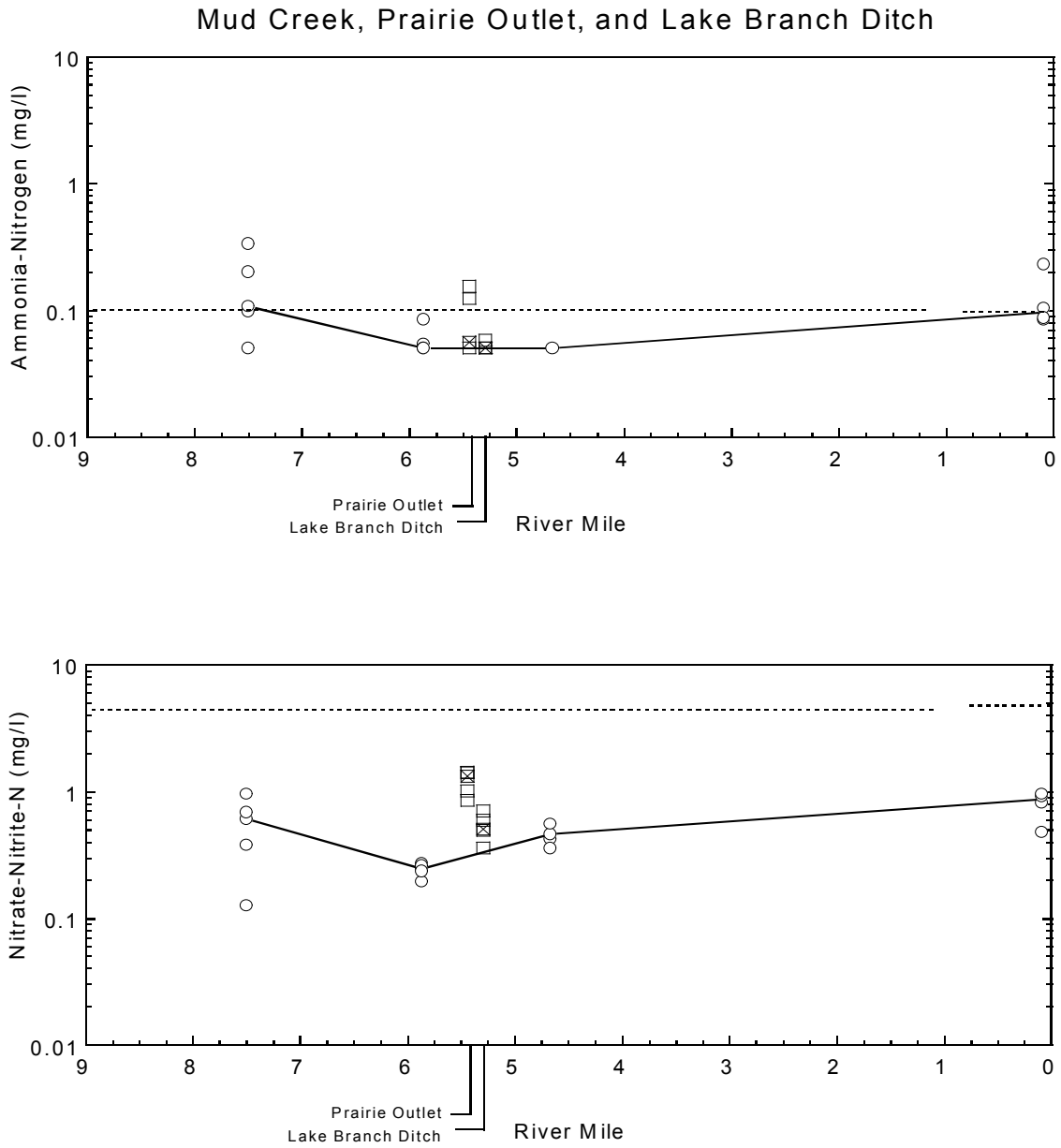


Figure 60. Longitudinal scatter plots (daytime grabs) of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in Mud Creek (circles), Prairie Outlet, and Lake Branch Ditch (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Mud Creek while an 'X' depicts the medians for Prairie Outlet and Lake Branch Ditch. Dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

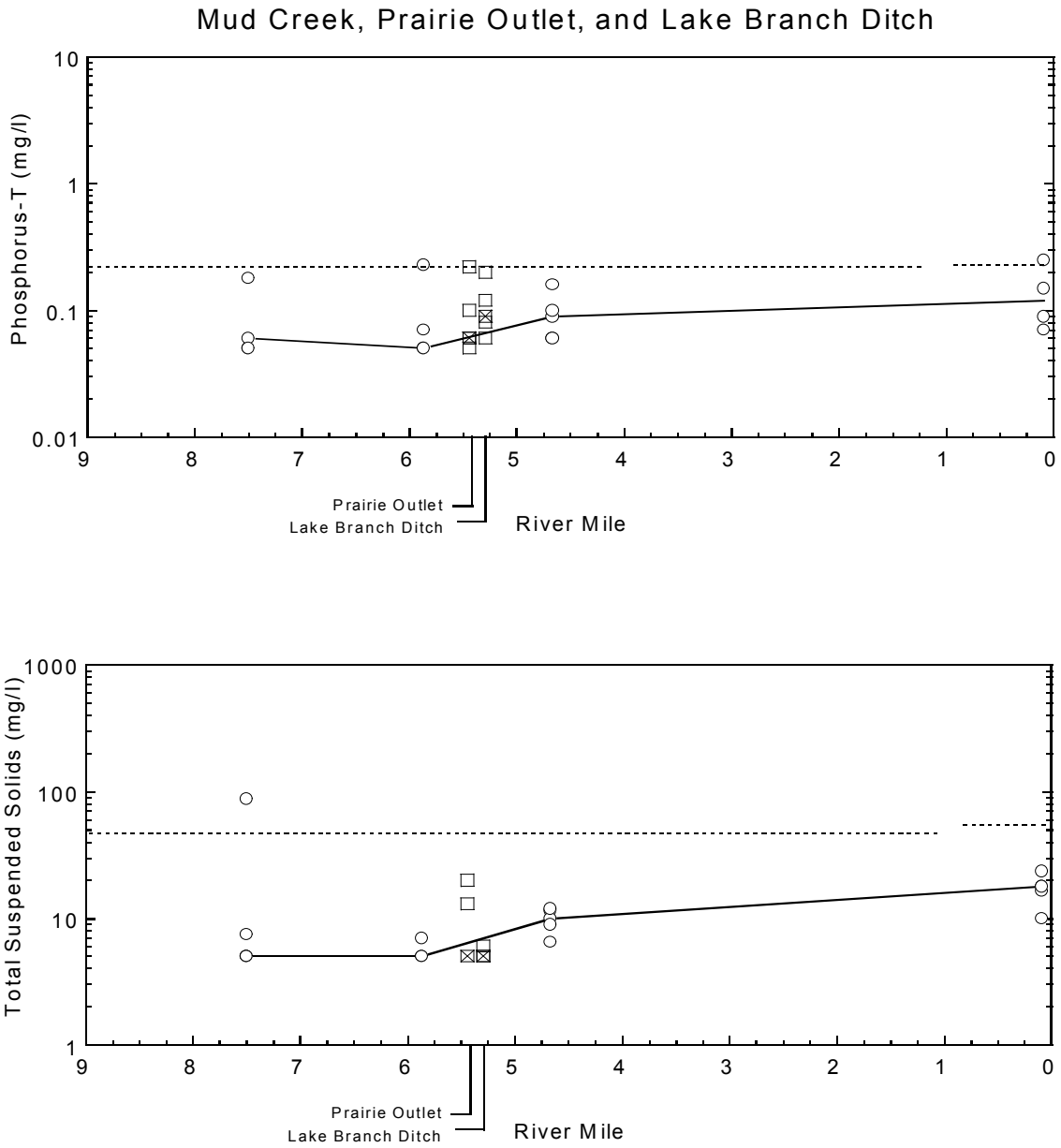


Figure 61. Longitudinal scatter plots (daytime grabs) of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in Mud Creek (circles), Prairie Outlet, and Lake Branch Ditch (both represented by squares) during the 1999 survey. The solid line depicts the median value at each river mile sampled in Mud Creek while an 'X' depicts the medians for Prairie Outlet and Lake Branch Ditch. Dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Limited bacteriological sampling (two fecal coliform and one *E. coli* per site) revealed concentrations of fecal coliform above recreational criterion at all sites in the basin on July 28 after recent precipitation with the highest values recorded in Prairie Outlet (21000 colonies/100 ml) and Lake Branch Ditch (9000 colonies/100 ml). *E. coli* exceeded recreational criterion at all sites on September 8.

Water samples analyzed for organic compounds at RM 0.09 in Mud Creek reveal aldrin concentrations above criterion on August 25 (Table 8, Appendix Table A-3).

Dividing Branch
Dividing Branch drains an 11.0 mi^2 area before entering Greenville Creek at RM 15.21. Three sites (RMs 3.87, 3.51, and 0.10) were sampled in this tributary during the 1999 survey (Figure 62, Tables 6 and 7, Appendix Table A-1).

While median D.O. percent saturations ranged from 84% at RM 0.10 to 96% at RM 3.51, concentrations fell below WWH criterion at RM 3.87 on August 11. Median BOD_5 concentrations decreased longitudinally from 3.4 mg/l upstream at RM 3.87 to 2 mg/l near the mouth at RM 0.10. Ammonia-N remained low with most values less than the MDL and a basin maximum of 0.057 mg/l. Nitrate-nitrite-N median and maximum concentrations of 0.104 mg/l and 0.922 mg/l were measured for the basin. Phosphorus concentrations were also generally low (site medians # 0.08 mg/l) with maximums measured at RM 0.10 (0.44 mg/l) and RM 3.87 (0.25 mg/l) on July 28 following a rain event. All TSS concentrations recorded downstream at RM 0.10 were less than the MDL of 5 mg/l. Slightly higher concentrations were measured at the two upstream sites with values ranging from 6 mg/l to 22 mg/l.

Bacteriological sampling in Dividing Branch was limited to a total of four fecal coliform samples and two *E. coli* samples. Fecal coliform concentrations exceeded the primary contact recreation criterion at RMs 3.87 and 0.10 while *E. coli* concentrations exceeded criterion at RMs 3.51 and 0.10. Several manganese concentrations exceeded criterion at RMs 3.87 and 3.51 while iron exceeded criterion on one occasion at RM 3.51. Additionally, while within water quality criteria, the highest cadmium concentration of the entire survey (2.2 µg/l) was recorded in Dividing Branch at RM 3.87 on August 11.

Bridge Creek, Bolton Run, Poplar Ditch, and McQuay Ditch
Daytime grab water chemistry samples were collected from Bridge Creek (RM 0.28), Bolton Run (RM 0.60), Poplar Ditch (RM 0.50), and McQuay Ditch (RM 0.50) during the 1999 survey (Figure 63, Tables 6 and 7, Appendix Table A-1). Bridge Creek, Bolton Run, Poplar Ditch, and McQuay Ditch enter Greenville Creek at RMs 17.77, 12.81, 12.32, and 11.56, respectively.

Median D.O. percent saturations of 65% and 62%, respectively, were recorded in Bolton Run and McQuay Ditch with concentrations falling below WWH water quality criterion at both sites on September 8, during lower flows. Higher values were measured in Bridge Creek and Poplar Ditch with respective median percent saturations of 116% and 96%. All BOD_5 concentrations measured in the four tributaries were less than or equal to the MDL of 2 mg/l.

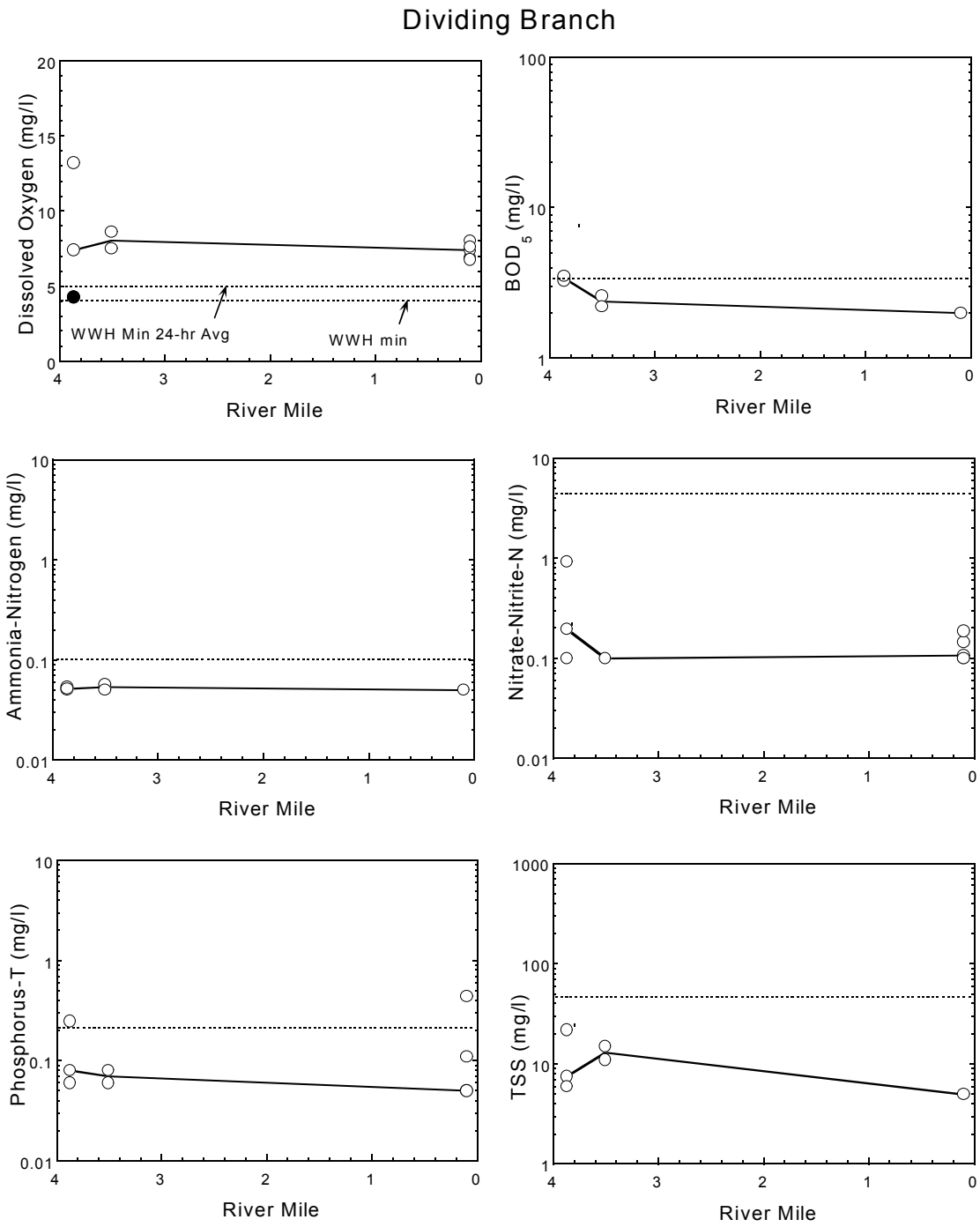


Figure 62. Longitudinal scatter plots of water chemistry results (daytime grabs) in Dividing Branch during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid circles.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

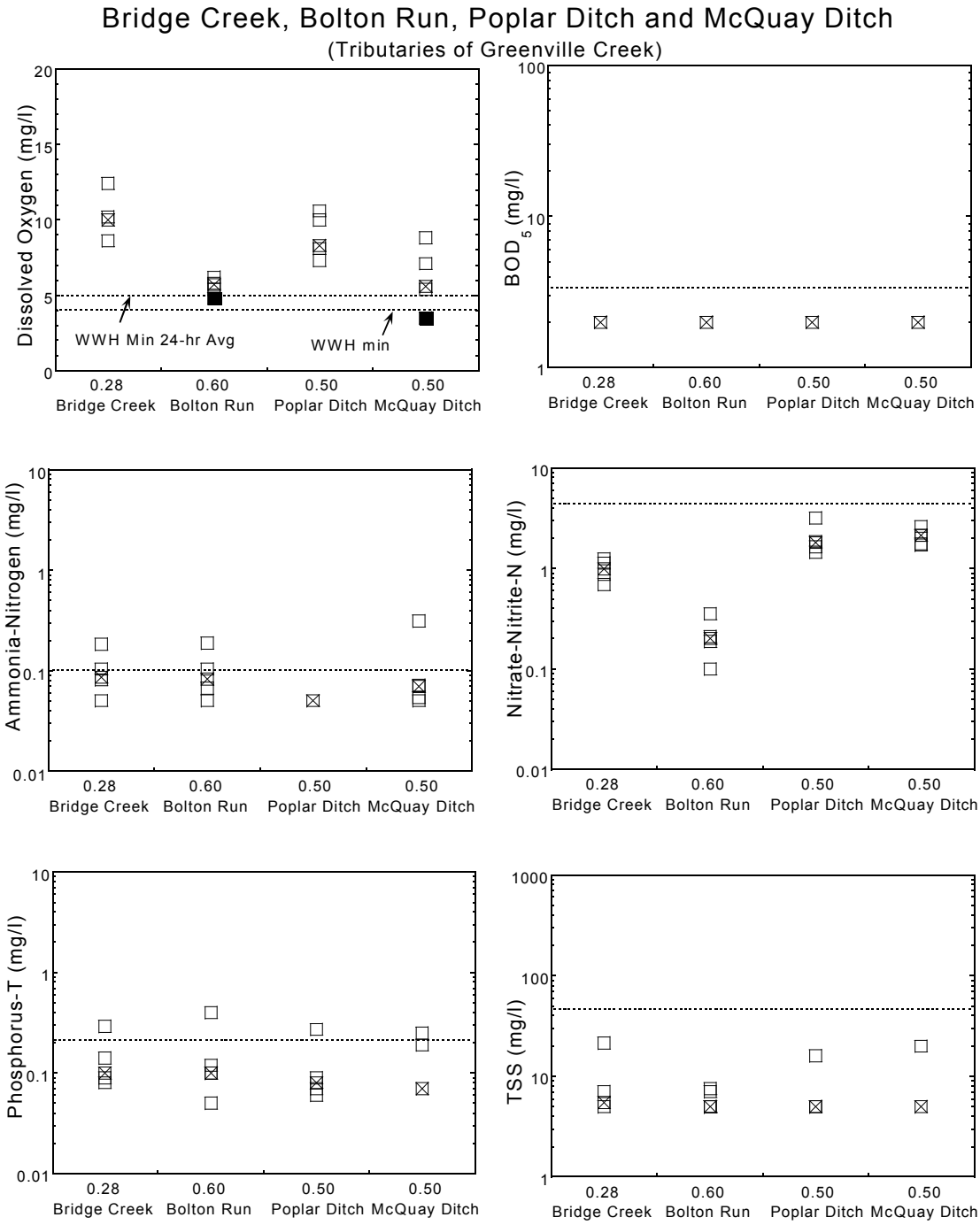


Figure 63. Scatter plots of water chemistry results (daytime grabs) in Bridge Creek, Bolton Run, Poplar Ditch, and McQuay Ditch during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The median at each site is depicted by an 'X'. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid squares.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Ammonia-N concentrations were generally low with medians ranging from 0.05 mg/l in Poplar Ditch to 0.086 mg/l in Bridge Creek. Excluding Poplar Ditch where all ammonia-N values were less than the MDL, maximum values ranged from 0.182 mg/l in Bridge Creek to 0.314 mg/l in McQuay Ditch. Nitrate-nitrite-N concentrations remained below the 90th percentile reference concentration (4.60 mg/l) in all four tributaries with site medians ranging from 0.2 mg/l in Bolton Run to 2.12 mg/l in McQuay Ditch. Phosphorus concentrations were also generally low with medians ranging from 0.07 mg/l in McQuay Ditch to 0.1 mg/l in Bridge Creek and Bolton Run. Values above the 90th percentile reference concentration (0.206 mg/l) were recorded at all sites on July 28 following a rain event.

TSS concentrations also remained low with the highest values recorded in Bridge Creek (median and maximum of 5.5 mg/l and 21.5 mg/l). Two fecal coliform samples and one *E. coli* sample were collected in each of the four tributaries during the survey. Concentrations exceeded primary contact recreation criteria in eleven of the twelve (92%) samples. The highest concentrations of fecal coliform (10686 colonies/100 ml) and *E. coli* (2005 colonies/100 ml) occurred on September 8 in McQuay Ditch. Manganese concentrations in Bolton Run exceeded criterion in all samples while one value above criterion was recorded in McQuay Ditch.

Painter Creek Subbasin (Painter Creek, Tributaries @ RMs 12.13 and 10.81, Little Painter Creek, and Heller Ditch)

Painter Creek drains 47.7 mi^2 and enters the Stillwater River at RM 29.82 downstream of Covington. The basin is impacted by a variety of factors. Sycamore Ditch, a tributary of Painter Creek (confluence RM 15.05), receives the discharge from the Arcanum WWTP at RM 0.4. Additionally, listed on the National Priorities List (NPL) of hazardous waste sites in 1983, the Arcanum Iron & Metal (AIM) Superfund site operated as a lead battery reprocessing facility from the early 1960's until 1982 within a half mile of Sycamore Ditch. Historically, contaminated runoff (lead, cadmium, zinc) from AIM entered Sycamore Ditch via a drainage tile upstream of the WWTP at RM 0.5. Cleanup of the AIM site, completed in November of 1999, included the removal of 4,000 cubic yards of lead-acid battery casing chips and excavation and disposal of contaminated soils.

Painter Creek also receives the discharges from the Village of Arcanum's numerous CSOs between RMs 16.1 and 15.2. Additionally, the Painter Creek drainage area has 15 livestock feedlot operations which total 1,749 animal units (84% swine) and produce 1,660 tons of waste a year (MVRPC 1998). Poor habitat (minimal riparian, channelization) and general agricultural runoff also impact much of the Painter Creek basin.

During the 1999 survey, the MWH aquatic life use designation and water quality criteria applied in Painter Creek from the headwaters to Darke County (RM 5.5) while the EWH aquatic life use designation applied from RM 5.5 to the mouth. The WWH use designation applied in Little Painter Creek and Heller Ditch. The two unnamed tributaries entering Painter Creek at RMs 12.13 and 10.81 did not have aquatic life use designations during the 1999 survey; therefore water quality criteria identified for the limited resource water (LRW) use designation applied (OAC rule 3745-1-07).

A Datasonde continuous monitor recorded hourly D.O. concentration, D.O. percent saturation, temperature, pH and conductivity from July 7-9 at RM 8.92 in Painter Creek in 1999 (Figure 46, Table 7, Appendix Table A-2). Dissolved oxygen concentrations generally remained above water quality criteria with 4 of the 48 measurements below the MWH minimum of 3.0 mg/l. D.O. percent saturations, however, fluctuated widely from 33% to 275%. Temperatures were elevated at the site (median 25.32EC), exceeding the maximum criterion of 29.4EC in 19% of the measurements. The site also experienced significant diurnal pH fluctuation with values ranging from 7.64 SU to 8.84 SU. Conductivity remained low with respective median and maximum values of 713 µmhos/cm and 789 µmhos/cm.

Water chemistry grab samples were collected from seven locations (RMs 17.90, 16.20, 15.48, 14.98, 8.92, 3.50, and 0.80) in Painter Creek. RM 1.07 was sampled in the tributary entering Painter Creek at RM 12.13 and RM 1.68 was sampled in the tributary entering Painter Creek at RM 10.81. Additionally, Little Painter Creek, entering Painter Creek at RM 3.35, was sampled at RM 1.18 and Heller Ditch, a tributary of Little Painter Creek (confluence RM 5.9) was sampled near the mouth at RM 0.05 (Figures 64-68, Tables 6 and 7, Appendix Table A-1).

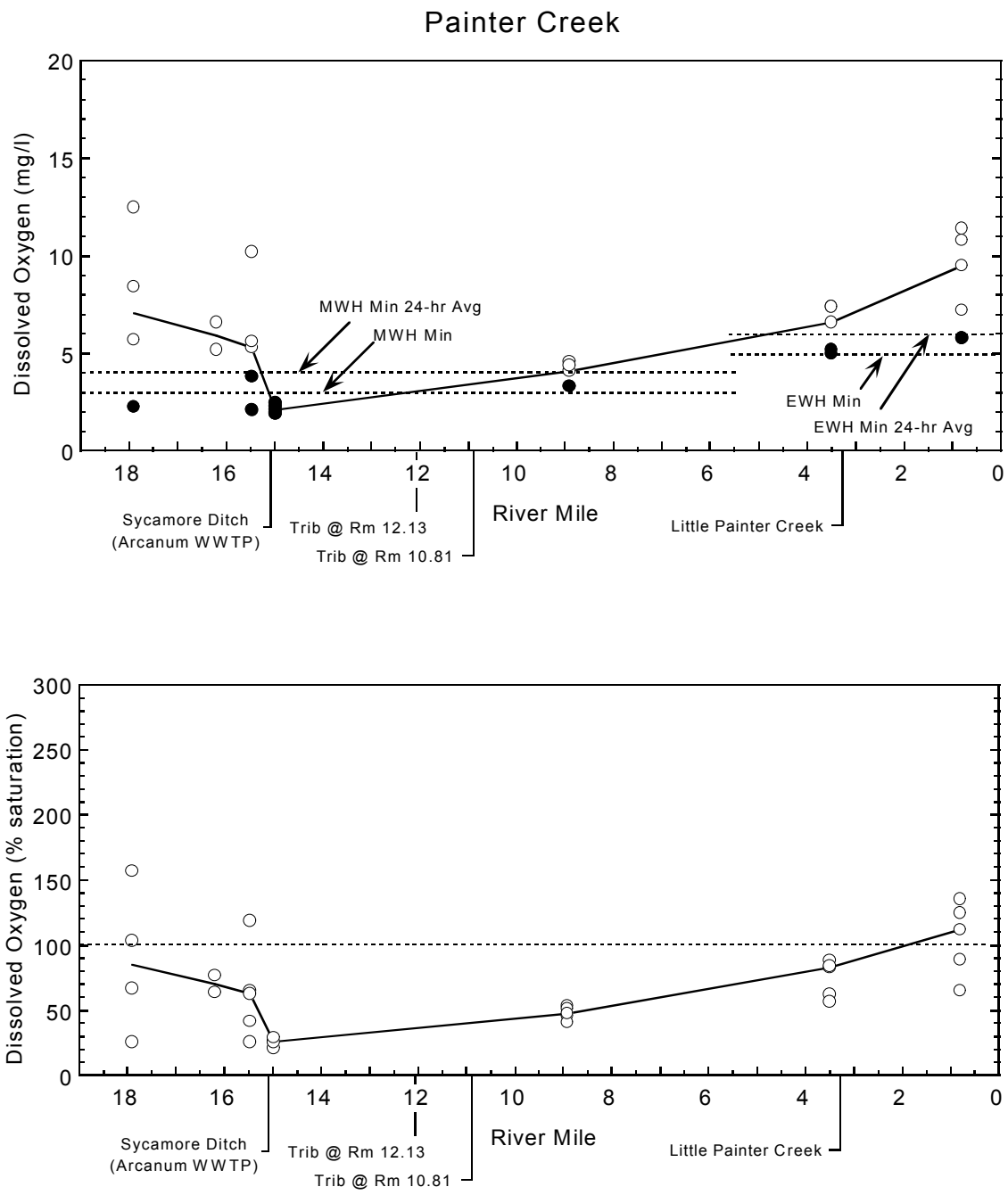


Figure 64. Longitudinal scatter plots (daytime grabs) of dissolved oxygen concentrations (upper figure) and percent dissolved oxygen saturations (lower figure) in Painter Creek during the 1999 survey. The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the upper figure. Values below the water quality criteria are indicated by solid circles.

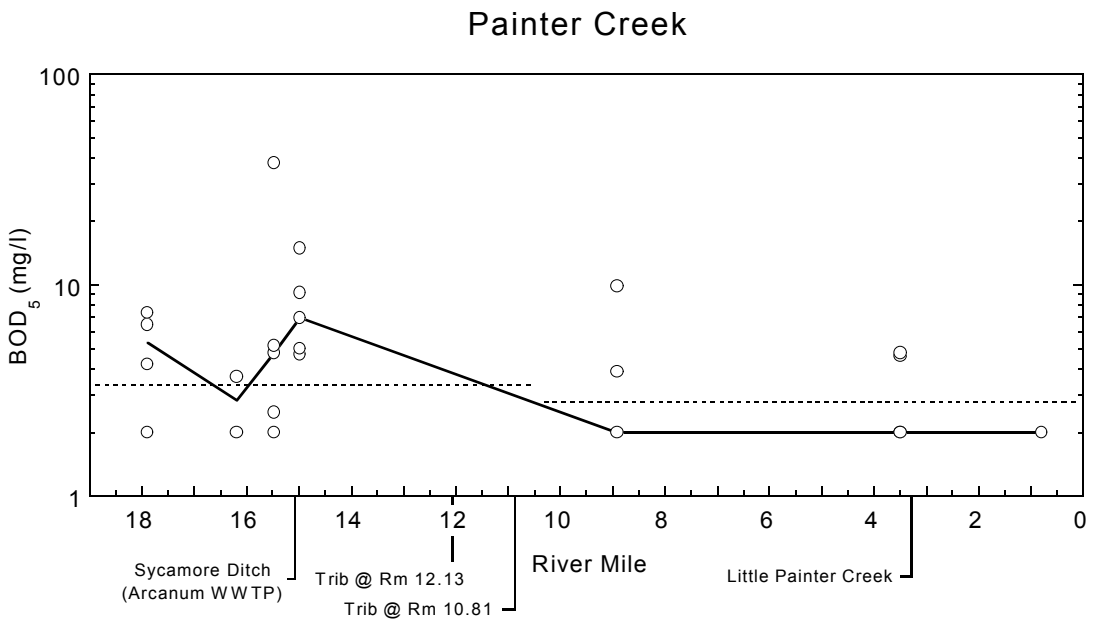


Figure 65. Longitudinal scatter plot (daytime grabs) of BOD_5 concentrations in Painter Creek during the 1999 survey (MDL is 2 mg/l). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Numerous daytime D.O. concentrations dropped below applicable water quality criteria in Painter Creek (RMs 17.90, 15.48, 14.98, 8.92, 3.50, and 0.80). Some of the lowest values in the entire survey, however, were measured downstream of Sycamore Ditch at RM 14.98 with all concentrations below the minimum MWH criterion of 3.0 mg/l and percent saturations ranging from 21% to 29%. This section of Painter Creek, downstream of the Arcanum WWTP and all of the Village CSOs, is a shallow, narrow, channelized, agricultural ditch totally lacking in riparian cover. Extreme nutrient enrichment was evidenced by the extensive algal growth (described in field notes as "pea soup") at the site throughout the survey. Median D.O. percent saturations at other Painter Creek sites ranged from 48% at RM 8.92 to 112% at RM 0.80. Dissolved oxygen concentrations below applicable criteria were also recorded in both of the unnamed tributaries to Painter Creek (confluences at RMs 12.13 and 10.81), Little Painter Creek, and Heller Ditch. (Flow diminished throughout the summer in these tributaries such that, with the exception of the Little Painter Creek site, samples could not be collected during the last two sampling periods of the survey.)

The majority (75%) of BOD_5 concentrations measured in the upper reaches (RMs 17.90-14.98) of Painter Creek were elevated above the 90th percentile reference concentration (overall median and maximum of 5 mg/l and 38 mg/l) with consistently elevated values recorded downstream of Sycamore Ditch at RM 14.98 (median and maximum values of 7 mg/l and 15 mg/l). Lower concentrations were measured at downstream sites (RMs 8.92-0.80) with 27% of values greater than the reference concentration and overall median and maximum values of 2 mg/l and 10 mg/l. BOD_5 concentrations recorded in the four tributaries were generally low with the highest values measured in Little Painter Creek (median of 4.4 mg/l and maximum of 9.7 mg/l).

Downstream of the Arcanum WWTP (Sycamore Ditch) and all Village CSOs, the highest median ammonia-N concentration of the entire survey (4.47 mg/l) was measured in Painter Creek at RM 14.98 with three of five samples exceeding water quality criterion. (The Arcanum WWTP, required to analyze ammonia-N twice a week, reported final effluent ammonia-N concentrations of 0.1 mg/l for all samples in July and September. Respective median and maximum final effluent concentrations of 0.3 mg/l and 1.5 mg/l (August 13) were recorded at the facility in August.) Median ammonia-N concentrations at other sites in Painter Creek ranged from 0.05 mg/l (RMs 17.90, 8.92, and 0.80) to 0.135 mg/l at RM 15.48. Ammonia-N medians measured in the four tributaries ranged from 0.061 mg/l in Heller Ditch to 0.686 mg/l in the unnamed tributary entering Painter Creek at RM 12.13.

Nitrate-nitrite-N remained low at most sites in the Painter Creek subbasin with an overall median of 0.1 mg/l for all values measured. The highest concentrations in the basin (median and maximum values of 1.84 mg/l and 4.96 mg/l) were recorded in Painter Creek near the mouth (RM 0.80). (Nitrate-nitrite-N loadings from Little Painter Creek (median and maximum values of 0.213 mg/l and 2.89 mg/l) may have contributed to the higher levels at this downstream site.) An overall phosphorous median of 0.16 mg/l was recorded for all sites in the subbasin with peak concentrations measured in Painter Creek downstream of Sycamore Ditch at RM 14.98 (median and maximum values of 0.72 mg/l and 0.98 mg/l). Higher levels were also recorded upstream at RM 15.48 (median 0.28 mg/l). Phosphorous concentrations remained low in Little Painter Creek

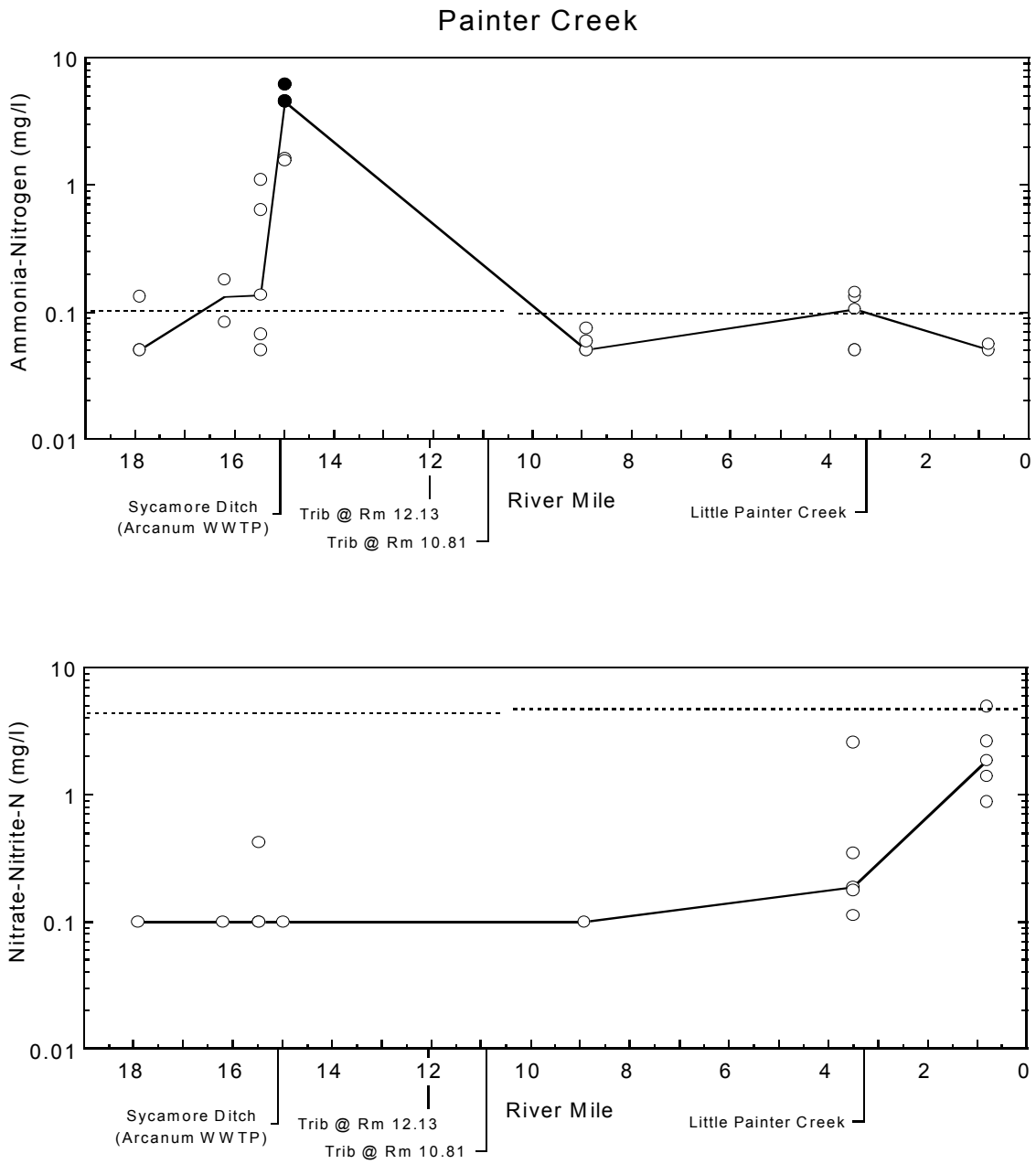


Figure 66. Longitudinal scatter plots (daytime grabs) of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in Painter Creek during the 1999 survey (MDL is 0.05 mg/l for NH_3-N and 0.1 mg/l for NO_3-NO_2-N). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for ammonia-nitrogen are shown as solid circles.)

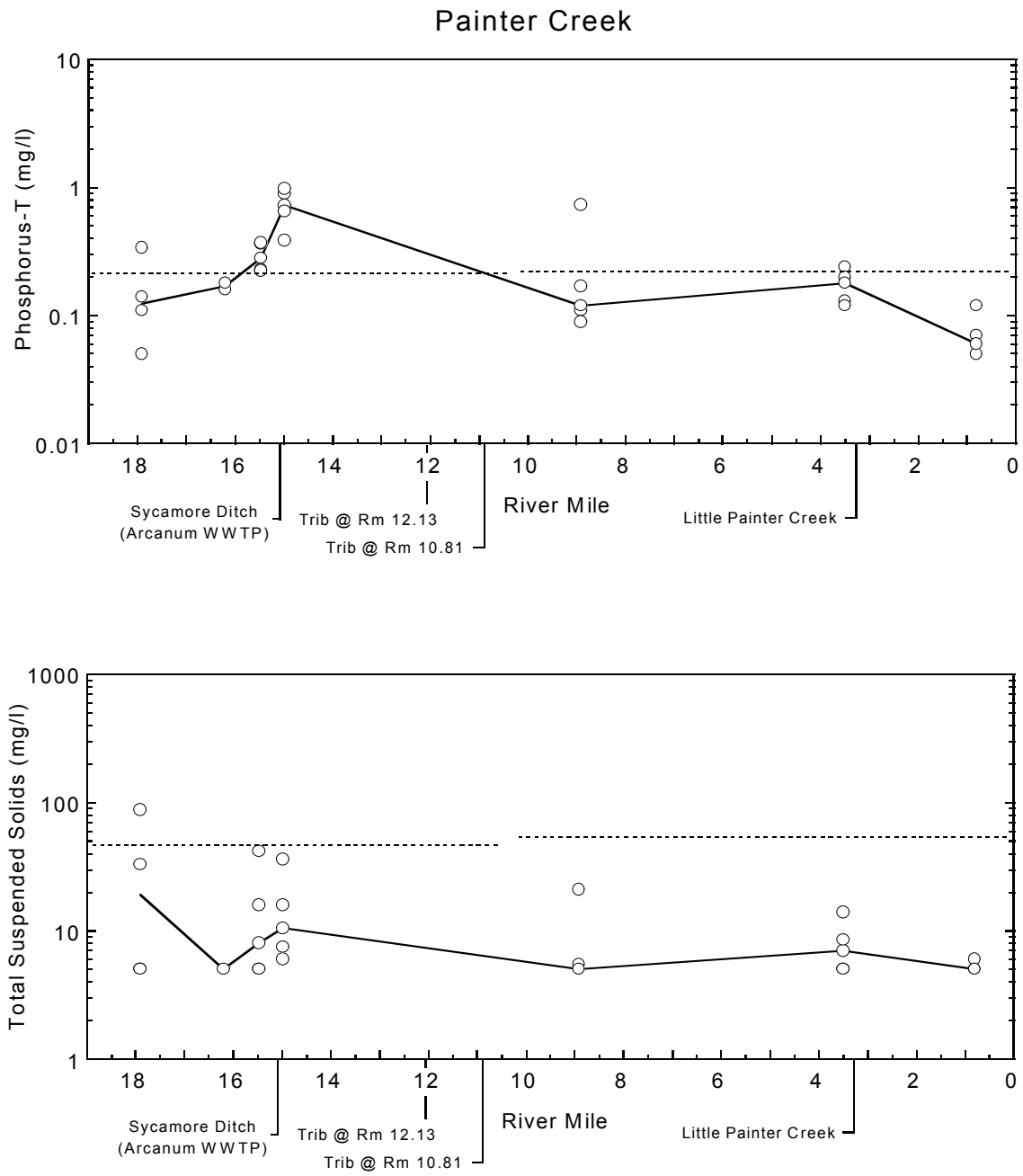


Figure 67. Longitudinal scatter plots (daytime grabs) of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in Painter Creek during the 1999 survey (MDL is 0.05 mg/l for TP and 5 mg/l for TSS). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

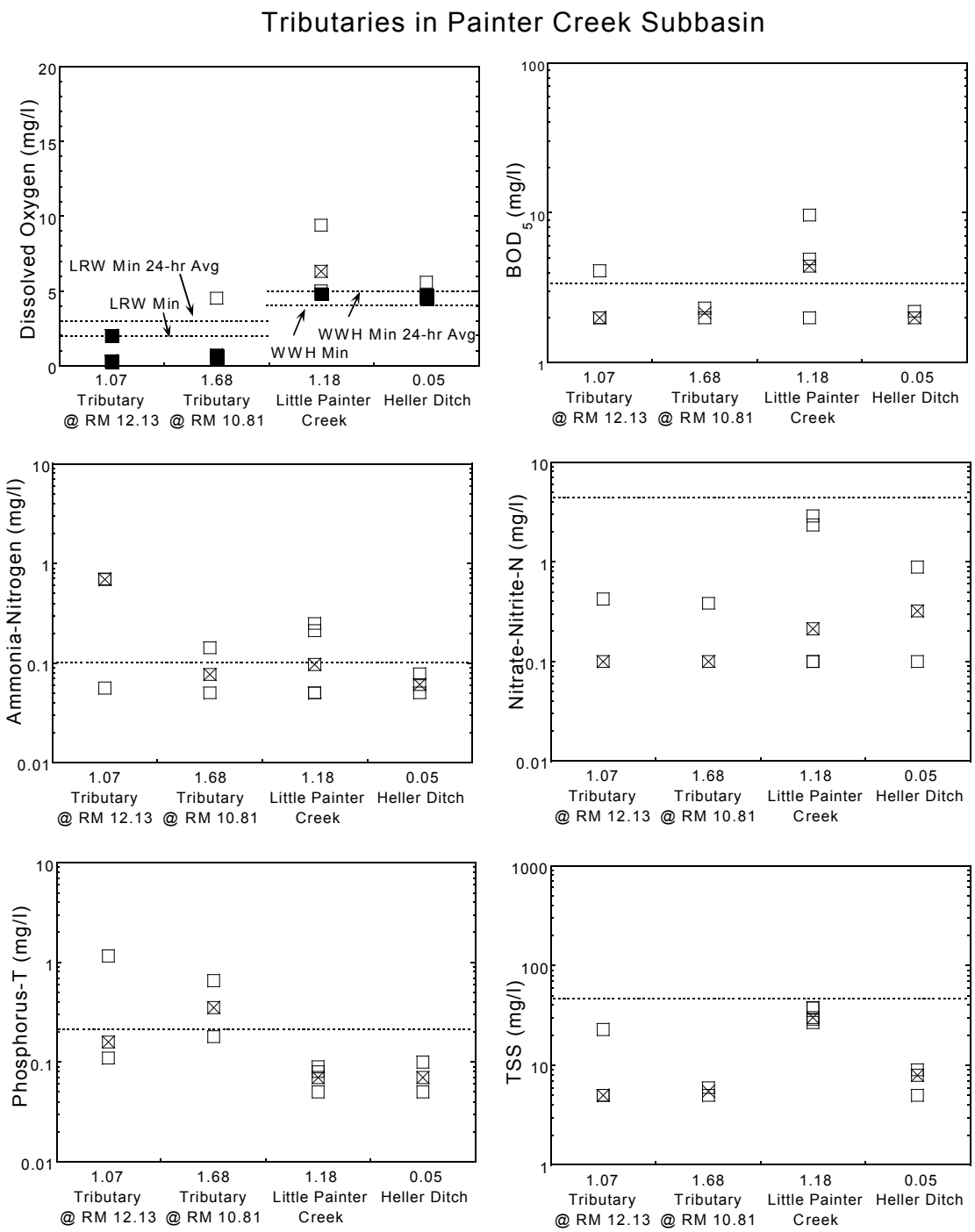


Figure 68. Scatter plots of water chemistry results (daytime grabs) in tributaries to Painter Creek @ Rms 12.13 and 10.81, Little Painter Creek, and Heller Ditch during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The median at each site is depicted by an 'X'. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid squares.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

and Heller Ditch (medians of 0.07 mg/l) while respective medians of 0.16 mg/l and 0.35 mg/l were measured in the unnamed tributaries entering Painter Creek at RMs 12.13 and 10.81. TSS concentrations were typically low in Painter Creek with the highest values (median and maximum of 19 mg/l and 88 mg/l) measured at RM 17.90. Higher values were generally recorded after a rain event. Somewhat higher levels were consistently measured in Little Painter Creek (RM 1.18) with median and maximum concentrations of 30 mg/l and 38 mg/l.

Bacteriological sampling in the Painter Creek subbasin was limited to a total of 17 fecal coliform and nine *E. coli* samples. Fecal coliform exceeded maximum primary contact recreation criterion in Painter Creek at all sites sampled on July 27 (RMs 16.20, 15.48, 14.98, and 8.92) with a high of 44000 colonies/100 ml recorded at RM 15.48 downstream of several Arcanum CSOs. (The Arcanum rainfall station recorded 0.63 inches of precipitation during the 24-hour period beginning at 8 a.m. on July 26 (MCD 1999)). The two *E. coli* values recorded during the survey at RM 0.80 in Painter Creek were also above recreational criterion.

Copper (32 µg/l) exceeded water quality criterion at RM 14.98 downstream of Sycamore Ditch on August 10. The Arcanum WWTP, required to monitor specific metals on a quarterly basis, reported a final effluent copper concentration of 173 µg/l for August 13. (The facility reported final effluent copper concentrations of 10 µg/l in each of the preceding two quarters in 1999.) All other copper concentrations measured in the basin during the survey were less than or equal to the MDL of 10 µg/l. COD, conductivity, chloride, and sodium were also elevated at RM 14.98 throughout the survey.

While within water quality criteria the highest arsenic (38 µg/l) and zinc (103 µg/l) concentrations of the entire survey were recorded in the unnamed tributary to Painter Creek (confluence 12.13) on July 28 and at RM 15.48 in Painter Creek on August 24, respectively. Lead (8 µg/l) was also elevated at RM 15.48 on August 24. Precipitation occurred in the Painter Creek basin on both dates. Additionally, while the majority (73%) of aluminum concentrations measured in the basin were less than or equal to the MDL (200 µg/l), concentrations measured at the Little Painter Creek site were consistently elevated (respective median and maximum values of 827 µg/l and 1280 µg/l). Concentrations of iron and manganese above water quality criteria were common throughout the basin.

Water samples were analyzed for organic compounds twice at three sites in Painter Creek (RMs 15.48, 14.98, and 0.80) and once in each of the unnamed tributaries to Painter Creek (Table 8, Appendix Table A-3). All seventeen detections (15 compounds) occurred in the Painter Creek mainstem during the second sampling event following recent precipitation (August 24-26). Concentrations of pentachlorophenol and aldrin exceeded water quality criteria at RM 15.48. Dieldrin exceeded criteria at RMs 14.98 and 0.80. Additionally, concentrations of 4,4'-DDT exceeded criteria at RM 0.80.

Ludlow Creek Subbasin (Ludlow Creek, Tributary to Ludlow Creek @ RM 11.80, Browns Ditch, Feitshams Ditch, Hog Run, Brush Creek, and Tributary to Brush Creek @ RM 5.92)
Ludlow Creek, draining approximately 63.8 mi^2, enters the Stillwater River at RM 21.00 near the Village of Ludlow Falls. Brush Creek, the largest tributary in the subbasin with a drainage area of 23.1 mi^2, enters Ludlow Creek at RM 2.63. The Barrett Paving Materials quarry intermittently discharges from a settling pond to Brush Creek at RM 0.15. There are numerous unsewered communities in the basin including Pitsburg, Potsdam, and Ludlow Falls on Ludlow Creek and Phillipsburg in the headwaters of Brush Creek. Hog Run, draining 9.7 mi^2, receives the discharge from the Laura WWTP at RM 0.3 before entering Ludlow Creek at RM 5.73. The discharge from Franklin Monroe High School enters an unnamed tributary to Ludlow Creek (confluence RM 11.80) near RM 0.46. Additionally, seven animal feedlot operations are located in the Darke County portion of the basin totaling 909 animal units (62% swine and 35% dairy) and producing 863 tons of waste annually (MVRPC 1998).

Water chemistry daytime grab samples were collected at five sites in the mainstem of Ludlow Creek (RMs 12.65, 6.40, 3.49, 2.33, and 0.65) during the 1999 survey. Three sites were sampled in Brush Creek (RMs 7.85, 7.17, and 0.45) and one site (RM 0.30) was sampled in the unnamed tributary entering Brush Creek at RM 5.92. Additionally, four smaller tributaries entering Ludlow Creek at RMs 11.80, 10.08, 8.38, and 5.73, respectively, were sampled during the 1999 survey as follows: unnamed tributary (RM 0.45), Browns Ditch (RM 0.30), Feitshams Ditch (RM 0.60), and Hog Run (RM 0.20) (Figures 69-74, Tables 6 and 7, Appendix Table A-1). During the 1999 survey, the WWH aquatic life use designation and water quality criteria applied in Ludlow Creek, Brush Creek, Browns Ditch, Feitshams Ditch, and Hog Run. Given that the two unnamed tributaries in the subbasin did not have aquatic life use designations during the 1999 survey, water quality criteria identified for the limited resource water (LRW) use designation applied (OAC rule 3745-1-07).

Daytime D.O. percent saturations measured in Ludlow Creek were generally below 100% with medians ranging from 63% at RM 6.40 to 82% at RM 3.49. Concentrations fell below WWH water quality criteria at RMs 12.65, 6.40, and 3.49 on occasion. Low flows and excessive algal growth caused wide D.O. swings in Browns Ditch and Feitshams Ditch. Percent saturations of 30% to 183% were measured in Browns Ditch while values in Feitshams Ditch ranged from 26% to 260%. Concentrations in both tributaries fell below WWH criteria on two occasions. Dissolved oxygen measured in the unnamed tributary to Ludlow Creek and in Hog Run remained relatively stable with respective median percent saturations of 83% and 79%.

Brush Creek dissolved oxygen levels were consistently depressed in the headwaters (RMs 7.85 and 7.17) with respective median percent saturations of 34% and 39%. Three of five concentrations at both sites fell below the minimum WWH criterion of 4.0 mg/l. This section of Brush Creek is downstream of two large storm sewers which carry storm and septic runoff from the unsewered community of Phillipsburg. Dissolved oxygen levels measured downstream at RM 0.45 improved considerably (median concentration and percent saturation 8.6 mg/l and 90%). Lower flows and abundant algal growth frequently pushed D.O. to supersaturated levels at RM 0.30 in the unnamed tributary to Brush Creek (median percent saturation 172%).

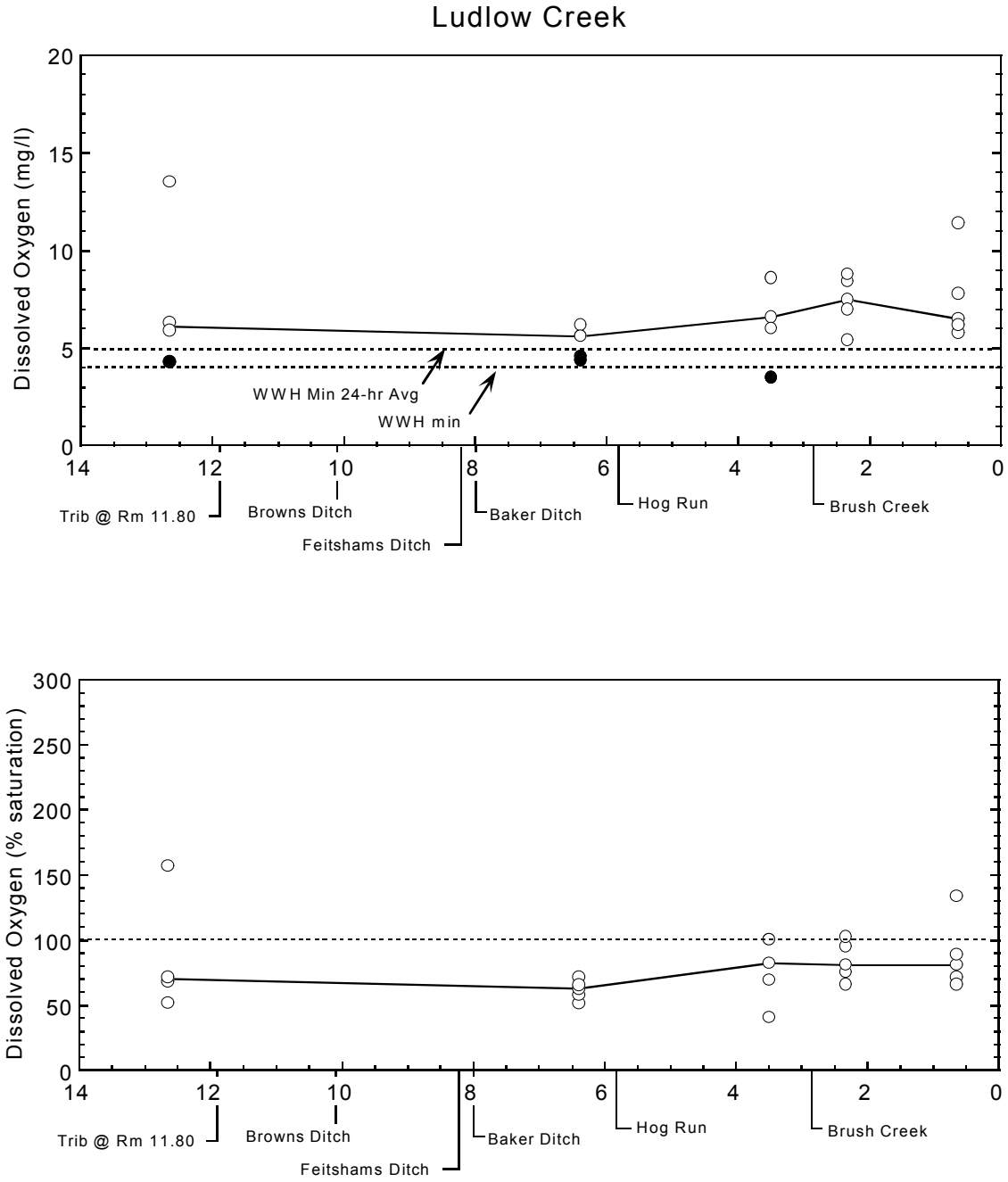


Figure 69. Longitudinal scatter plots (daytime grabs) of dissolved oxygen concentrations (upper figure) and percent dissolved oxygen saturations (lower figure) in Ludlow Creek during the 1999 survey. The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the upper figure. Values below the water quality criteria are indicated by solid circles.

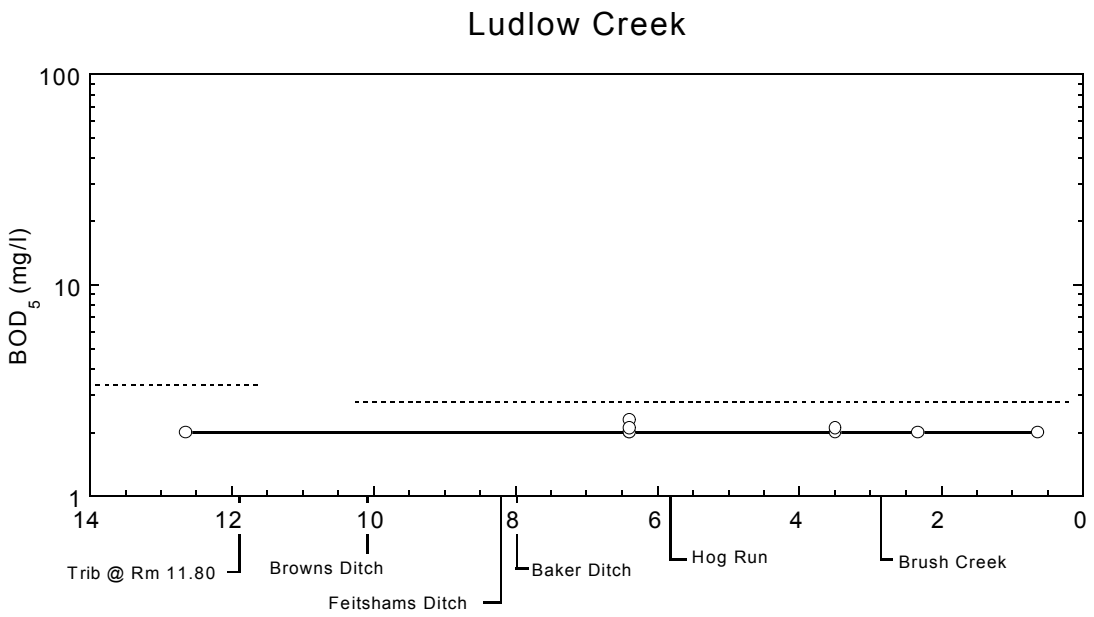


Figure 70. Longitudinal scatter plot (daytime grabs) of BOD_5 concentrations in Ludlow Creek during the 1999 survey (MDL is 2 mg/l). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

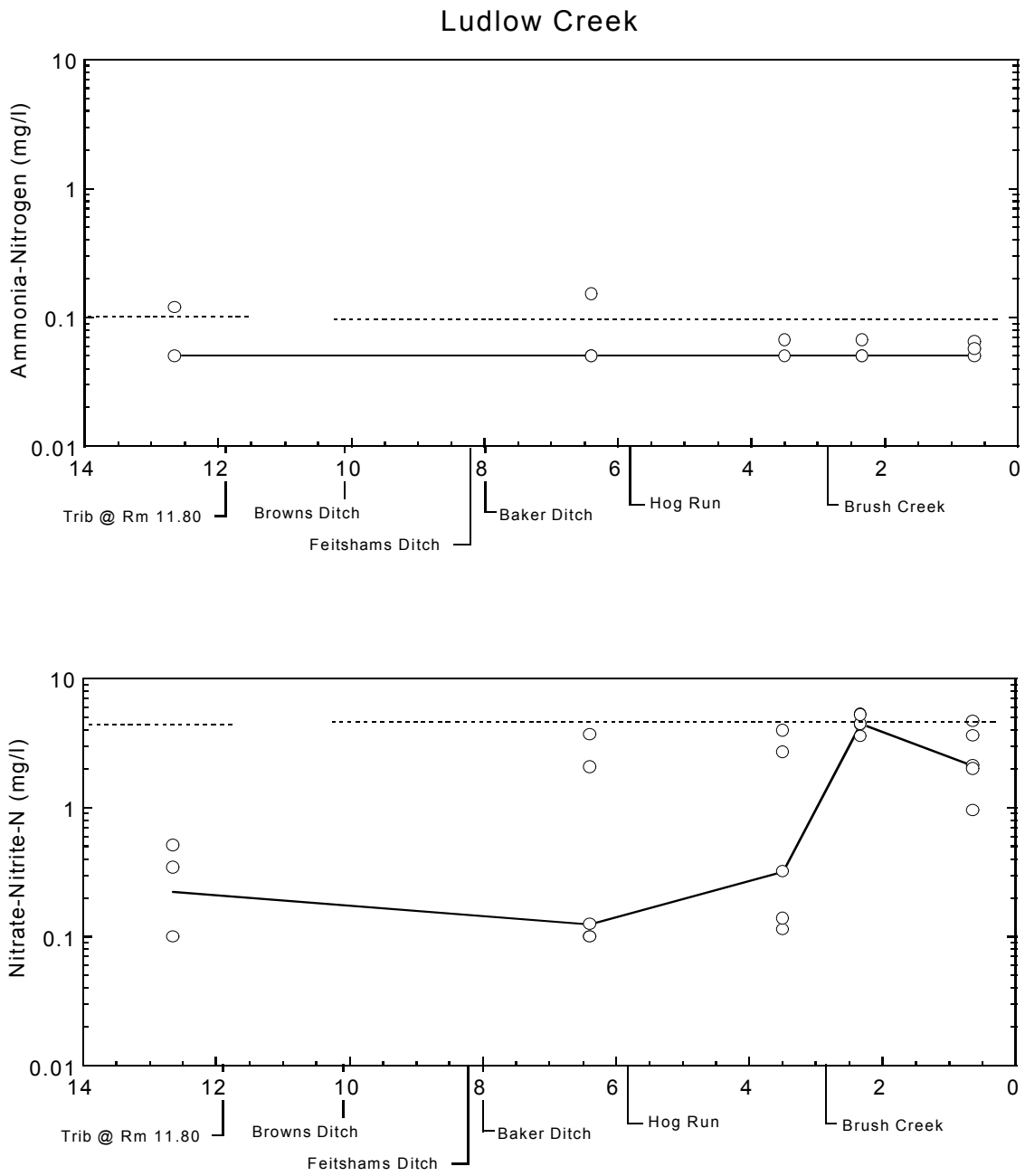


Figure 71. Longitudinal scatter plots (daytime grabs) of ammonia-N (upper figure) and nitrate-nitrite-N (lower figure) concentrations in Ludlow Creek during the 1999 survey (MDL is 0.05 mg/l for NH_3-N and 0.1 mg/l for NO_3-NO_2-N). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

The majority (80%) of BOD_5 concentrations measured in the Ludlow Creek subbasin were less than the MDL (2 mg/l). A maximum of 9.3 mg/l was recorded on September 9 at RM 0.20 in Hog Run downstream of the Laura WWTP. (The facility reported a final effluent $CBOD_5$ concentration of 9 mg/l on this day.) Values were also typically higher downstream of Phillipsburg at RM 7.85 in Brush Creek (respective median and maximum values of 3.3 mg/l and 8 mg/l).

Ammonia-N concentrations recorded in the mainstem of Ludlow Creek remained low with 75% of values less than the MDL of 0.05 mg/l and a maximum concentration of 0.152 mg/l (RM 6.40). Concentrations measured at sites in the four smaller tributaries also remained low with medians ranging from 0.05 mg/l (Feitshams Ditch and the unnamed tributary to Ludlow Creek) to 0.145 mg/l (Browns Ditch). Consistently elevated levels of ammonia-N, however, were measured downstream of Phillipsburg at RM 7.85 in Brush Creek with three of five samples exceeding water quality criterion. Respective median and maximum concentrations of 2.7 mg/l (the second highest of any site in the survey) and 4.68 mg/l were recorded at the site. Ammonia-N measured at downstream sites (RMs 7.17 and 0.45) in Brush Creek and at RM 0.30 in the unnamed tributary to Brush Creek were not elevated.

Nitrate-nitrite-N remained low in much of the Ludlow Creek mainstem with the majority of values (92%) less than applicable 90th percentile reference concentrations. Peak values were recorded at RM 2.33 downstream of the Brush Creek confluence (median of 4.44 mg/l and maximum of 5.28 mg/l). Brush Creek nitrate-nitrite-N median concentrations ranged from 1.34 mg/l at RM 7.17 to 5.93 mg/l at RM 0.45. Elevated concentrations (6.11 mg/l on July 14 and 8.68 mg/l on September 9) were also occasionally recorded at RM 0.45 in the unnamed tributary to Ludlow Creek downstream of the Franklin Monroe High School discharge. The highest nitrate-nitrite-N values of the entire 1999 Stillwater survey, however, were measured in Hog Run at RM 0.20, downstream of the Laura WWTP (median and maximum concentrations of 11.6 mg/l and 19.6 mg/l, respectively).

While an overall median phosphorus concentration of 0.1 mg/l was calculated for the mainstem of Ludlow Creek, much higher values were recorded downstream of Phillipsburg in the Brush Creek headwaters at RMs 7.85 and 7.17 (respective medians of 0.57 mg/l and 0.34 mg/l). The highest phosphorus levels in the Ludlow Creek subbasin, however, occurred downstream of the Laura WWTP in Hog Run (RM 0.20) with median and maximum values of 1.55 mg/l and 2.93 mg/l, respectively.

TSS concentrations were typically low in the Ludlow Creek subbasin with an overall median of 5 mg/l. Somewhat higher values were observed at RM 0.45 in the unnamed tributary downstream of Franklin Monroe High School (median and maximum values of 6.5 mg/l and 24 mg/l). The highest TSS concentrations in the basin (respective median and maximum values of 22 mg/l and 48.5 mg/l) were measured in the Ludlow Creek mainstem at RM 0.65.

Bacteriological sampling in the Ludlow Creek subbasin was limited to a total of 22 fecal coliform and 18 *E. coli* samples. Fecal coliform samples were collected on July 28 at four sites: Ludlow Creek RM 12.65, the unnamed tributary to Ludlow Creek, Browns Ditch, and Feitshams

Ditch. Concentrations at all four sites exceeded applicable criteria with a high of 29000 colonies/100 ml recorded at RM 0.45 downstream of the Franklin Monroe High School WWTP discharge in the unnamed tributary to Ludlow Creek (confluence RM 11.80). (The Arcanum rainfall station recorded 0.63 inches of precipitation during the 24-hour period beginning at 8 a.m. on July 26 (MCD 1999)). Fecal coliform and *E. coli* samples were collected from each of the remaining nine sites in the Ludlow Creek basin on August 12 and August 26. Exceeding maximum primary contact recreation criteria, the highest fecal coliform (7545 colonies/100 ml) and *E. coli* (9804 colonies/100 ml) concentrations were measured in Brush Creek at RM 7.85 downstream of the unsewered community of Phillipsburg on August 12, a day of lower flows. *E. coli* concentrations above recreation criteria were also recorded on August 12 at RMs 2.33 and 0.65 in Ludlow Creek and in Hog Run. *E. coli* concentrations measured on August 26 exceeded criteria at RMs 6.40 and 0.65 in Ludlow Creek, and at RMs 7.85 and 0.45 in Brush Creek.

While the majority (92%) of copper concentrations recorded in the Ludlow Creek basin were less than or equal to the MDL of 10 µg/l, higher values were consistently measured at RM 0.20 in Hog Run. Copper exceeded water quality criterion at this site on September 9 (36 µg/l) . (The Laura WWTP is not required to monitor for metals in the final effluent.) Compared to other sites in the basin, concentrations of barium and strontium were also elevated in Hog Run (respective medians of 243 µg/l and 1720 µg/l).

Iron and manganese exceeded water quality criteria in the basin occasionally. Additionally, concentrations of arsenic at RM 0.30 in the unnamed tributary to Brush Creek were somewhat elevated (median and maximum values of 12 µg/l and 20 µg/l). COD concentrations measured in Browns Ditch (260 mg/l) and at RM 12.65 in Ludlow Creek (193 mg/l) were exceptionally elevated (the highest in the entire survey) on July 14. (COD was not elevated at any other site in the entire survey on this day; nor were any other parameters elevated at these two sites on July 14.)

Water samples were analyzed for organic compounds twice at four sites in Ludlow Creek (RMs 12.65, 6.40, 2.33, and 0.65), at RM 0.20 in Hog Run, and at two sites in Brush Creek (RMs 7.85 and 0.45) (Table 8, Appendix Table A-3). Eight of the thirteen organic compounds (and 28 of the 36 detections) found were pesticides. The most frequently detected compound was atrazine (25% of detections) while delta-hexachlorocyclohexane and gamma-hexachlorocyclohexane each accounted for 11% of detections. Concentrations of dieldrin exceeded criteria at RMs 12.65 and 6.40 in Ludlow Creek. Gamma-hexachlorocyclohexane exceeded criteria on September 9 at RM 0.20 in Hog Run and at RM 7.85 in Brush Creek. Heptachlor also exceeded criteria in Hog Run on September 9.

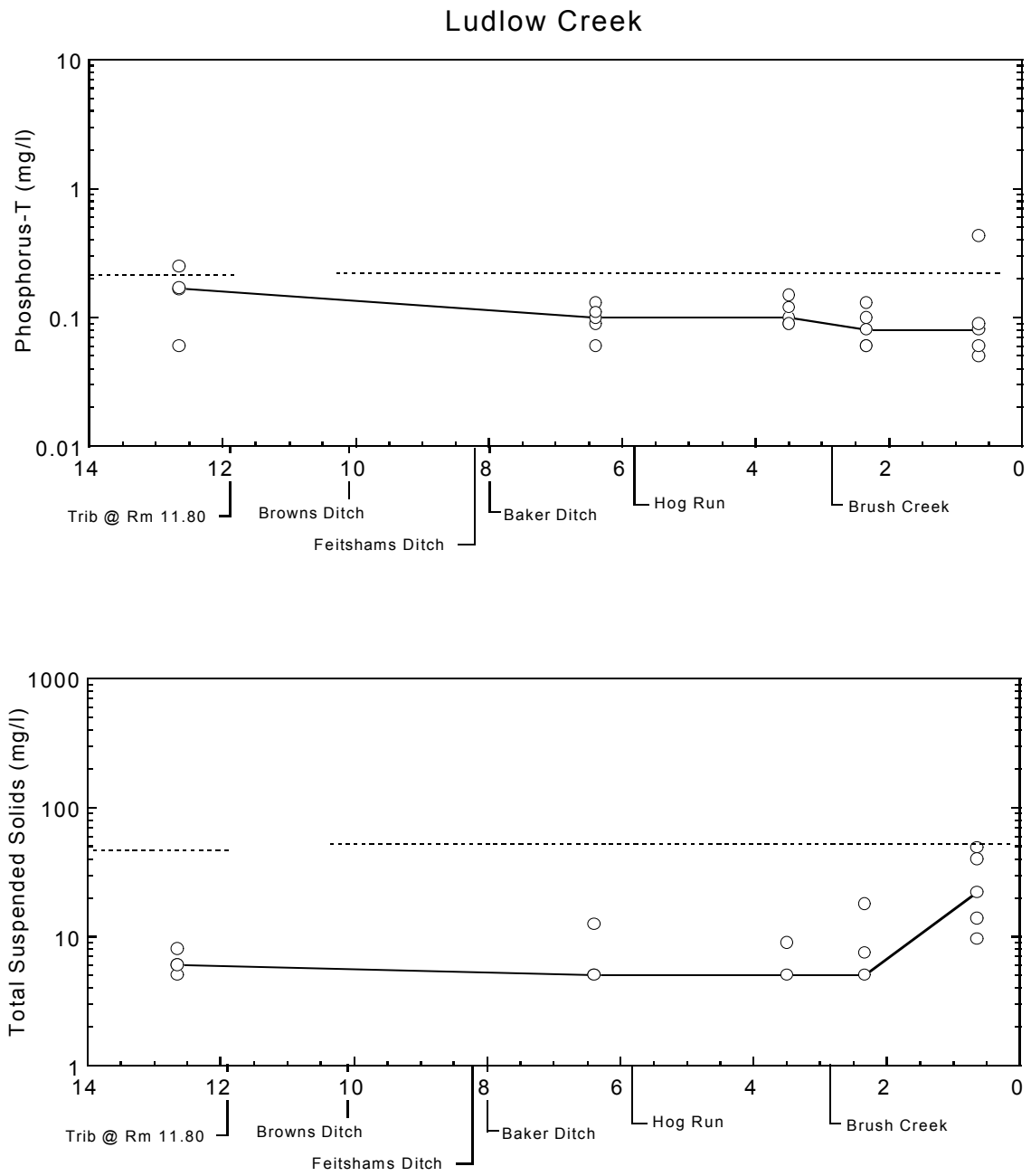


Figure 72. Longitudinal scatter plots (daytime grabs) of total phosphorus (upper figure) and total suspended solids (lower figure) concentrations in Ludlow Creek during the 1999 survey (MDL is 0.05 mg/l for TP and 5 mg/l for TSS). The solid line depicts the median value at each river mile sampled while the dotted lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

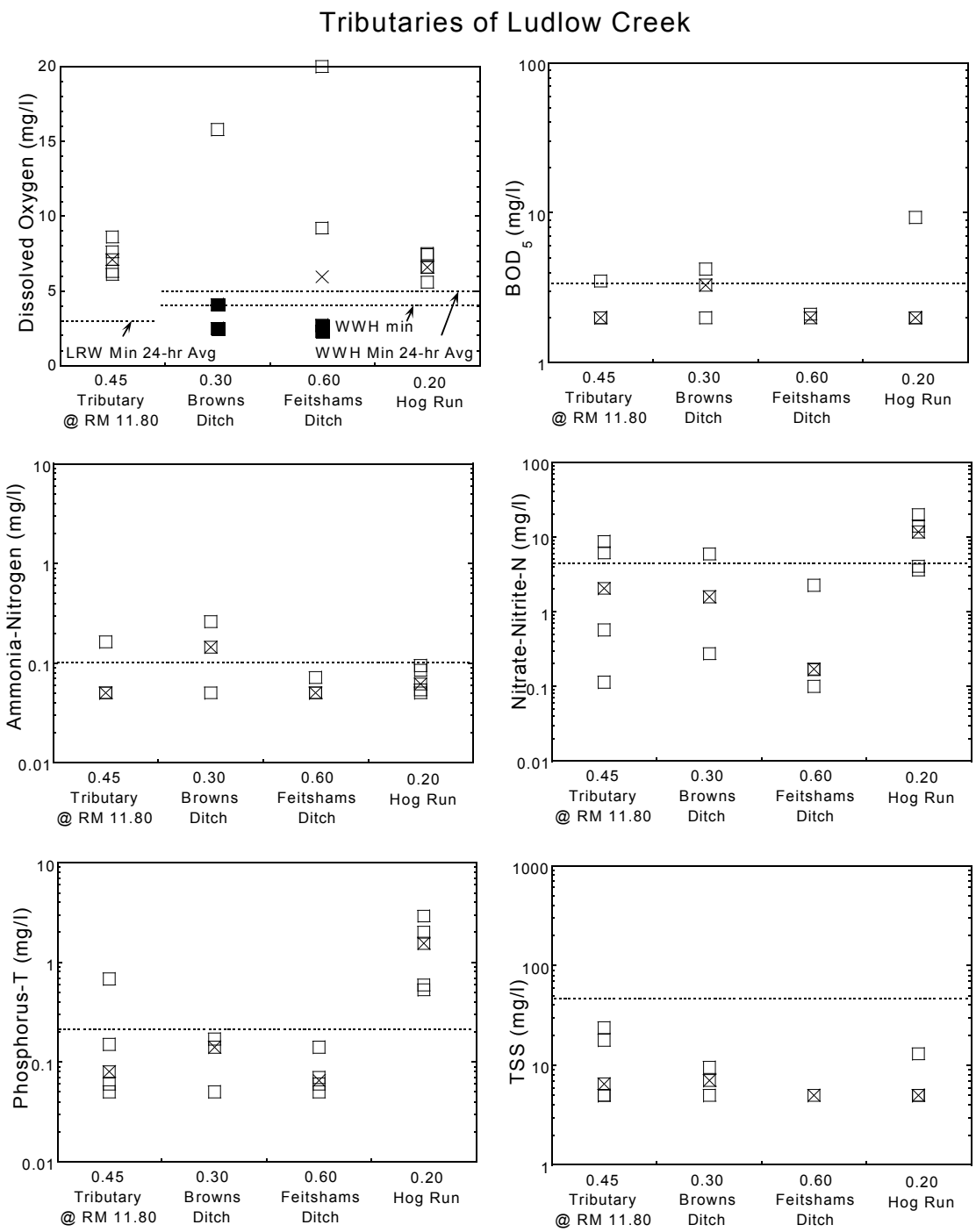


Figure 73. Scatter plots of water chemistry results (daytime grabs) in a tributary to Ludlow Creek @ Rm 11.80, Browns Ditch, Feitshams Ditch, and Hog Run during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The median at each site is depicted by an 'X'. Water quality criteria are shown in the dissolved oxygen plot. (Values below criteria are shown as solid squares.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

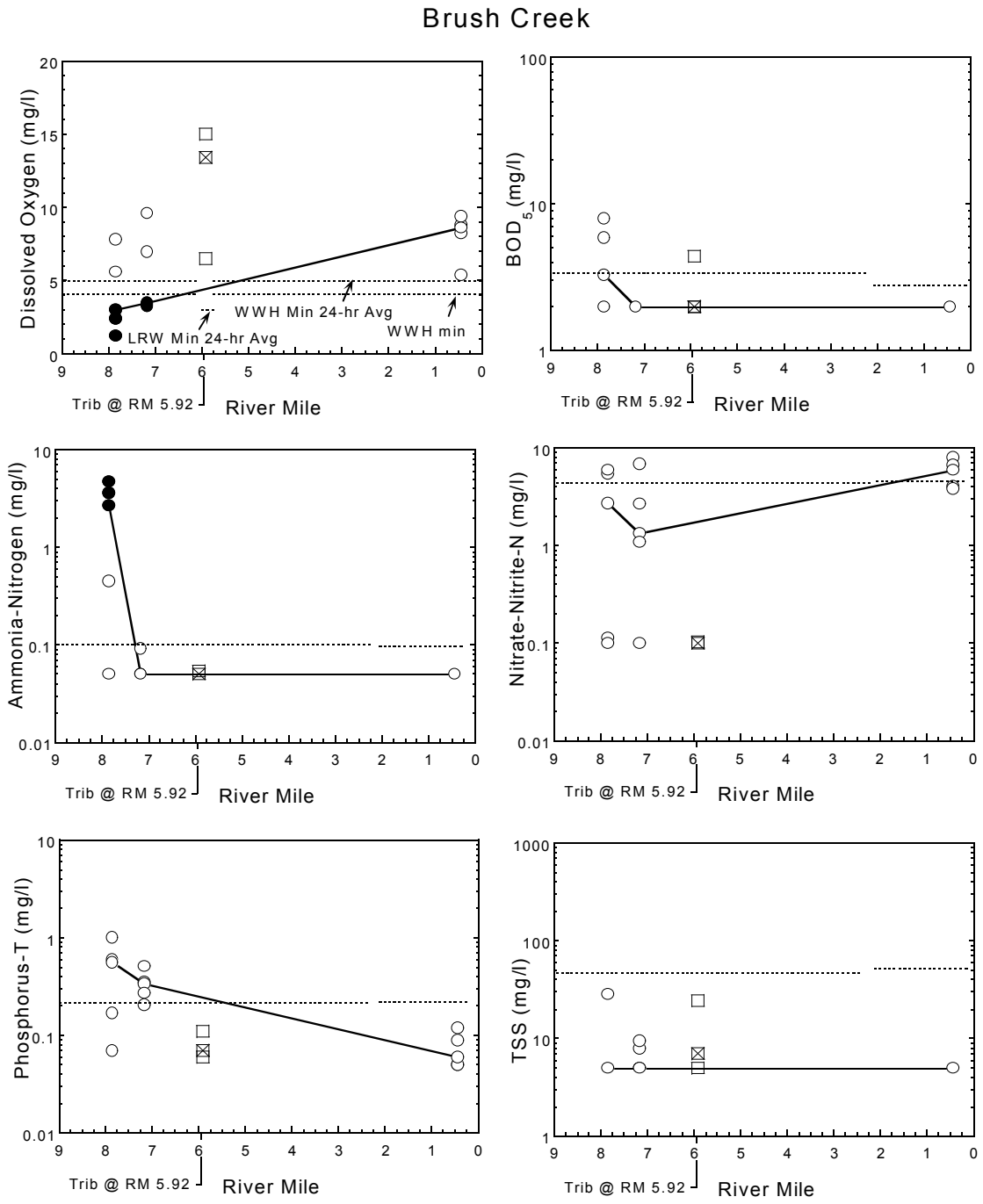


Figure 74. Longitudinal scatter plots of water chemistry results (daytime grabs) in Brush Creek (circles) and a tributary to Brush Creek @ Rm 5.92 (squares) during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled in Brush Creek while an 'X' depicts the median for the tributary. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for dissolved oxygen and ammonia-nitrogen are shown as solid circles.)

Mill Creek

Mill Creek drains approximately 6.0 mi^2 before entering the Stillwater River at RM 14.04. Flowing through Dayton International Airport (DIA) property, the headwaters of Mill Creek receive stormwater runoff from various airport facilities and have also been subjected to a variety of spills (mostly fuel) throughout the years. Additionally, contaminated releases (predominately propylene glycol) from DIA's stormwater retention basin historically entered Mill Creek upstream of Old Springfield Road (RM 3.67). Exceptionally elevated concentrations of ammonia-N, COD, and BOD_5 were typically documented in the discharges from the retention basin especially from 1993-1995. In 1996 DIA installed a Deicing Fluid Control System (DFCS) which among other items included airplane deicing aprons, diversion structures, and central storage lagoons which pumped the deicing fluids to the Montgomery County Sanitary Sewers. Largely successful, the majority of deicing fluid runoff is recaptured for reuse or wasting to the sanitary sewers while the remaining 10-30% of uncaptured deicing fluid is attributable to "windblow" from the aprons or off of the aircraft.

Daytime grab water chemistry samples were collected from four sites (RMs 3.67, 2.62, 1.18, and 0.32) in Mill Creek downstream of DIA during the 1999 survey (Figure 75, Tables 6 and 7, Appendix Table A-1). Dissolved oxygen concentrations fell below WWH water quality criterion at RMs 3.67 and 2.62 on July 29. These sites also generally experienced much greater variation in percent saturations than downstream sites with values ranging from 55% to 184% at RM 3.67 and from 54% to 185% at RM 2.62. Field crews typically observed lower flows and algae at both upstream sites. BOD_5 concentrations were consistently elevated above the 90th percentile headwater reference concentration at RM 3.67 (median and maximum values of 5.1 mg/l and 8.4 mg/l). Concentrations measured at the three downstream sites (RMs 2.62 - 0.32) remained low with 80% of values less than the MDL of 2 mg/l.

Ammonia-N concentrations at upstream sites (RMs 3.67 and 2.62), frequently elevated above the 90th percentile headwater reference concentration (0.1 mg/l), exceeded water quality criterion at RM 3.67 on July 15 (0.443 mg/l). All concentrations measured downstream at RMs 1.18 and 0.32 were less than the MDL of 0.05 mg/l.

Nitrate-nitrite-N concentrations remained low at RMs 3.67 and 2.62 with respective medians of 0.1 mg/l and 0.24 mg/l. Concentrations increased significantly downstream at RM 1.18 (median and maximum of 5.1 mg/l and 8.24 mg/l) and remained at higher levels at RM 0.32 (median and maximum of 3.1 mg/l and 4.35 mg/l). (Field crews observed a package plant discharge from a nursing home upstream of RM 1.18; this situation is being further investigated.) Phosphorus concentrations recorded in the basin remained low at all sites with an overall median of 0.07 mg/l.

TSS concentrations measured in the basin were generally low. Somewhat higher TSS levels were observed at RM 3.67 with values ranging from 8 mg/l to 31 mg/l and a median concentration of 13.5 mg/l. Bacteriological sampling (fecal coliform and *E. coli*) at Mill Creek sites on August 12 revealed *E. coli* concentrations above the recreational criterion at RMs 3.67 and 1.18. Additionally, concentrations of manganese and iron exceeded criteria at RM 3.67 on two occasions.

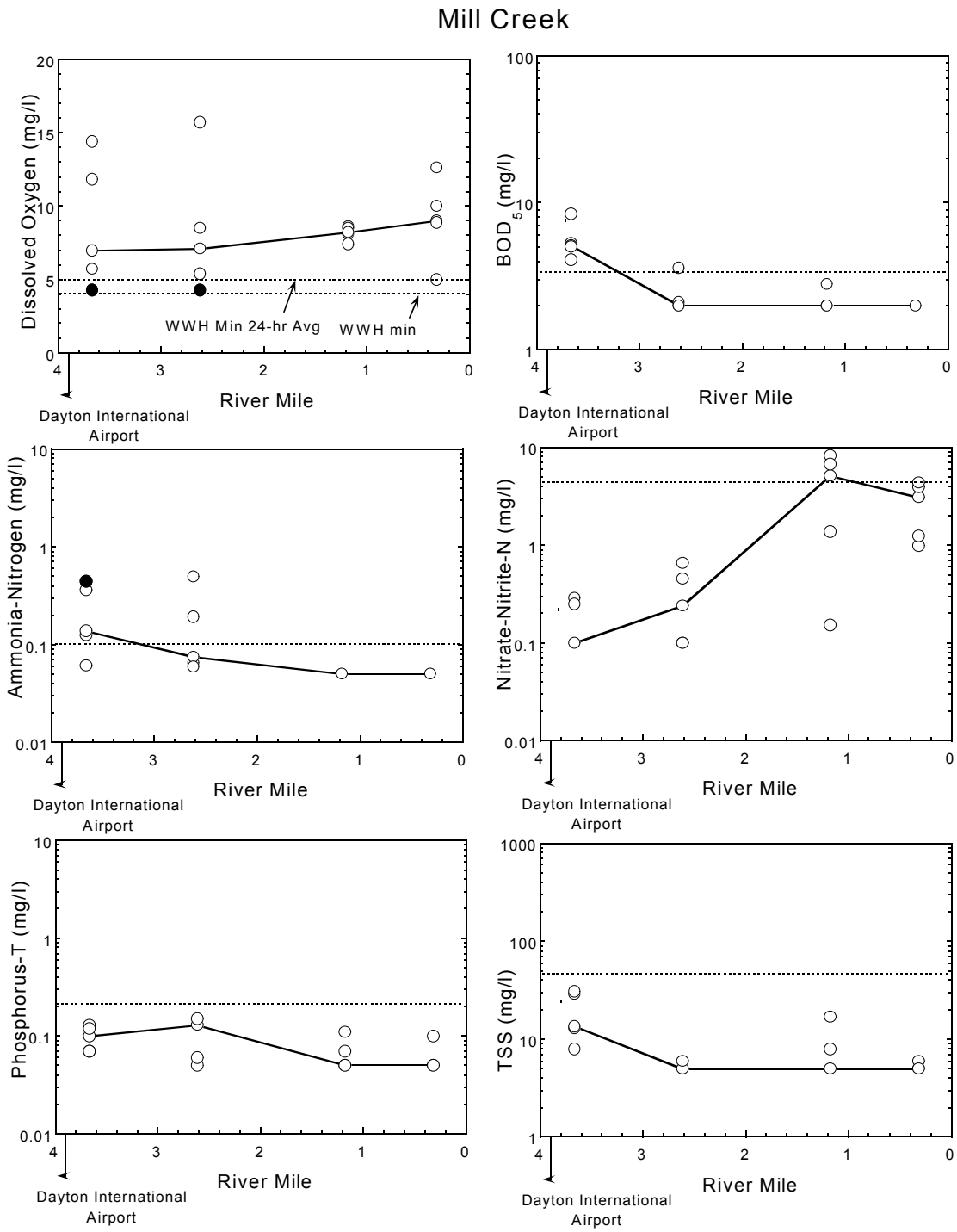


Figure 75. Longitudinal scatter plots of water chemistry results (daytime grabs) in Mill Creek during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The solid line depicts the median value at each river mile sampled. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria for dissolved oxygen and ammonia-nitrogen are shown as solid circles.)

Water samples were analyzed for organic compounds (Table 8, Appendix Table A-3) twice at three sites in Mill Creek (RMs 3.67, 2.62, and 0.32). Seven of the nine compounds (10 of the 12 detections) found were pesticides. The most frequently detected compound was heptachlor epoxide (25% of detections). Heptachlor exceeded water quality criteria at RM 2.62 on August 12.

OtherTributaries to the Stillwater River:
Numerous small tributaries to the Stillwater River were sampled during the 1999 survey (Figures 76-77, Tables 6 and 7, Appendix Table A-1). Daytime grab water chemistry samples were collected from the following locations: RM 0.81 in Boyd Creek (confluence RM 54.23), RM 0.97 in Trotters Creek (confluence RM 34.32), RM 1.2 in Opossum Run (confluence RM 23.48), RM 0.50 in Rocky Run (confluence RM 22.61), RM 0.4 in Jones Run (confluence RM 15.81), RM 0.12 in Brush Creek (confluence RM 14.20), and RM 0.60 in Pigeye Creek (confluence RM 13.19). Additionally, four unnamed tributaries to the Stillwater River were sampled as follows: RM 0.33 in the tributary entering the Stillwater River at RM 64.96, RM 1.20 in the tributary entering the Stillwater at RM 51.02, RM 0.60 in the tributary entering the Stillwater at RM 38.30, and RM 0.75 in the tributary entering the Stillwater at RM 32.60. (Samples were collected at RM 1.00 of Canyon Run on July 29 only; the stream was totally dry on other water chemistry sampling days. No elevated values were documented.)

During the 1999 survey, the WWH aquatic life use designation and water quality criteria applied in Boyd Creek, Trotters Creek, Opossum Run, Rocky Run, Jones Run, and Pigeye Creek while EWH criteria applied in Brush Creek. Water quality criteria identified for the LRW use designation applied (OAC rule 3745-1-07) in the four unnamed tributaries in the subbasin which did not have aquatic life use designations during the survey.

Dissolved oxygen concentrations measured in Trotters Creek and Brush Creek were consistently depressed with respective median percent saturations of 52% and 56%. Three of five values in Trotters Creek and four of five values in Brush Creek fell below applicable water quality criteria. Low flows significantly impacted both sites. (Brush Creek became interstitial for the last three sampling events.). Lower D.O. values were also generally recorded in Boyd Creek (median percent saturation 69%) with the September 7 concentration (4.9 mg/l) falling below WWH criterion. Low flows exacerbated the impact of habitat modification (minimal riparians, channelization) and agricultural runoff in two of the unnamed tributaries (confluences at RMs 64.96 and 38.30) causing excessive algal growth and wide D.O. swings. Concentrations at both sites fell below LRW criteria during the last week of the survey.

The majority (79%) of BOD_5 concentrations measured in the eleven tributaries were less than the MDL (2 mg/l) and 80% of ammonia-N concentrations were less than or equal to the 90th percentile headwater reference concentration of 0.1 mg/l. Higher BOD_5 and ammonia-N values were recorded at RM 0.60 in the unnamed tributary to the Stillwater River at RM 38.30 (respective medians of 3.7 mg/l and 0.141 mg/l). (This tributary flows through a farm field with unrestricted livestock access.)

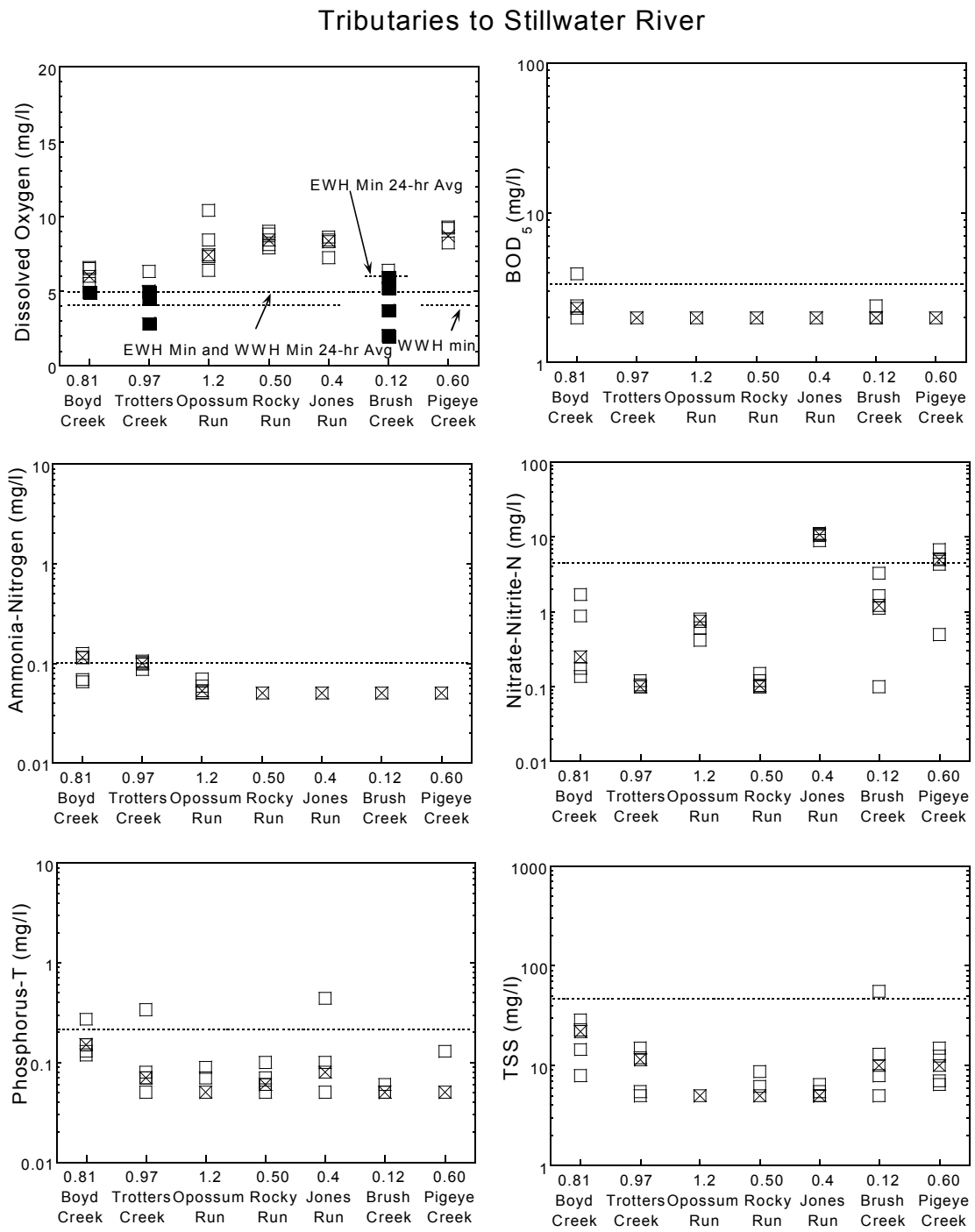


Figure 76. Scatter plots of water chemistry results (daytime grabs) in tributaries to the Stillwater River during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The median at each site is depicted by an 'X'. Water quality criteria are shown in the dissolved oxygen plot. (Values exceeding criteria are shown as solid squares.) Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

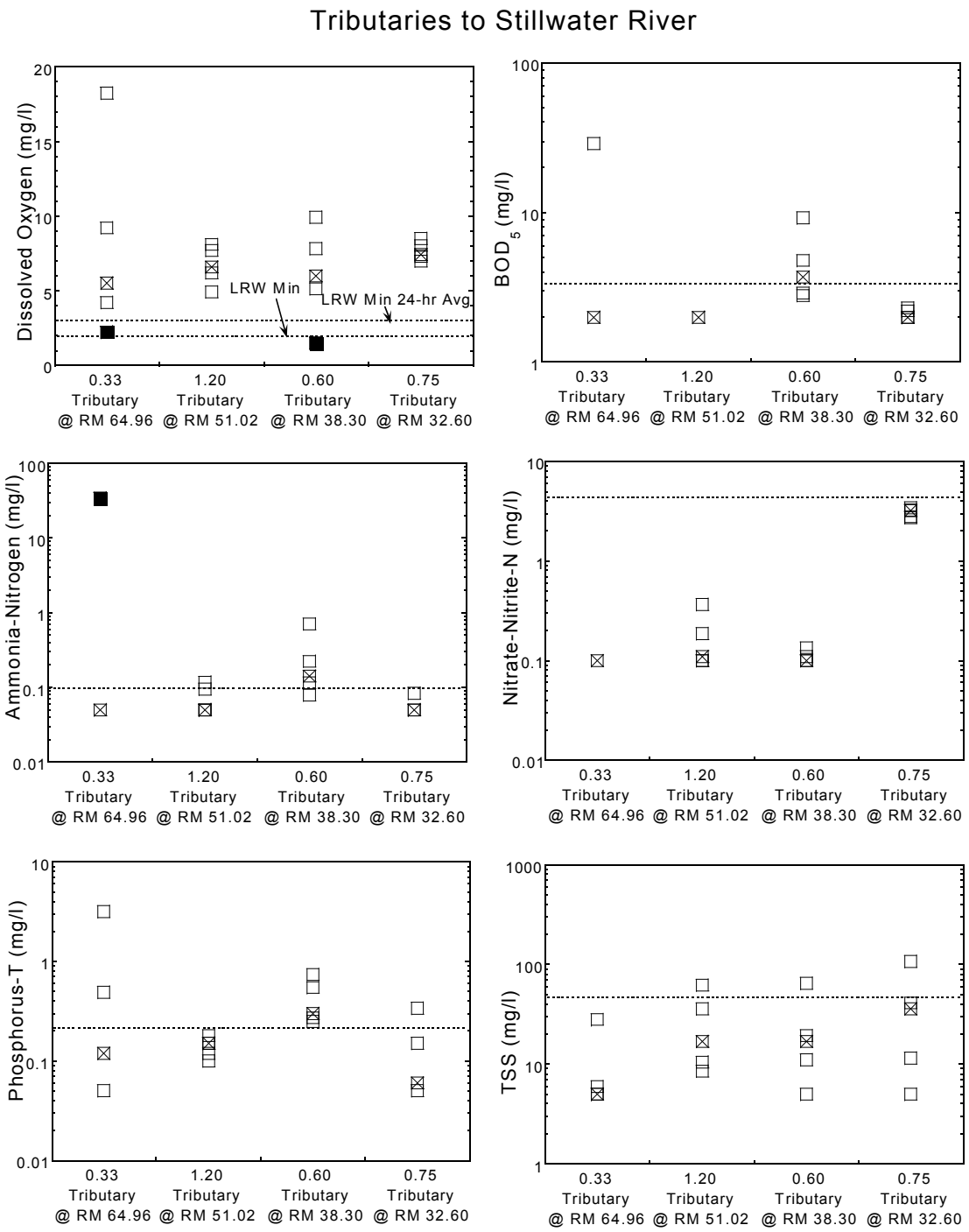


Figure 77. Scatter plots of water chemistry results (daytime grabs) in tributaries to the Stillwater River during the 1999 survey. Left to right from the top: dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS). The median at each site is depicted by an 'X'. Water quality criteria are shown in the dissolved oxygen plot. Dotted lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Values exceeding criteria are shown as solid squares.)

On September 7, field crews observed numerous dead fish at RM 0.33 (Brock Cosmos Road) in the unnamed tributary to the Stillwater River at RM 64.96. This small tributary drains several animal feedlot operations. Exceeding water quality criterion, the highest ammonia-N concentration of the survey (34.2 mg/l) was recorded at this site on this day. Manganese (2020 µg/l) and fecal coliform (25000 colonies/100 ml) also exceeded applicable criteria. Additionally, concentrations of BOD_5 (29 mg/l), COD (129 mg/l), alkalinity (631 mg/l), conductivity (1750 µmhos/cm), TKN (44.7 mg/l), phosphorus (3.14 mg/l), total dissolved solids (TDS) (932 mg/l), chloride (76 mg/l), arsenic (33 µg/l), barium (181 µg/l), iron (5470 µg/l), potassium (117 mg/l), and sodium (36 mg/l) were elevated at the site on this day. Field investigators were unable to determine the source.

Nitrate-nitrite-N concentrations remained low in most of the tributaries with the majority (86%) of values less than the 90th percentile headwater reference concentration (4.60 mg/l). Higher concentrations (median and maximum values of 4.99 mg/l and 6.82 mg/l) were measured in Pigeye Creek. (Field crews noted a discharge from a VFW post upstream of this site; this situation is being further investigated.) Some of the highest nitrate-nitrite-N concentrations of the entire survey, however, were recorded at RM 0.40 in Jones Run (median of 10.8 mg/l and maximum of 11.1 mg/l). (Potential sources include the Memorial Holiness Campground which apparently has underdrains discharging to a sewer leading to Jones Run approximately one mile upstream of this site. Ohio EPA is currently in the process of issuing an NPDES permit to this facility. Additionally, Hope Platt, an unsewered subdivision with numerous failing systems, is located is the same vicinity as the campground.)

Generally, phosphorus concentrations measured in the eleven tributaries were not elevated with 80% of values less than the 90th percentile headwater reference concentration (0.206 mg/l). Consistently elevated values, however, were measured at RM 0.60 in the unnamed tributary to the Stillwater River at RM 38.30 (median and maximum values of 0.3 mg/l and 0.74 mg/l). Typically, maximum values at sites were recorded on higher flow days.

Of the eleven tributaries, the highest TSS concentrations were recorded at RM 0.75 in the unnamed tributary to the Stillwater River at RM 32.60 (median and maximum values of 36 mg/l and 108 mg/l). (Some results at this site may be somewhat compromised in that substrate may have inadvertently been disturbed, thus introducing sediments into the sample.) Frequency of bacteriological sampling varied in the tributaries with a combined total of 21 fecal coliform and 14 *E. coli* samples. Fecal coliform concentrations recorded in three of the four unnamed tributaries exceeded the maximum criteria applicable to all waters once with exceedences ranging from 21000 colonies/100 ml (tributary at RM 38.30) to 60000 colonies/100 ml (tributary at RM 32.60). Fecal coliform concentrations above primary contact recreation criteria were also measured in Boyd Creek, Trotters Creek, and Pigeye Creek (60000 colonies/100 ml). Additionally, *E. coli* concentrations exceeded applicable criteria in the unnamed tributary (confluence RM 51.02), Boyd Creek, Opossum Run, Rocky Run, and Pigeye Creek.

Mercury exceeded the non-drinking water human health water quality criterion (0.012 µg/l) on August 24 in two of the unnamed tributaries (confluences at RMs 64.96 and 51.02), and in Boyd Creek (see Stillwater mainstem discussion above for possible explanation). Manganese and iron

exceeded criteria frequently in Trotters Creek while occasional exceedences were recorded in Boyd Creek and Brush Creek. Additionally, while well within water quality criteria, higher arsenic concentrations were consistently recorded in the unnamed tributary entering the Stillwater River at RM 51.02 (median 13 µg/l).

Water samples were analyzed for organic compounds twice in Trotters Creek and Brush Creek (Table 8, Appendix Table A-3). Four compounds were detected in Trotters Creek with Dieldrin exceeding criteria at the site on July 14. Five compounds were detected in Brush Creek with all concentrations within applicable criteria.

Table 6. Exceedences of Ohio EPA water quality criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Stillwater River study area during 1999 (units are Fg/l for metals and organics, #colonies/100ml for fecal coliform and *E. coli*, EC for temperature, µmhos/cm for conductivity, SU for pH, and mg/l for all other parameters).

Stream (use designation [a])	River Mile	Parameter [b] (value)
Stillwater River	65.00	Dissolved oxygen (4.50[‡])
-Headwaters to RM 56.97		pH (9.04[Ä])
(SRW, WWH, PCR, AWS, IWS)		Manganese-T (149*)
-RM 18		Mercury-T (0.224[#])
(SRW, EWH, PCR, PWS, AWS, IWS)		Iron-T (1060*)
-All other segments		*E. coli* (238[¨])
(SRW, EWH, PCR, AWS, IWS)		
	62.97	Mercury-T (0.223[#])
	61.80	Dissolved oxygen (3.40[‡‡])
		Manganese-T (193*, 262*, 184*, 138*, 108*)
		E. coli (254[¨])
	58.97	Dissolved oxygen (3.50[‡‡])
		Manganese-T (139*, 170*, 142*, 111*, 146*)
		Mercury-T (0.223[#])
		Iron-T (1960*, 2160*, 3150*, 1910*, 1260*)
		E. coli (406[¨¨], 831[¨¨])
	57.90	Dissolved oxygen (4.40[‡], 3.20[‡‡], 3.40[‡‡], 2.60[‡‡])
		Manganese-T (144*, 154*, 166*, 174*, 167*)
		Mercury-T (0.233[#])
		Iron-T (1630*, 1520*, 1440*, 1550*)
	56.97	Dissolved oxygen (4.30[‡], 4.80[‡], 4.80[‡])
		Manganese-T (138*, 192*, 150*, 132*, 125*)
		Mercury-T (0.219[#])
		Iron-T (1090*, 1160*, 1160*)
		Dieldrin (0.0043[#])
	50.20	Dissolved oxygen (5.70[‡])
		Manganese-T (105*)
		Mercury-T (0.226[#])
		E. coli (697[¨¨])
		Dieldrin (0.0043[#])
	47.75	Mercury-T (0.240[#])
		E. coli (384[¨¨])

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Stillwater River (continued)	44.17	Manganese-T (102*) Copper-T (63**) Mercury-T (0.300[#], 0.233[#]) Iron-T (1100*) *E. coli* (344[""]) Dieldrin (0.0037[#])
	37.77	Manganese-T (151*, 116*) Iron-T (1700*, 1280*, 1250*) *E. coli* (150[")]
	33.50	Dissolved oxygen (5.50[‡]) Manganese-T (130*, 106*, 112*, 114*) Iron-T (2350*, 2160*) Fecal coliform (3350[""]) *E. coli* (171[")] Dieldrin (0.0024[#])
	32.55	Dissolved oxygen (5.20[‡]) Manganese-T (146*, 205*, 295*) Iron-T (1110*, 1400*, 1040*)
	27.85	Dissolved oxygen (5.45[‡])
	25.12	Iron-T (1080*)
	21.50	Iron-T (1040*, 1120*)
	18.20	Manganese-T (133[Ù]*, 90[Ù])
	15.05	Heptachlor (0.0029*[#])
	14.65	Dissolved oxygen (5.70[‡])
	13.60	Dissolved oxygen (5.90[‡]) Iron-T (1150*) Aldrin (0.0067[#]) Heptachlor (0.0021*)
	11.40	Dissolved oxygen (5.30[‡]) Iron-T (1090*)
	9.10	Manganese-T (106*) Iron-T (1060*, 1360*, 1150*, 1020*)

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Stillwater River (continued)	8.75	Iron-T (1190*, 1340*, 1060*) Aldrin (0.0062[#]) Dieldrin (0.0081*[#])
	4.96	Manganese-T (112*, 108*) Iron-T (1280*, 1600*, 1370*, 1260*) Aldrin (0.0064[#]) Dieldrin (0.0078*[#])
	1.92	Manganese-T (104*, 162*) Iron-T (1390*, 3480*) Aldrin (0.0062[#]) Dieldrin (0.0074*[#])
Tributary to Stillwater River @ RM 64.96 (UNDESIGNATED)	0.33	Dissolved oxygen (2.20[‡]) Manganese-T (2020***) Mercury-T (0.210[#]) Ammonia-N (34.20**[F]) Fecal coliform (25000[""])
South Fork Stillwater River (WWH, PCR, AWS, IWS)	1.26	Dissolved oxygen (3.90[‡‡]) Mercury-T (0.217[#]) *E. coli* (504[""])
	0.40	Manganese-T (136*) Mercury-T (0.223[#]) *E. coli* (306[""])
Tributary to South Fork Stillwater River @ RM 0.94 (UNDESIGNATED)	1.56	Mercury-T (0.213[#])
Woodington Run (WWH, PCR, AWS, IWS)	3.36	Dissolved oxygen (3.40[‡‡], 4.20[‡], 4.00[‡] , 4.40[‡]) Manganese-T (402*, 101*, 193*) Mercury-T (0.230[#]) *E. coli* (254[")]
	0.72	Dissolved oxygen (4.70[‡]) Mercury-T (0.220[#])
North Fork Stillwater River (MWH, PCR, AWS, IWS)	8.90	Dissolved oxygen (2.20[‡‡], 3.80[‡]) Manganese-T (372*, 275*, 189*, 531*, 791*) Mercury-T (0.211[#]) Iron-T (1220*, 1360*, 3610*, 2580*) Ammonia-N (1.88*[B], 1.76*[B], 3.22*[B]) Fecal coliform (2500[""]) *E. coli* (324[""])

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
North Fork Stillwater River (continued)	7.12	Dissolved oxygen (2.80[‡‡], 3.80[‡], 3.50[‡]) Manganese-T (160*, 304*, 499*, 697*) Mercury-T (0.206[#]) Iron-T (1740*, 1960*) *E. coli* (453[""])
	0.40	Dissolved oxygen (3.20[‡], 3.20[‡]) Manganese-T (355*, 238*, 113*, 242*) Mercury-T (0.233[#]) Iron-T (1140*, 5280*[4]) Fecal coliform (1750[")] *E. coli* (478[""]) gamma-Hexachlorocyclohexane (0.011*[J]) Dieldrin (0.0075*[#])
Boyd Creek (WWH, PCR, AWS, IWS)	0.81	Dissolved oxygen (4.90[‡]) Manganese-T (101*) Mercury-T (0.241[#]) Iron-T (1930*) Fecal coliform (1036[", 1200[")] *E. coli* (1091[""])
Tributary to Stillwater River @ RM 51.02 (UNDESIGNATED)	1.20	Mercury-T (0.250[#]) *E. coli* (1445[""""])
Swamp Creek -Headwaters to RM 6.5 (MWH, PCR, AWS, IWS)	12.05	Manganese-T (189*, 550*, 521*, 1150**, 1860**) Mercury-T (0.224[#]) Iron-T (3550*)
-RM 6.5 to mouth (WWH, PCR, AWS, IWS)	8.85	Dissolved oxygen (3.80[‡], 3.20[‡], 3.70[‡]) Manganese-T (190*, 433*, 126*, 122*, 240*) Mercury-T (0.229[#]) Iron-T (1040*)
	6.51	Dissolved oxygen (2.50[‡‡]) Manganese-T (213*, 423*, 167*, 140*, 261*) Mercury-T (0.213[#]) Iron-T (1490*) Fecal coliform (6636[""]) *E. coli* (531[""])

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Swamp Creek (continued)	4.44	Dissolved oxygen (3.80[‡‡]) Manganese-T (165*, 233*, 173*, 160*, 262*) Mercury-T (0.210[#]) Iron-T (1020*) Fecal coliform (2200[""])
	2.85	Manganese-T (104*, 186*, 109*, 112*) Mercury-T (0.203[#]) Ammonia-N (0.452*[F]) Fecal coliform (8545[""]) *E. coli* (192[")]
	2.20	pH (9.40[Ä]) Temperature (32.0**) Ammonia-N (0.390*[F]) Manganese-T (177*) Iron-T (1870*) Fecal coliform (45000[""]) *E. coli* (2005[""]) Aldrin (0.015*[#])
	1.59	Dissolved oxygen (4.40[‡], 4.50[‡]) Manganese-T (126*, 147*, 358*) Iron-T (3840*) Fecal coliform (2400[""], 4800[""]) *E. coli* (2005[""]) Aldrin (0.034*[#])
	0.28	Dissolved oxygen (3.60[‡‡], 4.80[‡]) Manganese-T (130*, 103*, 110*, 130*, 126*) Iron-T (1580*) *E. coli* (1184[""]) gamma-Hexachlorocyclohexane (0.012*) Dieldrin (0.012*[#])
Grassy Fork (UNDESIGNATED)	0.82	Dissolved oxygen (2.60[‡], 2.50[‡]) Manganese-T (1460**, 2460***) Mercury-T (0.201[#])
Tributary to Swamp Creek @ RM 3.54 (UNDESIGNATED)	0.45	Dissolved oxygen (1.40[‡‡]) Manganese-T (2160***) *E. coli* (2005[""""]) Dieldrin (0.01[#])

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Indian Creek (WWH, PCR, AWS, IWS)	6.11	Dissolved oxygen (2.52‡‡, 3.00‡‡, 4.20‡) Temperature (28.0*) Manganese-T (918*, 1240**, 1190**, 1070**) Iron-T (1200*, 3350*, 2650*, 4450*) Ammonia-N (0.820*[B])
	1.93	Dissolved oxygen (4.00‡, 3.80‡‡, 4.80‡) Manganese-T (439*, 316*, 254*, 192*, 191*) Iron-T (1020*, 2110*) *E. coli* (306"") Dieldrin (0.002#)
	0.48	Dissolved oxygen (4.80‡, 3.80‡‡, 4.80‡) Manganese-T (241*, 155*) *E. coli* (453"")
Tributary to Stillwater River @ RM 38.30 (UNDESIGNATED)	0.60	Dissolved oxygen (1.50‡‡) Fecal coliform (21000""")
Trotters Creek (WWH, PCR, AWS, IWS)	0.97	Dissolved oxygen (4.90‡, 4.50‡, 2.80‡‡) Manganese-T (112*, 152*, 139*, 186*, 164*) Iron-T (1130*, 1840*, 1010*) Fecal coliform (2500"") Dieldrin (0.0079*#)
Harris Creek (WWH, PCR, AWS, IWS)	5.20	Manganese-T (124*, 140*, 152*, 157*) Iron-T (1170*, 1460*, 1210*) Fecal coliform (3100"", 2200"") *E. coli* (2005"")
	2.02	Iron-T (1420*) Fecal coliform (4700"") *E. coli* (406"") gamma-Hexachlorocyclohexane (0.011*) Dieldrin (0.0032#) bis(2-Ethylhexyl)phthalate (14*)
Ballinger Run (WWH, PCR, AWS, IWS)	2.75	Dissolved oxygen (3.60‡‡, 4.50‡, 3.40‡‡, 3.60‡‡) Manganese-T (350*, 210*, 671*, 1490**) Iron-T (6730*[4], 2600*, 3670*, 4460*)

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Ballinger Run (continued)	1.40	Dissolved oxygen (4.30‡) Total Dissolved Solids(1890*, 1990*, 7550*, 2530*) Conductivity (2500*, 9930*, 3990*) Manganese-T (118*, 377*, 178*, 312*, 373*) Ammonia-N (3.06*[L]) Fecal coliform (121000"", 21000"")
	0.59	Conductivity (2460*) Fecal coliform (50000"") *E. coli* (531"") Heptachlor (0.0035*#)
Tributary to Stillwater River @ RM 32.60 (UNDESIGNATED)	0.75	Fecal coliform (60000"""")
Greenville Creek -At RM 22.3 (SRW, EWH, PCR, PWS, AWS, IWS) -All other segments (SRW, EWH, PCR, AWS, IWS)	26.60	*E. coli* (275")
	24.60	Dissolved oxygen (5.60‡) *E. coli* (341"")
	23.08	Dissolved oxygen (5.90‡) *E. coli* (201")
	19.55	Iron-T (2830*) Fecal coliform (2000") *E. coli* (164")
	18.34	Manganese-T (122*) Iron-T (1850*) Fecal coliform (5636"") *E. coli* (207") Aldrin (0.0063#) gamma-Hexachlorocyclohexane (0.015*)
	16.22	Dissolved oxygen (4.80‡‡) Naphthalene (0.62#) gamma-Hexachlorocyclohexane (0.013*, 0.011*)
	13.70	Manganese-T (104*)
	10.86	*E. coli* (222") gamma-Hexachlorocyclohexane (0.012*) Dieldrin (0.0026#)

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Greenville Creek (continued)	9.92	Dissolved oxygen (5.50‡) Fecal coliform (2400"", 1200") *E. coli* (1652"") gamma-Hexachlorocyclohexane (0.012*)
	6.10	*E. coli* (150") Aldrin (0.0072#) gamma-Hexachlorocyclohexane (0.011*) Dieldrin (0.0099*#) Heptachlor (0.0046*#)
	1.45	gamma-Hexachlorocyclohexane (0.012*)
Dismal Creek (WWH, PCR, AWS, IWS)	4.70	Manganese-T (189*, 153*, 128*)
	1.76	Dissolved oxygen (3.80‡‡, 4.20‡) Manganese-T (151*, 112*, 116*, 192*) Iron-T (1200*, 1030*) Fecal coliform (1264") *E. coli* (455"")
	0.10	Dissolved oxygen (3.50‡‡, 4.60‡, 2.80‡‡) Manganese-T (142*, 118*, 149*, 354*) *E. coli* (146")
Kraut Creek (WWH, PCR, AWS, IWS)	5.95	Iron-T (1740*) *E. coli* (164")
	0.60	*E. coli* (249")
West Branch Greenville Creek (WWH, PCR, AWS, IWS)	7.36	Fecal coliform (2000") *E. coli* (344"")
	5.78	*E. coli* (531"")
	0.30	Iron-T (1020*)
Mud Creek -At RM 0.3 (WWH, PCR, PWS, AWS, IWS) -All other segments (WWH, PCR, AWS, IWS)	7.50	Dissolved oxygen (2.50‡‡, 3.80‡‡, 4.00‡) Manganese-T (628*) Iron-T (11300*%) Fecal coliform (2100"") *E. coli* (238")
	5.87	Fecal coliform (1900") *E. coli* (137")

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Mud Creek (continued)	4.67	Temperature (29.0*) Fecal coliform (2300[""]) *E. coli* (697[""])
	0.09	Dissolved oxygen (4.80[‡], 4.60[‡]) Iron-T (1060*) Fecal coliform (2000["]) *E. coli* (137["]) Aldrin (0.0071[#])
Prairie Outlet (WWH, PCR, AWS, IWS)	0.80	Manganese-T (140*) Fecal coliform (21000[""]) *E. coli* (697[""])
Lake Branch Ditch (UNDESIGNATED)	0.40	Fecal coliform (9000[""""]) *E. coli* (1184[""""])
Bridge Creek (WWH, PCR, AWS, IWS)	0.28	Fecal coliform (2000["]) *E. coli* (344[""])
Dividing Branch (WWH, PCR, AWS, IWS)	3.87	Dissolved oxygen (4.30[‡]) Manganese-T (137*, 183*) Fecal coliform (1500["])
	3.51	Manganese-T (236*, 129*) Iron-T (1050*) *E. coli* (406[""])
	0.10	Fecal coliform (1200["]) *E. coli* (324[""])
Bolton Run (WWH, PCR, AWS, IWS)	0.60	Dissolved oxygen (4.80[‡]) Manganese-T (174*, 204*, 134*, 150*, 167*) Fecal coliform (1200["], 2900[""]) *E. coli* (2005[""])
Poplar Ditch (WWH, PCR, AWS, IWS)	0.50	Fecal coliform (2600[""], 2500[""]) *E. coli* (207["])
McQuay Ditch (WWH, PCR, AWS, IWS)	0.50	Dissolved oxygen (3.50[‡‡]) Manganese-T (148*) Fecal coliform (1400["], 10686[""]) *E. coli* (2005[""])

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Painter Creek -Headwaters to Darke County (RM 5.5) (MWH, PCR, AWS, IWS) - Darke County line to mouth (EWH, PCR, AWS, IWS)	17.90	Dissolved oxygen (2.25‡‡) Manganese-T (407*) Iron-T (1860*)
	16.20	Manganese-T (118*, 180*) Fecal coliform (5900"")
	15.48	Dissolved oxygen (2.10‡‡, 3.80‡) Manganese-T (243*, 420*, 170*, 139*, 191*) Fecal coliform (44000"") Pentachlorophenol (11*) Aldrin (0.02*#)
	14.98	Dissolved oxygen(2.50‡‡, 2.10‡‡,1.90‡‡, 2.30‡‡, 2.00‡‡) Manganese-T (192*, 235*, 314*, 369*, 505*) Iron-T (1480*, 1940*, 1360*) Copper-T (32*) Ammonia-N (4.47*F, 4.60*F, 6.17*F) Fecal coliform (9636"") Dieldrin (0.0094*#)
	8.92	Dissolved oxygen (3.30‡) Manganese-T (107*, 192*) Fecal coliform (9000"")
	3.50	Dissolved oxygen (5.20‡, 5.00‡) Manganese-T (138*, 199*)
	0.80	Dissolved oxygen (5.80‡) *E. coli* (135", 238") 4,4'-DDT (0.0074*#) Dieldrin (0.008*#)
Tributary to Painter Creek @ RM 12.13 (UNDESIGNATED)	1.07	Dissolved oxygen (2.00‡, 0.25‡‡, 0.30‡‡) Manganese-T (2450***, 1460**)
Tributary to Painter Creek @ RM 10.81 (UNDESIGNATED)	1.68	Dissolved oxygen (0.50‡‡, 0.70‡‡) Manganese-T (1910**)
Little Painter Creek (WWH, PCR, AWS, IWS)	1.18	Dissolved oxygen (4.80‡) Manganese-T (109*, 137*) Iron-T (1190*, 1390*, 1260*, 1700*, 1440*)
Heller Ditch (WWH, PCR, AWS, IWS)	0.05	Dissolved oxygen (4.50‡, 4.70‡) Manganese-T (159*)

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Opossum Run (WWH, PCR, AWS, IWS)	1.20	*E. coli* (199[˝], 344[˝˝])
Rocky Run (WWH, PCR, AWS, IWS)	0.50	*E. coli* (384[˝˝])
Ludlow Creek (WWH, PCR, AWS, IWS)	12.65	Dissolved oxygen (4.30[‡]) Fecal coliform (5000[˝˝]) Dieldrin (0.0041[#], 0.005[#])
	6.40	Dissolved oxygen (4.60[‡], 4.40[‡]) Manganese-T (164*) *E. coli* (178[˝]) Dieldrin (0.0038[#])
	3.49	Dissolved oxygen (3.50[‡‡]) Manganese-T (196*)
	2.33	*E. coli* (189[˝])
	0.65	Iron-T (1530*) *E. coli* (441[˝˝], 344[˝˝])
Tributary to Ludlow Creek @ RM 11.80 (UNDESIGNATED)	0.45	Fecal coliform (29000[˝˝˝])
Browns Ditch (WWH, PCR, AWS, IWS)	0.30	Dissolved oxygen (2.50[‡‡], 4.10[‡]) Manganese-T (132*, 122*) Fecal coliform (6455[˝˝])
Feitshams Ditch (WWH, PCR, AWS, IWS)	0.60	Dissolved oxygen (2.70[‡‡], 2.30[‡‡]) Fecal coliform (1300[˝])
Hog Run (WWH, PCR, AWS, IWS)	0.20	Copper-T (36*) *E. coli* (152[˝]) gamma-Hexachlorocyclohexane (0.014*) Heptachlor (0.0054*[#])
Brush Creek -Rm 0.5 to mouth (SRW, WWH, PCR, AWS, IWS) -All other segments (WWH, PCR, AWS, IWS)	7.85	Dissolved oxygen (3.00[‡‡], 2.40[‡‡], 1.20[‡‡]) Manganese-T (191*) Ammonia-N (2.70*[B], 3.62*[L], 4.68*[L]) Fecal coliform (7545[˝˝]) *E. coli* (9804[˝˝], 782[˝˝]) gamma-Hexachlorocyclohexane (0.012*)

Table 6. Continued.

Stream (use designation [a])	River Mile	Parameter [b] (value)
Brush Creek (continued)	7.17	Dissolved oxygen (3.40‡‡, 3.50‡‡, 3.30‡‡)
	0.45	*E. coli* (190¨)
Brush Creek (EWH, PCR, AWS, IWS)	0.12	Dissolved oxygen (5.20‡, 5.90‡, 3.70‡‡, 2.00‡‡) Manganese-T (143*)
Mill Creek (WWH, PCR, AWS, IWS)	3.67	Dissolved oxygen (4.30‡) Manganese-T (111*, 109*) Iron-T (1580*, 1240*) Ammonia-N (0.443*L) *E. coli* (211¨)
	2.62	Dissolved oxygen (4.30‡) Heptachlor (0.0067*#)
	1.18	*E. coli* (318¨¨)
Pigeye Creek (WWH, PCR, AWS, IWS)	0.60	Fecal coliform (60000¨¨) *E. coli* (2005¨¨)

a Use designations:

SRW - State Resource Water

Aquatic Life Habitat	Water Supply	Recreation
EWH - exceptional warmwater habitat	PWS - public water supply	PCR - primary contact
WWH - warmwater habitat	IWS - industrial water supply	
MWH - modified warmwater habitat	AWS - agricultural water supply	
LRW - limited resource water		

.[At a minimum, LRW criteria apply to 'undesignated' surface waters.]

b Bacteriological data (fecal coliform, *E. coli*) are shown to gauge the potential for impacts to receiving waters and do not represent actual exceedences of criteria.

-Actual exceedences of the average primary contact recreation (PCR) criteria are based on a geometric mean of not less than five samples within a thirty-day period whereas PCR maximum criteria represent the values which are not to be exceeded in more than ten percent of the samples in a thirty-day period.

-Requirements associated with the maximum criteria applicable to all waters include: samples must be collected during steady state flow representative of dry weather conditions; at least two or more samples must exceed criteria when five or fewer samples are collected, or criteria must be exceeded in more than twenty percent of the samples when more than five samples are taken.

-Additionally, bacteriological samples collected during the survey were not analyzed within the required holding time and, again, are included in this table only to gauge the potential for impacts.

Table 6. Continued.

*	exceedence of numerical criteria for prevention of chronic toxicity (CAC).
**	exceedence of numerical criteria for prevention of acute toxicity (AAC).
***	exceedence of numerical criteria for prevention of lethality (FAV).
#	exceedence of numerical criteria for the protection of human health (non-drinking).
‡	value is below the EWH minimum 24-hour average dissolved oxygen (D.O.). criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O. criterion (4.0 mg/l) or value is below the LRW minimum 24-hour average D.O. criterion (3.0 mg/l) as applicable.
‡‡	value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the MWH minimum at any time D.O. criterion (3.0 mg/l) or value is below the LRW minimum at any time D.O. criterion (2.0 mg/l) as applicable.
"	value is above the average Primary Contact Recreation (PCR) criteria (See note *b* above). (fecal coliform 1000/100ml; *E. coli* 126/100ml)
""	value is above the maximum Primary Contact Recreation (PCR) criteria (See note *b* above). (fecal coliform 2000/100ml; *E. coli* 298/100ml)
"""	value is above maximum criteria applicable to all waters (See note *b* above). (fecal coliform 5000/100ml; *E. coli* 576/100ml)
Ä	exceedence of the pH criteria (6.5-9.0).
Ù	exceedence of the public water supply criterion (applies within 500 yards of surface water intakes).
4	exceedence of agricultural water supply criterion.
J	The analyte was positively identified; the associated numerical value is estimated.
B	Ammonia exceedence is based on both field and laboratory analyzed pH.
F	Ammonia exceedence is based on field analyzed pH.
L	Ammonia exceedence is based on laboratory analyzed pH.

Table 7. Number of exceedences of Ohio EPA water quality criteria (OAC 3745-1) for dissolved oxygen (D.O.), and minimum D.O. values measured by Datasondes® during hourly diel sampling of the Stillwater River basin, 1999.

Stream(Use Designation[1])	RM	Number of Measurements Below Minimum at Any Time Criteria	Minimum D.O. Value Recorded
Stillwater River -Headwaters to RM 56.97 (SRW, WWH, PCR, AWS, IWS)	62.97	20	1.95
North Fork Stillwater River (MWH, PCR, AWS, IWS)	4.16 0.40	13 12	1.79 2.31
Swamp Creek -RM 6.5 to mouth (WWH, PCR, AWS, IWS)	2.85	2	3.93
Indian Creek (WWH, PCR, AWS, IWS)	1.93	10	3.27
Painter Creek -Headwaters to RM 5.5 (MWH, PCR, AWS, IWS)	8.92	4	2.69

[1] See Table 6 for explanation of abbreviations.

Table 8. Frequency of organic compounds detected in water samples collected in the Stillwater River study area during 1999 (number of water quality criteria exceedences/number of detections).

Parameter	Stillwater River (mainstem)	Swamp Creek (subbasin)	Greenville Creek (subbasin)	Painter Creek (subbasin)	Ludlow Creek (subbasin)	Mill Creek (mainstem)	Other	TOTAL Stillwater Basin
Pesticides								
Alachlor*	-	*/1	-	-	*/1	-	-	*/2
Aldrin	4/4	2/2	3/3	1/1	-	-	-	10/10
alpha-Hexachlorocyclohexane	-/3	-/3	-/5	-/1	-	-/1	-/4	-/17
Atrazine*	*/26	*/9	*/1	*/1	*/9	-	*/4	*/50
beta-Hexachlorocyclohexane	-	-	-	-	-	-/1	-	-/1
4,4'-DDE*	-	-	-	*/1	-	-	-	*/1
4,4'-DDT	-	-	-	1/1	-	-	-	1/1
delta-Hexachlorocyclohexane*	*/13	-	*/7	*/2	*/4	*/1	-	*/27
Dieldrin	7/7	3/3	2/2	2/2	3/3	-	3/3	20/20
Endosulfan I	-	-	-	-/1	-	-	-	-/1
Endosulfan II	-/1	-	-	-	-	-	-	-/1
Endrin Aldehyde*	-	-	-	-	-	-	*/1	*/1
gamma-Hexachlorocyclohexane(Lindane)	-/17	1/3	7/11	-/1	2/4	-/1	2/5	12/42
Heptachlor	2/2	-	1/1	-	1/1	1/1	1/1	6/6
Heptachlor epoxide*	*/3	*/2	*/5	*/1	*/3	*/3	*/5	*/22
Hexachlorobenzene	-	-/1	-/1	-	-	-/2	-/1	-/5
Metolachlor*	*/26	*/9	*/2	-	*/3	-	-	*/40
Simazine	-/7	-/1	-	-	-	-	-	-/8
Semivolatile compounds (SVOCs)								
bis(2-Ethylhexyl)phthalate	-/5	-/2	-	-/1	-/2	-/1	1/3	1/14
Pentachlorophenol	-	-/1	-	1/1	-	-	-	1/2
Volatile compounds (VOCs)								
Bromodichloromethane*	-	-	-	-	*/2	-	-	*/2
Chloroethane*	-	-	-	-	*/1	-	-	*/1
Chloroform	-/1	-	-	-	-/2	-	-/2	-/5
cis-1,2-Dichloroethene*	-	-	-	*/1	-	-	-	*/1
Dibromochloromethane*	-	-	-	-	*/1	-	-	*/1
Naphthalene	-	-	1/1	-	-	-	-	1/1
Tetrachloroethene	-	-	-	-/1	-	-	-	-/1
Toluene	-	-	-	-	-	-/1	-	-/1
Trichloroethene	-/1	-	-	-/1	-	-	-	-/2
TOTAL	**13/116**	**6/37**	**14/39**	**5/17**	**6/36**	**1/12**	**7/29**	**52/286**

* No applicable water quality criteria available for parameter.

Chemical Water Quality Changes (Figures 50 - 65)

Stillwater River

Eight years (1989-1990, 1994-1999) of monthly ambient monitoring in the Stillwater River at Pleasant Hill (RM 27.85) for flow, ammonia-N, nitrate-nitrite-N, total phosphorus, and TSS are summarized in Figure 78. Annual median stream flow (for water chemistry sampling days) ranged from 48 cfs (1994) to 313 cfs (1996). Concentrations of ammonia-N were generally low throughout the period with 73% of values at or below the minimum detection limit of 0.05 mg/l. Somewhat higher concentrations were measured in 1996 (33% of values > MDL and a maximum of 0.41 mg/l) and 1998 (45% of values > MDL and a maximum of 0.5 mg/l). An overall maximum ammonia-N concentration of 2.70 mg/l was recorded in December of 1994 for the eight year period. Annual median nitrate-nitrite-N concentrations ranged from 1.06 mg/l (1994) to 5.38 mg/l (1998) with overall median and maximum values of 3.2 mg/l and 11.7 mg/l (February 1998) recorded for the eight year period. An overall phosphorus median of 0.15 mg/l was recorded for the eight years. Annual phosphorus medians ranged from 0.09 mg/l (1995) to 0.22 mg/l (1999) with maximums of 1.2 mg/l (May 1998) and 1.1 mg/l (March 1998) for the period. Median total suspended solids at the site ranged from less than the MDL of 5 mg/l in 1997 to 19.5 mg/l in 1999. Most parameter concentrations which were elevated above applicable 90th percentile reference values coincided with higher flow days, indicative of impacts associated with non-point runoff in the basin.

Ohio EPA previously conducted an intensive biological and water quality study of the Stillwater River basin in 1990. Additionally, a much more limited survey of the Stillwater basin was conducted in 1995. May through September stream flows for 1999, 1995 and 1990 as measured by USGS gage stations in the Stillwater River at Pleasant Hill (RM 27.85) and Englewood (RM 8.82) are compared in Figure 79. Mean daily flows measured at both gages were significantly higher in 1990 compared to 1999 with 1995 flows generally falling in the middle. With the exception of June, monthly mean discharges measured in the Stillwater River in 1990 from May through September were 85-200% above normal while mean monthly flows in 1999 were 60-80% below normal for the same five months. Median flows of 270 cfs (1990), 178 cfs (1995) and 83 cfs (1999) were measured at Pleasant Hill for the five month period (May through September) while medians of 367 cfs (1990), 264 cfs (1995) and 104 cfs (1999) were recorded at Englewood. A similar pattern was observed on specific water chemistry sampling days with much higher flows recorded during the 1990 and 1995 surveys compared to 1999. For specific water chemistry sampling days, median flows of 262 cfs (1990), 135 cfs (1995) and 36.5 cfs (1999) were measured at Pleasant Hill while medians of 225 cfs (1995), 213 cfs (1990) and 48.5 cfs (1999) were recorded at Englewood. Maximum flows measured at the Pleasant Hill gage on sampling days ranged from 75 cfs (1999) to 2810 cfs (1990) while maximums at Englewood ranged from 89 cfs (1999) to 3110 cfs (1990).

A comparison of 1999, 1995, and 1990 median water chemistry results for select parameters in the mainstem is presented in Figures 80-81. Water samples were collected from twenty-six (26) sites in the mainstem in 1999, two sites in 1995, and sixteen (16) sites in 1990 (including the West Milton and Englewood WWTPs mixing zones). There were ten (10) sites common to both the 1999 and 1990 surveys (RMs 62.97, 61.80, 56.97, 32.55, 32.10, 27.85, 25.12, 18.20, 11.40, and

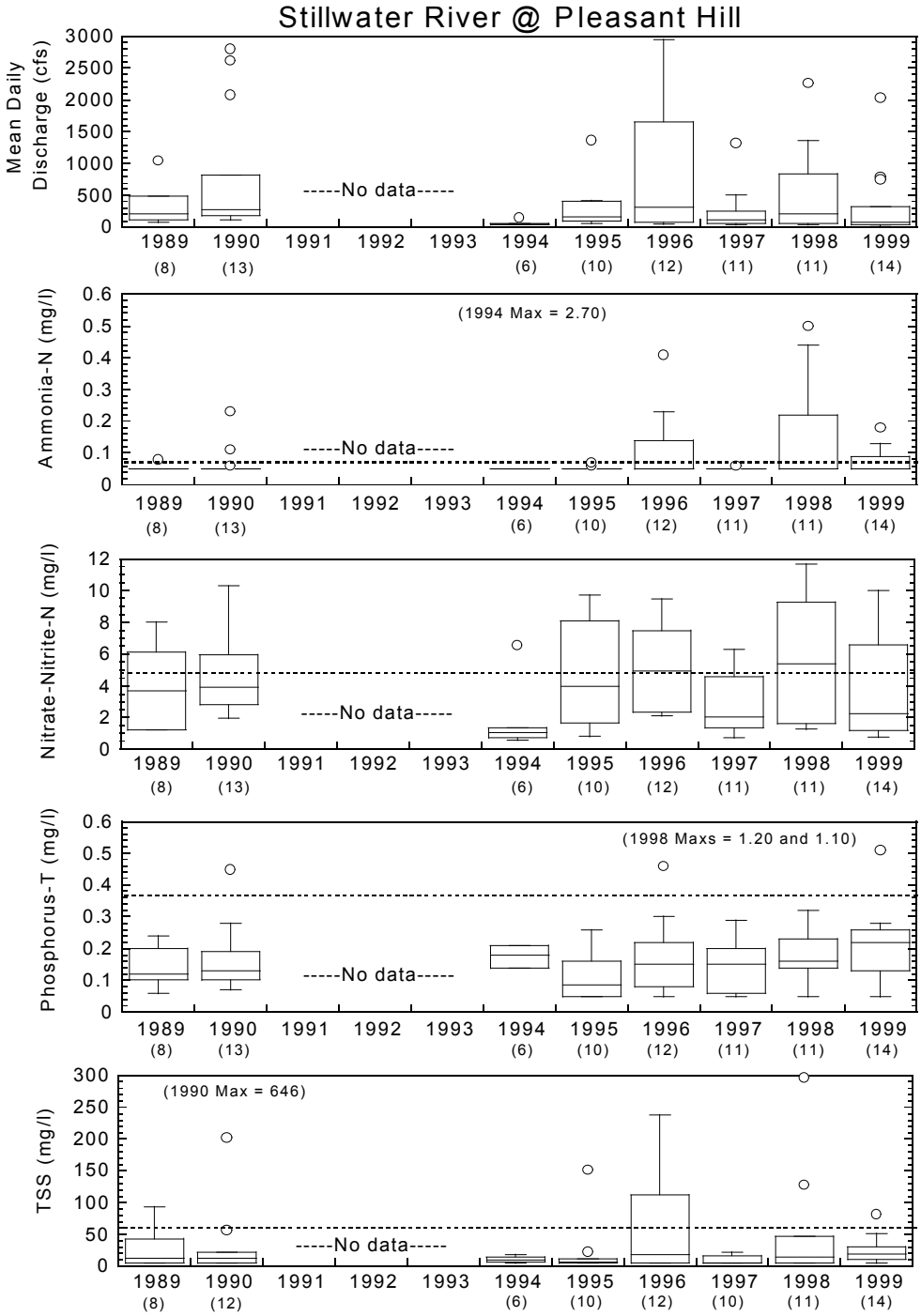


Figure 78. Yearly distributions of mean daily discharge (on water chemistry sampling days), ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) from monthly monitoring in the Stillwater River at Pleasant Hill (RM 27.85). Dashed lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (The number of samples in each year is indicated in parentheses.)

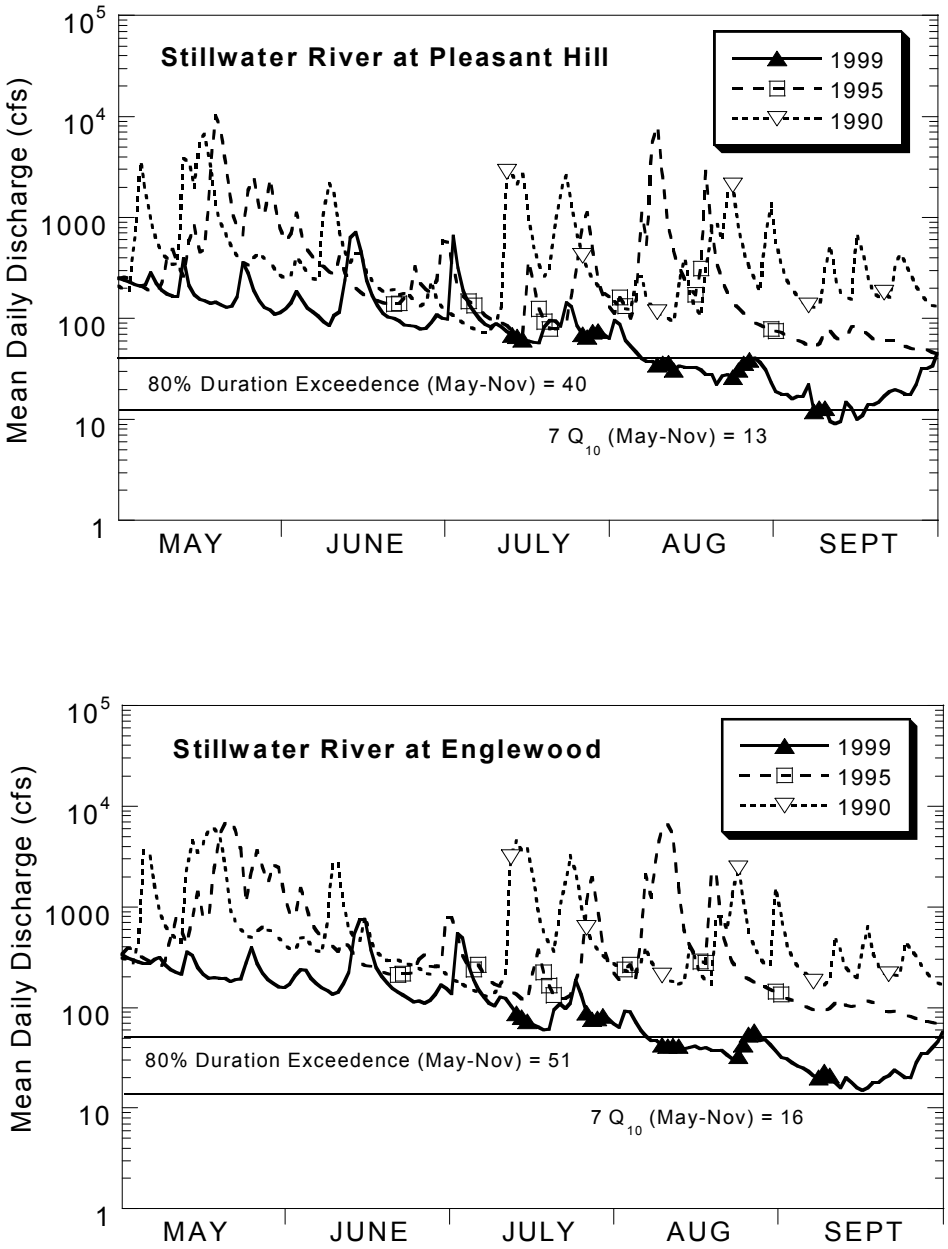


Figure 79. Flow hydrographs (1999, 1995, and 1990) for the Stillwater River at Pleasant Hill (RM 27.85) and Englewood (RM 8.82). Low flow conditions ($7Q_{10}$) and 80% duration exceedence flows for Pleasant Hill and Englewood are based on USGS stations #03265000 (period of record 1916-1928, 1934-1997) and #03266000 (period of record 1925-1997), respectively. Markers indicate river discharge on water chemistry sampling days for each survey.

4.96), one site (RM 43.50) common to both the 1995 and 1990 surveys, and one site (RM 61.80) which was sampled in all three survey years. (Given the minimal sampling in the mainstem in 1995, the following discussion is limited to the 1999 and 1990 surveys.) Dissolved oxygen median concentrations (daytime grabs) were higher in 1990 compared to 1999 at eight of the ten sites common to both surveys. While numerous 1999 D.O. daytime grab concentrations fell below applicable water quality criteria, all 1990 grab concentrations remained above criteria. Three sites in the mainstem (RMs 62.97, 58.0, and 56.97) were monitored with Datasonde continuous monitors during the 1990 survey. Similar to 1999, significant diurnal flux was documented at RM 62.97 in 1990 with lower levels measured at RMs 58.0 and 56.97. Nutrient loading (CSOs, the Ansonia WWTP, agricultural runoff) and poor habitat (channelization, narrow riparian, open canopies) impact this section of the mainstem.

Given the lower MDL for BOD_5 in 1990 (1 mg/l) relative to 1999 (2 mg/l), concentrations recorded during the 1999 and 1990 surveys in the mainstem appear relatively comparable with respective overall medians of 2.7 mg/l and 1.4 mg/l for all sites sampled (excluding mixing zones).

Concentrations of ammonia-N recorded during both surveys were generally low with medians at most sites approaching the MDL of 0.05 mg/l. Higher concentrations were documented in the headwaters during both surveys. The highest mainstem ammonia-N concentrations recorded in 1990 occurred at RMs 61.80 and 56.97 (respective medians of 0.12 mg/l and 0.08 mg/l). The highest 1999 concentrations occurred at RMs 57.90 and 56.97 (respective medians of 0.215 mg/l and 0.202 mg/l) downstream of the Ansonia WWTP and CSOs.

Nitrate-nitrite-N levels measured in the mainstem in 1990 far exceeded those recorded in 1999. Results reflect the substantial precipitation and higher stream flows in 1990 compared to 1999 and the concomitant impact of non-point source runoff. An overall median of 3.08 mg/l was recorded for all 1990 mainstem concentrations (excluding mixing zone sites) compared to a median concentration of only 0.3 mg/l for 1999 sites. Interestingly, the highest 1999 nitrate-nitrite-N values (median 2.08 mg/l) as well as the lowest 1990 concentrations (median 2.54 mg/l) were recorded at RM 32.10 downstream of the Covington WWTP. The highest 1990 concentrations were recorded in the channelized headwaters at RM 61.80 (median 6.19 mg/l) and RM 62.97 (median 5.00 mg/l).

Excluding the two mixing zone sites sampled in 1990, the overall median for all phosphorus concentrations recorded in the mainstem remained unchanged (0.17 mg/l for both 1999 and 1990). However, the overall median for phosphorus values recorded at the ten sites common to both surveys increased from 0.17 mg/l in 1990 to 0.20 mg/l in 1999. Site medians at the ten common sites were generally higher in 1999 (0.07 mg/l at RM 61.80 to 0.77 mg/l at RM 32.10) compared to 1990 (0.05 mg/l at RM 62.97 to 0.20 mg/l at RM 11.40) with the highest values in both surveys typically recorded downstream of WWTPs. Results suggest that the majority of phosphorus loading in the mainstem during both surveys emanated from point sources rather than from non-point sources and that higher flow periods masked the impact of point source phosphorus loading in the mainstem.

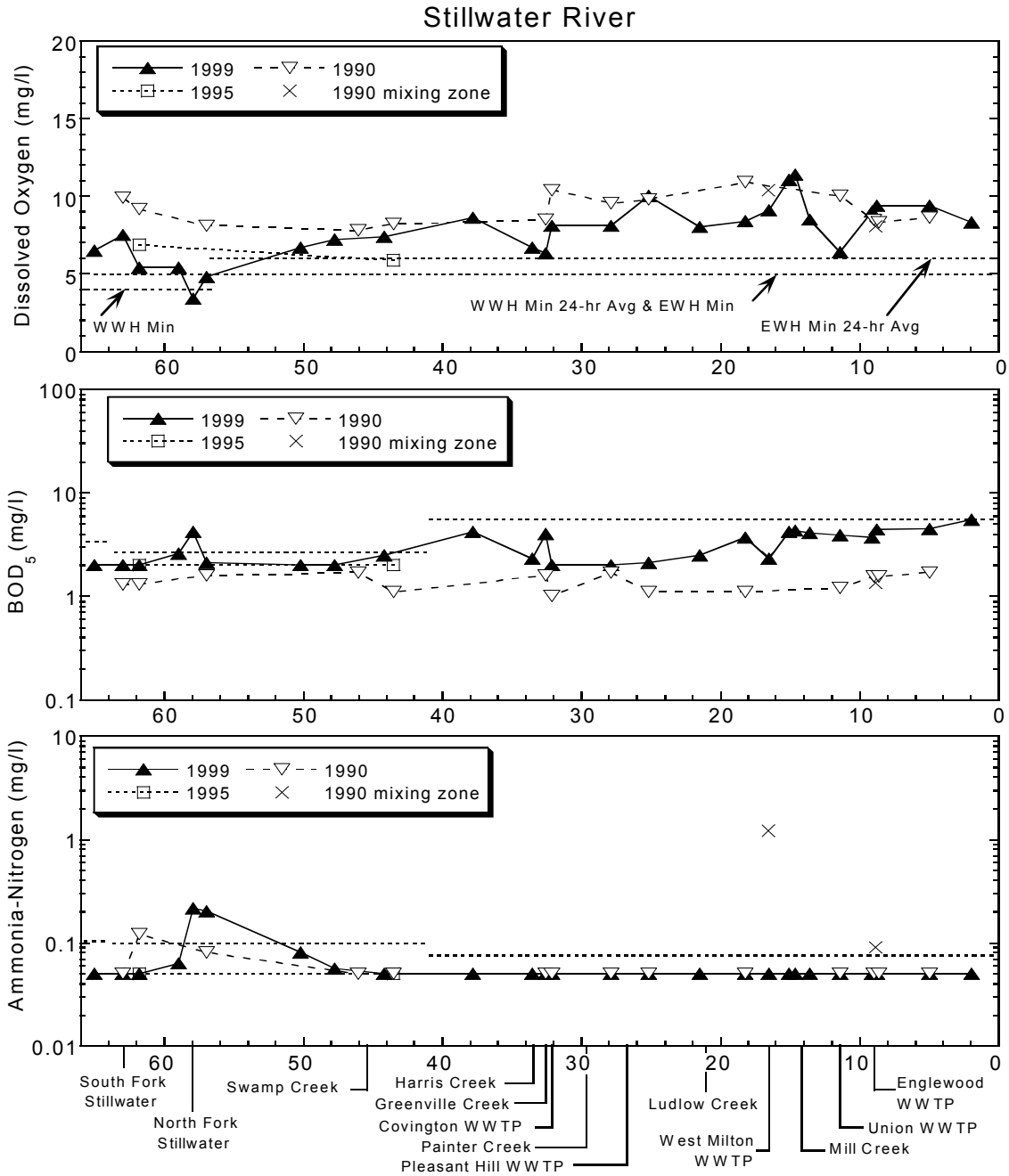


Figure 80. Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, and ammonia-nitrogen in the Stillwater River (1999, 1995 and 1990). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Note: The 1999 and 1995 MDL for BOD_5 is 2 mg/l; the 1990 MDL is 1 mg/l).

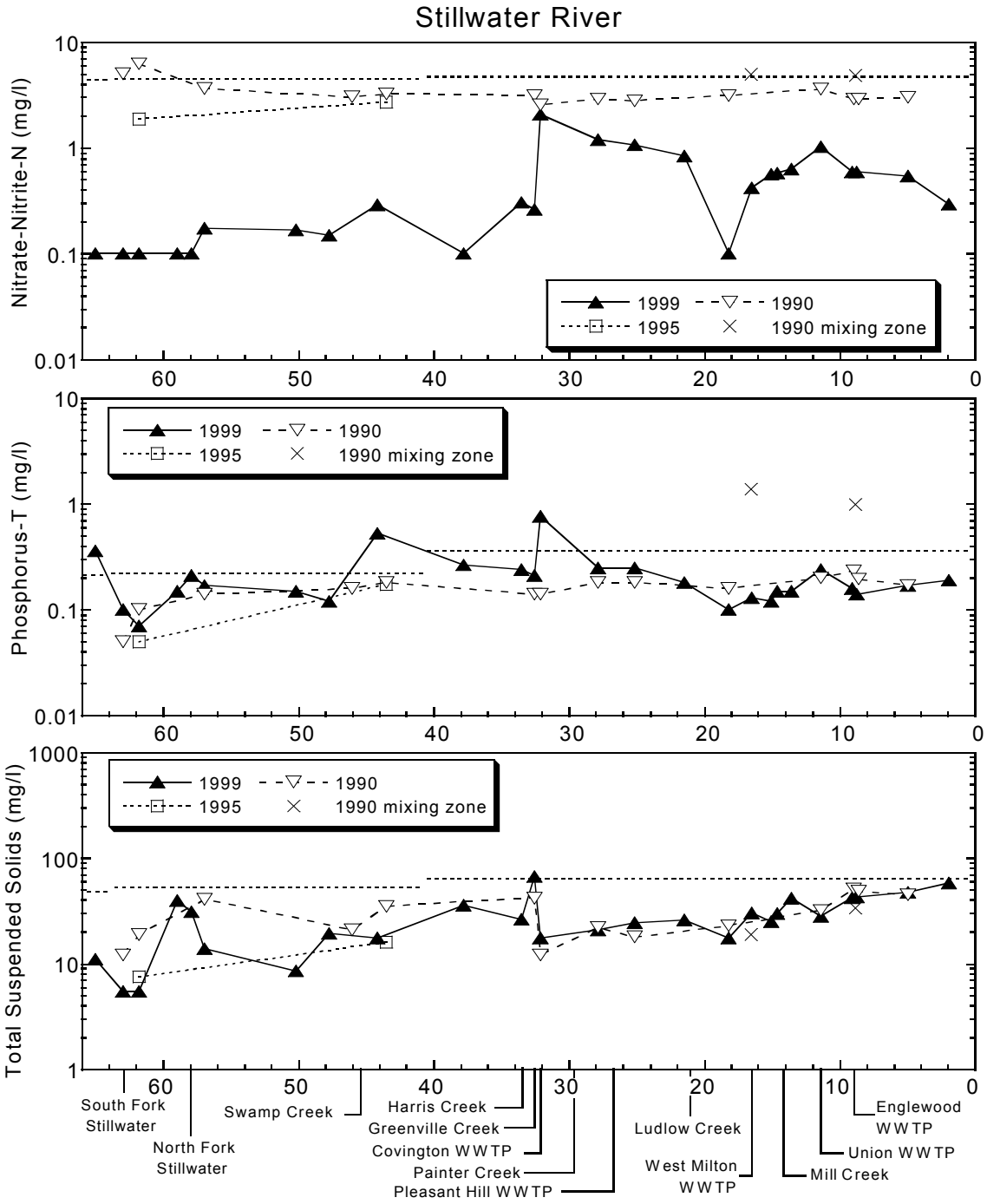


Figure 81. Median concentrations of nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids in the Stillwater River (1999, 1995 and 1990). Dashed horizontal lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

An overall median of 30 mg/l was measured for all TSS concentrations recorded at the ten common sites in the mainstem during the 1990 survey compared to 18.5 mg/l for the 1999 survey. Elevated individual concentrations typically coincided with higher flow days in both years. Some of the highest concentrations recorded in both surveys occurred at RM 32.55 in the Covington dam pool (1999 median 67 mg/l, 1990 median 42 mg/l). Of the total 45 fecal coliform samples collected from the 26 mainstem sites sampled in 1999, only one value was elevated above the average Primary Contact Recreation criterion. In comparison, 47% of the total 91 samples collected at the 14 non-mixing zone sites during the 1990 survey exceeded the average PCR criterion. The highest median concentrations in 1990 were recorded in the headwaters at RMs 56.97 and 61.80 (respective medians of 4900 colonies/100 ml and 4800 colonies/100 ml). (*E. Coli* samples were not collected in 1990.)

South Fork Stillwater River and North Fork Stillwater River
Water chemistry daytime grab samples were collected in the South Fork Stillwater River in 1995 at RM 1.00 and in the North Fork Stillwater River in 1990 at RM 0.40. Respective median water chemistry results are compared to 1999 samples collected at RM 1.26 in the South Fork and at RM 0.40 in the North Fork in Figure 82.

Median dissolved oxygen measured in the South Fork Stillwater River at RMs 1.26 (1999) and 1.00 (1990) approached 7 mg/l. Concentrations of BOD_5, ammonia-N, and TSS remained low in the South Fork during both surveys while 1995 nitrate-nitrite-N concentrations were substantially higher than 1999 values (respective medians of 2.54 mg/l and 0.1 mg/l). Somewhat higher phosphorus levels were measured in 1999 (median 0.1 mg/l) compared to 1995 (median 0.05 mg/l) in this tributary. Fecal coliform concentrations remained below the average PCR criterion in both years.

Daytime grab D.O. concentrations measured at RM 0.40 in the North Fork Stillwater River dropped below water quality criterion on two occasions in 1999 but remained above criterion in 1990 (respective medians of 4.2 mg/l and 8.5 mg/l). Datasonde continuous monitors, however, recorded significant diurnal fluctuation and numerous concentrations below water quality criterion at the site during both survey years. BOD_5 median concentrations were not elevated in either year. While 1999 concentrations of ammonia-N, nitrate-nitrite-N, and phosphorus remained low, levels were elevated at the site in 1990 (respective 1990 medians of 0.11 mg/l, 3.09 mg/l, and 0.50 mg/l). Median TSS concentrations approximated 20 mg/l in both survey years. One of two fecal coliform samples collected in 1999 exceeded PCR criterion while 1990 concentrations exceeded criterion in 4 of 6 samples.

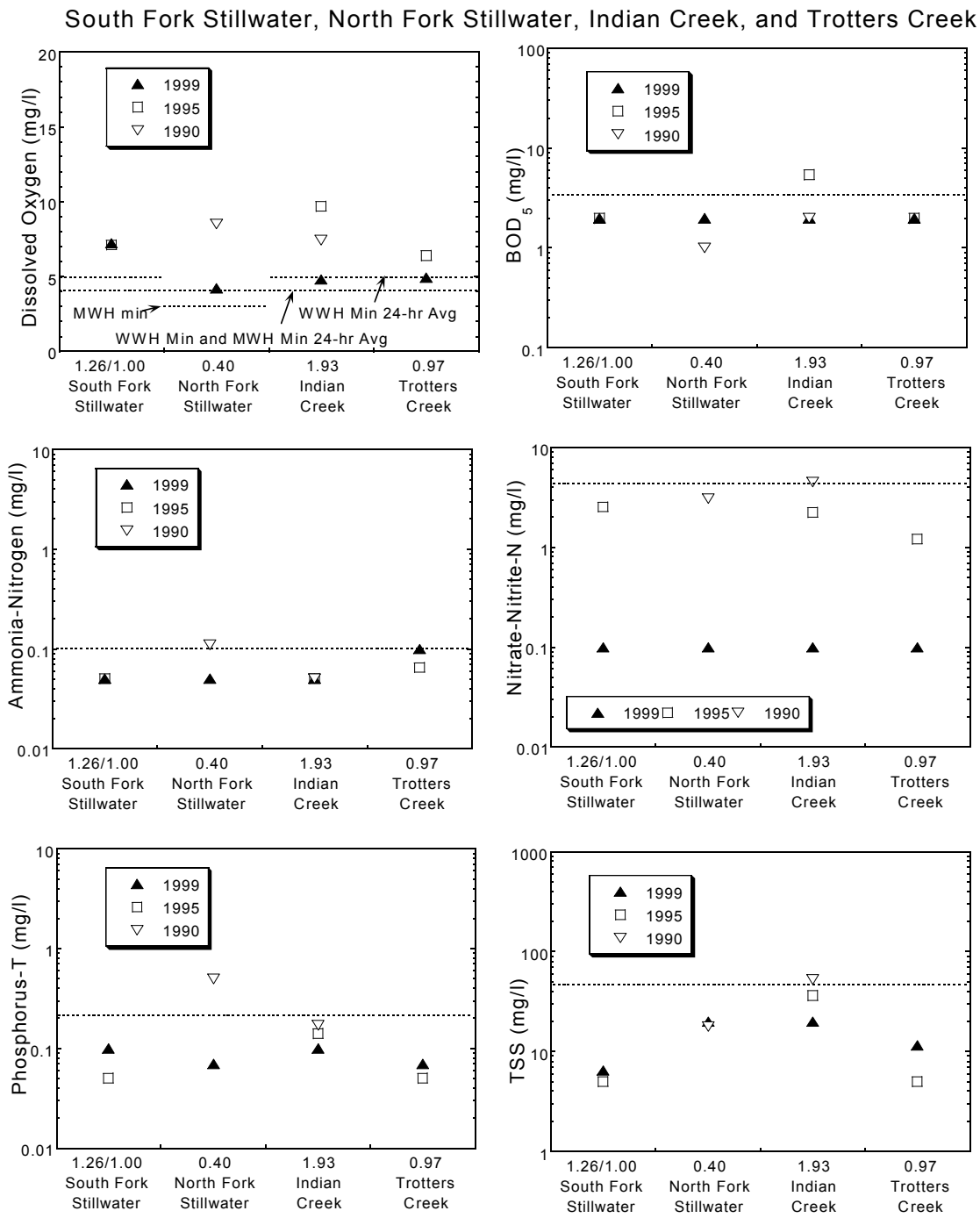


Figure 82. Left to right from the top: Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in tributaries in the Stillwater basin (1999, 1995 and 1990). Water quality criteria are shown in the dissolved oxygen plot. Dashed lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Swamp Creek Subbasin (Swamp Creek and Indian Creek)
Water samples were collected at eight sites in Swamp Creek during the 1999 survey, two sites (RMs 8.85 and 5.74) in 1995, and three sites (RMs 8.85, 4.44, and 1.59) in 1990 (Figures 83-84). Two sites (RMs 4.44 and 1.59) were common to the 1999 and 1990 surveys while one site (RM 8.85) was sampled in all three survey years. Figure 82 presents median water chemistry results for RM 1.93 in Indian Creek for 1999, 1995, and 1990.

Lower median D.O. concentrations were typically recorded in Swamp Creek and Indian Creek during the 1999 survey with numerous daytime grab values below water quality criteria. All D.O. concentrations measured in 1995 and 1990 remained above criteria. Median BOD_5 concentrations in Swamp Creek were generally low at common sites with somewhat higher values measured at RM 1.59 downstream of the Versailles WWTP (medians $ 3 mg/l in 1999 and 1990). Higher BOD_5 values were recorded in 1995 (median 5.4 mg/l) at the Indian Creek site compared to 1990 and 1999 (median of 2 mg/l in both years).

Median ammonia-N remained low at RM 8.85 of Swamp Creek in all three survey years. Respective medians measured in 1999 and 1990 at common sites downstream ranged from 0.079 mg/l to 0.15 mg/l at RM 4.44 and from 0.157 mg/l to 0.05 mg/l at RM 1.59. A median ammonia-N concentration of 0.05 mg/l was recorded at RM 1.93 in Indian Creek for all three surveys. However, ammonia-N exceeded WWH water quality criteria at the site on one occasion in 1995 (8.16 mg/l).

Median 1999 nitrate-nitrite-N concentrations, low at the six Swamp Creek sites upstream of the Versailles WWTP with medians ranging from 0.1 mg/l to 0.5 mg/l, increased to 4.42 mg/l at RM 1.59 downstream of the WWTP. Median nitrate-nitrite-N concentrations of 0.84 mg/l (RM 8.85) and 1.74 mg/l (RM 5.74) were recorded in 1995 in Swamp Creek while 1990 median values ranged from 2.46 mg/l (RM 4.44) to 3.94 mg/l (RM 1.59). Reflecting the higher flows, a similar pattern was observed at the Indian Creek site with substantially higher concentrations recorded in 1990 (median 4.53 mg/l) and 1995 (median 2.25 mg/l) compared to 1999 (median 0.1 mg/l).

Phosphorus levels were elevated in Swamp Creek in 1999 with an overall median of 0.24 mg/l recorded for all concentrations and exceptionally elevated values recorded downstream of the Versailles WWTP at RM 1.59 (median 2.33 mg/l) and RM 0.28 (median 1.56 mg/l). While 1995 medians were not elevated in Swamp Creek, 1990 median phosphorus concentrations increased longitudinally from 0.17 mg/l at RM 8.85 to 0.57 mg/l at RM 1.59. Phosphorus medians recorded at RM 1.93 in Indian Creek ranged from 0.1 mg/l in 1999 to 0.17 mg/l in 1990.

Higher TSS medians were documented in both Swamp Creek and Indian Creek during the 1990 and 1995 surveys reflecting the higher flows in those years. Fecal coliform concentrations in Swamp Creek frequently exceeded the PCR criteria in all three surveys. Exceptionally elevated values, however, were measured in 1990. Fourteen of 20 samples collected at Swamp Creek sites in 1990 exceeded PCR criteria with six of those samples greater than 60000 colonies/100 ml. Fecal coliform concentrations measured at the Indian Creek site frequently exceeded PCR criteria in 1995 and 1990 with the highest concentrations again recorded during the 1990 survey.

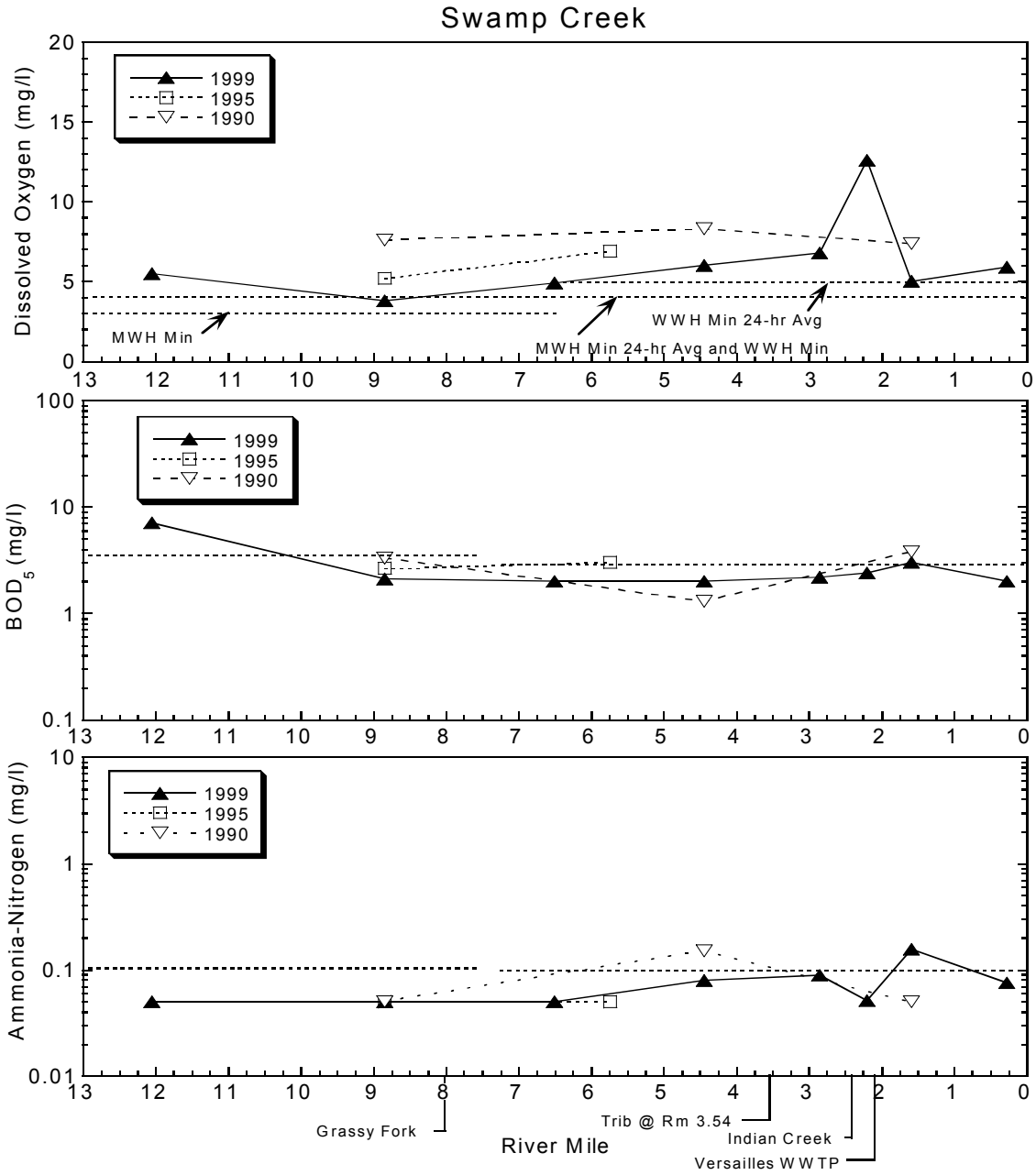


Figure 83. Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, and ammonia-nitrogen in Swamp Creek (1999, 1995 and 1990). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Note: The 1999 and 1995 MDL for BOD_5 is 2 mg/l; the 1990 MDL is 1 mg/l).

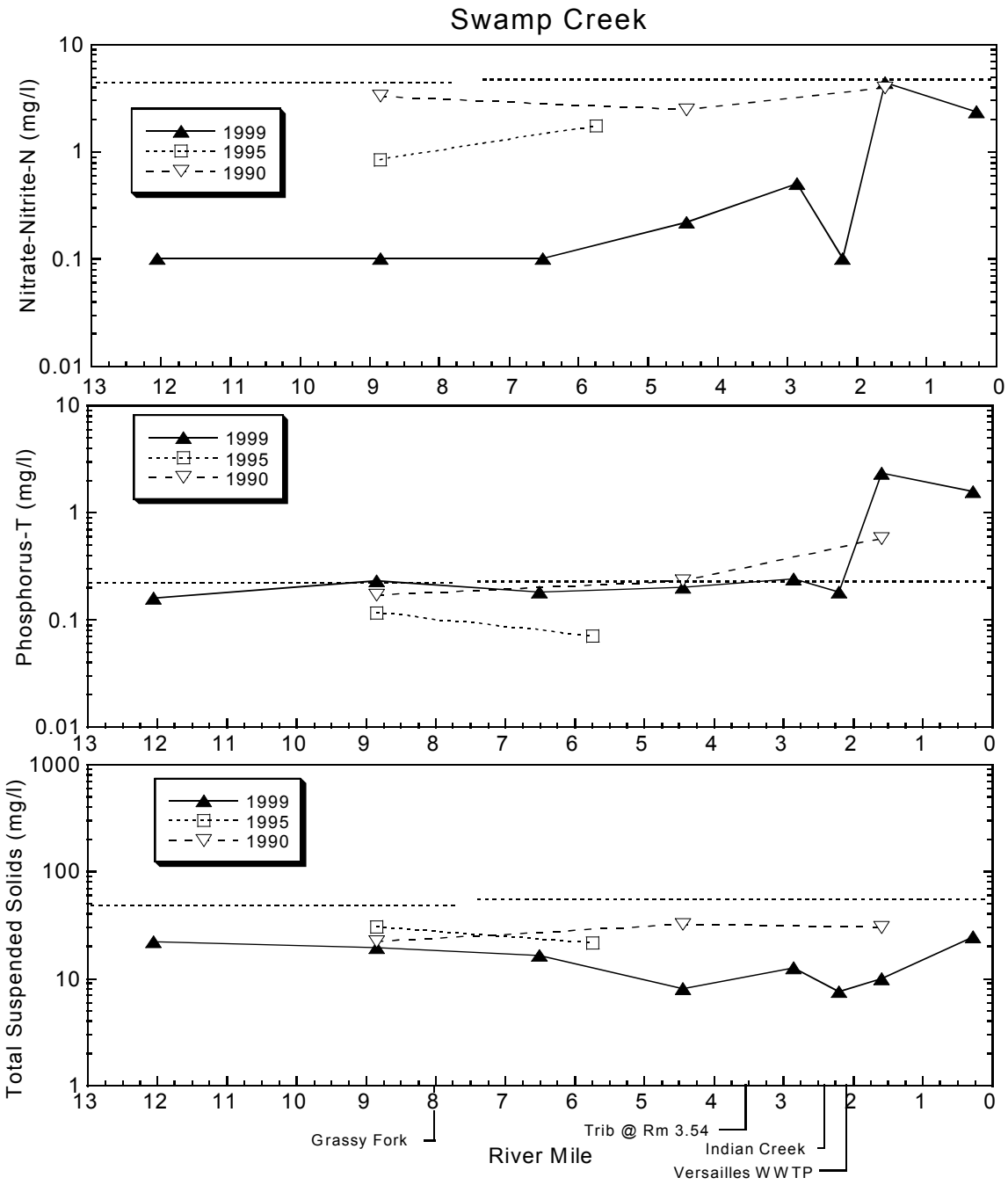


Figure 84. Median concentrations of nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids in Swamp Creek (1999, 1995 and 1990). Dashed horizontal lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Trotters Creek
One site (RM 0.97) was sampled in this tributary during both the 1999 and 1995 surveys (Figure 82). Dissolved oxygen concentrations remained above WWH criteria in 1995 but fell below criteria in three of five samples in 1999. All BOD_5 concentrations were less than the MDL of 2 mg/l in both surveys. Ammonia-N, total phosphorus, and TSS were somewhat higher at the site in 1999 with respective median values of 0.1 mg/l, 0.07 mg/l, and 11.5 mg/l. Comparable medians of 0.07 mg/l, 0.05 mg/l, and 5 mg/l were recorded in 1995, respectively. All 1999 nitrate-nitrite-N concentrations were less than 0.12 mg/l with much higher values recorded in 1995 (median and maximum values of 1.21 mg/l and 12.3 mg/l). Fecal coliform samples, collected twice at the site in 1999 and five times in 1995, exceeded PCR criterion on one occasion in each survey.

Harris Creek and Ballinger Run
Water samples were collected in Harris Creek at RMs 5.20 and 2.02 during the 1999 survey and from RM 0.90 in 1995 (Figure 85). Additionally, RMs 2.75, 1.40, and 0.59 were sampled in Ballinger Run in 1999 and RMs 2.75 and 1.00 were sampled in 1995 (Figure 86). Dissolved oxygen concentrations measured in Harris Creek during both surveys remained above WWH water quality criteria. Concentrations at RM 1.40 in Ballinger Run, however, fell below criterion once in 1999 and all values measured in the headwaters at RM 2.75 fell below WWH criteria in 1999 reflecting the impact of continually diminishing flows. Median D.O. concentrations in Ballinger Run increased longitudinally in both years with 1999 values ranging from 3.6 mg/l at RM 2.75 to 9 mg/l at RM 0.59 and 1995 medians of 5.5 mg/l at RM 2.75 and 7.2 mg/l at RM 1.00. BOD_5 median concentrations of 2 mg/l were recorded in Harris Creek at all sites. BOD_5 concentrations measured in Ballinger Run were generally higher in 1999 compared to 1995 with respective overall median values of 3.1 mg/l compared to 2.3 mg/l.

Harris Creek 1999 ammonia-N median values decreased from 0.137 mg/l at RM 5.20 to 0.06 mg/l at RM 2.02, comparable to the 1995 median of 0.05 mg/l measured at RM 0.90. Ballinger Run ammonia-N concentrations were consistently elevated in 1999 with median values ranging from 0.134 mg/l at RM 0.59 downstream of the Bradford WWTP to 0.516 mg/l at RM 1.40. (The Village of Bradford's CSOs discharge between RMs 1.8 and 0.8.) Concentrations exceeded water quality criterion on one occasion in 1999 at RM 1.40 (3.06 mg/l). Median ammonia-N concentrations measured in the 1995 survey increased longitudinally from 0.05 mg/l at RM 2.75 to 0.31 mg/l at RM 1.00. Two 1995 values (6.91 mg/l and 3.50 mg/l) exceeded water quality criteria downstream of the Bradford WWTP and CSOs at RM 1.00.

Harris Creek 1999 nitrate-nitrite-N and phosphorus concentrations significantly increased downstream of the Ballinger Run confluence. Nitrate-nitrite-N medians increased from 0.34 mg/l at RM 5.20 to 1.94 mg/l at RM 2.02 while respective phosphorus medians increased from 0.15 mg/l to 0.64 mg/l. Respective median nitrate-nitrite-N and total phosphorus medians of 1.35 mg/l and 0.21 mg/l were measured in 1995 at RM 0.90 in Harris Creek. Nitrate-nitrite-N concentrations measured in Ballinger Run during the 1999 survey were low at upstream sites (medians < 0.4 mg/l) but increased markedly downstream of the Bradford WWTP at RM 0.59 (median 4.95 mg/l). Nitrate-nitrite-N median values of 3.04 mg/l (RM 1.00) and 4.52 mg/l (RM

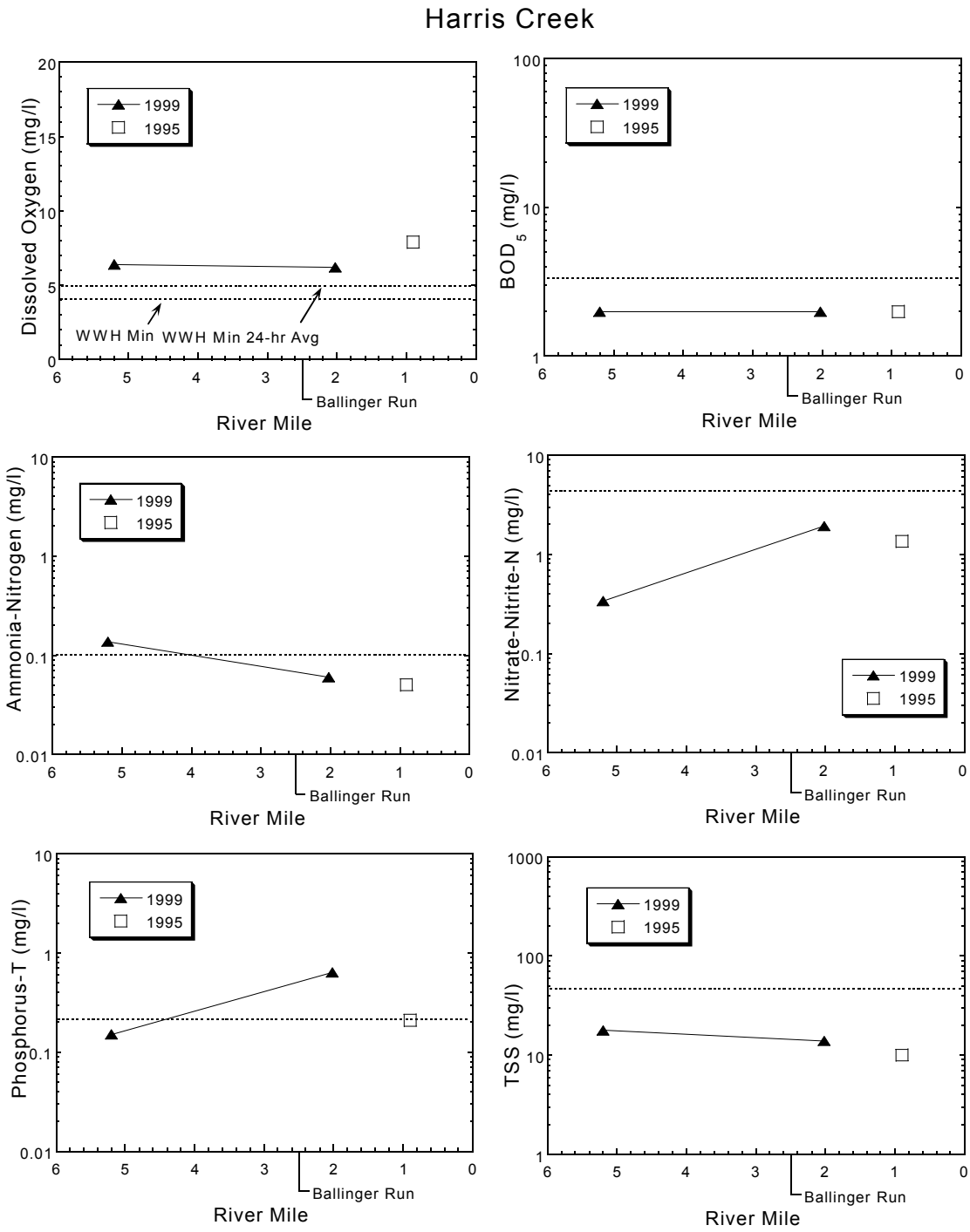


Figure 85. Left to right from the top: Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in Harris Creek (1999 and 1995). Water quality criteria are shown in the dissolved oxygen plot. Dashed lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

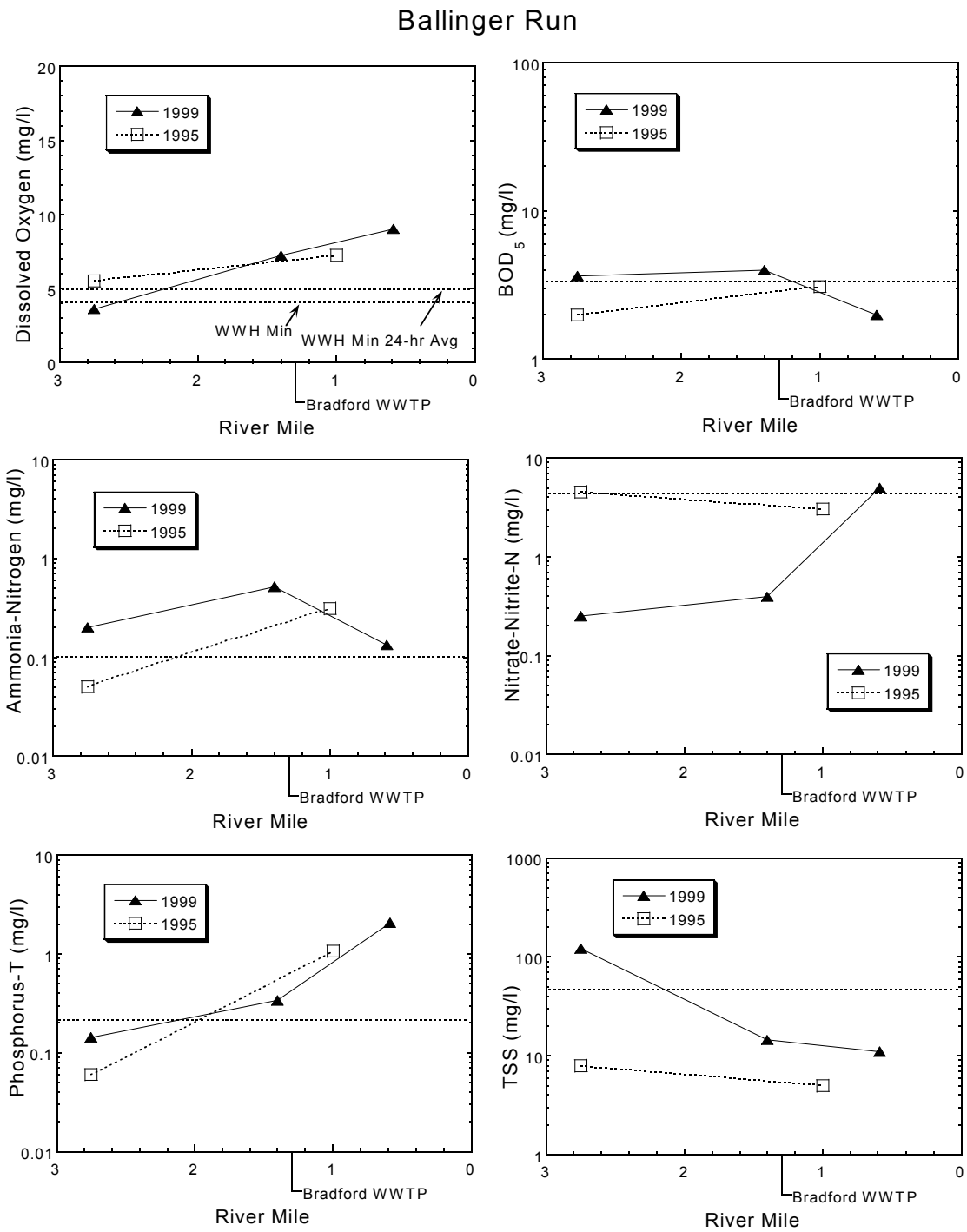


Figure 86. Left to right from the top: Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in Ballinger Run (1999 and 1995). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

2.75) were recorded in Ballinger Run in 1995. Phosphorus levels increased longitudinally in Ballinger Run in both surveys with substantially elevated values at sites downstream of the Bradford WWTP. Median phosphorus increased from 0.14 mg/l (RM 2.75) to 2.08 mg/l (RM 0.59) in 1999 and from 0.06 mg/l (RM 2.75) to 1.08 mg/l (RM 1.00) in 1995.

An overall median TSS concentration of 16.5 mg/l was recorded for the two 1999 Harris Creek sites and a median of 10 mg/l was measured at RM 0.90 in 1995. Excluding the exceptionally elevated 1999 values recorded in the headwaters at RM 2.75 (median 122 mg/l), Ballinger Run TSS concentrations were low with 1999 medians below 15 mg/l and 1995 medians less than 8 mg/l. Fecal coliform exceeded the PCR criterion in Harris Creek on occasion in both surveys. Higher fecal coliform concentrations were typically recorded at downstream sites in Ballinger Run during both surveys with exceptionally elevated concentrations recorded at RMs 1.40 (21000-121000 colonies /100 ml) and 0.59 (50000 colonies /100 ml) during the 1999 survey.

Greenville Creek

May through September stream flows for 1999 and 1990 as measured by the USGS gage station in Greenville Creek near Bradford (RM 6.10) are compared in Figure 87. Similar to the Stillwater mainstem, mean daily flows were magnitudes higher in 1990 compared to 1999. Excluding June, monthly mean discharges measured in Greenville Creek in 1990 from May through September were 125-240% above normal. Mean monthly flows in 1999 were 50-80% below normal for the same five months. An overall median flow of 144 cfs was measured in 1990 for the May through September period compared to 38 cfs for 1999. On specific water chemistry sampling days flows ranged from 75 cfs to 1480 cfs in 1990 while 1999 flows ranged from 9.2 cfs to 35 cfs.

A comparison of 1999 and 1990 median water chemistry results for select parameters is presented in Figures 88-89. Water samples were collected from thirteen (13) sites in Greenville Creek in 1999 and eleven (11) sites in 1990 (including the Greenville WWTP mixing zone). There were four sites common to both the 1999 and 1990 surveys (RMs 34.48, 19.55, 16.22, and 6.10).

Daytime grab D.O. concentrations were relatively comparable with 1990 site medians ranging from 7.5 mg/l to 9.6 mg/l and 1999 medians ranging from 6.6 mg/l to 10.2 mg/l. Concentrations fell below EWH water quality criteria in 1999 on one occasion each at RMs 24.60, 23.08, 16.22, and 9.92. All 1990 grab concentrations remained above criteria. Five sites (RMs 22.3, 19.55, 18.0, 16.22, and 13.70) were monitored with Datasonde continuous monitors during the 1990 survey. Datasonde D.O. concentrations remained above the minimum EWH criterion of 5 mg/l in both survey years with minimal diurnal variation.

Given the lower MDL for BOD_5 in 1990 (1 mg/l) relative to 1999 (2 mg/l), concentrations recorded during the 1999 and 1990 surveys were comparable with medians in both years approaching applicable MDLs. Ammonia-N concentrations recorded during both surveys were generally low with medians at most sites approaching the MDL of 0.05 mg/l. Higher median values (0.123 mg/l, 0.079 mg/l, and 0.098 mg/l, respectively) were documented in 1999 at sites downstream of the Greenville WWTP (RMs 18.34, 16.22, and 13.70).

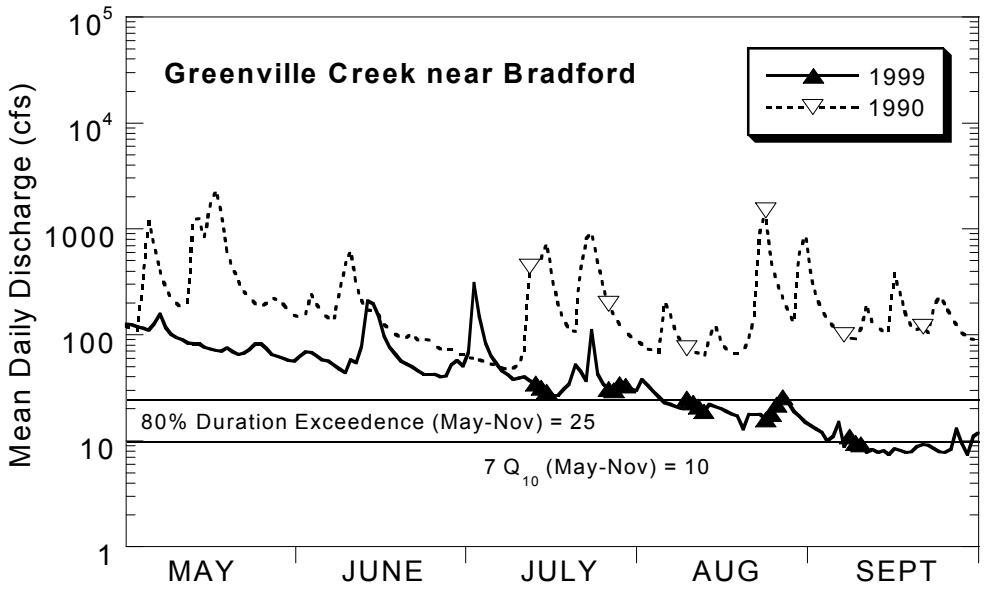


Figure 87. Flow hydrograph (1999 and 1990) for Greenville Creek near Bradford (RM 6.10). Low flow conditions ($7Q_{10}$) and 80% duration exceedence flows are based on USGS station #03264000 (period of record 1930-1997). Markers indicate river discharge on water chemistry sampling days for each survey.

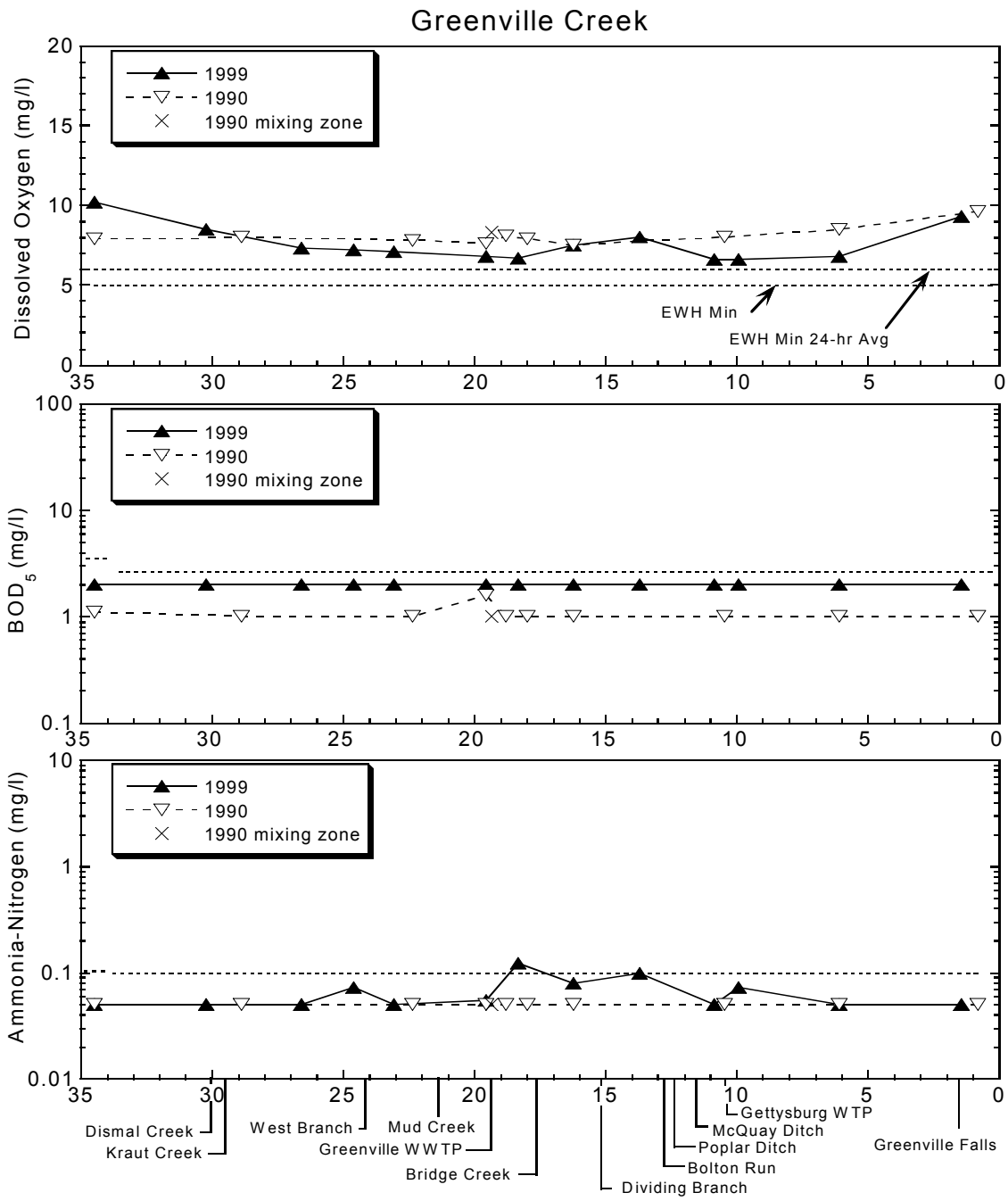


Figure 88. Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, and ammonia-nitrogen in Greenville Creek (1999 and 1990). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Note: The 1999 MDL for BOD_5 is 2 mg/l; the 1990 MDL is 1 mg/l).

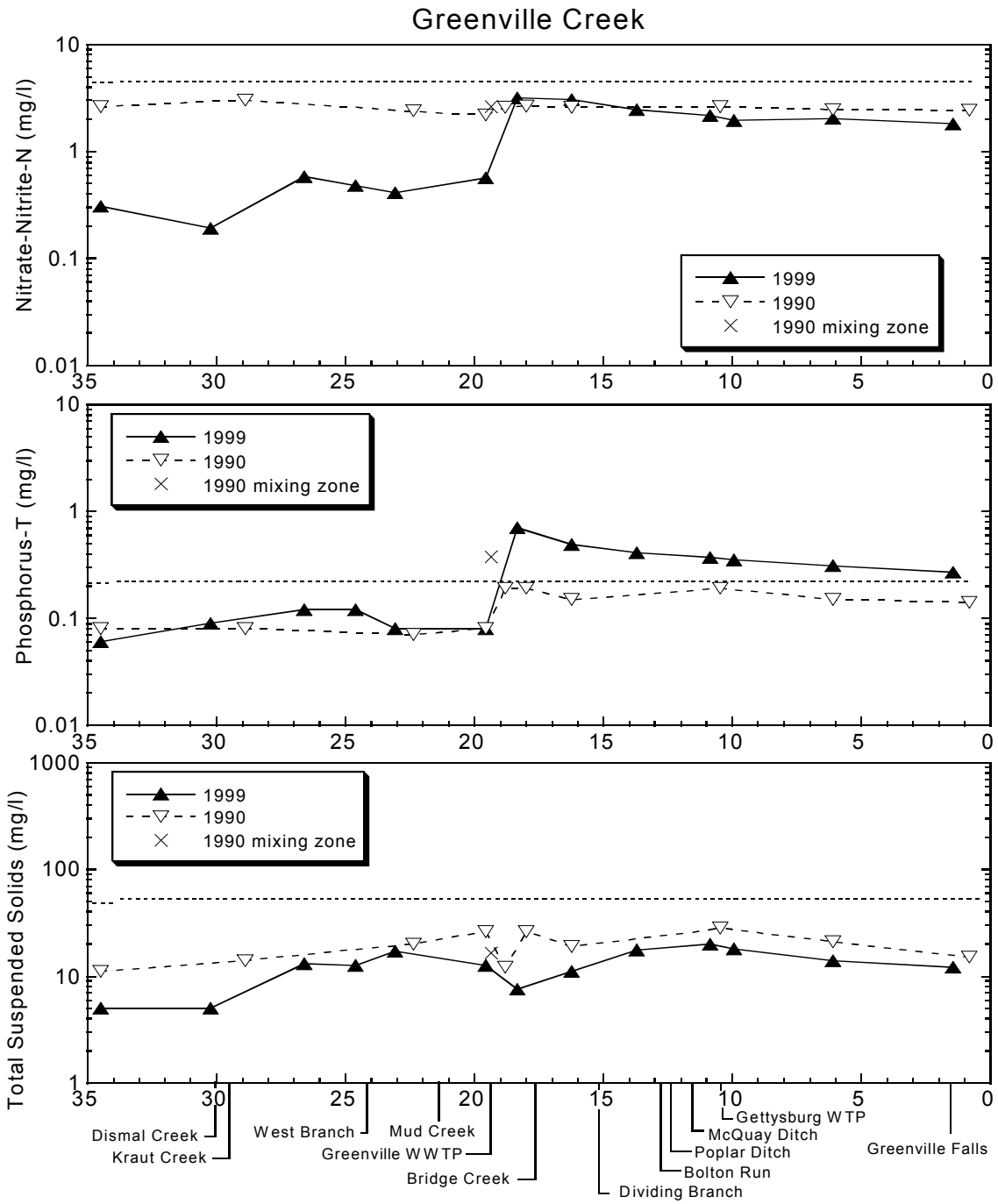


Figure 89. Median concentrations of nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids in Greenville Creek (1999 and 1990). Dashed horizontal lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Nitrate-nitrite-N concentrations measured throughout Greenville Creek in 1990 were relatively stable with site medians ranging from 2.18 mg/l to 3.02 mg/l. Concentrations observed in 1999; however, increased markedly at sites downstream of the Greenville WWTP. An overall median of 0.45 mg/l was measured in 1999 for the upper six sites (RMs 34.48-19.55) compared to 2.17 mg/l for the lower seven site (RMs 18.34-1.45).

Phosphorus concentrations remained relatively low at sites upstream of the Greenville WWTP in both 1999 and 1990 with respective overall medians for all concentrations of 0.1 mg/l and 0.08 mg/l. Concentrations increased downstream of the Greenville WWTP in both surveys but the increase was much more pronounced in 1999. An overall median of 0.165 mg/l was measured for all phosphorus concentrations downstream of the WWTP in 1990 (excluding the mixing zone) compared to an overall median of 0.35 mg/l in 1999.

TSS concentrations were typically higher in 1990 compared to 1999 with respective overall medians of 20.5 mg/l and 12.5 mg/l. Of the total 26 fecal coliform samples collected from the thirteen sites sampled in 1999, four values were elevated above Primary Contact Recreation criteria. In comparison, 56% of the total 70 samples collected at the ten non-mixing zone sites during the 1990 survey exceeded PCR criteria.

Mud Creek and Prairie Outlet

Water samples were collected in Mud Creek at four sites (RMs 7.50, 5.87, 4.67, and 0.09) during the 1999 survey and at three sites (RMs 5.87, 4.67, and 0.09) in the 1990 survey. Additionally, RM 0.80 was sampled in Prairie Outlet in both survey years (Figure 90). Daytime grab D.O. concentrations measured in Mud Creek in 1999 frequently fell below WWH criteria at the headwater site (RM 7.50) and near the mouth (RM 0.09) while all values measured in Mud Creek and Prairie Outlet remained above criteria in 1990. BOD_5 and ammonia-N concentrations were relatively low during both surveys with most site medians approximating applicable MDLs. The highest ammonia-N values were measured in 1999 at RMs 7.50 (median 0.107 mg/l) and RM 0.09 (median 0.096 mg/l).

Similar to the rest of the Stillwater watershed, much lower nitrate-nitrite-N concentrations were recorded in the two tributaries in 1999 compared to 1990. Median 1999 nitrate-nitrite-N values in Mud Creek ranged from 0.25 mg/l to 0.87 mg/l while 1990 site medians ranged from 1.14 mg/l to 2.36 mg/l. Higher concentrations were typically measured at the Prairie Outlet site during both surveys with medians of 1.32 mg/l in 1999 and 2.9 mg/l in 1990. Phosphorus levels were relatively comparable in Mud Creek in 1999 and 1990 with respective overall median values of 0.07 mg/l and 0.085 mg/l. Prairie Outlet concentrations also remained low with survey medians less than 0.1 mg/l. The highest phosphorus concentrations in both surveys occurred near the mouth of Mud Creek at RM 0.09 (median 0.12 mg/l in 1999 and 0.20 mg/l in 1990).

Reflecting higher flows, TSS concentrations measured in the basin were generally much higher in 1990 compared to 1999. Mud Creek medians ranged from 5 mg/l to 18 mg/l during the 1999 survey while 1990 medians ranged from 31 mg/l to 100 mg/l. A TSS median of 5 mg/l was measured at the Prairie Outlet site during both surveys. Fecal coliform exceeded PCR criteria at

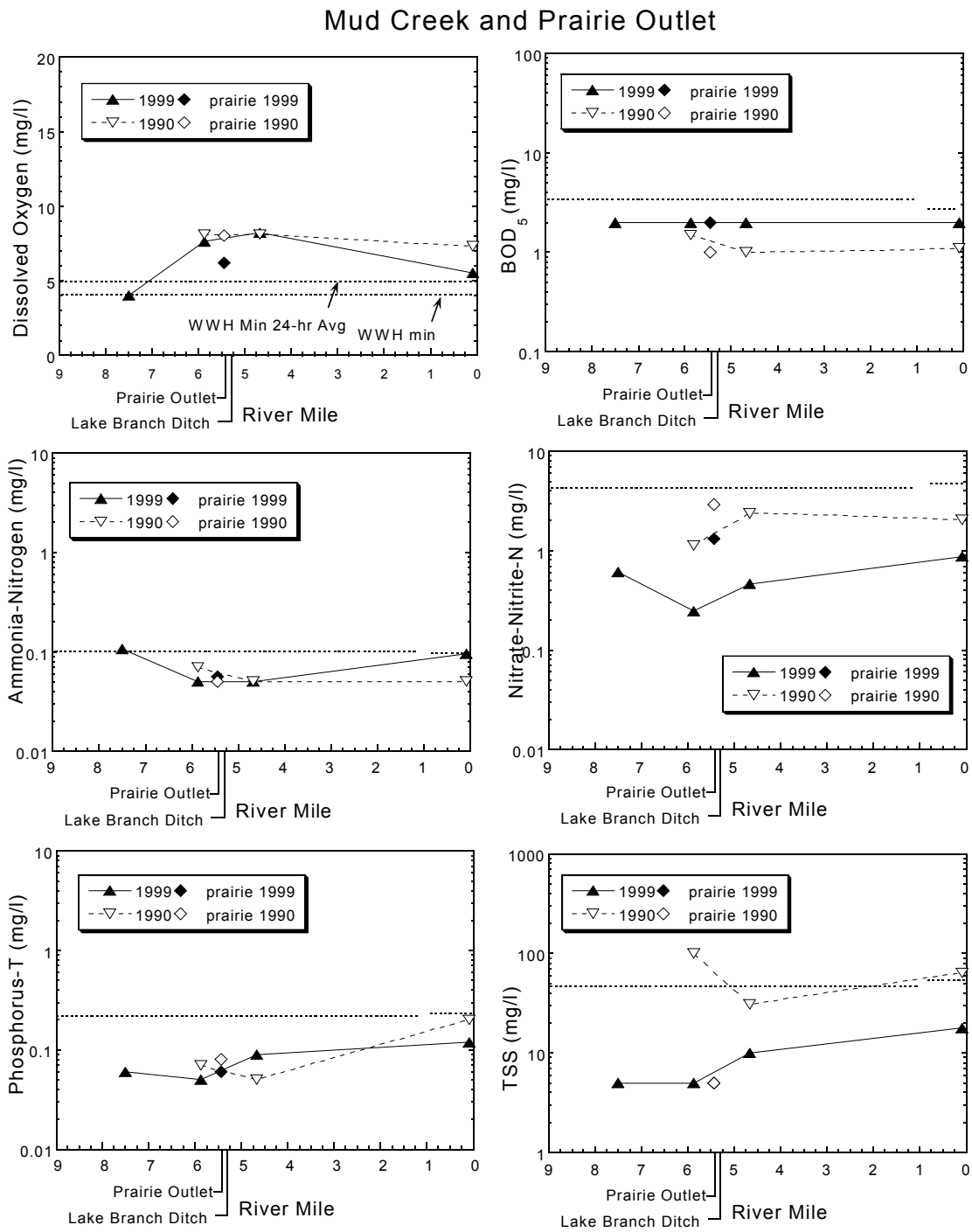


Figure 90. Left to right from the top: Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in Mud Creek and Prairie Outlet (1999 and 1990). Water quality criteria are shown in the dissolved oxygen plot. Horizontal dashed lines in other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Note: The 1999 MDL for BOD_5 is 2 mg/l; the 1990 MDL is 1 mg/l).

all five 1999 basin sites on July 28 after recent precipitation. Fecal coliform concentrations also exceeded PCR criteria in 56% of the 1990 samples with the majority of elevated values recorded on high flow days.

Painter Creek

Seven sites were sampled in Painter Creek in 1999 (RMs 17.90, 16.20, 15.48, 14.98, 8.92, 3.50, and 0.80) compared to three sites in 1995 (RMs 17.90, 14.98, and 0.80) and three sites (RMs 15.48, 14.98, and 0.80) in 1990 (Figures 91-92). Compared to previous surveys, D.O. concentrations were depressed throughout much of Painter Creek during 1999 with numerous values below applicable water quality criteria. The majority of values measured in 1995 and 1990 remained above criteria. The lowest D.O. levels were recorded downstream of the Village of Arcanum (CSOs) at RM 15.48 (medians of 5.3 mg/l in 1999 and 6.6 mg/l in 1990) and downstream of Sycamore Ditch (Arcanum WWTP) at RM 14.98 (medians of 2.1 mg/l in 1999, 5.45 mg/l in 1995, and 7.9 mg/l in 1990).

The highest BOD_5 concentrations measured in Painter Creek during all three surveys occurred at RM 14.98 downstream of Sycamore Creek (medians of 7 mg/l in 1999, 4.1 mg/l in 1995 and 2 mg/l in 1990). Elevated BOD_5 values were also documented in 1999 at RM 17.90 (median 5.35 mg/l) and RM 15.48 (median 4.8 mg/l). Similarly, RM 14.98 also experienced the highest ammonia-N concentrations in all surveys with medians of 4.47 mg/l (1999), 0.52 mg/l (1995) and 0.38 mg/l (1990). Ammonia-N values exceeded water quality criterion at the site on three occasions in 1999. Ammonia-N was also consistently elevated above applicable 90th percentile reference concentrations in 1999 at RMs 16.20, 15.48, and 3.50 with respective medians of 0.131 mg/l, 0.135 mg/l and 0.105 mg/l.

With the exception of RM 0.80 (median and maximum values of 1.84 mg/l and 4.96 mg/l), nitrate-nitrite-N concentrations were much lower in Painter Creek during the 1999 survey with all site medians less than 0.2 mg/l. Respective overall median and maximum values of 1.75 mg/l and 12.5 mg/l were recorded in 1990 versus 1995 values of 4.24 mg/l and 10.1 mg/l. Phosphorus levels were highest downstream of Sycamore Ditch at RM 14.98 in all surveys with recorded medians of 0.72 mg/l (1999), 0.28 mg/l (1995) and 0.32 mg/l (1990). Elevated phosphorus values were also measured in 1999 at RM 15.48 (median 0.28 mg/l).

TSS concentrations were generally low in Painter Creek with an overall median value near the MDL of 5 mg/l recorded in each survey year. Maximum concentrations were measured on high flow days during the 1990 survey with values ranging from 182 mg/l (RM 14.98) to 505 mg/l (RM 0.80). Consistently elevated levels, however, were recorded in 1999 in the headwaters at RM 17.90 (median and maximum values of 19 mg/l and 88 mg/l). (Given the drought conditions and low flows in 1999, it is possible that sediments may have inadvertently been introduced into the sample at this headwater site due to increased sampling difficulty.)

Fecal coliform concentrations measured in Painter Creek generally exceeded the PCR criteria on higher flow days during each survey. Of the twelve fecal coliform samples collected in 1999, four exceeded the maximum PCR criterion with a high of 44000 colonies/100 ml recorded at RM

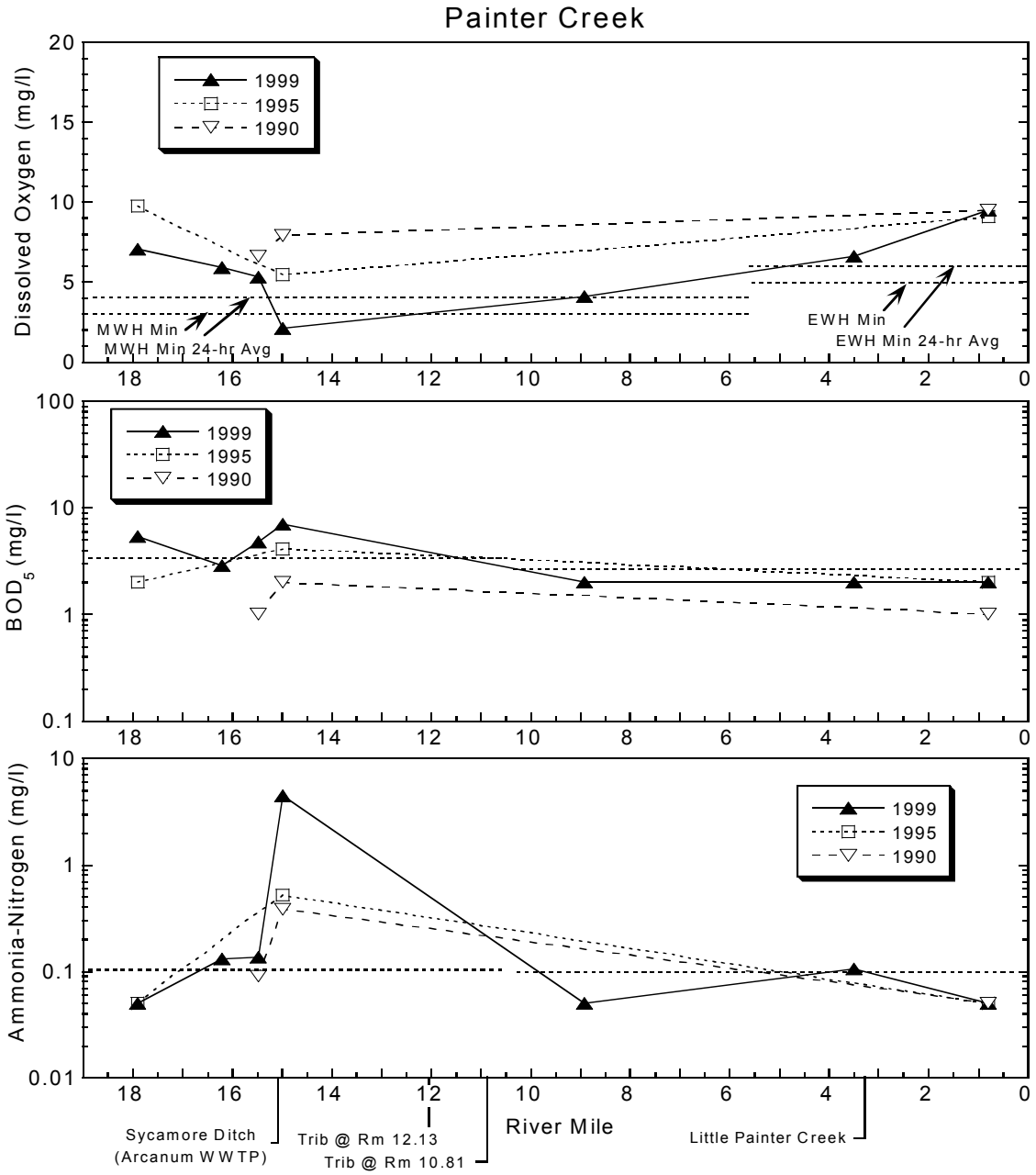


Figure 91. Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, and ammonia-nitrogen in Painter Creek (1999, 1995 and 1990). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in the other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion. (Note: The 1999 and 1995 MDL for BOD_5 is 2 mg/l; the 1990 MDL is 1 mg/l).

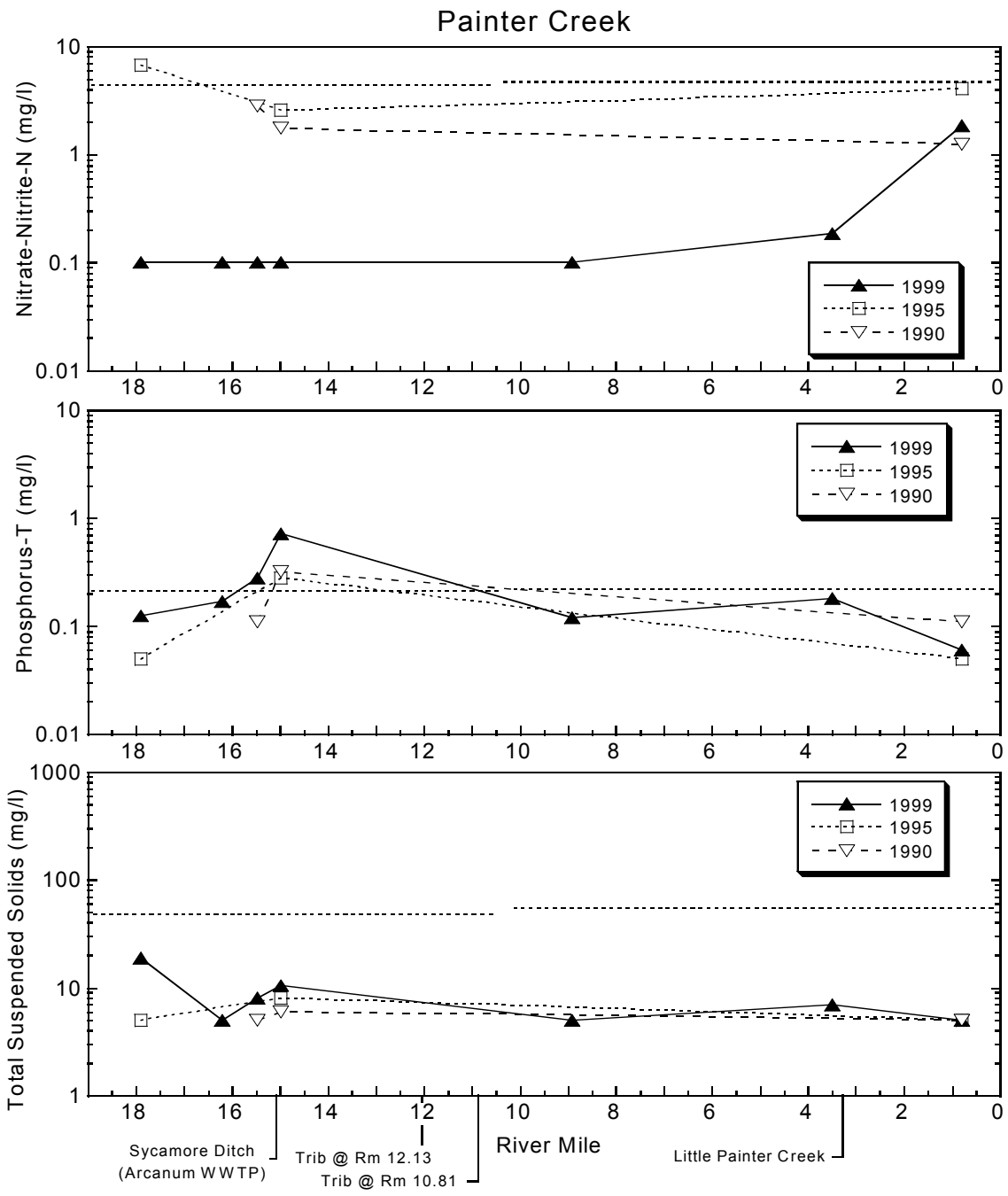


Figure 92. Median concentrations of nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids in Painter Creek (1999, 1995 and 1990). Dashed horizontal lines represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

15.48 downstream of Arcanum CSOs. Two of the thirteen 1995 samples and nine of the twenty 1990 samples collected were elevated above PCR criteria. Six of the 1990 samples were exceptionally elevated with concentrations ranging from 11000 colonies/100 ml to greater than 60000 colonies/100 ml.

Brush Creek (Ludlow Creek subbasin)

Brush Creek was sampled at RMs 7.85, 7.17, and 0.45 in 1999 and at RMs 7.85 and 0.45 in 1995 (Figure 93). Dissolved oxygen levels measured in Brush Creek in 1999 downstream of Phillipsburg at RMs 7.85 and 7.17 were consistently depressed with three of five concentrations at both sites falling below minimum WWH criterion. Concentrations measured in 1995 remained above criteria with median values of 7.35 mg/l at RM 7.85 and 8.25 mg/l at RM 0.45. With the exception of higher levels recorded at RM 7.85 in 1999 (median and maximum values of 3.3 mg/l and 8 mg/l), BOD_5 concentrations remained low in Brush Creek during both surveys.

Ammonia-N concentrations were elevated downstream of Phillipsburg at RM 7.85 in both years. Median and maximum values of 0.18 mg/l and 0.77 mg/l were measured at the site in 1995. Ammonia-N values recorded at the site in 1999, however, were exceptionally elevated with respective median and maximum concentrations of 2.7 mg/l and 4.68 mg/l and three of five concentrations exceeding water quality criterion. Nitrate-nitrite-N median concentrations ranged from 1.34 mg/l at RM 7.17 to 5.93 mg/l at RM 0.45 in 1999. Higher concentrations were recorded during 1995 with medians of 6.42 mg/l at RM 7.85 and 7.31 mg/l at RM 0.45. Phosphorus levels were elevated downstream of Phillipsburg in 1999 at RMs 7.85 and 7.17 (respective medians of 0.57 mg/l and 0.34 mg/l).

TSS concentrations remained low at all sites during both survey years. One of six fecal coliform samples collected in Brush Creek in 1999 exceeded the PCR criterion (7545 colonies/100 ml at RM 7.85). Three of eight samples collected in 1995 exceeded criteria with the highest values measured downstream of Phillipsburg at RM 7.85 (3300 colonies/100 ml on two occasions).

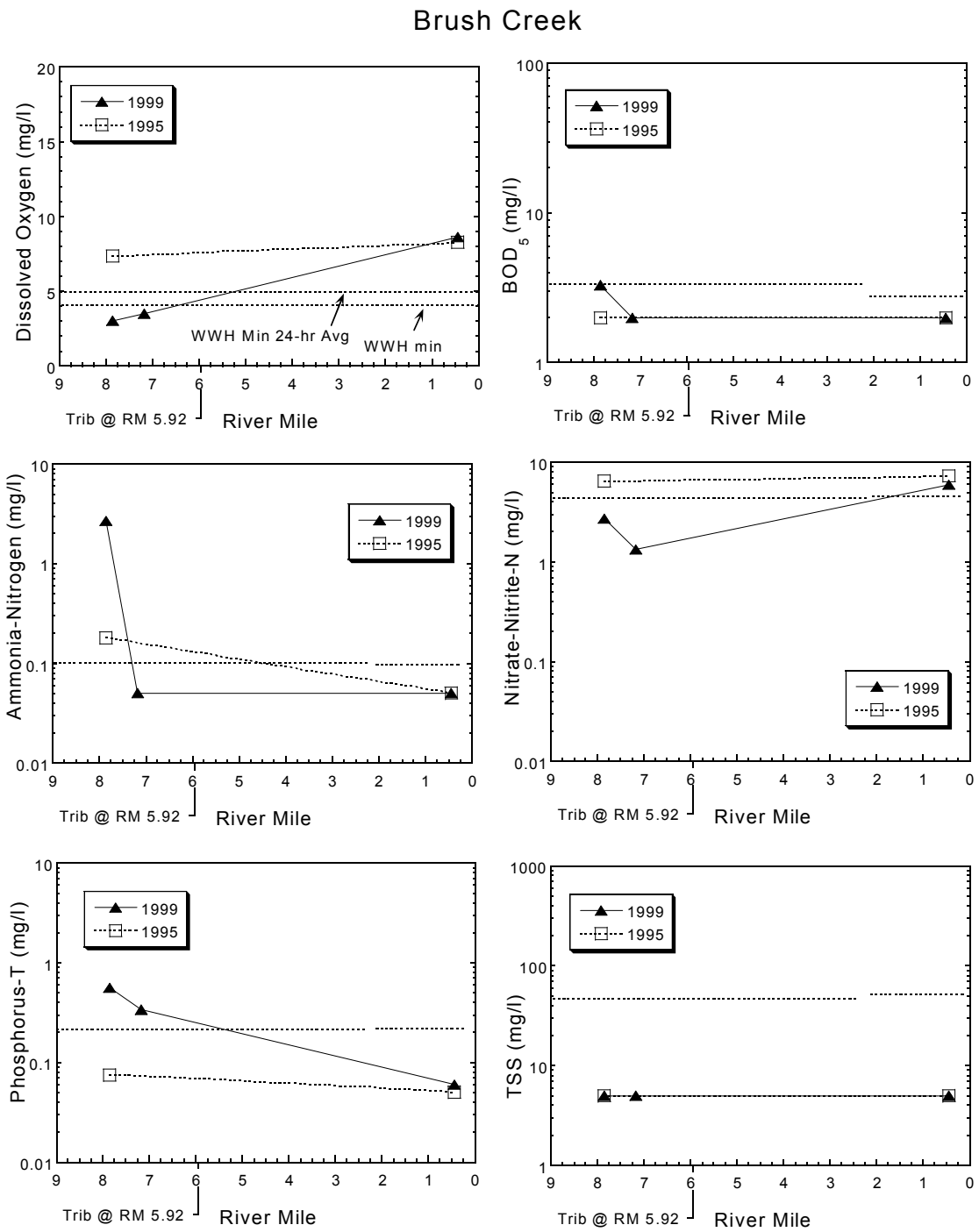


Figure 93. Left to right from the top: Median concentrations of dissolved oxygen, 5-day biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrite-nitrogen, total phosphorus, and total suspended solids (TSS) in Brush Creek (1999 and 1995). Water quality criteria are shown in the dissolved oxygen plot. Dashed horizontal lines in other plots represent the 90th percentile concentration from reference sites of similar size in the Eastern Corn Belt Plains (ECBP) ecoregion.

Spills, Overflows, and Unauthorized Releases

Pollutant discharges from spills, overflows, permit violations, and other unauthorized releases are a significant source of lethal and sub-lethal stresses for the aquatic community in the Stillwater watershed. Approximately 80 spills have been recorded by the Ohio EPA Emergency Response Section during the six-year period from 1995 to 2000. Table 9. documents spills reported in the Stillwater River watershed from 1995 -2000.

The Dayton International Airport (owned by the City of Dayton) accounted for 41.3% (33/80) of the reported spills during the six-year reporting period. Deicing fluids (ethylene and propylene glycols), urea and potassium acetate were routinely discharged to Mill Creek during the winter months (30 events). Jet fuel entering Mill Creek from the Dayton Airport was also documented in three events. Glycols used in deicing fluids remove the oxygen from the water column and are the source of fish kills in addition to causing odor and foaming problems. An under drain and lagoon-collection system was installed between 1996 and 1997, and has reduced the amount of contaminants leaving the site.

Agriculture is the dominant industry in the watershed. Agricultural related spills were responsible for 30% (24/80) of all reported spills in the Stillwater basin. Impacts from improper handling of animal manure accounted for 20% (16/80) of the reported spills from 1995-2000. Large animal feedlot (hog and chicken) operations contain their manure in lagoons. The manure in the lagoons may either overflows or is improperly applied to farm fields and flows into the adjacent waterways, resulting in fish kills. Darke County accounted for all of the reported manure spills in the basin.

Milk was the other agricultural waste discharged to the watershed, accounting for 10% (8/80) of the spill reports. Heartland Processing in Union City Indiana had four separate milk spills in the Dismal Creek-Greenville Creek watershed during 2000. Milk and milk by-products are also used in animal feed operations. Milk and milk byproducts remove oxygen from the water column and can cause fish kills.

Petroleum related materials (motor oil, diesel fuel, jet fuel, gasoline and heating oil) were found in 17.5% (14/80) of all spills in the watershed.

The most troublesome spill trend occurred in the Dismal Creek-Greenville Creek watershed. The City of Greenville obtains its drinking water from Greenville Creek. Eight separate spill events originating in Indiana caused a threat to the drinking water supply of Greenville from 1995 to 2000. Heartland Processing in Union City, Indiana had four milk spills in a four-month period during 2000. Other spills emanating from Indiana were liquid manure from an animal feed lot, a sewage bypass, wood preservative from a lumber yard, and oil from an unknown source.

Table 9. Spills reported in the Stillwater River Watershed from 1995-2000.

Date	Entity	County	Waterway	Material	Quantity
10/24/2000	Indiana farmer	Darke	Dismal Ck-Greenville Ck	liquid manure	unk
9/14/2000	unknown farmer	Darke	trib to Stillwater	liquid manure	unk
7/24/2000	Heartland Processing	Darke	Dismal Ck-Greenville Ck	milk	unk
7/23/2000	KevinSchmittmyer	Darke	Ballinger Run	hog manure	500,000 gal
7/22/2000	Heartland Processing	Darke	Dismal Ck-Greenville Ck	milk	unk
6/22/2000	Heartland Processing	Darke	Dismal Ck-Greenville Ck	milk	unk
5/11/2000	Englewood WWTP	Montgomery	Stillwater	pesticide discharge	unk
3/30/2000	Dayton Airport	Montgomery	Mill Creek	petroleum material	unk
3/20/2000	Heartland Processing	Darke	Dismal Ck-Greenville Ck	milk	200 gal
3/13/2000	1934 Needmore (Kroger)	Montgomery	trib to Stillwater	floor stripping solvent	unk
1/30/2000	Dayton Airport	Miami	Mill Creek	Ethylene Glycol	unk
1/11/2000	Parkview Farms	Darke	Maple Swamp Ditch	Hog manure	unk
11/11/1999	Union City, Ind. WWTP	Darke	Connor Ditch-Greenville Ck	sewage bypass	unk
10/16/1999	Dayton Airport	Montgomery	Mill Creek	dead fish ?	unk
10/6/1999	Shell Oil	Darke	Greeneville Creek	gasoline	unk
8/5/1999	Carroll & Wampler	Montgomery	trib to Stillwater	milky white material	unk
7/8/1999	unk	Montgomery	Stillwater	petroleum material	unk
6/30/1999	2069 Ravenwood Ave.	Montgomery	Stillwater	diesel fuel	25 gal
5/1/1999	David Dipner	Darke	unk trib to Stillwater River	liquid manure	unk
4/25/1999	Don Jamison	Miami	Canyon Run	Milk byproducts	300 gal
2/23/1999	unk spiller	Darke	Brush Creek	solvent	unk
1/22/1999	Greenville WWTP	Darke	Greenville Creek	sewage bypass	unk
1/15/1999	A. Brown & Sons.	Montgomery	Moehler Ditch/Brush Creek	Heating oil	unk
1/8/1999	Dayton Airport	Montgomery	Mill Creek	Propylene Glycol	unk
11/28/1998	Ohio Valley Farms	Darke	trib to Stillwater	milk product hog feed	15000gal
11/8/1998	Alfred Post	Darke	trib to Stillwater	liquid manure (hog)	unk
7/20/1998	unknown	Montgomery	Stillwater	floating brown material	unk
7/15/1998	C.E.Wright & Sons	Darke	trib to Dismal Creek	diesel fuel	100 gal
4/9/1998	Paul Miller	Miami	Stillwater	trash,paint cans,shingles	unk
3/24/1998	Dayton Airport	Montgomery	Mill Creek	propylene glycol	unk
3/24/1998	Corning Corp.	Darke	Greenville Creek	Hydraulic fluid	20-50 gal
3/14/1998	Mr. Trent	Miami	Brush Creek	diesel fuel	30 gal
1/30/1998	unknown driver	Miami	Stillwater	diesel fuel	unk
12/23/1997	Lumber yard in Indiana	Darke	Dismal Ck-Greenville Ck	wood preservative	unk
12/15/1997	Dayton Airport	Montgomery	Mill Creek	Propylene Glycol	unk
9/23/1997	Dayton Airport	Montgomery	Mill Creek	Propylene Glycol	unk
9/22/1997	Dayton Airport	Montgomery	Mill Creek	Propylene Glycol	unk
6/28/1997	Miller Bros Sand&Gravel	Montgomery	Stillwater River	oil	25 gal
5/30/1997	Dayton Airport	Montgomery	Mill Creek	Jet Fuel	50 gal
5/9/1997	Meadows of Catalpa	Montgomery	trib to Stillwater	paint wastes	unk
4/30/1997	GTI Inc	Darke	storm sewer to Greenville Ck	urethane	20 gal

Date	Entity	County	Waterway	Material	Quantity
11/25/1996	Dayton Airport	Miami	Mill Creek	urea	unk
11/23/1996	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
10/16/1996	Dayton Airport	Miami	Mill Creek	urea	unk
9/23/1996	7757 Jay Rd.	Miami	ditch to Stillwater	oil	2.5 gal
9/20/1996	7777 Jay Rd.	Miami	ditch to Stillwater	oil	3 gal
9/17/1996	Jaysville-StJohn/US36	Darke	Greenville Creek	petroleum material	unk
8/19/1996	Cal Nane Farms	Darke	Painter Creek trib	Chicken Manure	unk
8/8/1996	Miller Brothers	Montgomery	Stillwater	unauthorized discharge	unk
8/8/1996	originated in Indiana	Darke	Greenville Creek	oil	unk
7/23/1996	Dayton Airport	Montgomery	Mill Creek	jet fuel	150 gal
7/18/1996	Covington WWTP	Miami	Stillwater	sewage bypass	unk
7/13/1996	unk	Miami	Stillwater	tires, paint cans, trash	unk
5/30/1996	SR55&SR48	Miami	Stillwater	white ammonia material	unk
4/18/1996	Dayton Airport	Montgomery	Mill Creek	Urea	unk
3/3/1996	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
12/31/1995	Dayton Airport	Miami	Mill Creek	deicing fluid (glycol)	unk
12/30/1995	Dayton Airport	Miami	Mill Creek	deicing fluid (glycol)	unk
12/2/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
12/1/1995	Dayton Airport	Miami	Mill Creek	deicing fluid (glycol)	unk
11/2/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
10/5/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
9/29/1995	Bryant Farm	Darke	Indian Creek	manure	600,000 gal
8/22/1995	Covington Flea Market	Miami	Stillwater	motor oil	unk
7/12/1995	unknown	Montgomery	Trib to Stillwater	white milky stuff	unk
6/29/1995	Gas Station	Darke	West Branch Creek trib	petroleum material	unk
6/25/1995	unkown	Montgomery	Stillwater	Milky foamy substance	100 gal
6/25/1995	unk	Darke	Kraut Creek	diesel fuel	unk
4/9/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
3/23/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
3/7/1995	Dayton Airport	Miami	Mill Creek	deicing fluid (glycol)	unk
3/6/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
3/4/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	100 gal
3/2/1995	Dayton Airport	Montgomery	Mill Creek	ethylene glycol/diesel	5 gal
2/27/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
2/19/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
2/15/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
2/2/1995	Dayton Airport	Miami	Mill Creek	deicing fluid (glycol)	unk
1/15/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk
1/10/1995	Dayton Airport	Montgomery	Mill Creek	deicing fluid (glycol)	unk

Chemical Sediment Quality

Sediment samples were collected in 29 locations in the 1999 study area to assess levels of contaminants present in stream sediments. In addition to particle size, sediments were typically analyzed for 18 metals, 59 volatile organic compounds (VOC's), 93 semivolatile organic compounds, 19 organochloride pesticides,7 PCB (polychlorinated biphenyl) compounds and nutrients. Whenever possible, composite samples from a cross-section of the stream channel were collected with silts and clays comprising at least 30% of the sample (Figure 94, Table 10) Sediments composed of sand and larger sized particles (>60 microns) are often stable inorganic silicate minerals and not usually associated with contaminants. Given that the finer grained silts and clays (<60 microns) are much more chemically, physically and biologically interactive, collection efforts were biased toward collecting these types of sediments.

Select parameters were ranked based upon stream sediment classification guidelines developed by MacDonald (2000), Persuad (1993) and Ohio EPA (1995).

Consensus-Based sediment quality guidelines for freshwater ecosystems were developed by MacDonald, Ingersoll and Berger (2000) to be used as effective tool for assessing sediment quality. Sediment Quality Goals (SQGs) were developed using 12 previously published freshwater ecosystem studies derived from a variety of approaches. A consensus-based SQG developed 28 chemicals of concern matching sediment chemistry and toxicity data to provide a unifying synthesis of existing SQGs. The consensus-based SQGs are predictive of toxicity in sediments containing mixtures of contaminants, but do not consider the potential for bioaccumulation. Each of the 28 chemicals is evaluated in the following categories:
Threshold effect concentration (TEC) - Below which adverse effects are unlikely to occur.
Extreme effect concentration (EEC) -Above which adverse effects usually or always occur.
Between the TEC and EEC - Between which adverse effects frequently occur.

The Ohio EPA sediment guidelines are used to evaluate sediment metals. Relative concentrations are addressed rather than direct toxicity. Sediment results were tabulated by Ohio EPA based upon ecoregional reference sites considered to be at unimpacted background levels. Metals are statistically ranked for each ecoregion based upon concentrations from non-elevated to extremely elevated. The category breakdown is as follows:

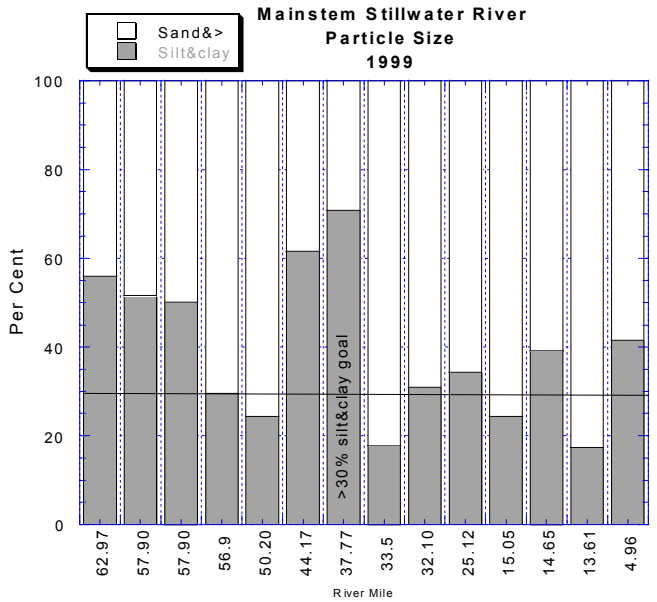
non-elevated - Sediment values < the median background value plus one standard deviation;
slightly elevated - Sediment values > the median background value plus one standard deviation but < the median background value plus two standard deviations;
elevated - Sediment values > the median background value plus two standard deviations but < the median background value plus four standard deviations;
highly elevated - Sediment values > the median background value plus four standard deviations but< the median value plus eight times the standard deviation;
extremely elevated - Sediment values > the median background value plus eight standard deviations.

Table-10. Sediment particle size analysis detected in Stillwater River study area during 1999.

Location Particle size (microns)	Percent of Sample							
	Sand & greater (>60)	Coarse Silt (60-30)	Med Silt (30-15)	Fine Silt (15-8)	V.Fine Silt (8-4)	Coarse Clay (4-2)	Med Clay (2-1)	Fine Clay (<1)
#2 Stillwater River RM 62.97	44	0	5.4	25.3	7.2	3.6	3.6	10.8
#5 Stillwater River RM 57.90	48.4	0	0	21.1	7.0	2.3	4.7	16.4
#5 Stillwater River RM 57.90	49.9	0	0	14.3	7.2	7.2	7.2	14.3
#6 Stillwater River RM 56.9	70.5	3.1	9.4	4.7	4.7	1.6	1.6	4.7
#7 Stillwater River RM 50.20	75.6	1.5	7.6	4.6	1.5	1.5	3.0	4.6
#9 Stillwater River RM 44.17	38.4	0	7.0	17.6	3.5	7.0	7.1	19.4
#10 Stillwater River RM 37.77	29.2	4.6	4.6	7.7	13.9	6.2	9.3	24.6
#11 Stillwater River RM 33.5	82.3	1.8	3.5	1.8	1.8	0	3.6	5.3
#13 Stillwater River RM 32.10	69.1	0	8.8	6.6	4.4	2.2	4.4	4.4
#15 Stillwater River RM 25.12	65.7	0	14.0	4.7	4.7	3.1	3.2	6.2
#19 Stillwater River RM 15.05	75.6	5.4	6.8	1.4	1.4	1.4	4.1	4.1
#20 Stillwater River RM 14.65	60.9	6.3	15.7	4.7	1.6	3.0	3.1	6.3
#21 Stillwater River RM 13.61	82.6	3.2	4.8	0	1.6	1.6	3.2	3.2
#25 Stillwater River 4.96	58.5	0	0	12.8	3.2	3.2	8.0	14.4

Table 10 (cont.) Sediment particle size analysis detected in Stillwater study area during 1999.

Location Particle size (microns)	Percent of Sample Sand & greater (>60)	Coarse Silt (60-30)	Med Silt (30-15)	Fine Silt (15-8)	V.Fine Silt (8-4)	Coarse Clay (4-2)	Med Clay (2-1)	Fine Clay (<1)
# 85 Mud Creek RM 4.67	57.7	4.2	19.8	5.6	2.8	2.8	2.8	4.2
# 98 Painter Creek RM 14.98	53.0	3.4	8.4	13.4	3.4	1.7	6.8	10.1
# 101 Painter Creek RM 0.80	71.4	0	29.1	3.2	3.2	3.2	0	0
# 113 Ludlow Creek RM 0.65	82.5	2.5	7.5	0	2.5	0	2.5	2.5
# 120 Brush Creek RM 0.45	74.6	2.8	8.4	2.8	2.8	1.4	2.8	4.2
# 125 Mill Creek RM 2.62	76.7	4.4	14.6	1.5	0	1.5	1.5	0



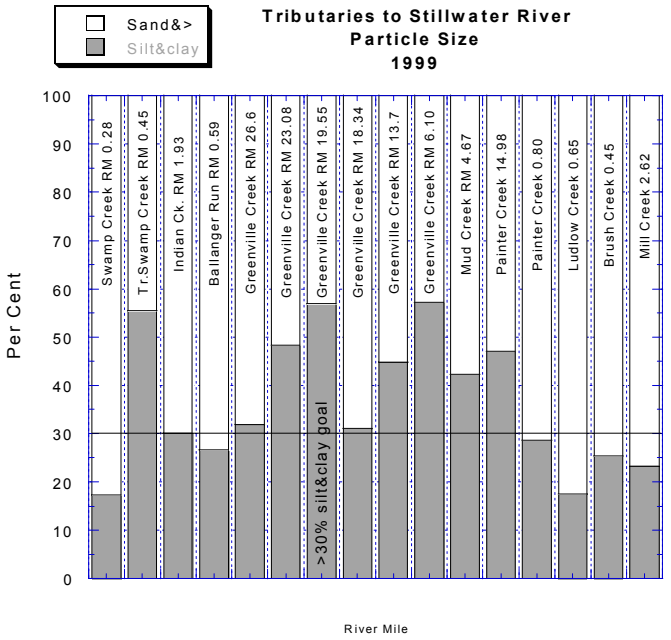


Figure 94. Summary of particle size collected in the Stillwater Watershed during 1999.

Utilizing biologically based guidelines to protect sediment-dwelling organisms, the Ontario system establishes three ecotoxic effect levels: No Effect Level, Lowest Effect Level (LEL), and the Severe Effect Level (SEL). Concentrations above the LEL are expected to affect sediment use by some benthic organisms, while levels which exceed the SEL are expected to detrimentally affect the majority of benthic organisms. Given differences in background levels for heavy metals in Ohio versus the Ontario Great Lakes watershed, only the SEL was used for heavy metals and nutrient analysis in this report. The Ontario system is one of the 12 SQGS used in the MacDonald (2000) guidelines.

Sediment quality in the mainstem and tributaries was generally very good. Fifty-four percent (7/13) of the sediment sites on the mainstem exhibited exceptional sediment quality, with all metal detections below the Ohio non elevated guidelines, all metals below the MacDonald Threshold Effect Concentration, and no man made organic compounds detected in the sediment. Tributary sites had only 19% (3/16) of sites with exceptional sediment quality.

Acetone was detected in 21% (6/29) of sediment samples, including some sites listed as having no quantifiable organic contamination. This chemical is used to clean sampling equipment and is a residual from cleaning and not considered being in the environment.

Sediment Metals and Nutrients

Stillwater River (RMs 62.97-4.96) (Table 11)
Eighteen metals were analyzed in the sediment samples taken in the Stillwater River and its tributaries. Of the eighteen metals, 12 were evaluated by one of the three guidelines. Ohio guidelines were used to evaluate 11 metals (Al, As, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Ni, and Zn). Ontario SEL guidelines were used to evaluate 8 metals (As, Cd, Cu, Fe, Pb, Mn, and Zn). MacDonald SQGS were used to evaluate eight metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn. Six of the eighteen metals (Ca, Mg, Na, K, Se, and Sr) were not evaluated by any guideline.

A limited suite of nutrient parameters were evaluated in this report. Ontario Severe Effect Level (SEL) guidelines were used to evaluate Total Organic Carbon, Total Kjeldahl Nitrogen, and Total Phosphorus. Ohio and MacDonald SQGS do not have nutrient sediment parameter guidelines. No sediment guidelines were used to evaluate sediment ammonia.

There were 29 sediment samples collected in the study area of the Stillwater River Basin. Mainstem sites accounted for 13 of the sediment sites and the tributaries accounted for 16 sediment sites. Of the 12 metals included in the various sediment classifications, 87% (139/156) of concentrations recorded at the 13 mainstem sites were ranked “non-elevated”, “slightly elevated”, or below detection limit by all applicable guidelines. Metal toxicity is compounded when a combination of metals are in the elevated or higher category. Barium (3/13), manganese (3/13) and aluminum (3/13) were the metals most frequently ranked “elevated” or higher per Ohio EPA guidelines at the mainstem sites. Seventy-five percent of the sites on the mainstem

(9/12) recorded all of the evaluated metals in the "non elevated" or "slightly elevated" category. Forty-two percent (5/12) of the mainstem sites had all of the evaluated metals in the "non elevated" category.

Metal contamination was not found to be a problem on the mainstem. Three sites stand out as not being exceptional, but are only highlighted because they show some contamination. River mile 62.97 at SR 49 is in the ditched part of the headwater. This site is influenced by muddy substrate and agricultural activities. Four metals (Aluminum, Arsenic, Barium, and Manganese) were found to be in the "elevated" category. Arsenic was found to be between the MacDonald TOC and EEC, indicating adverse effects frequently may occur.

Strontium (2120 mg/kg) at River Mile 62.97 was at the highest level seen on the survey and the highest value recorded on record in the Southwest District office. Strontium is not evaluated by the Ohio or Ontario guidelines but has chemical characteristics similiar to that of calcium. Median levels of Strontium for the Little Miami River Survey were 149 mg/kg with one value in northern Clark County documented at 720 mg/kg. Median Strontium values for the Stillwater survey were 244 mg/kg. Strontium is believed to be associated with outwash sands and gravels carried by glaciers from evaporite rock formations of Celestite ($SrSO4$) centered in the Middle Bass Island region of Lake Erie.

River mile 57.9 is immediately downstream from the confluence with North Fork Stillwater River. The Ansonia Waste Water lagoons discharge into the North Fork of the Stillwater River just upstream from the confluence. Thick grey to black sediment deposits covered the substrate of the river bed of the North Fork Stillwater River. This sediment deposition extended into the mainstem at the confluence but dissipates about 200 meters downstream. Sediments collected in this depositional area contained Arsenic, Barium, Chromium, Copper and Iron in the "elevated" category and Aluminum and Manganese in the "highly elevated" category per the Ohio EPA guidelines . All 58% (7/12) of the evaluated metals were in the " elevated" or "highly elevated" category. None of the metals were found to be in the "extremely elevated" category. Arsenic was found to be between the MacDonald TOC and EEC, indicating adverse effects frequently may occur.

River mile 32.1 had some sediment from the Covington WWTP located in pockets downstream outfall. In general there was algae growing on the rocks with a fluffy tan deposit covering the substrate. Sediments collected from the Covington lowhead Dam to the Bridge Street bridge had Aluminum, and Zinc in the "elevated" range, Barium and Mercury in the "highly elevated" range, and Copper in the "extremely elevated" range. Copper and Mercury were found to be between the MacDonald TOC and EEC, indicating adverse effects frequently may occur. This would be considered the worst sediment metal contamination found on the mainstem.

Table 11. Concentrations (mg/kg) of metals in sediment samples collected in the Stillwater River study area during 1999. Parameter concentrations were evaluated based on Ohio EPA sediment metal reference sites (1995), MacDonald(2000) Sediment Quality Guidelines (SQG) and Persuad (1993).

Stillwater----------Sediment Concentration (mg/kg dry weight)----------							
River Mile	Al-T O	As-T POM	Ba-T O	Ca-T *	Cd-T POM	Cr-T P O	Cu-T P O
#2) 62.97	21800C	14.9 C ö	202 C	161000	0.408 A (	<36.0	19.2A (
#5) 57.9	**33200 D**	20.4 C ö	248 C	48100	0.531 A (	38.3 C (	30.9 C (
#6) 56.97	12800 B	7.41 A (	89.5 A	34800	0.291 A (	17.7 A (	14.2 A (
#7) 50.2	12600 B	6.41 A (	80.9 A	54300	0.25 A (	16.3 A (	11.9 A (
#9) 44.17	11100 A	4.36 A (	89.2 A	16200	0.233 A (	15.2 A (	10.6 A (
#10) 37.77	15000 B	4.27 A (	90.2 A	16400	0.19 A (	15.8 A (	8.44 A (
#11) 33.5	7630 A	3.85 A (	60.8 A	43200	0.176A (	<20.3	8.79 A (
#13) 32.1	20100 C	7.68 A (	**325 D**	60300	0.685 B (	<41.1	**94.6 E** ö
#15) 25.12	11700 B	7.89 A (	102 B	82700	0.189 A (	<17.7	11.2 A (
#19) 15.05	7240 A	3.66 A (	56.3 A	48100	0.175 A (	<16.4	8.7 A (
#20) 14.65	11300 A	5.24 A (	95.4 A	68300	0.254 A (	<23.8	13.5 A (
#21) 13.6	5950 A	4.18 A (	47.2 A	54800	0.178 A (	<20.5	9.59 A (
#25) 4.96	11000 A	4.13 A (	89.9 A	32800	0.186 A (	<17.0	10.7 A (

Table 11.(cont.) Concentrations (mg/kg) of metals in sediment samples collected in the Stillwater River study area during 1999.

Stillwater----------Sediment Concentration (mg/kg dry weight)----------								
River Mile	Fe-T [PO]	Hg-T [PM]	K-T *	Mg-T *	Mn-T [PO]	Na-T *	Ni-T [PO]	NH_3-N *
#2) 62.97	17900 A	<0.065	7200	30000	646 C	<6000	<48.0	33.4
#5) 57.9	29800 C	<0.064	9880	17300	**748 D**	<6170	<49.4	89.3
#6) 56.97	12400 A	<0.033	3990	12500	244 A	<2850	<22.9	18.1
#7) 50.2	12300 A	<0.032	3800	18400	309 A	<2710	<21.7	38.7
#9) 44.17	9920 A	0.029 **(**	3550	6080	180 A	<2530	<20.3	26.0
#10) 37.77	9950 A	0.025 **(**	3690	4720	260 A	<2640	<21.1	33.5
#11) 33.5	8840 A	<0.033	2030	14900	205 A	<3380	<27.0	<12.8
#13) 32.1	17800 A	**0.252 ö**	4110	12300	467 C	<6850	<54.8	Nd
#15) 25.12	11700 A	<0.036	2950	22400	386 B	<2950	<23.6	25.4
#19) 15.05	7890 A	0.036 **(**	1640	13100	186 B	<2730	<21.9	27.0
#20) 14.65	11000 A	<0.041	3180	19100	241 A	<3970	<31.8	41.8
#21) 13.6	7920 A	0.121 **(**	1370	15800	172 A	<3470	<27.4	32.8
#25) 4.96	9740 A	0.038 **(**	2830	8480	214 A	<2830	<22.6	22.6

Table 11.(cont.) Concentrations (mg/kg) of metals in sediment samples collected in the Stillwater River study area during 1999.

Stillwater River Mile	Pb-T [PO]	Se-T *	Sr-T *	Zn-T[POM]	TOC [P]	pH *	COD *	P-T [P]
	Sediment Concentration (mg/kg dry weight)							
#2) 62.97	<48.0	<2.40	2120	106 B (	3.6%	7.6	51000	939
#5) 57.9	<49.2	<2.47	465	117 B (	4.5%	7.7	41000	1610
#6) 56.97	<22.8	<1.14	199	53 A (	3.2%	7.6	21600	569
#7) 50.2	<21.7	<1.08	156	50.5A (	4.5%	7.36	7980	578
#9) 44.17	<20.3	<1.01	101	49.6A (	3.8%	7.17	73800	661
#10) 37.77	<21.1	<1.06	136	45.9A (	3.6%	7.34	55000	480
#11) 33.5	<27.0	<1.35	112	37.2A (	4.1%	7.59	17800	509
#13) 32.1	<54.8	<2.74	206	182 C (	9.1%	7.62	NA	NA
#15) 25.12	<23.6	<1.18	206	47.3A (	2.1%	7.61	31800	568
#19) 15.05	<21.9	<1.09	91.3	40.4A (	2.7%	7.37	60000	567
#20) 14.65	<31.8	<1.59	171	45.3A (	3.6%	7.56	69400	770
#21) 13.6	<27.4	<1.37	97.2	37.7A (	3.5%	7.41	58700	617
#25) 4.96	<22.6	<1.13	86.5	51. A (	5.8%	7.41	104000	490

All sites are Eastern Corn Belt Plains

NA Compound not analyzed.
* Not evaluated by Ohio EPA (1995), MacDonald(2000) or Ontario (1993).
[P] Evaluated by Ontario (1993).
[O] evaluated by Ohio EPA (1995)
[M] evaluated by MacDonald (2000)

Ohio EPA Guidelines:
[A] Non-elevated
[B] Slightly elevated
[C] *Elevated*
[D] **Highly elevated**
[E] **Extremely elevated**

Ontario Guidelines:
• **$ Severe Effect Level (SEL)**

MacDonald (2000) Sediment Quality Guidelines (SQG)
Three toxicity ranges:
<TEC (Threshold Effect Concentration (TEC)- Below which adverse effects are unlikely to occur.
TEC-EEC Ö above which adverse effects frequently occur
>EEC ; Extreme Effect Concentration (EEC) -above which adverse effects usually or always occur

Stillwater Tributaries (Table 12)
Of the 12 metals included in the various sediment classifications, the majority (76%-146/192) of concentrations recorded at the 16 tributary sites were ranked "non-elevated", "slightly elevated", or Below Detection Limit by all applicable guidelines.

Aluminum, Barium, and Chromium, (50% (8/16), 50% (8/16), 38% (6/16)) were the metals most frequently ranked "elevated" or higher per Ohio EPA guidelines in the tributaries. Aluminum and Barium are commonly found in the soils of Southwestern Ohio and have been in the elevated or higher category in other stream surveys. Chromium is usually not found this often in the elevated or higher category.

A total of 38% (6/16) of the tributary sites documented sediment metals in the "highly elevated" or "extremely elevated" category as evaluated by the Ohio guidelines.

The most metal contaminated tributaries on the survey were Greenville Creek (RM19.55) , Painter Creek (RM 0.80), and Swamp Creek (RM 0.28).

Greenville Creek (RM 19.55) at Ohio Street in Greenville is impacted by a sewage overflow. A Notice of Violation was issued to the City of Greenville on September 29, 1999. A major 12" septic line was discharging into the storm sewer, ultimately discharging into Greenville Creek at Ohio Street. Copper in the sediment was found to be "extremely elevated" by the Ohio guidelines. Copper also exceeded the Ontario "Severe Effect Level" and the MacDonald "Extreme Effect Concentration", indicating that adverse effects usually or always occur. Aluminum and Barium were found to be highly elevated when compared to the Ohio guidelines. Arsenic and Chromium were found to be in the "elevated" category by the Ohio guidelines. Arsenic was found to be between the MacDonald TOC and EEC, indicating adverse effects frequently may occur. There may be additional sources upstream, considering the number of spills in the Dismal Creek-Greenville Creek drainage basin during the last six years.

Painter Creek (RM 0.80) at Sugargrove Road has no immediately visible reasons for having the most metal contaminated sediment on the entire survey. The substrate is limestone and was very difficult to collect any sediment samples. The sediment sample was taken from one pocket of sediment 15 feet downstream (river right) from a small drainage ditch leading from an old barn at the top of the hill. Manganese, Zinc, and Cadmium were classified in the Ohio "extremely elevated" category , Barium was in the "highly elevated" category, and Aluminum was in the Ohio "elevated" category. Manganese was detected over the Ontario "Severe Effect Level". Zinc was classified over the Ontario "Severe Effect Level" and the MacDonald "Extreme Effect Concentration" indicating that adverse effects usually or always occur. Cadmium was detected between the MacDonald TOC and EEC, indicating adverse effects frequently may occur. In addition nutrient toxicity was also present. Total Organic Carbon and Phosphorus were in the Ontario "Severe Effect Level". Sediment levels of Cadmium, Zinc, TOC, COD, ammonia, and phosphorus were the highest recorded on the entire survey.

Swamp Creek (RM 0.28) has the highest levels of Aluminum (50,900mg/kg), Barium(304 mg/kg) Chromium (54.6 mg/kg), and Manganese (3,430 mg/kg) found in the entire Stillwater survey. Aluminum and Manganese were in the Ohio "extremely elevated" category. Barium and Chromium were in the "highly elevated" category. Manganese was detected over the Ontario "Severe Effect Level". Zinc and chromium were detected between the MacDonald TOC and EEC, indicating adverse effects frequently may occur. Years of roadside dumping of trash, oily wastes and used industrial products are evident along the trail that leads through the wooded riparian along the creek. Remnants of trash and metal items could be found in the creek bed.

Table 12. Concentrations (mg/kg) of metals in sediment samples collected in the Stillwater Tributaries study area during 1999. Parameter concentrations were evaluated based on Ohio EPA sediment metal reference sites (1995), MacDonald(2000) Sediment Quality Guidelines (SQG) and Persuad (1993).

River	**----------Sediment Concentration (mg/kg dry weight)----------**						
River	Al-T [o]	As-T [POM]	Ba-T [o]	Ca-T *	Cd-T [POM] [POM]	Cr-T [POM]	Cu-T
Swamp Ck. #46 0.28	**50900 E**	12.2 B Ö	**304 D**	28900	0.675 B (	**54.6D** Ö	25.7 B (
Trib.Swamp Ck. #48 0.45	**28200 D**	9.84 B Ö	156 C	68900	0.484 A (	30.2 C (	19 A (
Indian Creek #50 1.93	**38000 E**	13.4 B Ö	**222 D**	97000	0.52 A (	**42.6 D** (	18.9 A (
Ballinger Run #58 0.59	14300 B	6.86 A (	112 B	54200	0.349 A (	21.1 A (	16.3 A (
Greenville Ck. #62 26.6	12300 B	6.77 A (	109 B	62300	0.383 A (	<26.7	14.2 A (
Greenville Ck. #64 23.08	12800 B	8.52 A (	118 B	53600	0.442 A (	<23.7	17.4 A (
Greenville Ck. #65 19.55	**25600 D**	15.4 C Ö	**218 D**	64500	0.702 A (	32.7 C (	**601.0E** ; •
Greenville Ck. #66 18.34	11500 A	7.61 A (	127 B	74600	0.536 A (	<23.2	33.4C Ö
Greenville Ck. #68 13.7	19500 C	9.09 A (	176 C	63000	0.63 B (	26.5 C (	26.5 C (
Greenville Ck. #71 6.1	**24200 D**	10.3 B Ö	207 C	55400	0.48 A (	28.1 C (	21.5 B (
Mud Creek #85 4.67	11400 A	8.59 A (	114 B	44800	0.334 A (	<22.8	12.2 A (
Painter Creek #98 14.98	6830 A	6.56 A (	63.9 A	19200	0.272 A (	<17.0	15.3 A (
Painter Creek #101 0.80	18900 C	7.4 A (	**215 D**	64800	**1.94 E** Ö	<69.4	25.4 B (
Ludlow Creek #113 0.65	15800 C	6.28 A (	138 C	103000	0.215 A (	<25.8	8.6 A (
Brush Creek #120 0.45	8330 A	5.98 A (	61.8 A	58400	0.235 A (	<20.1	16.8 A (
Mill Creek #125 2.62	12000 B	7.86 A (	75.6 A	45500	1.02 C Ö	<22.0	22.8 B (

Table 12 (cont.) Concentrations (mg/kg) of metals and nutrients in sediment samples collected in the Stillwater Tributaries study area during 1999.

River River Mile *	----------Sediment Concentration (mg/kg dry weight)---------- Fe-T PO	Hg-T M	K-T *	Mg-T *	Mn-T PO	Na-T *	Ni-T POM	NH_3-N
Swamp Ck. #46 0.28	32500 C	<0.105	12800	14500	**3430 E** •	<8040	<64.3	ND
Trib.Swamp Ck. #48 0.45	24000 B	<0.042	7140	17500	321 A	<3970	<31.7	ND
Indian Creek #50 1.93	26900 B	<0.068	9460	34300	516 C	<5910	<47.3	ND
Ballinger Run #58 0.59	14300 A	0.038 (	3610	19900	419 B	<3010	<24.1	ND
Greenville Ck. #62 26.6	12400 A	0.065 (	2670	19600	288 A	<4450	<35.6	26.4
Greenville Ck. #64 23.08	13000 A	0.067 (	3160	18900	235 A	<3940	<31.6	36.8
Greenville Ck. #65 19.55	21200 A	0.072 (	6730	19200	597 C	<4810	<38.4	46.2
Greenville Ck. #66 18.34	12900 A	**0.173** (	3110	22500	307 A	<3880	<31.1	30.8
Greenville Ck. #68 13.7	17400 A	0.072 (	4300	18600	474 C	<3580	<28.6	36.6
Greenville Ck. #71 6.1	19600 A	0.063 (	5790	14900	424 B	<4130	<33.1	74.2
Mud Creek #85 4.67	13700 A	<0.046	2280	15200	367 B	<3800	<30.1	29.5
Painter Creek #98 14.98	6650 A	0.067 (	1700	5660	102 A	<2830	<22.6	46.6
Painter Creek #101 0.80	19900 A	<0.154	4630	13900	**2000 E** •	<11600	<92.6	114
Ludlow Creek #113 0.65	11600 A	<0.054	5160	17200	398 B	<4300	<34.4	NA
Brush Creek #120 0.45	9250 A	<0.029	2010	18800	279 A	<3360	<26.9	<12
Mill Creek #125 2.62	12800 A	0.034 (	3670	19800	185 A	<3670	<29.4	40.2

Table 12.(cont.) Concentrations (mg/kg) of metals and nutrients in sediment samples collected in the Stillwater Tributaries study area during 1999.

River	----------Sediment Concentration (mg/kg dry weight)----------							
River Mile	Pb-T POM	Se-T *	Sr-T *	Zn-T POM	TOC P	pH *	COD*	P-T P
Swamp Ck. #46 0.28	<64.3	<3.21	347	199 C Ö	2.0%	7.9	NA	NA
Trib.Swamp Ck. #48 0.45	<31.7	1.75	433	99.2 B (	2.8%	7.6	NA	NA
Indian Creek #50 1.93	<47.3	<2.36	612	121 B Ö	2.7%	7.8	NA	NA
Ballinger Run #58 0.59	31.3 A (	<1.2	100	113 B (	3.7 %	7.6	NA	NA
Greenville Ck. #62 26.6	<35.6	<1.78	142	56.1 A (	3.8%	7.7	240000	778
Greenville Ck. #64 23.08	<31.6	<1.58	128	65.5 A (	4.9 %	6.5	192000	558
Greenville Ck. #65 19.55	<38.4	<1.92	181	137 B Ö	5.1%	7.3	73000	945
Greenville Ck. #66 18.34	47.4 B	<1.55	149	112 B (	4.1%	7.5	72500	1060
Greenville Ck. #68 13.7	<28.6	<1.43	155	176 C Ö	3.8%	7.6	34700	985
Greenville Ck. #71 6.1	<33.1	<1.65	161	91 A (	3.8%	7.5	57700	1020 b
Mud Creek #85 4.67	<30.4	<1.52	89.7	54.7 A (	4.0%	7.4	16800	692
Painter Creek #98 14.98	<22.6	<1.13	51.5	55.4 A (	6.5%	7.7	91000	472
Painter Creek #101 0.80	<92.6	<4.63	85.6	**467 E ;**	**18% •**	7.8	334000	**2040 •**
Ludlow Creek #113 0.65	<34.4	<1.72	182	55.9 A (	2.4%	7.5	NA	NA
Brush Creek #120 0.45	<26.9	<1.34	63.1	49 A (	2.7%	7.6	35400	616
Mill Creek #125 2.62	<29.4	<1.47	59.5	96.9 A (	3.6%	7.3	13100	530

Table 12.(cont.) Concentrations (mg/kg) of metals and nutrients in sediment samples collected in the Stillwater Tributaries study area during 1999.

All sites are Eastern Corn Belt Plains
NA Compound not analyzed.
* Not evaluated by Ohio EPA (1995), MacDonald(2000) or Ontario (1993).
P Evaluated by Ontario (1993).
O Evaluated by Ohio EPA (1995)
M Evaluated by MacDonald (2000)

Ohio EPA Guidelines:
A Non-elevated
B Slightly elevated
C *Elevated*
D **Highly elevated**
E **Extremely elevated**

Ontario Guidelines:
• $ **Severe Effect Level (SEL)**

MacDonald (2000) Sediment Quality Guidelines (SQG)
Three toxicity ranges:
<TEC (Threshold Effect Concentration (TEC)- Below which adverse effects are unlikely to occur.
TEC-EEC Ö above which adverse effects frequently occur
>EEC ; Extreme Effect Concentration (EEC) -above which adverse effects usually or always occur

Sediment Organics (Table 13)
Organic compounds detected in sediment samples were are divided into two groups. One group of compounds which have quantifiable values (compounds detected are compared to a known standard at five different concentrations) and the second group are compounds whose peaks match the computer's spectral database, but are not compared to a known standard. The latter group of reported compounds is called tentatively identified compounds (TIC). Tentatively identified compound information is not as reliable as quantifiable compound information and is only used for screening in this report. The computer is approximately 80% accurate on TIC identification and concentrations can be off as much as 100%.

Stillwater River
Sediments from the mainstem documented 77% (10/13) of the locations without any quantifiable organic compounds. The most common organic compound found in 23% (3/13) of mainstem sediment locations were 3&4 Methylphenol. The compounds 3- Methylphenol (meta-cresol) and 4- Methylphenol (para-cresol) are found in coal tar and petroleum and have been used as a wood preservative in railroad ties and telephone poles.

Twenty- five different tentatively identified compounds were detected in the sediments of the mainstem. The majority of compounds detected were in the single digit part per million (mg/kg) range and were not evaluated by any of the guidelines. The most common compounds detected can be placed into three categories: Aliphatic hydrocarbons, Fatty acids and sterols. The aliphatic

hydrocarbons Nonacosane ($C_{29}H_{60}$) found in 85% (11/13) of samples, Heptacosane ($C_{27}H_{56}$) found in 85% (11/13) of samples, and Pentacosane ($C_{25}H_{52}$) found in 77% (10/13) of samples are related to plant material. Nonacosane and Heptacosane are associated with the wax produced by the cuticle of corn (Zea mays)[1]. The fatty acids Hexadecanoic (Palmitic) Acid ($C_{16}H_{32}O_2$) found in 92% (12/13) of samples, 9-Hexadecanoic (Oelic) Acid found in 62% (8/13) of samples , and Tetradecanoic (Myristic) acid found in 46% (6/13) of samples are fatty acids from animal and plant origins. The sterols, Sitosterol found in 92% (12/13) of samples is a major plant lipid and cholesterol 69% (9/13) of samples is the major component in animal cell membranes. The majority of these compounds can be associated with the degradation of organic products such as plant material and sewage sludge.

Stillwater Tributaries

Sediments from the Stillwater tributaries documented 63% (10/16) of the locations without any quantifiable organic compounds. Polyaromatic hydrocarbons were detected at 25% (4/16) of tributary sites. Legacy concentrations of DDT in the form of breakdown products were found at Painter Creek RM 14.98 (4,4'-DDE 15.8 µg/kg) and Greenville Creek RM 18.34 (4,4'-DDD 13.9µg/kg). Both DDE and DDD concentrations exceeded the Ontario "Lowest Effect Level" and between the MacDonald TOC and EEC, indicating adverse effects frequently may occur.

Greenville Creek at Ohio Street RM 19.55 had 10 different PAHs detected in sediments for a total PAH concentration of 16.6 mg/kg . Chrysene, Pyrene, and Fluoranthene exceeded the MacDonald "Extreme Effect Concentration", indicating that adverse effects usually or always occur. Benz(a) anthracene, Benzo(a)pyrene, and Phenanthrene were between the MacDonald TOC and EEC and exceeded the Ontario "Lowest Effect Level ." The sources of this contamination was discussed in the metal section of this report. Sewage discharging from a Ohio Street storm sewer is a likely source.

Greenville Creek at Jaysville-St.Johns Street RM 18.34 had 11 different PAHs detected for a total of 14.17 mg/kg. This site is downstream from the Ohio Street site (RM 19.55) and demonstrates the extent of contamination spreading downstream. Chrysene, Pyrene, and Fluoranthene exceeded the MacDonald "Extreme Effect Concentration", indicating that adverse effects usually or always occur. Benz(a) anthracene, Benzo(a)pyrene, and Phenanthrene were between the MacDonald TOC and EEC and exceeded the Ontario "Lowest Effect Level". The legacy compound 4,4'-DDD (a degradation product of DDT) was also found between the MacDonald TOC and EEC and exceeded the Ontario "Lowest Effect Level".

PAH contamination at Ballinger Run RM 0.59 is believed to be associated with the combined sewer overflows of Bradford sewer system flowing into Ballinger Run. Three PAH compounds (Fluoranthene, Phenanthrene, and Pyrene) exceeded the Ontario "Lowest Effect Level" and were between the MacDonald TOC and EEC.

Painter Creek (RM 0.80) at Sugargrove Road had Fluoranthene and 4,4'-DDE which exceeded Ontario "Lowest Effect Level" and between the MacDonald TOC and EEC. This contamination

is believed to be related to the contents of an old barn that had a drainage pathway leading to the sampling location.

Twenty- five different tentatively identified compounds were detected in the sediments of the Stillwater tributaries. The majority of compounds detected were in the single digit part per million (mg/kg) range and were not evaluated by any of the guidelines. The most common compounds detected can be placed into three categories: Aliphatic hydrocarbons, Fatty acids and sterols.

The aliphatic hydrocarbons Nonacosane ($C_{29}H_{60}$) found in 63% (10/16) of samples, Heptacosane ($C_{27}H_{56}$) found in 81% (13/16) of samples, and Pentacosane ($C_{25}H_{52}$) found in 69% (11/16) of samples are associated with plant material. Nonacosane and Heptacosane are associated with the wax produced by the cuticle of corn (Zea Mays)[3]. The fatty acids Hexadecanoic Acid ($C_{16}H_{32}O_2$) found in 100% (16/16) of samples and 9-Hexadecanoic Acid found in 75% (12/16) of samples are fatty acids from plant origins and sewage. The sterols, Sitosterol found in 100% (16/16) of samples is a major plant lipid and cholesterol found in 63% (10/16) of samples is the major component in animal cell membranes.

[3] E. Lichtfouse (1994) Isotope and Molecular evidence for direct input of maize leaf wax n-alkanes into crop soils. *Org.Geochem. Vol 22, No. 2, pp. 349-351*

Table 13. Sediment concentrations of semi-volatile, volatile, pesticide, and PCB compounds (priority pollutant scan) detected in the Stillwater River study area during 1999. Individual compounds were evaluated by the MacDonald (2000) Sediment Quality Guidelines (MacDonald 2000) and (Persuad 1993).

Landmark River Mile	Analysis Performed	Compound Detected	Result
#2 Stillwater River	1) VOC	Acetone n	0.116 Fg/kg
RM 62.97	2) BNA		BDL
SR 49	3) Pesticides		BDL
TOC = 3.6%	4) PCBs		BDL
#5 Stillwater River	1) VOCs		BDL
RM 57.9	2) BNA	3&4 Methylphenol*	1.3 mg/kg
Ansonia WWTP	3) Pesticides		BDL
TOC = 4.5%	4) PCBs		BDL
#6) Stillwater River	1) VOCs		BDL
RM 56.97	2) BNA		BDL
Biesner Road	3) Pesticides		BDL
TOC = 3.2%	4) PCBs		BDL
#7) Stillwater River	1) VOCs	Toluene	0.317 mg/kg
RM 50.20	2) BNA	3&4 Methylphenol*	0.83 mg/kg
Union City Rd.	3) Pesticides		BDL
TOC = 4.5%	4) PCBs		BDL
#9) Stillwater River	1) VOCs	Acetone n	0.156 mg/kg
RM 44.17	2) BNA	3&4 Methylphenol*	2.4 mg/kg
Barnes Rd.	3) Pesticides		BDL
TOC = 3.8%	4) PCBs		BDL
#10) Stillwater River	1) VOCs		BDL
RM 37.77	2) BNA		BDL
SR 185	3) Pesticides		BDL
TOC = 3.6%	4) PCBs		BDL
#11) Stillwater River	1) VOCs		BDL
RM 33.5	2) BNA		BDL
Cov.-Bradford Rd	3) Pesticides		BDL
TOC = 4.1%	4) PCBs		BDL

Table 13. Continued.

Landmark River Mile	Analysis Performed	Compound Detected	Result
#13) Stillwater River RM 32.10 Bridge St. TOC = 9.1%	1) VOCs	Acetone n	0.142 mg/kg
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#15) Stillwater River RM 25.12 Penny Rd. TOC = 2.1%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#19) Stillwater River RM 15.05 Garland Rd. TOC = 2.7%	1) VOCs		BDL
	2) BNA		BDL
			BDL
	3) Pesticides		BDL
	4) PCBs		
#20) Stillwater River RM 14.65 Adj. Landfill TOC = 3.6%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#21) Stillwater River RM 13.60 Dst. Landfill trib. TOC = 3.5%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#25) Stillwater River RM 4.96 Philadelphia Dr. TOC = 5.8%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#46) Swamp Creek RM 0.28 Martz Rd. TOC = 2.0%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#48) Tributary to Swamp Creek RM 0.45 SR 47 TOC = 2.8%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL

Table 13. Continued.

Landmark River Mile	Analysis Performed	Compound Detected	Result
#50) Indian Creek	1) VOCs		BDL
RM 1.93	2) BNA		BDL
Conover Rd.	3) Pesticides		BDL
TOC = 2.4%	4) PCBs		BDL
# 58) Ballinger Run	1) VOCs	Acetone n	0.0623 mg/kg
RM 0.59	2) BNA	Flouranthene £ Ö	1.2 mg/kg
Bradford-Bloomer Rd.		Phenanthrene £ Ö	0.73 mg/kg
TOC = 3.7%		Pyrene £ Ö	0.99 mg/kg
	3) Pesticides		BDL
	4) PCBs		BDL
#62) Greenville Creek	1) VOCs		BDL
RM 26.6	2) BNA		BDL
Daly Rd.	3) Pesticides		BDL
TOC = 3.8%	4) PCBs		BDL
#64) Greenville Creek	1) VOCs		BDL
RM 23.08	2) BNA		BDL
Wagner Rd.	3) Pesticides		BDL
TOC = 4.9%	4) PCBs		BDL
#65) Greenville Creek	1) VOCs		BDL
RM 19.55	2) BNA	Benz(a)anthracene £ Ö	0.96 mg/kg
Ohio St.		Benzo(a) pyrene £ Ö	1.2 mg/kg
TOC = 5.1%		Benzo(b)Fluoranthene *	1.8 mg/kg
		Benzo(g,h,i)perylene £	1.2 mg/kg
		Benzo(k)Fluoranthene £	1.2 mg/kg
		Chrysene £ ;	1.8 mg/kg
		Fluoranthene £ ;	3.4 mg/kg
		Indeno(1,2,3-cd) pyrene £	1.3 mg/kg
		Phenanthrene £ Ö	1.3 mg/kg
		Pyrene £ ;	2.5 mg/kg
		Total PAH £ Ö	16.6 mg/kg
	3) Pesticides		BDL
	4) PCBs		BDL

Table 13. Continued.

Landmark River Mile	Analysis Performed	Compound Detected	Result
#66 Greenville Creek	1) VOCs		BDL
RM 18.34	2) BNA	Benz(a)anthracene £ Ö	0.98 mg/kg
Jaysville-St. Johns St.		Benzo(a) pyrene £ Ö	1.1 mg/kg
TOC = 4.1%		Benzo(b)Fluoranthene *	1.3 mg/kg
		Benzo(g,h,i)perylene £	0.92 mg/kg
		Benzo(k)Fluoranthene £	0.85 mg/kg
		bis(2-Ethylhexyl)phthalate*	0.76 mg/kg
		Chrysene £ ;	1.3 mg/kg
		Fluoranthene £ ;	2.7 mg/kg
		Indeno(1,2,3-cd) pyrene £	0.96 mg/kg
		Phenanthrene £ Ö	1.3 mg/kg
		Pyrene £ ;	2.0 mg/kg
		Total PAH £ Ö	14.17 mg/kg
	3) Pesticides	4,4'-DDD Ö	13.9 Fg/kg
	4) PCBs		BDL
#68) Greenville Creek	1) VOCs		BDL
RM 13.7	2) BNA		BDL
Bears Mill	3) Pesticides		BDL
TOC = 3.8%	4) PCBs		BDL
#71 Greenville Creek	1) VOCs		BDL
RM 6.10	2) BNA		BDL
SR 721	3) Pesticides		BDL
TOC = 3.8%	4) PCBs		BDL
#85) Mud Creek	1) VOCs		BDL
Rm 4.67	2) BNA		BDL
Bykert Rd.	3) Pesticides		BDL
TOC = 4.0%	4) PCBs		BDL
#98) Painter Creek	1) VOCs		BDL
RM 14.98	2) BNA	Fluoranthene £ Ö	1.3 mg/kg
Pitsburg-Laura Rd.	3) Pesticides	4,4'-DDE £ Ö	15.8 Fg/kg
TOC = 6.5%	4) PCBs		BDL
#101) Painter Creek	1) VOCs		BDL
RM 0.80	2) BNA		BDL
Sugargrove Rd.	3) Pesticides		BDL
TOC = 18.0%	4) PCBs		BDL

. .

Table 13. Continued.

Landmark River Mile	Analysis Performed	Compound Detected	Result
#113) Ludlow Creek RM 0.65 Dst. Ludlow Falls TOC = 2.4%	1) VOCs	Acetone **n**	0.0906 mg/kg
	2) BNA	3&4 Methylphenol*	1.6 mg/kg
	3) Pesticides		BDL
	4) PCBs		BDL
#120 Brush Creek RM 0.45 Ellerman Rd. TOC = 2.7%	1) VOCs		BDL
	2) BNA		BDL
	3) Pesticides		BDL
	4) PCBs		BDL
#125) Mill Creek RM 2.62 County Line Rd. TOC = 3.6%	1) VOCs	Acetone **n**	0.159 mg/kg
	2) BNA	bis(2-Ethylhexyl)phthalate*	0.79 mg/kg
	3) Pesticides		BDL
	4) PCBs		BDL

1) Volatile Organic Compounds (VOC) U.S .EPA Method 8260
2) Base Neutral & Acid Extractables (BNA) U.S. EPA Method 8270
3) Pesticides U.S. EPA Method 8081
4) Polychlorinated biphenyls (PCBs) U.S. EPA Method 8082A

Ontario Sediment Guidelines

0.4 > Lowest Effect Level
• > Severe Effect Level
* not evaluated by MacDonald or Ontario
BDL Below Detection Limit

n This chemical is used to clean sampling equipment and is believed to be residual from cleaning.

MacDonald (2000) Sediment Quality Guidelines (SQG)
Three toxicity ranges:
<TEC (Threshold Effect Concentration (TEC)- Below which adverse effects are unlikely to occur.
TEC-EEC Ö above which adverse effects frequently occur
>EEC cts usually or always occur. . . . . .

Fish Tissue

Fish samples for contaminant analysis were collected from the Stillwater River at ten locations in 1994 and one location in 1998. Mercury concentrations in all but one sample exceeded the risk based consumption advisory level of one meal per week for a 154 1bs person and assuming an 8 oz meal (Figure 95). For a small child or women of child-bearing age, no consumption would be advised. Because mercury concentrations were elevated at all sites, diffuse nonpoint sources, primarily air deposition, is the suspected major source of contamination. However, mercury concentrations in sediment samples collected downstream from the Covington WWTP were highly elevated compared to other streams in Ohio. The Covington WWTP as a source of mercury contamination, or other unidentified proximate sources, should be investigated.

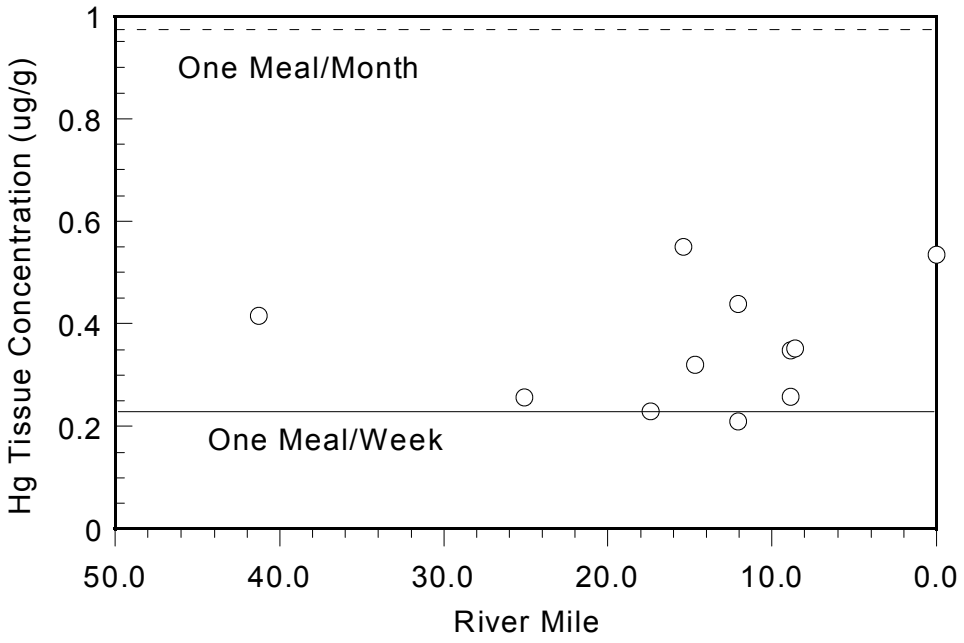


Figure 95. Mercury concentrations in fillets of smallmouth bass collected from the Stillwater River, 1994 and 1998. Risk based consumption limits are shown for a 70 kg (154 lbs) adult. For small children or women of child-bearing age, no consumption would be advised based on these concentrations.

Physical Habitat Quality For Aquatic Life

Basin Summary

Habitat quality in the Stillwater Basin ranges from excellent to very poor. Most of the small tributaries (< 20 mi^2), including those to Greenville Creek, and the headwaters of larger tributaries (Ludlow Creek and Painters Creek) have been modified into an agricultural drainage network. Consequently, the headwaters lack habitat attributes typical of natural, warmwater streams. Channelized streams, that is those that have been either straightened or "dipped" (*e.g.*, Figure 96) become, by design, simplified drainage conveyances, and therefore lack habitat features required to support a diverse fish community. Also, because channelized steams expedite drainage, and typically drain land that is tiled for drainage, residual base flow is often very low. The streams that most typify these conditions are the entire Swamp Creek subbasin and the catchment upstream from Ansonia, including the North Fork (Figure 97). Though tributaries to Greenville Creek draining from the south have been similarly modified, they differ in that they generally have more groundwater and a higher gradient. The higher gradient and flow allow for faster reestablishment of natural habitat conditions following channelization, especially increased particle size distribution, and the higher base flow obviously provides more water during the summer and fall. On average, there were 1.96 high influence modified habitat attributes noted in the Greenville Creek tributaries compared to 2.80 for the upper Stillwater tributaries (including Swamp Creek - Table 14). The difference is significant in that an accumulation of two or more high influence attributes are likely to preclude fish communities from meeting WWH (Rankin 1989).

Greenville Creek, lower reaches of Trotters Creek, Harris Run, Painter Creek and Ludlow Creek, and the Stillwater mainstem downstream from Beamsville have either not been channelized or have recovered. Consequently some problems associated with channelization (*i.e.*, lack of cover, poor substrates, poor channel development) are absent; however, excessive sedimentation, a direct result of the poor habitat conditions upstream, has nearly all of the riffles moderately embedded with fine gravel, sand or silt in all streams. Despite riffle embeddedness, the lower 40 miles of the Stillwater River generally has excellent habitat. The river is characterized by riffle-pool-run sequences, a wide forrested riparian corridor, and glacial till providing a variety of substrate sizes. The importance of the wooded riparian corridor cannot be overstated as it is responsible for helping to attenuate sediment impacts exported from the completely channelized headwaters.

Figure 96. Photograph of a tributary to Swamp Creek upstream from SR 47 near Versailles. This stream has very poor habitat for aquatic life, and is typical of the streams colored red in Figure 97.

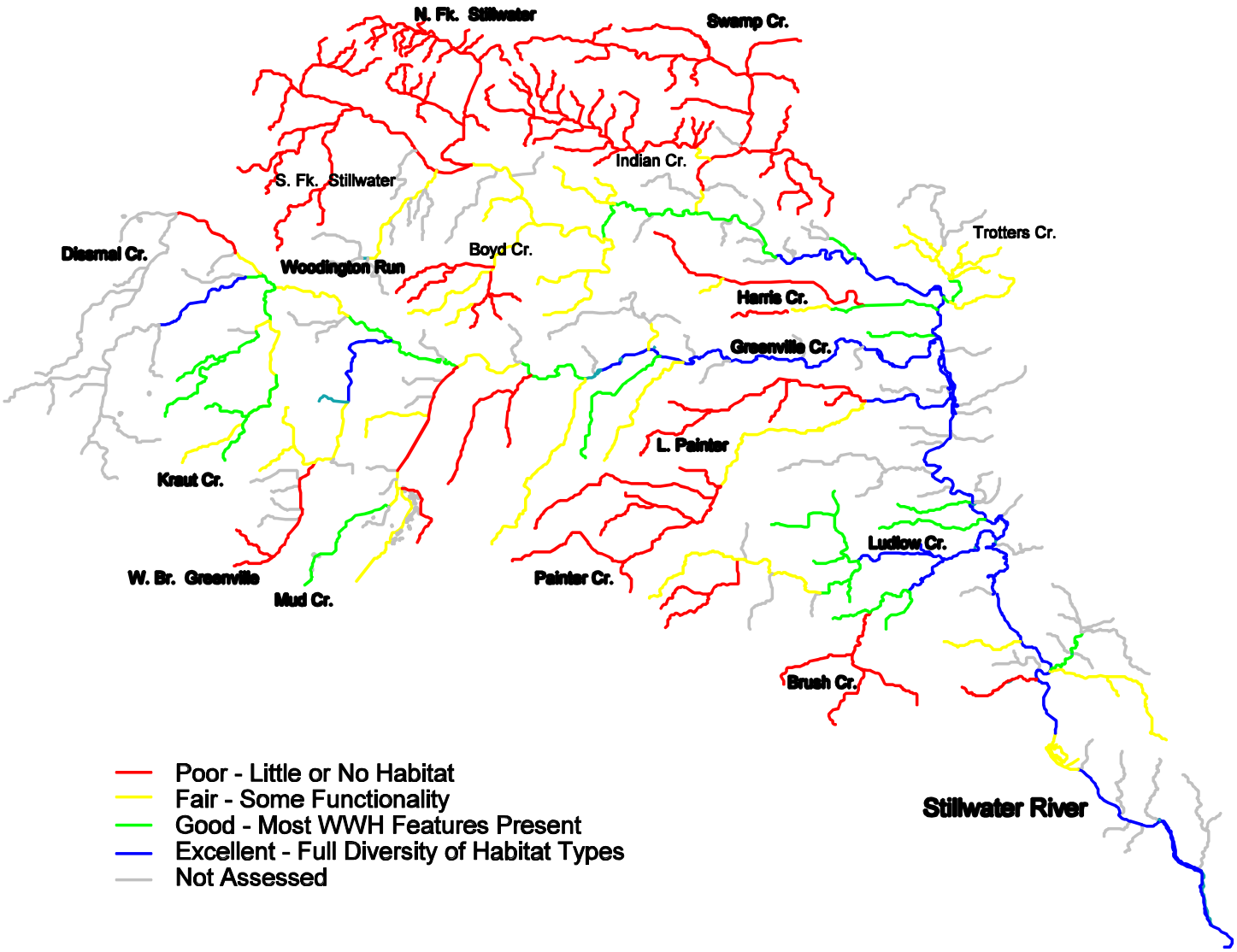


Figure 97. Narrative ranges of habitat quality for streams in the Stillwater River basin, 1999.

Table 14. Qualitative Habitat Evaluation Index matrix of attributes.

Biological Assessment - Macroinvertebrate Communities

For the 1999 survey, 60 macroinvertebrate sites in the Stillwater river basin were evaluated using the quantitative Invertebrate Community Index (ICI) metric scoring system (Table 16). An additional 83 sites were evaluated with qualitative samples based on a multiple habitat composite collection using dipnets and handpicks.

Macroinvertebrate assemblages in headwater sites and stream segments downstream from pollution sources were affected by the low amount of stream flow during the summer of 1999 (see Table 15) in combination with point and nonpoint pollution stressors. Headwater streams (less than 5 square miles drainage), which had little or no riparian vegetation (eg., many of the MWH proposed streams) and/or which were downstream from agricultural/animal operations (AFOs), were generally inhabited by poor to fair macroinvertebrate communities (Stillwater River headwaters, North Fork Stillwater, Swamp Creek, and their tributaries). Better quality headwater streams generally had good riparian buffer zones along the stream banks and were located in the watershed in areas that: 1) were not as congested with agricultural/animal operation facilities, as in the upper Greenville Creek headwaters and tributaries (Kraut Creek, West Branch Greenville Creek), or 2) were not impacted by a high degree of urbanization (Jones Run, Rocky Run, McQuay Ditch, and Poplar Ditch -Figure 98). The drought like conditions affected the larger drainage areas through less upstream dilution available for CSO and WWTP discharges. Compared to 1990 and 1982, stream segments downstream from Ansonia, Greenville, and Elmwood CSOs and WWTPs supported lower quality macroinvertebrate communities in 1999 (Figures 99 and 100).

A total of 338 macroinvertebrate taxa were collected at 143 sites in the Stillwater River Basin in 1999. Thirty-one taxa of mayflies were collected including the intolerant (sensitive) genera/species *Acerpenna pygmaeus*, *Pseudocloeon propinquus*, *Diphetor hageni*, *Paracloeodes* sp. 3, *Nixe* sp., *Stenonema exiguum*, and *Brachycercus* sp. Three taxa of stoneflies were collected including the intolerant *Neoperla clymene* complex and *Agnetina capitata* complex. Thirty-three taxa of caddisflies were collected including the intolerant genera/species *Protoptila* sp., *Neophylax* sp., and *Mystacides sepulchralis*. Intolerant dipterans included the genera/species *Antocha* sp., *Corynoneura celeripes*, *Thienemaniella taurocapita*, *Cladotanytarsus vanderwulpi* group Type 5, and *Stempellinella* sp. Twelve species of mussels were collected in the basin including the intolerant species *Anodontoides ferussacianus*, *Strophitos undulatus undulatus*, *Lasmigona compressa*, *Lasmigona costata*, *Amblema plicata plicata*, and *Lampsilis ventricosa*.

Rare taxa collected from the basin were the two mayflies *Brachycercus* sp. and *Hexagenia bilineata*; the dragonfly *Didymops transversa*; and the dipterans *Ablabesmyia simpsoni*, *Labrundinia maculata*, *Stempellina* sp., and *Chelifera* sp. Coolwater species collected were the alderfly *Nigronia fasciatus*; the caddisflies *Ceratopsyche slossonae* and *Glossosoma* sp.; and the midges *Zavrelimyia* sp., *Eukiefferiella devonica* group, *Parametriocnemus* sp., *Polypedilum (Polypedilum) aviceps*, *Micropsectra* sp., and *Paratanytarsus* n. sp. 1.

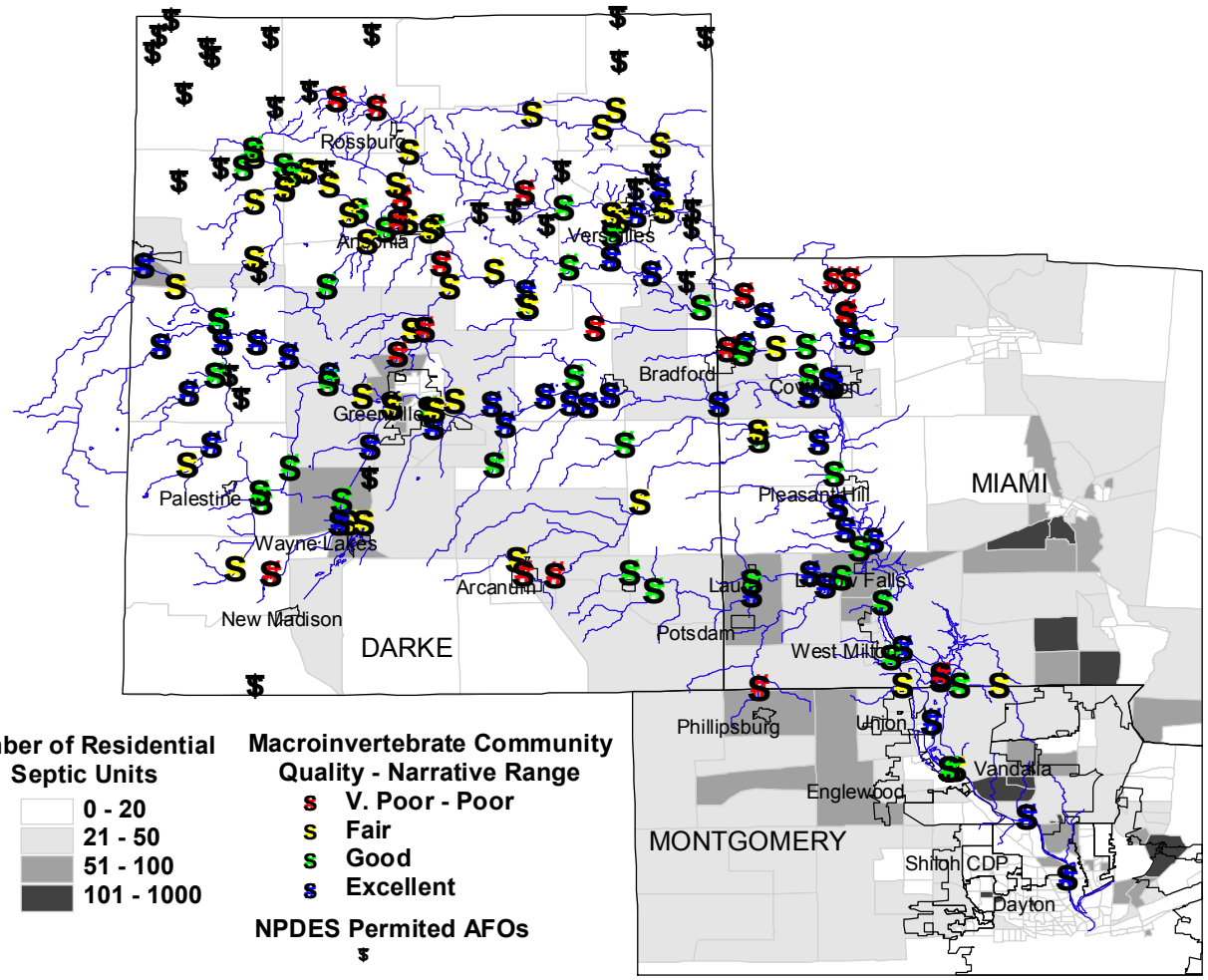


Figure 98. Macroinvertebrate community quality by narrative range, 1999, in relation to NPDES permitted animal feeding operations (AFOs) and density of residential units served by on-site sewage disposal.

Stillwater River

Twenty-eight sites were sampled for macroinvertebrates in 1999 on the Stillwater mainstem from the headwaters to the mouth. Benthic community performance generally increased from fair in the headwaters, to marginally good and good in the WWH section of the river, and were mostly exceptional in the lower mainstem (Table 16). These scores were much lower in the MWH and WWH sections of the Stillwater River compared to the 1990 survey in which macroinvertebrates were in attainment or nonsignificant departure of the EWH biocriterion at every site sampled in the mainstem (Figure 99). This may be due to the lower than normal flow (Table 15) in the Stillwater river in 1999, compared to 1990, which may have intensified the effects of the point and nonpoint sources of pollution.

The upper mainstem from RM 65.8 to 61.8 has been channel modified and has little or no tree lined riparian zones, and there are animal feeding operations (AFOs) in the area. The benthic communities had fair to marginally good biological performance in this segment of the river in 1999. The communities were predominated by caddisflies and pollution tolerant snails and/or flatworms. In 1990, the site at SR 49 (RM 63.0) scored an ICI value in the exceptional range with mayflies, caddisflies, and tanytarsini midges predominant. The higher flow in 1990 may have diluted the effect of the pollution sources.

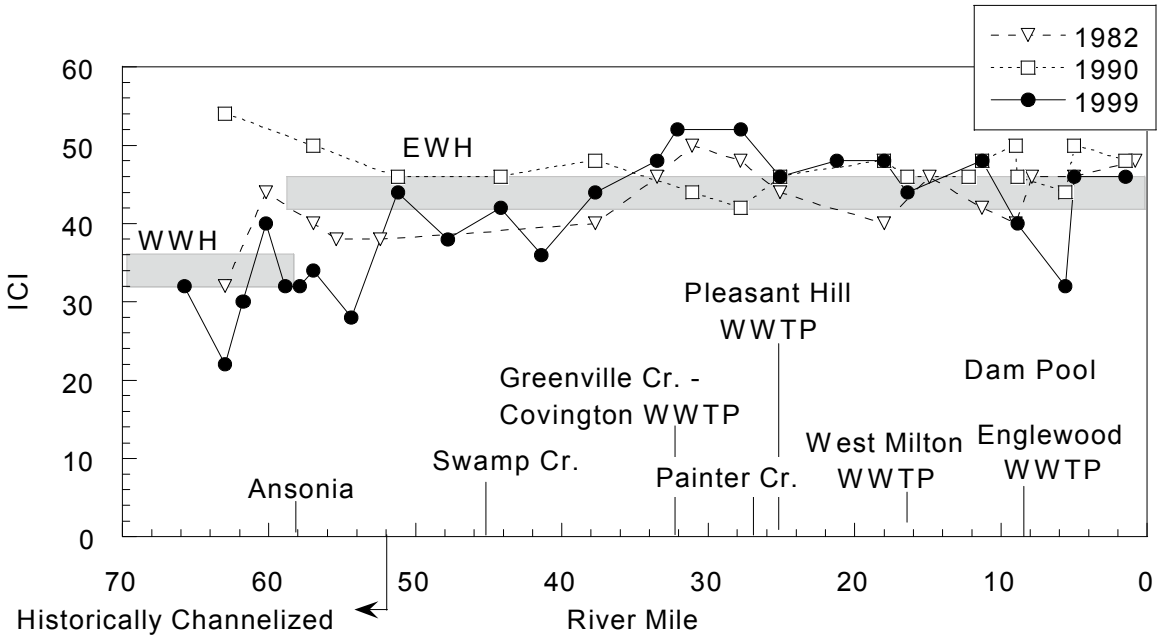


Figure 99. Invertebrate Community Index (ICI) scores for the Stillwater River, 1999, 1990 and 1982 in relation to municipal wastewater dischargers. The village of Arcanum discharges via Painter Creek, Versailles via Swamp Creek, and Ansonia via the North Fork.

In the Warmwater Habitat (WWH) designated section of the Stillwater River from RMs 60.2 to 54.4, the ICI scores decreased from 38 (good), upstream from Ansonia, to 28-34 (fair to marginally good) in the town of Ansonia and downstream from the Ansonia CSOs and WWTP. The site downstream from Ansonia at Beisner Road (RM 57.0) had ICI scores of 34 (marginally good) in 1999, 50 (exceptional) in 1990, and 40 (good) in 1982. It appeared as though the lower flow in 1999, and possibly in connection with lesser water quality upstream from Ansonia, had a more profound effect on the impact from sources in Ansonia.

Macroinvertebrate communities in the lower Stillwater River from RMs 51.2 to 1.6 scored ICI values mostly in the very good to exceptional range. Exceptions were ICI scores in the good range at RM 47.8 and RM 41.4, and a marginally good evaluation downstream from the Englewood WWTP at RM 8.3. Previous years have shown similar decreases in the benthic community downstream from the Englewood WWTP, but the lower flow in 1999 appeared to have a more profound effect on the impact from the WWTP on the benthic community.

Stillwater River and Tributaries (Upstream From Ansonia)
Tributaries in the upper Stillwater basin with drainage areas less than 2-3 square miles (North Fork Stillwater RM 10.5, South Fork Stillwater RM 5.5, and Trib. to Stillwater River (RM 60.22) had very little flow in their stream beds; most of the macroinvertebrate sampling was limited to a pooled area under a bridge. Typically, these streams had no riffle or run areas. The stream channels upstream and downstream from the bridges were mostly agricultural ditches with overgrown grass covering the stream. Many of these tributaries had AFOs in their watersheds. These tributaries had very poor to fair macroinvertebrate community performance with 1 to 5 EPT taxa collected and mostly facultative or tolerant taxa predominant.

Streams between 5 and 10 square miles drainages (North Fork Stillwater RM 8.3, Sycamore Ditch, Trib. to South Fork Stillwater River (RM 0.94), and Trib. to Stillwater River (RM 64.96)) had better flow and substrate types (again mostly under the bridges) but most were still grass-lined ditches. Because the stream width was greater than in the smaller than 5 mi^2 drainages, the grass along these streams did not cover the stream entirely. The streams heavily impacted by AFOs in their drainage had large amounts of algae in the stream. These streams had very poor to marginally good macroinvertebrate community performance with 1 to 7 EPT taxa. Woodington Run RM 4.9 had a better tree-lined riparian zone and good macroinvertebrate performance with 8 EPT taxa and mayflies/caddisflies predominating the natural substrates.

The South Fork and tributaries were also open grass-lined ditches. However, at the mouth of the South Fork at RM 0.4, there were some indications of a recovering stream channel with some hints of sinuosity and a slightly higher QHEI (30 at RM 5.5 to 40 at RM 0.4). Macroinvertebrate communities improved from a low fair evaluation predominated by beetles/snails and only 3 EPT taxa at RM 5.5 to a marginally good evaluation predominated by caddisflies/beetles and 7 EPT taxa at RM 0.4.

Boyd Creek and Tributaries Upstream From Swamp Creek
Macroinvertebrate communities in Boyd Creek improved from a low fair evaluation (non-attainment of MWH biocriterion) predominated by snails/clams and 4 EPT taxa at RM 3.5 to a high fair evaluation (attainment of MWH biocriterion) predominated by caddisflies/mayflies/snails and 5 EPT taxa at RM 0.8. Two tributaries to Boyd Creek supported very poor macroinvertebrate communities; both were predominated by snails/clams/leeches and each had only 2 EPT taxa. The habitat at the Trib. to Boyd Creek (RM 2.46) at SR 118 was limiting, and the Trib. to Boyd Creek (RM 2.67) at Horatio-Harris Creek Road may have reflected impacts from upstream AFOs.

The Trib. to Stillwater River (RM 51.0) at Oliver Etter Road had a good macroinvertebrate community with caddisflies/mayflies predominant and 7 EPT taxa. There was a good riparian zone and no upstream impacts or sources of pollution were observed.

Swamp Creek, Indian Creek, and Tributaries
Drainage basins approximately 10 square miles or less (Swamp Creek RMs 12.1 and 8.9, Indian Creek RM 6.1, Grassy Fork RM 0.9, and the Trib. to Swamp Creek (RM 3.54)) had poor to fair benthic community performance with 1 to 5 EPT taxa and pollution tolerant or facultative organisms predominating the natural substrates. These locations were grass-lined ditches bordering agricultural/AFO operations.

Macroinvertebrates in Indian Creek at Conover Road (RM 2.0) had marginally good performance in both 1990 and 1999, with 8 to 10 EPT taxa collected and caddisflies/mayflies predominant. At SR 47 (RM 0.5) the benthic community was only fair in 1999 with 3 EPT taxa and flatworms predominant compared to an evaluation of marginally good in 1982 with 7 EPT taxa and caddisflies predominant.

Swamp Creek from the headwaters (RM 12.1) to Pitsanbarger Road (RM 6.5) supported fair macroinvertebrate communities in 1990 and 1999. The stream channel in this section is ditchlike with grass banks. There is a good tree-lined riparian zone at Long Road (RM 4.4) where benthic communities in 1982, 1990, and 1999 were evaluated as marginally good to good. The macroinvertebrate communities in Swamp Creek demonstrated substantial improvement downstream from the Versailles WWTP (RM 2.1) in 1990 and 1999 with ICI scores in the marginally good to very good range, compared to the poor performance observed in 1982. This reflected improvements in waste treatment.

Trotter Creek and Tributaries Upstream From Covington
Apple Ditch, Bennet Ditch and Rudy Ditch had drainage areas less than 5 square miles and were near intermittent at the sampling locations in 1999. The Trib. to Stillwater River (RM 38.3) had unrestricted livestock access which apparently affected water quality. Macroinvertebrate communities at these sites were evaluated as very poor to poor with facultative leeches/midges/snails predominant and 0-1 EPT taxon collected. Trotter Creek, Sigmond Ditch, and the Trib. to Stillwater River (RM 32.6) had good to very good macroinvertebrate

performance with mayflies/caddisflies predominant and 9-13 EPT taxa collected.

Harris Creek and Ballinger Run
The Trib. to Harris Creek at RM 8.05 was approximately 2 square miles in drainage and sampled on September 22 near the origin of stream flow at RM 0.2. Only facultative organisms were present and represented very poor macroinvertebrate performance.

Ballinger Run was very poor at RM 1.4 with no EPT taxa collected and tolerant or facultative organisms predominating the natural and artificial substrates. Black muck, solids deposition, and a septic odor observed during sampling indicated a possible Bradford CSO impact. Downstream from the Bradford WWTP, the site at RM 6.4 had an ICI score (32) in the marginally good range.

Harris Creek was sampled at RMs 5.2, 1.9, and 1.1 and had good to very good macroinvertebrate performance with 6 to 13 EPT taxa collected from the natural substrates and ICI scores of 38 and 44 at two of the sites.

Greenville Creek
Macroinvertebrates were sampled at seventeen sites on the Greenville Creek mainstem in 1999. Generally, the sites had ICI scores in the very good to exceptional range, except for a modified site in a dam pool (RM 22.6) and sites impacted by the Greenville WWTP and CSOs (RMs 19.5 to 18.4). At most sites, three or more sensitive taxa were collected. Eight sensitive taxa and one rare taxon were collected from Mill Road (RM 10.9) and SR 721 (RM 6.2). The macroinvertebrate communities sampled in Greenville Creek in 1990 were generally in the exceptional range. Compared to 1990, the 1999 macroinvertebrate ICI scores were lower at sites downstream from Greenville CSOs and the Greenville WWTP. The lower flow in Greenville Creek in 1999 (Table 15) may have exacerbated the impact from the Greenville CSOs and WWTP.

Macroinvertebrates in the upper Greenville Creek mainstem in 1999 were exceptional, compared to the upper Stillwater River mainstem in 1999 which was mostly fair. The upper Stillwater River and tributaries were more ditchlike, had more grass banks instead of tree-lined riparian zones, and had a heavier concentration of AFOs in their watersheds. Effects from these sources in the upper Stillwater basin may have been more intense in the low flow year of 1999; however, these sources were not as prevalent in the upper Greenville Creek basin and, as such, did not show an impact to the macroinvertebrate community.

Greenville Creek Tributaries Upstream From Greenville
Smaller drainage streams with less than 5 square miles supported poor to marginally good macroinvertebrate communities (West Branch Greenville Creek RM 10.7, Tributary to Kraut Creek, Spring Branch, Mud Creek RM 2.0, Prairie Outlet, and Lake Branch Ditch RM 4.1). Many of these smaller drainages did not have good tree-lined riparian zones or did not have as good flow conditions as the larger size streams in this basin.

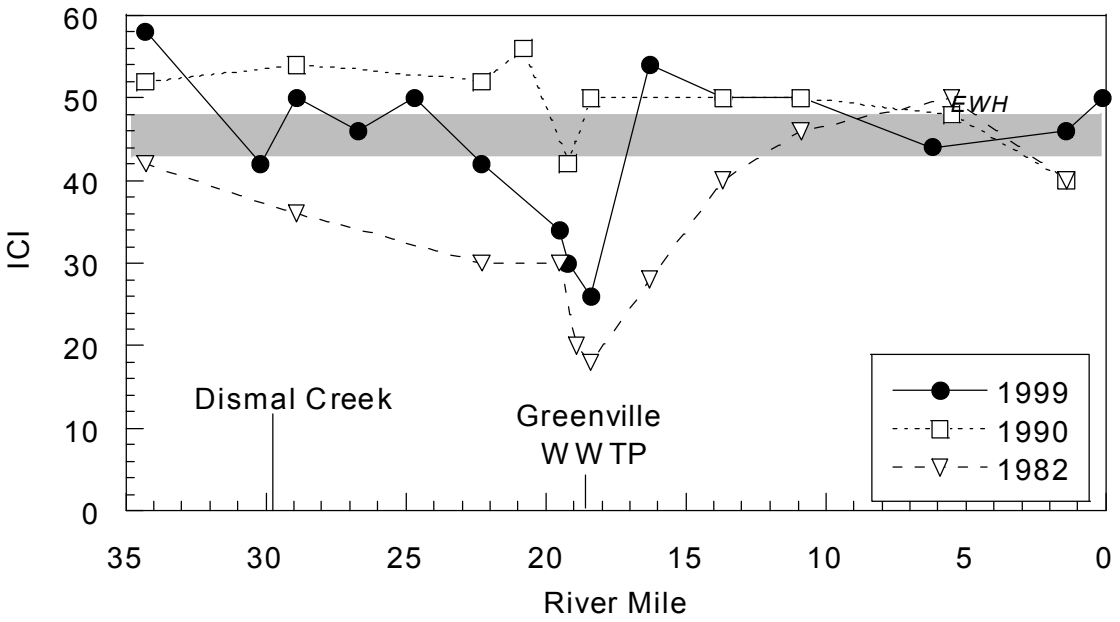


Figure 100. Invertebrate Community Index (ICI) scores for Greenville Creek, 1999, 1990 and 1982 in relation to the Greenville WWTP and Dismal Creek. The village of Union City, Ohio discharges via land application to Dismal Creek.

The creeks and tributaries sampled with drainage areas greater than 5 square miles generally supported good to exceptional macroinvertebrate communities (West Branch Greenville Creek, Kraut Creek, North Fork Kraut Creek, Dismal Creek, Mud Creek, and Lake Branch Ditch). These streams had generally higher QHEI scores, better riparian zones, and land use was not as heavily predominated by AFO activities than comparable size streams in the upper Stillwater and Swamp Creek basins.

Mud Creek was dry at the 2 square mile site area at Weaver Station Road on August 10. The leading edge of the stream was at RM 7.7 (Hollansburg-Simpson Road) on that date. The organisms collected were typical of flow limited sites near stream origination. The downstream sites scored ICIs of good (at RM 5.9) to exceptional (at RMs 4.7 and 0.1).

Greenville Creek Tributaries Downstream From Greenville

Bridge Creek, Dividing Branch RM 0.4, McQuay Ditch and Poplar Ditch supported very good to exceptional macroinvertebrate communities with 8 to 14 EPT taxa and mayfly/caddisfly predominance on the natural substrates. Dividing Branch (RM 3.1) and Bolton Run were evaluated as marginally good with 4 to 7 EPT taxa and caddisfly predominance. Most of these sites had QCTV scores greater than the ecoregional expectation. All of these tributaries, except for Dividing Branch at RM 3.1, had tree-lined riparian zones at the sampling locations.

Painter Creek

The sampling locations for Painter Creek at RM 17.9 (1.5 square miles) and Heller Ditch at RM 0.1 (2.6 square miles) supported macroinvertebrate communities in the high fair to marginally good range, considered to be attaining the MWH biocriterion expectations. Two other Painter Creek tributaries between 3 and 5 square mile drainage areas had no flow or were dry except for water under the bridge. Painter Creek in Arcanum at Ivester Park at RM 16.3 was dry the week of August 18; Painter Creek upstream at RM 17.9 had surface flow the week before on August 10. At RM 16.3 water was restricted to the channel immediately downstream from a CSO located at the downstream edge of the park.

Quantitative samples were collected at RM 15.5 upstream from the Arcanum WWTP tributary. This site was rated poor (ICI = 10) and the next site below the WWTP scored very poor (ICI = 4). Pollution tolerant oligochaetes and midges were the predominant organisms collected from the artificial substrate samplers; there were no caddisflies and only 1 or 2 mayflies collected at these sites.

Macroinvertebrate community conditions improved from fair at RM 8.9 (ICI = 26) to good at RM 4.4 (ICI = 40). The site near the mouth at RM 1.1 supported a very good community (ICI = 44) with high EPT taxa richness and low densities of tolerant organisms present. Painter Creek RM 1.1 (2 species) and Heller Ditch (2 species) were the only sites in this subbasin where intolerant macroinvertebrates were collected.

Lower Stillwater Tributaries (Covington to Engelwood)

Jones Run, Opossum Run, Pigeye Creek, Rocky Run, and Mill Creek (RM 1.2 and RM 2.6) are small drainage tributaries (approximately 5 square miles or less) with a good deal of urbanization adjacent to their watersheds including the municipalities of Pleasant Hills and West Milton. However, as of 1999, there was no substantial urbanization directly in these watersheds at the sampling locations. Jones Run, Rocky Run, Mill Creek RM 1.2 and Opossum Run supported good to very good macroinvertebrate communities with 9-13 EPT taxa, QCTV scores (38.9 to 39.4) achieving the WWH ecoregion expectations, and caddisflies and/or mayflies predominant on the natural substrates. Mill Creek at RM 0.3 (6.0 square mile drainage) scored an ICI value of 52 (exceptional). Pigeye Creek was sampled at the leading edge of steam origination at RM 0.6. Mill Creek RM 2.6 was located downstream from the Dayton International Airport. These sites were evaluated as fair with lower QCTV scores (27.1 and 35.3) and 5-6 EPT taxa collected.

Ludlow Creek and Tributaries

Drainages in the Ludlow Creek basin less than 2.0 square miles had little or no flow (Baker Ditch, Brown Ditch, and Feitshams Ditch). The Tributary to Ludlow Creek (RM 11.80) supported a marginally good macroinvertebrate community with 8 EPT taxa and mayflies/caddisflies predominant.

Brush Creek at RM 7.1 has a 4.8 square mile drainage. Most of the macroinvertebrate sampling

was conducted in the pooled section under the bridge; the rest of the creek at this point was an overgrown grass-lined ditch with no riffle/run zone. The macroinvertebrate community was poor with no EPT taxa collected and leeches/snails predominant. The site on Brush Creek at RM 0.4 (23.4 square mile drainage) had improved flow with riffle/run zones and a well protected tree-lined riparian zone. The community at this site was evaluated as very good with 14 EPT taxa (including one stonefly taxon) and caddisflies/water pennies as predominant organisms.

Similarly, a headwater site on Ludlow Creek at RM 12.6 (3.4 square mile drainage) supported only a marginally good macroinvertebrate community, but downstream sites with better flow and habitats, supported good and very good macroinvertebrate communities.

Table 15. Mean average monthly flows for USGS gage locations in the Stillwater River Basin for the years 1982, 1990, and 1999. Average, maximum, and minimum values are monthly average values for the period of record, 1931-1999.

Location	Year	Average Flow (cubic feet per second)			
		June	July	August	September
Greenville Creek near Bradford	1982	191	60.4	33.5	24.7
	1990	161	237	240	144
	1999	69.5	54.6	21.1	**9.47**
	Average	186	110	69.5	47.7
	Maximum	1142	502	723	425
	Minimum	21.6	13.9	8.93	**9.47**
Stillwater River at Mt. Pleasant	1982	502	106	51.1	31.8
	1990	412	728	446	245
	1999	169	114	38.1	18.2
	Average	468	272	148	116
	Maximum	3334	1295	1823	2127
	Minimum	33.7	22.2	14.1	14.9
Stillwater River at Englewood	1982	688	156	91.8	50.6
	1990	558	1054	500	277
	1999	223	135	47.2	24.8
	Average	580	365	206	141
	Maximum	4244	1582	2438	1998
	Minimum	52.2	300	19.7	17.9

Table 16. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Sugar Creek basin, June - October, 1998. Aquatic life uses listed are those currently designated in the Ohio Water Quality Standards.

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
Stillwater River (14-200) WWH /MWH Proposed											
65.8	5.1	Moderate	-	38	-	7	-	Caddisflies	35.0	32	Marginally Good
65.0	8.2	Moderate	-	27	-	5	-	Cad, snails	26.7	20	Fair
63.8	13.6	Moderate	-	38	-	10	-	Cad,flatworms	34.5	30	Marginally Good
63.0	29	814	27	35	47	7	9	Cad, snail,turb	32.0	22	Fair
61.8	30	968	38	44	62	8	10		32.8	**30**	Fair
Stillwater River (14-200) WWH Existing											
60.2	39	843	34	42	58	7	16		33.2	**38**	Good
58.9	51	583	36	52	70	16	19		39.1	**32**[ns]	Marginally Good
57.9	71	1403	40	45	62	5	6	Turb,midge	35.3	32	Marginally Good
57.0	72	395	39	44	63	3	6		32.9	**34**[ns]	Marginally Good
Stillwater River (14-200) EWH /WWH Proposed											
54.4	81	402	39	61	75	12	12		35.3	**28***	Fair
Stillwater River (14-200) EWH											
51.2	106	407	41	48	67	13	16		39.3	**44**[ns]	Very Good
47.8	112	224	43	61	80	12	13		39.1	**38***	Good
44.4	175	294	43	53	75	14	15		34.4	**42**[ns]	Very Good
41.4	189	646	38	40	64	11	17		35.3	**36***	Good
37.7	207	285	34	48	67	12	19		38.8	**44**[ns]	Very Good
33.5	232	378	43	50	67	19	20		41.3	**48**	Exceptional
32.1	437	936	39	61	73	20	23		41.1	**52**	Exceptional
27.8	503	404	35	50	62	16	19	Cad,may,Tany	42.1	52	Exceptional
25.1	514	703	26	63	72	19	22		40.9	**46**	Exceptional
21.2	528	1211	50	67	87	20	25		41.4	**48**	Exceptional
18.0	599	3693	29	63	71	20	22	Cad,midge,may	39.1	48	Exceptional
16.0	607	3857	32	56	64	19	22		41.2	**44**[ns]	Very Good
11.3	638	2372	26	51	57	18	19		41.3	**48**	Exceptional
8.86	650	3993	34	33	47	13	15		42.5	**40***	Good
8.85A	650	Moderate	-	37	-	14	-	Cad,Tany.midge	42.2	48	Exceptional
8.85B	650	Moderate	-	34	-	9	-	Cad,blackfly	37.3	36	Good
8.3	652	2826	24	30	43	7	12	Cad,midge,may	29.7	32	Marginally Good
5.0	664	884	23	58	65	21	22		42.1	**46**	Exceptional
1.6	674	1728	25	37	47	15	17		42.5	**46**	Exceptional

Table 16. (continued)

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
Pigeye Creek (14-201) WWH											
0.6	5.9	Low	-	34	-	5	-	Cad, snails	35.3	20	Fair
Mill Creek (14-202) WWH											
2.6	3.1	Low	-	27	-	6	-	Baetids,snails	27.1	22	Fair
1.2	5.5	Low-Mod	-	33	-	11	-	May,isopods	38.9	36	Good
0.3	6.0	174	39	36	55	13	13		35.3	**52**	Exceptional
Brush Creek (14-203) EWH Existing/WWH Proposed											
0.1	17.3	2	9	34	39	11	11	Mid,cad,may	38.6	36	Good
Jones Run (14-204) WWH											
0.4	2.5	Moderate	-	34	-	10	-	Cad,isopods	39.1	36	Good
Rocky Run (14-205) WWH											
0.5		Low-Mod	-	42	-	12	-	Cad,may	39.4	40	Good
Opossum Run (14-206) WWH Existing/EWH Proposed											
1.4		Moderate	-	45	-	9	-	Cad,may,mid	39.1	46	Exceptional
Painter Creek (14-208) MWH											
17.9	1.5	Low	-	31	-	8	-	Flatworms	32.6	30	Fair
15.5	3.3	517	29	25	42	0	1		19.1	**10***	Poor
14.7	4.6	1133	17	15	23	1	2		19.9	**4***	
8.9	25	539	29	33	43	7	8		33.2	**26**	Fair
Painter Creek (14-208) EWH Existing/WWH Proposed											
4.4	33	331	34	40	58	11	12	Cad,may,mid	39.4	40	Good
1.1	47	142	35	41	58	13	18		41.4	**44**	Very Good
Little Painter Creek (14-209) MWH Proposed											
1.2		Low	-	18	-	1	-	Clam,snail,turb	32.6	14	Fair
Ludlow Creek (14-210) MWH Proposed											
12.6	3.4	Moderate	-	31	-	4	-	Cad,may,mid	32.9	32	Marginally Good
Ludlow Creek (14-210) WWH Existing											
6.4	26.0	Moderate	-	37	-	10	-	Cad,may	41.3	44	Very Good
3.5	38.0	Low-Mod	-	44	-	19	-	Cad,may,penny	41.6	42	Very Good
2.3	62	74	34	39	62	19	23		42.3	**40**	Good
Brush Creek (14-211) WWH Existing											
7.1	4.8	Low	-	12	-	0	-	Leech,snail	19.9	0	Very Poor
0.4	23.4	Low-Mod	-	38	-	14	-	Cad,penny	41.1	42	Very Good
Hog Run (14-213) WWH Existing											
0.2	9.3	Low-Mod	-	37	-	7	-	Cad,beetles	39.1	30	Marginally Good

Table 16. (continued)

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
Heller Ditch (14-217) MWH Proposed											
0.1	2.6	Low-Mod	-	31	-	9	-	Cad,may	35.3	34	Marginally Good
Harris Run (14-217) WWH Existing											
5.2	9.5	197	36	23	46	6	7		39.1	**44**	Very Good
1.9	17.0	80	20	31	42	11	11	Cad,beetle,mid	39.8	36	Good
1.1	17.6	38	21	37	48	13	14		40.6	**38**	Good
Ballinger Run (14-219) WWH Existing											
1.4	5.5	2	5	22	24	0	0		31.9	**0***	Very Poor
0.6	6.4	270	38	51	63	3	4		32.8	**32^{ns}**	Marginally Good
Greenville Creek (14-220) EWH Existing/WWH Proposed											
34.3	6.0	107	43	42	66	15	20		42.2	**58**	Exceptional
30.2	26	72	30	45	60	21	21		42.5	**42**	Very Good
28.9	69	148	41	54	71	19	20		42.2	**50**	Exceptional
26.7	73	118	36	49	65	25	26		42.3	**46**	Exceptional
24.7	76	516	51	57	81	19	22		41.3	**50**	Exceptional
22.6	106	101	24	18	37	3	7		38.6	**14***	Fair
22.3	107	161	36	46	68	13	16		40.6	**42**	Very Good
19.5	140	568	65	44	89	13	18		35.3	**34^{ns}**	Marginally Good
19.3A	140	Moderate	-	20	-	7	-	Cad,Elimia,turb	35.0	22	Fair
19.3B	140	Low-Mod	-	34	-	8	-	Elmid,Elim.,cad	35.7	28	Fair
19.2	140	764	49	32	61	5	11		33.4	**30***	Fair
18.4	142	539	37	35	59	6	10		32.0	**26***	Fair
16.3	153	460	45	55	76	20	23		40.9	**54**	Exceptional
13.4	174	Low-Mod	-	55	-	21	-	Cad,may,elmid	39.8	50	Exceptional
10.9	188	417	56	65	95	24	29		40.9	**50**	Exceptional
6.2	193	177	36	59	76	25	26		41.3	**44**	Very Good
1.4	200	595	41	57	70	23	25		42.3	**46**	Exceptional
0.1	201	901	37	39	56	13	15		41.6	**50**	Exceptional

Table 16. (continued)

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
McQuay Ditch (14-221) WWH Existing											
0.5		Low-Mod	-	32	-	13	-	Penny,cad,may	41.3	42	Very Good
Poplar Ditch (14-222) WWH Existing											
0.5	4.7	Low-Mod	-	32	-	9	-	Cad,may,elimia	41.4	42	Very Good
Bolton Run (14-223) WWH Existing											
0.6	5.9	Low	-	19	-	4	-	Cad,elmid,clam	39.1	24	Marginally Good
Dividing Branch (14-224) WWH Existing											
3.1		Moderate	-	32	-	7	-	Cad,mollusc,turb	38.4	28	Marginally Good
0.4		Low	-	42	-	12	-	Cad,may,elimia	38.4	42	Very Good
Bridge Creek (14-225) WWH Existing											
0.2	11.3	297	36	47	67	14	20		39.4	**54**	Exceptional
Mud Creek (14-226) WWH Existing											
7.7	2.0	Low	-	14	-	1	-	Molluscs,mid	31.9	16	Fair
5.9	3.7	92	26	32	45	10	10		41.6	**40**	Good
4.7	14.5	197	42	50	69	11	16		39.4	**58**	Exceptional
0.1	24	171	41	44	62	16	21		39.7	**54**	Exceptional
Prairie Outlet (14-227) WWH Existing											
0.8	2.8	184	27	28	43	5	7		35.0	**28***	Fair
West Branch Greenville Creek (14-228) WWH Existing											
10.7	2.6	Moderate	-	27	-	4	-	Snails	33.5	24	Fair
7.4	10.6	Low-Mod	-	46	-	12	-	Cad,may,mid	39.1	40	Good
5.8	18.3	Low-Mod	-	48	-	16	-	Cad,may,mid	39.8	38	Good
0.3	25.6	Moderate	-	28	-	11	-	Cad,may,mollusc	42.0	40	Good
Spring Branch (14-229) WWH Existing											
0.3	4.5	Low-Mod	-	36	-	10	-	Cad,mid,turb	36.9	28	Marginally Good
Kraut Creek (14-230) WWH Existing											
5.9	6.9	Low-Mod	-	43	-	12	-	Cad,may,elimia	39.4	46	Exceptional
0.6	22.5	Moderate	-	30	-	13	-	Cad,may,clams	42.5	42	Very Good
North Fork Kraut Creek (14-231) WWH Existing											
2.4		Moderate	-	48	-	15	-	Cad,may,mid	39.1	52	Exceptional
0.8	6.3	Low-Mod	-	39	-	9	-	Snails,cad,may	35.0	36	Good
Dismal Creek (14-232) WWH Existing											
4.7	12.0	169	34	41	58	11	13		39.3	**42**	Very Good
1.8	17.1	110	28	31	47	6	7	Cad,may,snails	36.9	32	Marginally Good
0.1	19.2	59	29	36	50	17	17		42.2	**36**	Good

Table 16. (continued)

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
Trotters Creek (14-234) WWH Existing											
0.9	14.4	Moderate	-	39	-	13	-	Cad,may,mid	40.8	44	Very Good
Swamp Creek (14-235) MWH Existing											
12.1		Low	-	25	-	2	-	May,mid	27.4	28	Fair
8.9	11.1	483	32	26	44	5	6		29.5	**28**	Fair
6.5	21	473	34	39	55	5	6		32.8	**30**	Fair
Swamp Creek (14-235) WWH Existing											
4.4	25	251	39	41	60	8	10	Cad,may,mid	33.2	44	Very Good
2.8	38	828	44	42	60	7	8		35.0	**42**	Very Good
2.4	58	2278	39	44	59	11	11		33.1	**26***	Fair
1.6	58.5	790	38	33	54	8	9		32.7	**34**[ns]	Marginally Good
0.2	63	150	41	32	57	6	10		38.4	**42**	Very Good
Indian Creek (14-236) MWH Proposed											
6.1		Low	-	15	-	1	-	Leechs,beetles	25.8	10	Poor
2.0	18.3	337	37	39	54	10	10		38.8	**32**	Marginally Good
Indian Creek (14-236) WWH Existing											
0.5	20	Low	-	31	-	3	-	Turbs,beetles	32.0	22	Fair
Boyd Creek (14-237) MWH Proposed											
3.5	2.2	Low	-	24	-	4	-	Snails,clams	31.9	16	Fair
0.8	14.1	Low	-	30	-	5	-	Cad,may,snail	37.3	30	Fair
North Fork Stillwater River (14-238) MWH Existing											
10.5	2.1	Moderate	-	15	-	0	-	Corixid,snails	16.1	2	Very Poor
8.3	4.6	Moderate	-	18	-	1	-	Corixid,snails	27.4	6	Very Poor
4.4	10.5	Low-Mod	-	25	-	4	-	Cad,may,turb	32.8	28	Fair
0.5	18.3	161	23	23	35	2	3		29.5	**12***	Poor
Woodington Run (14-239) MWH Existing											
4.9	4.8	Low	-	31	-	8	-	Elimia,cad,may	38.1	36	Good
1.1	10.1	Low	-	23	-	6	-	Elimia,clams	37.3	24	Fair
South Fork Stillwater River (14-240) WWH											
5.5	3.0	Low-Mod	-	20	-	3	-	Beetles,snails	32.9	16	Fair
1.3	12.4	Low-Mod	-	23	-	5	-	Cad,elimia,mid	32.9	26	Fair
0.4	16.7	Low-Mod	-	27	-	7	-	Cad,beetles	38.1	32	Marginally Good
Sycamore Ditch (14-241) MWH - Proposed											
0.2		Low-Mod	-	31	-	5	-	Mid,beetles,cad	31.9	26	Fair
Trib to Kraut Creek (14-245) WWH											
0.2	1.3	Low	-	32	-	5	-	Snails,cad,oligo	32.2	26	Fair

Table 16. (continued)

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
Trib to Stillwater RM 64.96 (14-246) WWH - Proposed											
0.3		Low-Mod	-	31	-	7	-	Cad,snails,clam	31.9	32	Marginally Good
Trib to Ludlow Creek (14-247) MWH - Proposed											
0.4	6.3	Moderate	-	29	-	8	-	Cad,may,elmid	35.3	28	Marginally Good
Trib to Stillwater RM 32.6 (14-250) WWH - Proposed											
0.6	1.8	Moderate	-	31	-	9	-	Isopod,cad,may	39.1	36	Good
Lake Branch Ditch (14-252) WWH											
4.1	1.7	Low-Mod	-	20	-	2	-	Isopods,midges	29.5	12	Poor
0.4	7.2	125	33	39	54	11	13		40.0	**54**	Exceptional
Trib to Harris RM 8.05 (14-253) WWH - Proposed											
0.2		Low-Mod	-	17	-	0	-	Midges,beetles	33.4	6	Very Poor
Sigmon Ditch (14-254) WWH - Proposed											
1.2	2.7	Low-Mod	-	31	-	10	-	Turb,cad,may	35.0	32	Marginally Good
Orr Ditch (14-255) WWH - Proposed											
0.7		Low	-	21	-	1	-	Mid,snail,leech	22.3	4	Very Poor
Bennet Ditch (14-256) WWH - Proposed											
0.6	1.2	Low	-	11	-	0	-	Midges,beetles	24.4	8	Poor
Apple Ditch (14-257) WWH - Proposed											
1.0		Low	-	17	-	0	-	Clam,leech,snail	24.4	2	Very Poor
Rudy Ditch (14-258) WWH - Proposed											
1.4		Low	-	25	-	0	-	Snail,midges	22.7	4	Very Poor
Trib to Swamp Creek RM 3.54 (14-259) MWH - Proposed											
0.4	9.2	498	34	27	40	6	6		26.7	**24**	Fair
Grassy Fork (14-260) MWH - Proposed											
0.9		Low-Mod	-	22	-	1	-	Mid,isopod,turb	22.9	12	Poor
Trib to Stillwater RM 38.3 (14-261) WWH - Proposed											
0.7		Low	-	15	-	1	-	Turbs,leeches	22.9	8	Poor
Trib to Stillwater RM 51.0 (14-262) WWH - Proposed											
2.8		Low	-	26	-	3	-	Clams	31.9	18	Fair
1.2	5.5	Moderate	-	33	-	7	-	Cad,clam,may	39.1	38	Good
Trib to Boyd Creek RM 2.67 (14-264) MWH - Proposed											
0.5	3.4	Moderate	-	25	-	2	-	Snail,leech,turb	24.4	6	Very Poor
Trib to Boyd Creek RM 2.46 (14-265) MWH - Proposed											
1.7		Low	-	29	-	2	-	Clam,snail,mid	27.1	6	Very Poor
Trib to Stillwater (14-266) MWH - Proposed											
0.4	0.8	Low	-	24	-	3	-	Beetles,mid	32.6	14	Fair

Table 16. (continued)

Stream River Mile	Drainage Area (mi.^{2})	Rel. Density (#/ft.^{2})[a]	No. Quant. Taxa	No. Qual. Taxa	Total No. Taxa	Qual. EPT[b]	Total EPT[b]	Qualitative Predominant Organisms[c]	QCTV[d]	*QICI*[e] **ICI**	Narrative Evaluation [f]
Trib to Stillwater RM 55.4 (14-267) MWH - Proposed											
0.8	3.4	Moderate	-	15	-	1	-	Mosquitoes	26.9	10	Poor
Trib to Stillwater RM 60.22 (14-268) MWH - Proposed											
0.3		Low-Mod	-	26	-	5	-	Clam,cad,mid	33.5	24	Fair
Trib to South Fork Stillwater RM 0.94 (14-269) MWH - Proposed											
1.5	3.4	Low-Mod	-	26	-	3	-	Mid,cad,snail	35.3	18	Fair

[a] Relative density is the number of organisms per square foot on the artificial substrates or the relative density (low-medium-high) of organisms on the natural substrates for qualitative sites only.

[b] EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness

[c] Qualitative predominant organisms on the natural substrates. Cad = caddisflies, May = mayflies, Mid = midges, Elmid = elmid beetles, Fingernail = fingernail clams, Turb = turbellarians (flatworms), Oligo = oligochaetes (worms), Penny = water pennies, Tany = tanytarsini midges.

[d] Qualitative Community Tolerance Value (QCTV) derived as the median of the tolerance values calculated for each qualitative taxon present

[e] The Qualitative ICI is a new qualitative assessment tool which is currently being developed for use with qualitative only sites.

[f] Narrative evaluation based on quantitative ICI score, or qualitative data. Marg.Good = marginally good.

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

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

Biological Assessment: Fish Community (1982 - 1999)

Stillwater River

The fish community sampled in the Stillwater River, excluding the Englewood Dam Pool, rated Very Good to Exceptional from its confluence with the Great Miami River upstream for 48 river miles (Figure 101; Table 17). Upstream from RM 48 the fish community declined precipitously due to poor habitat, and low dissolved oxygen concentrations spurred by a combination of nutrient and organic enrichment. Though the fish community met standards for EWH through RM 48, the footprint caused by poor habitat in the headwaters extended downstream an additional 15 miles. This is evident in the trajectory of recovery in both the IBI and MIwb scores, and in the performance of individual IBI metrics (Figure 102). Relative to community attributes expected at unimpacted sites, metrics sensitive to habitat, especially top carnivores (e.g., smallmouth bass), intolerant species (e.g., black redhorse), and sunfish scored less well than expected through RM 35, and in the case of top carnivores, performed erratically throughout the mainstem. The lower than expected abundance of top carnivores in the upper half of the Stillwater River is a tangible diminution of both recreational and aquatic life use. Habitat restoration in the headwaters is needed to reverse this condition.

As stated in the previous paragraph, the fish community in the headwaters of the Stillwater River were impaired beyond that imparted by poor habitat as the fish community failed even to meet standards set for waters with modified habitat. Upstream from Ansonia, large mats of living and decaying filamentous algae were present to varying degrees at every site, and where this condition was the worst a layer of anoxia resulted at the sediment-water interface. At these sites blackstripe topminnows were the most abundant fish species present. Blackstipe topminnows specialize in feeding on the pleuston (organisms living in the surface film) and consequently reside near the surface of the water. This habit likely renders them less vulnerable to low dissolved oxygen levels imparted by decaying algae.

As the habitat recovers down the run of the river, so does the fish community. The recovery is enabled because the riparian zone is forested along much of its length. Forested riparian zones allow for sediment export during flood events, and minimize additional sediment input from bank erosion. As the fish community recovers to full EWH performance, it does so spectacularly. The lower 30 miles of the mainstem supports one of the highest population of river redhorse in the state. River redhorse are highly intolerant of pollution and are a State Special Interest species because of their comparative rarity in the state. The presence of river redhorse in such abundance indicates that water quality and habitat has recovered to the point that several fish species extirpated from lower the Stillwater River could now be successfully reintroduced. Those species include the streamline chub, bigeye chub, and bluebreast darter.

Compared to 1990, the fish community in 1999 improved significantly, and compared to 1982, it improved dramatically (Figure 101). The greatest improvements occurred in two reaches, one downstream from Ansonia to Swamp Creek, and the other downstream from the West Milton WWTP. The effect of improved point source controls is readily apparent in the longitudinal plots

of IBI and MIwb scores (Figure 101) where the longitudinal decreases seen below Ansonia, Versailles (via Swamp Creek), Covington, West Milton and Englewood in both 1982 and 1990 were not present in 1999. What is not so obvious is the effect of agricultural best management practices (BMPs). The increased use of BMPs has improved the trajectory of recovery downstream from point sources in the upper half of the river. This is evident in the pattern of impact and recovery downstream from Ansonia and again downstream from Swamp Creek. By 1990, the gross point source impacts were largely abated, but index scores were not as high as those in 1999. The additional recovery in 1999 is attributed in large part to BMPs. The limiting factors now are the degraded condition of the headwaters, and land-applied manure.

Tributaries to the Stillwater River

From a basin-wide perspective, tributaries to Greenville Creek that are influenced by the Whitewater lobe, a geologic formation of glacial deposits that support high stream base flows, have high quality fish assemblages despite marginal to poor habitat. This is in contrast to most of the rest of the upper Stillwater basin where marginal to poor habitat quality results in marginal to poor fish communities. Obviously, the higher base flows afforded by the Whitewater lobe help to ameliorate habitat impacts in these tributaries.

Apart from the influence of the Whitewater lobe, a gradient of aquatic life quality exists with respect to pollution loads and habitat quality. IBI scores in Trotters Creek and its tributaries, Woodington Run, the mouth of Boyd Creek, and an unnamed tributary to the Stillwater at RM 51.02 were good, despite historic habitat alterations. The difference between those and the remainder of the upper Stillwater watershed is that the former have recovered more natural habitat features than the latter.

Another level of separation in IBI scores beyond that imparted by habitat quality, is due to land-applied manure. First, this is visually evident in Figure 103 by the concentration of poor to fair IBI scores in the northern third of the basin where animal feeding operations (AFOs) are most dense. Second, this is evident in the tendency for the fish community to score lower on the second pass in Swamp Creek and the North Fork Stillwater, but not in the rest of the basin (Wilcoxon Signed Ranks Test, $P = 0.0176$). And third, this was evidenced by the fish kill in Swamp Creek that occurred between the first and second passes (see *Swamp Creek Subbasin* below).

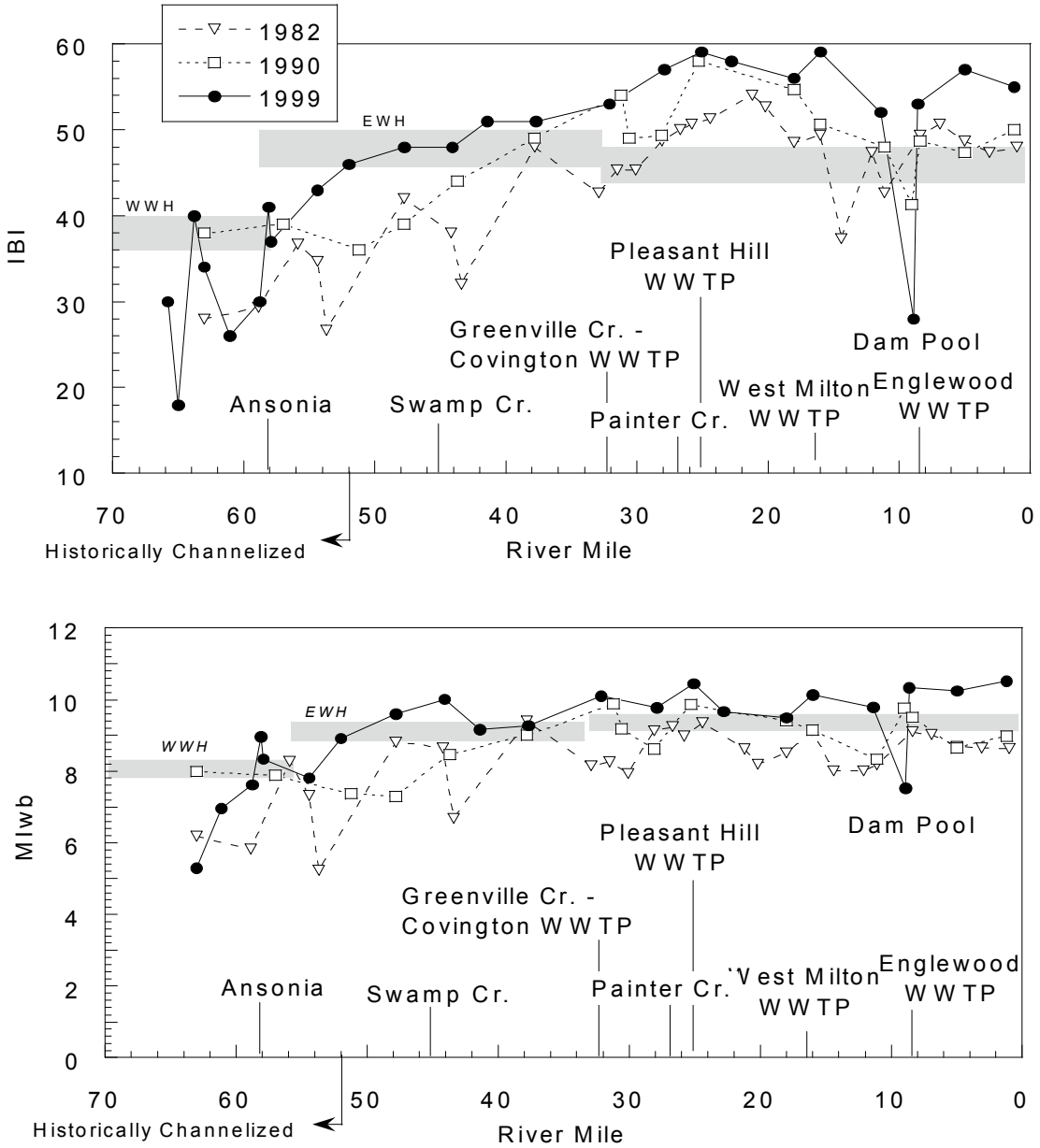


Figure 101. Plots of IBI (top panel) and MIwb (bottom panel) scores by river mile for the Stillwater River 1999, 1990, and 1982 in relation to point sources and major tributaries.

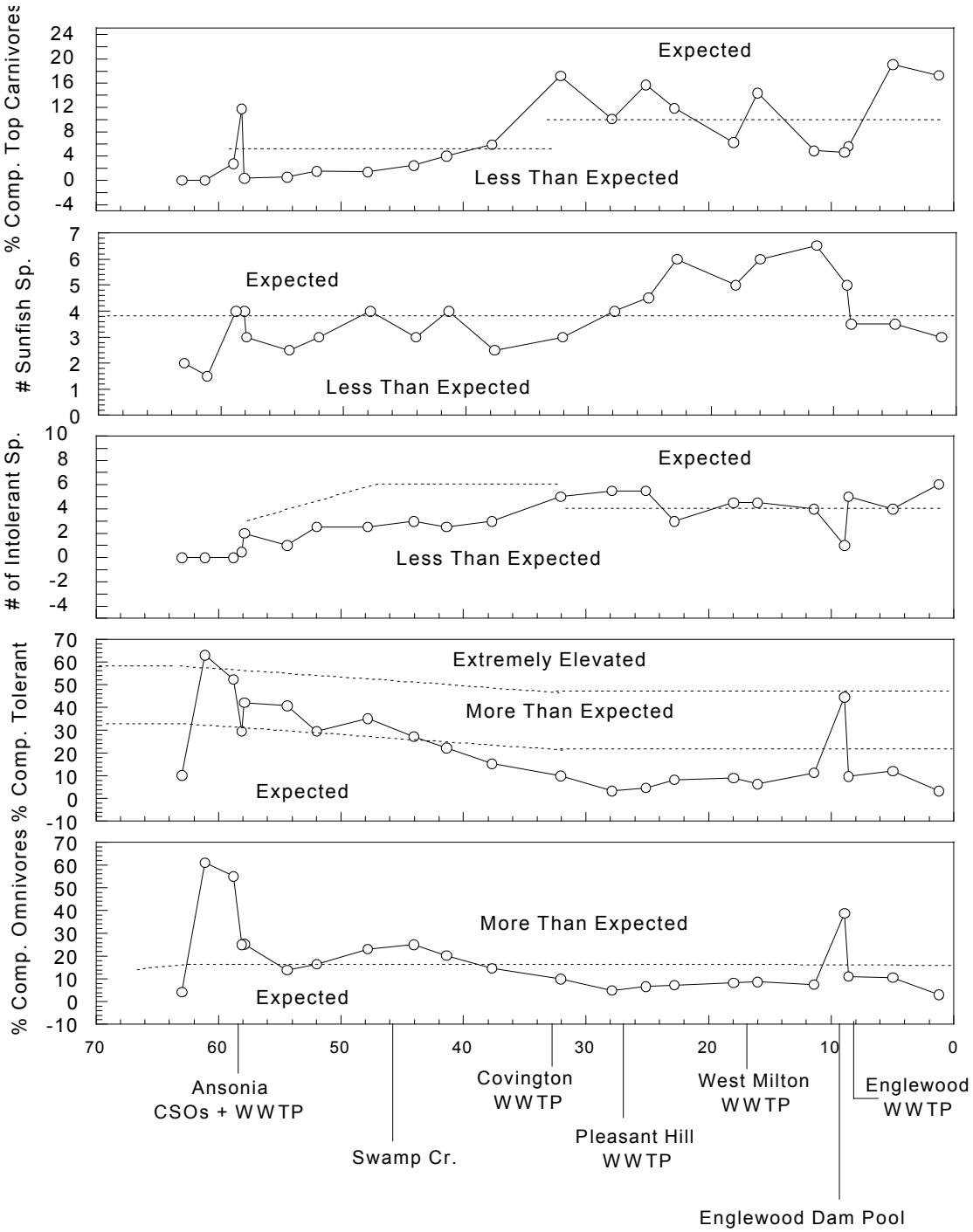


Figure 102. Plots of individual IBI metrics by river mile in relation to point sources and major tributaries to the Stillwater River, 1999. From the top panel, percentage of top carnivores, number of sunfish species, number of intolerant species, percentage of tolerant species, and percentage of omnivorous species.

Table 17. Fish community indices from samples collected in the Stillwater River Basin study area 1999.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Stillwater River (14-200) *WWH ECBP Existing - MWH Proposed*								
65.8	5	5.0	188	NA	30.5	NA	30	Fair
65.0	6	6.0	434	NA	31.0	NA	18*	Poor
63.8	16	16.0	506	NA	36.5	NA	40	Good
63.0	13	9.5	308	1.0	37.5	5.3*	34	Poor/Fair
61.1	20	17.0	1995	4.7	34.0	7.0	25	Fair
WWH ECBP Existing								
58.8	18	18.0	266	58.3	42.5	7.8ns	30*	M. Good/Fair
58.1	20	18.0	585	131.5	47.0	9.0	38	V. Good/M.Good
57.9	26	25.0	1472	5.2	48.0	8.3	37ns	Good/M. Good
54.4	26	22.5	1171	4.2	44.0	7.8	43	Good
EWH ECBP Existing								
52.0	30	27.5	865	22.3	73.0	9.0ns	46ns	V. Good
47.8	31	28.5	1518	11.3	73.5	9.6ns	48ns	V. Good
44.1	31	29.0	3110	36.3	73.0	10.2	47ns	Except./V. Good
41.4	34	29.5	915	34.2	75.0	9.2ns	50	V. Good/Except.
37.7	29	25.0	924	12.7	81.5	9.3	51	Exceptional
32.1	33	24.5	931	163.3	81.0	10.1	54	Exceptional
27.9	33	28.0	783	103.4	80.5	9.9	58	Exceptional
25.1	33	28.0	878	159.9	85.5	10.4	59	Exceptional
22.8	34	27.0	991	127.2	72.5	9.7	58	Exceptional
18.0	32	27.0	808	112.1	75.0	9.8	57	Exceptional
16.0	32	28.0	887	112.2	80.5	10.1	59	Exceptional
11.4	33	29.0	1020	251.6	76.5	9.8	52	Exceptional
EWH ECBP Existing - MWH-Impounded Proposed								
8.9	21	17.0	375	120.3	52.0	7.5	28*	Fair
EWH ECBP Existing								
8.6	33	27.0	1268	262.1	88.0	10.3	53	Exceptional
5.0	28	24.0	1069	302.8	85.5	10.5	59	Exceptional
1.2	27	24.5	1146	253.5	85.5	10.5	55	Exceptional
Pigeye Creek 14-201 *WWH Existing*								
0.6	8	8.0	510	NA	36.0	NA	36ns	M. Good

Table 17. Continued.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Mill Creek 14-202 *WWH Existing*								
2.6	3	3.0	46	NA	46.5	NA	22*	Poor
1.2	7	7.0	296	NA	57.0	NA	26*	Poor
0.3	10	10.0	3526	4.9	50.0	6.5*	44	Fair/Good
Brush Creek 14-203 *EWH ECBP Existing - WWH Proposed*								
0.1	13	11.5	1211	NA	63.0	NA	41	Good
Jones Run 14-204 *WWH Existing*								
0.4	5	5.0	164	NA	57.0	NA	28*	Fair
Opossum Run 14-206 *WWH Existing*								
0.8	9	9.0	612	NA	69.5	NA	46	V. Good
Painter Creek 14-208 *MWH Existing*								
16.9	8	8.0	420	NA	27.5	NA	28	Fair
16.2	5	5.0	343	NA	32.0	NA	16*	V. Poor
14.7	4	3.0	23	NA	28.0	NA	12*	V. Poor
9.7	16	14.5	810	48.3	40.5	5.6*	24	Poor
EWH ECBP Existing - WWH Proposed								
3.4	17	16.0	390	27.9	77.5	6.8*	33*	Fair
0.7	13	11.5	638	3.0	62.5	6.3*	33*	Fair
Little Painter Creek 14-209 *WWH Existing*								
0.4	18	18.0	2166	5.7	43.5	6.9*	34*	Fair
Ludlow Creek 14-210 *WWH ECBP Existing - MWH Proposed*								
12.6	11	11.0	1080	NA	50.5	NA	34	Fair
WWH ECBP Existing								
6.4	17	15.5	983	7.9	59.5	7.9ns	36ns	M. Good
3.5	13	12.0	712	8.3	77.0	8.1	44	Good
2.9	13	13.0	698	7.2	78.0	8.1	42	Good
2.3	13	12.5	507	9.0	76.0	7.9	40	Good

Table 17. Continued.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Brush Creek 14-211 *WWH ECBP Existing*								
7.1	10	10.0	546	NA	40.5	NA	38^{ns}	M. Good
0.4	13	13.0	1412	11.8	75.5	8.0	40	Good
Hog Run 14-213 *WWH ECBP Existing*								
0.2	16	16.0	744	8.7	70	7.9	48	Good/V. Good
Heller Ditch 14-217 *WWH ECBP Existing - MWH Proposed*								
0.1	8	8.0	4864	NA	42.5	NA	26	Poor
Harris Run 14-218 *WWH ECBP Existing - MWH Proposed*								
3.8	19	15.5	762	19.0	31.0	5.1	35	Poor/Fair
WWH ECBP Existing								
2.0	16	16.0	370	62.4	57.5	5.3*	30*	Poor/Fair
0.9	13	11.5	702	5.5	73.0	6.8*	42	Fair/Good
Ballinger Run 14-219 *WWH ECBP Existing - MWH Proposed*								
2.8	6	6.0	346	NA	30.0	NA	20*	Poor
WWH ECBP Existing								
1.4	10	7.5	240	NA	57.0	NA	25*	Poor
0.6	15	13.0	1408	5.1	61.5	5.0 *	34*	Poor/Fair
Greenville Creek 14-220 *EWH ECBP Existing - WWH Proposed*								
33.0	20	18.5	857	23.4	76.0	8.5	52	Good/Except.
30.2	23	20.5	2128	14.3	61.0	9.1	48	V. Good
28.9	24	22.5	691	35.2	48.5	8.4	45	Good/V. Good
26.5	21	20.0	357	57.6	56.5	7.9	48	Good/V. Good
24.6	26	23.5	807	44.9	71.5	8.5	50	Good/Except.
23.2	24	20.0	542	18.6	48.5	8.2	37^{ns}	Good/M. Good
21.7	23	20.0	337	13.9	71.5	8.5	47	Good/V. Good
19.6	18	15.5	270	7.4	45.0	7.5*	39*	Fair
19.3	*18*	*14.0*	*2127*	*3.7*		*7.4*	*34*	*Fair*
18.3	19	14.0	230	16.5	53.0	7.2*	36^{ns}	Fair/M. Good

Table 17. Continued.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Greenville Creek - Continued.								
			EWH ECBP Existing					
16.2	22	20.5	491	18.0	71.0	8.6*	37*	Good/M. Good
13.7	22	22.0	986	59.6	80.5	9.6	46ns	Except./V. Good
10.8	22	20.0	1043	23.5	85.5	8.9ns	48ns	V. Good
6.1	22	21.5	571	23.7	83.5	9.1ns	46ns	V. Good
3.7	23	19.0	680	14.5	75.0	8.2*	38*	Good/M. Good
1.4	28	27.0	1048	122.5	75.5	10.5	55	Exceptional
McQuay Ditch 14-221 *WWH ECBP Existing*								
1.6	10	10.0	2334	NA	55.5	NA	36	M. Good
Poplar Ditch 14-222 *WWH ECBP Existing*								
0.6	14	14.0	1482	NA	61.0	NA	52	Exceptional
Bolton Run 14-223 *WWH ECBP Existing*								
0.6	15	15.0	572	NA	44.5	NA	50	Exceptional
Dividing Branch 14-224 *WWH ECBP Existing*								
2.4	0	0.0	0	NA	40.5	NA	48	V. Good
Bridge Creek 14-225 *WWH ECBP Existing*								
1.4	12	10.0	451	NA	39.0	NA	38ns	M. Good
Mud Creek 14-226 *WWH ECBP Existing*								
6.1	21	17.5	293	NA	57.5	NA	54	Exceptional
4.7	20	17.5	425	16.2	46.0	8.1	51	Exceptional
2.1	0	0.0	0	0.0	35.0	7.3*	42	Fair/Good
Prairie Outlet 14-227 *WWH ECBP Existing*								
0.8	6	6.0	158	NA	39.5	NA	36ns	M. Good
W. Br. Greenville Cr 14-228 *WWH ECBP Existing*								
10.2	12	12.0	1674	NA	37.0	NA	42	Good
7.4	17	17.0	777	22.2	42.5	NA	52	Exceptional
5.3	22	22.0	1322	28.0	50.0	NA	56	Exceptional
0.3	23	23.0	1178	20.1	78.0	9.1	44	V. Good

Table 17. Continued.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Spring Branch 14-229 *WWH ECBP Existing*								
0.3	15	15.0	1110	NA	57.0	NA	48	V. Good
Kraut Creek 14-230 *WWH ECBP Existing*								
5.9	19	19.0	1332	NA	61.5	NA	54	Exceptional
4.4	16	16.0	619	NA	52.0	NA	50	Exceptional
0.6	19	19.0	1950	7.4	70.0	8.8	42	Good
N. Fk. Kraut Creek 14-231 *WWH ECBP Existing*								
2.1	13	13.0	784	NA	69.0	NA	42	Good
0.8	18	18.0	1150	NA	56.0	NA	46	V. Good
Dismal Creek 14-232 *WWH ECBP Existing*								
3.8	20	16.5	926	5.8	44.0	NA	27 *	Poor
2.2	15	12.5	914	3.3	53.0	NA	35 *	Poor/Fair
0.1	16	14.0	917	1.4	48.0	NA	36ns	Poor/M. Good
Trotters Creek 14-234 *WWH ECBP Existing*								
0.3	24	24.0	2606	22.4	73.5	9.4	48	Except./V. Good
Swamp Creek 14-235 *MWH ECBP Existing*								
8.9	20	15.5	444	NA	33.0	NA	27	Poor
6.5	14	10.0	246	2.3	34.5	4.8 *	17*	V. Poor
WWH ECBP Existing								
4.5	19	18.5	2018	4.4	42.0	6.5*	32*	Fair
2.9	22	18.5	1688	5.5	39.5	7.2*	27*	Fair/Poor
2.3	20	17.5	914	4.3	34.0	7.1*	34*	Fair
2.0	21	17.5	364	37.5	43.0	6.4*	32*	Fair
0.3	31	25.5	429	36.4	48.5	6.7 *	42	Fair/Good
Indian Creek 14-236 *WWH ECBP Existing - MWH Proposed*								
5.2	7	7.0	206	NA	37.5	NA	32	Fair
3.1	10	6.5	79	NA	30.0	NA	20*	Poor
WWH ECBP Existing								
0.5	24	21.5	773	38.5	47.0	7.8ns	41	M. Good/Good

Table 17. Continued.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Boyd Creek 14-237 *WWH ECBP Existing - MWH Proposed*								
3.5	10	10.0	414	NA	44.5	NA	34	Fair
WWH ECBP Existing								
0.8	12	12.0	420	4.2	54.5	6.1*	40	Fair/Good
N. Fk. Stillwater R. 14-238 *MWH ECBP Existing*								
10.5	2	2.0	18	NA	21.5	NA	12*	Poor
4.4	14	14.0	860	12.2	24.5	5.1	20*	Poor
0.4	20	16.0	351	30.1	36.0	7.2	27	Fair/Poor
Woodington Run 14-239 *WWH ECBP Existing*								
4.9	17	17.0	1142	5.7	51.5	NA	42	Good
1.1	13	13.0	436	2.1	50.5	NA	44	Good
S. Fk. Stillwater R. 14-240 *WWH ECBP Existing*								
5.5	10	10.0	302	NA	30.0	NA	36ns	M. Good
0.4	20	20.0	7906	19.0	44.0	NA	38ns	M. Good
Sycamore Ditch 14-241 *Undesignated - MWH ECBP Proposed*								
0.2	9	9.0	460	NA	34.5	NA	24	Poor
Trib. to Kraut Creek 14-245 *Undesignated - WWH ECBP Proposed*								
0.2	19	19.0	1384	NA	54.5	NA	46	V. Good
Trib. to Ludlow Cr. 14-247 *Undesignated - MWH ECBP Proposed*								
0.4	11	11.0	1248	NA	42.0	NA	26	Poor
Trib Stillwater 32.6 14-250 *Undesignated - WWH ECBP Proposed*								
0.6	5	5.0	1068	NA	63.5	NA	34*	Fair
Bitch Run 14-251 *Undesignated - WWH ECBP Proposed*								
0.1	12	12.0	334	NA	51.0	NA	42	Good
Lake Branch Ditch 14-252 *Undesignated - WWH ECBP Proposed*								
4.1	10	10.0	948	NA	30.0	NA	46	V. Good
0.7	20	20.0	874	NA	55.5	NA	54	Exceptional

Table 17. Continued.

Stream/ River Mile	Mean Species	Cumulative Species	Relative Number	Relative Weight	QHEI	Mean MIwb	Mean IBI	Narrative Evaluation
Stillwater 51.02/2.4 14-263 *Undesignated - WWH ECBP Proposed*								
0.3	9	9.0	758	NA	46.0	NA	44	Good
Trib. to Harris C. 14-253 *Undesignated - WWH ECBP Proposed*								
0.2	7	7.0	258	NA	44.0	NA	34*	Fair
Sigmon Ditch 14-254 *Undesignated - WWH ECBP Proposed*								
1.2	13	13.0	1074	NA	56.0	NA	40	Good
Bennett Ditch 14-256 *Undesignated - WWH ECBP Proposed*								
0.6	12	12.0	1010	NA	55.5	NA	42	Good
Trib. to Swamp Creek 14-259 *Undesignated - MWH ECBP Proposed*								
0.6	14	11.0	347	NA	36.5	NA	25	Poor
Trib Stillwater 38.3 14-261 *Undesignated - WWH ECBP Proposed*								
0.7	6	6.0	406	NA	70.5	NA	28*	Fair
Trib Stillwater 51.0 14-262 *Undesignated - WWH ECBP Proposed*								
1.3	14	14.0	484	8.9	54.0	NA	42	Good
Trib. to Boyd (2.67) 14-264 *Undesignated - MWH ECBP Proposed*								
0.5	5	5.0	120	NA	25.5	NA	30	Fair
Trib. to Boyd (2.46) 14-265 *Undesignated - MWH ECBP Proposed*								
1.2	9	9.0	632	NA	46.0	NA	30	Fair
Trib Stillwater 55.4 14-267 *Undesignated - MWH ECBP Proposed*								
0.8	3	3.0	146	NA	46.5	NA	26	Poor
Trib SF Stillwater 14-269 *Undesignated - MWH ECBP Proposed*								
1.6	7	7.0	134	NA	28.5	NA	32	Fair
Trib Stillwater 64.9 14-270 *Undesignated - MWH ECBP Proposed*								
1.1	7	7.0	562	NA	21.0	NA	30	Fair
0.3	15	15.0	4812	NA	41.5	NA	36	M. Good

Table 17. Continued.

Ecoregion Biological Criteria
Eastern Cornbelt Plains

	IBI			MIwb		
Site Type	EWH	WWH	MWH	EWH	WWH	MWH
Headwaters	50	40	24	NA	NA	
Wading	50	40	24	9.4	8.3	6.2
Boat	48	42	30†	9.6	8.5	6.6†

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

* - Indicates significant departure from applicable biological criteria (> 4 IBI units or > 0.5 MIwb units). Underlined scores are in the Poor to Very Poor range, though not necessarily a significant departure in the case of Modified Warmwater Habitat.

ns - Non significant departure from applicable biological criteria (#4IBI units or # 0.5 MIwb units).

† - Modified Warmwater Habitat criterion for impounded waters.

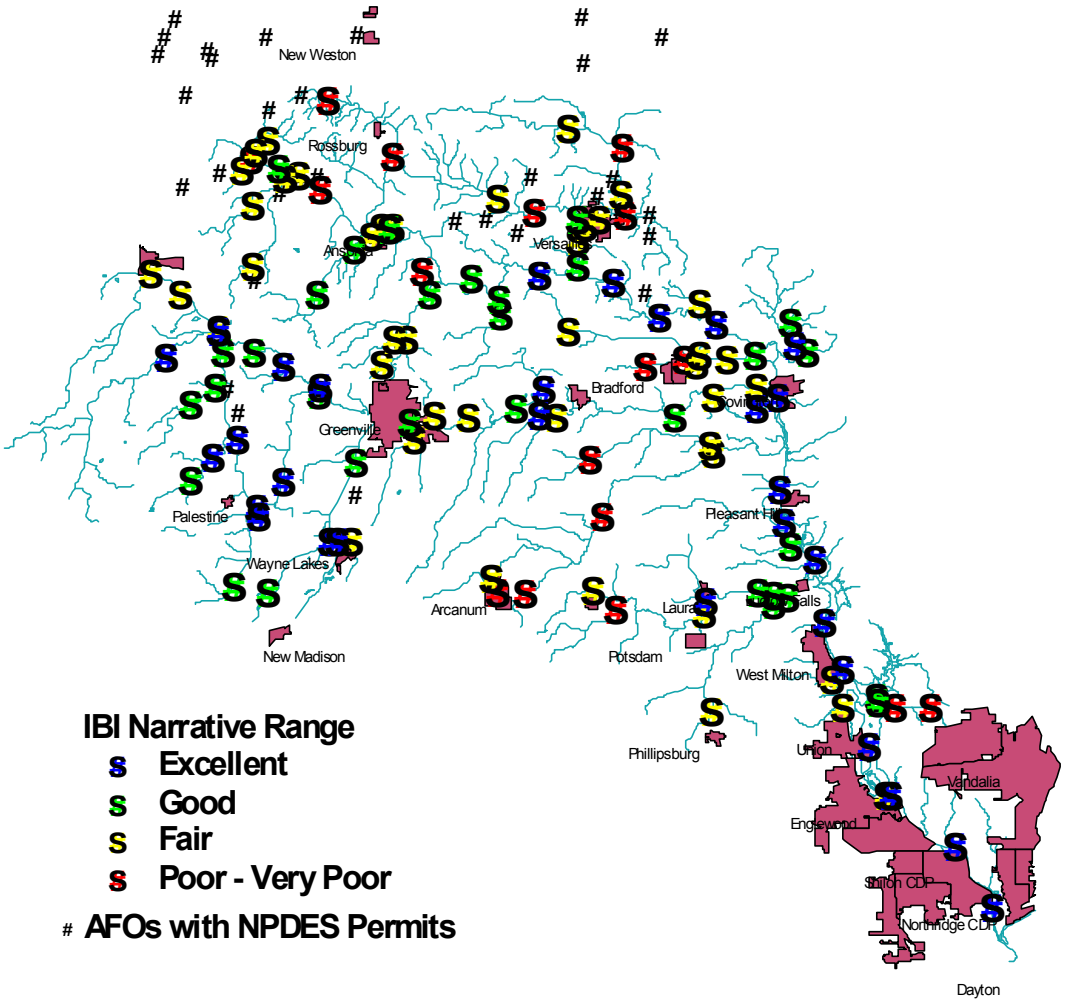


Figure 103. IBI scores by narrative range for locations sampled in the Stillwater River Basin, 1999 in relation to NPDES permitted animal feeding operations (AFOs).

Greenville Creek

Greenville Creek is designated as EWH. The fish communities sampled in Greenville Creek fully met standards for EWH at only five of fifteen sites sampled (Table 17). Four of the sites meeting EWH were in the lower sixteen miles of the stream. Though stretches of good habitat are present upstream from RM 16.2, habitat quality generally decreases due to channelization and impounding (Figure 104). The mean QHEI score for the nine sites evaluated upstream from RM 16.2 is 59.0, compared to 78.5 for the six sites downstream. Similarly, the number of modified attributes contrasts sharply between the two reaches. Sites upstream from RM 16.2 averaged 4.9 moderate influence modified habitat attributes, and 2.2 high influence modified habitat attributes. An accumulation of two or more high influence attributes essentially precludes EWH, but the number of moderate influence attributes, being less than six, makes meeting WWH realistic (OEPA 1999).

Site specific impacts were detectable at Croft Mill Road (RM 3.7), and the reach immediately downstream from Greenville including the Greenville WWTP (RM 19.6 - RM 16.2; Figure 105). The fish community at Croft Mill appeared degraded by organic enrichment as the bluntnose minnow, a tolerant, coprophagous omnivore was the most abundant fish species sampled. Otherwise the fish community was intact relative to upstream. The reach immediately upstream from the Greenville WWTP, aside from having degraded habitat, was apparently impacted by episodic toxicity from either urban stormwater, sewage discharge, or both. Three species were lost between sampling passes, and the abundances of remaining species were greatly diminished, especially that of darters. Downstream from the Greenville WWTP, no toxicity beyond that imparted from upstream was evident; however, organic enrichment was apparent in the elevated abundance of tolerant and omnivorous fishes at RM 16.2. The accumulation of stress from upstream habitat impacts, and nutrient and organic enrichment was responsible for the nonsignificant departure from EWH downstream from RM 16.2.

Compared to 1990, the fish community generally scored better downstream from Greenville due to improved sewage treatment, but scored worse upstream from Greenville presumably because of land-applied sewage from Union City as the pattern of impact was similar to that documented in 1982 (Figure 105). Compared to 1982, conditions in 1999 were as good or better everywhere but for Croft Mill Road (RM 3.7).

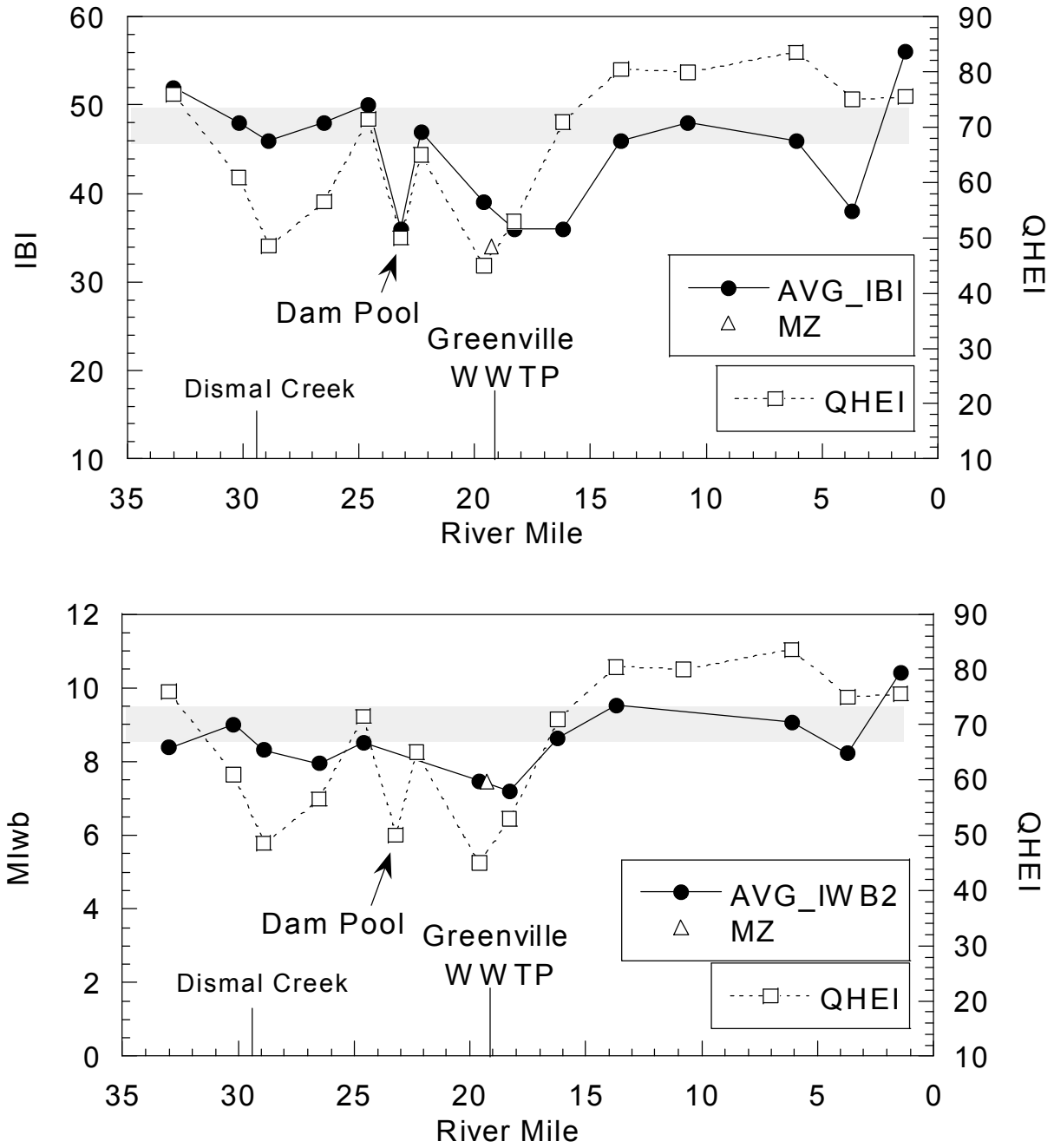


Figure 104. Longitudinal plots of IBI (top panel) and MIwb (bottom panel) scores, and QHEI scores (right axes) for locations sampled in Greenville Creek, 1999 in relation to the Greenville WWTP and Dismal Creek.

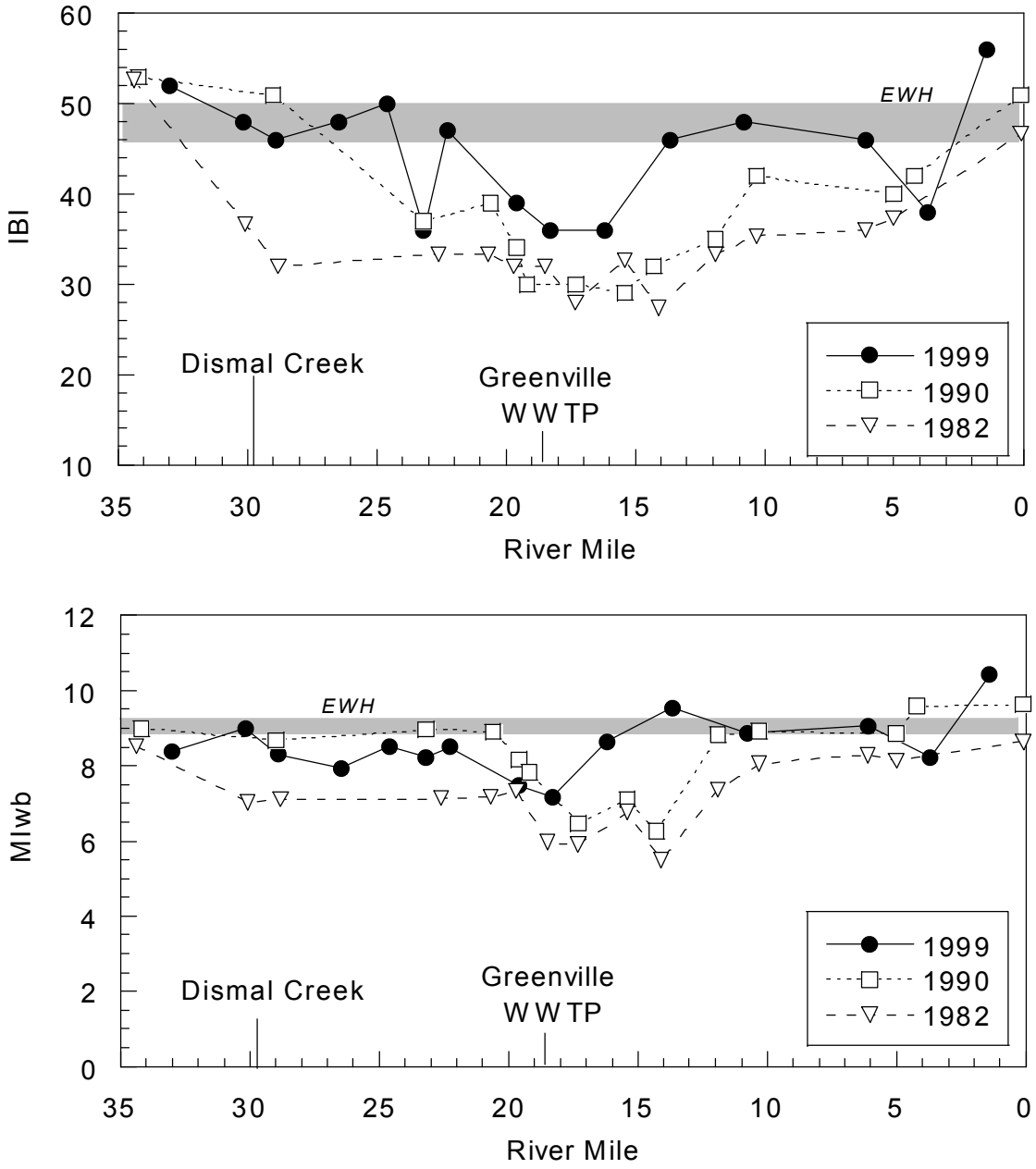


Figure 105. Longitudinal plots of IBI (top panel) and MIwb (bottom panel) scores for locations sampled in Greenville Creek, 1999, 1990 and 1982 in relation to the Greenville WWTP and Dismal Creek.

Swamp Creek Subbasin

Similar to the Stillwater River upstream from Ansonia, Swamp Creek and its tributaries were impaired by a combination of habitat degradation, and nutrient and organic enrichment. IBI scores at four of seven sites in Swamp Creek were significantly lower on the second pass as the result of a wide-spread fish kill. The epicenter of the kill occurred near Pittsenbarger Road where the creek was choked with masses of decaying filamentous algae, inside of which could be seen dead fish. The fish community sampled at Pittsenbarger Road failed to meet MWH (Table 17, Figure 106). Land applied manure was the source of the organic enrichment as evidenced by the high concentrations of fecal bacteria routinely found in water quality samples collected from Swamp Creek.

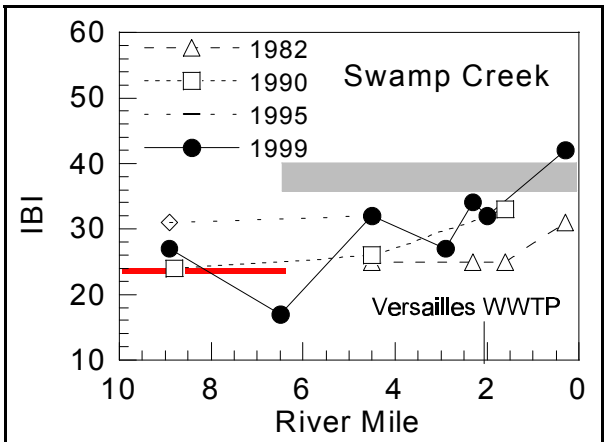


Figure 106. Plots of IBI scores by river mile for locations sampled in Swamp Creek, 1982 - 1999.

Indian Creek over most of its length was similarly affected by poor habitat and over-enrichment, but at Wolf Road, a failing septic system resulted in a layer of sewage sludge that covered approximately 75 m of stream. The only site in the subbasin having a fish community meeting WWH was the site at RM 0.5 on Indian Creek. Relative to 1982, the fish community showed the most improvement downstream from the Versailles WWTP reflecting treatment upgrades. Upstream from the WWTP, the improvement over 1982 reflects recovery from the effects of channelization.

Painter Creek

The fish community in Painter Creek is severely impaired by raw and poorly treated sewage entering the creek via combined sewer overflows in Arcanum, and minimally treated domestic sewage by the Arcanum sewage lagoon. The fish community at every site sampled in and downstream from Arcanum failed to meet either MWH or WWH, even at sites with excellent habitat, and immediately downstream from Arcanum the creek was nearly devoid of fish life. Conditions in 1999 were worse than those in 1995, 1990 or 1982 (Figure 107).

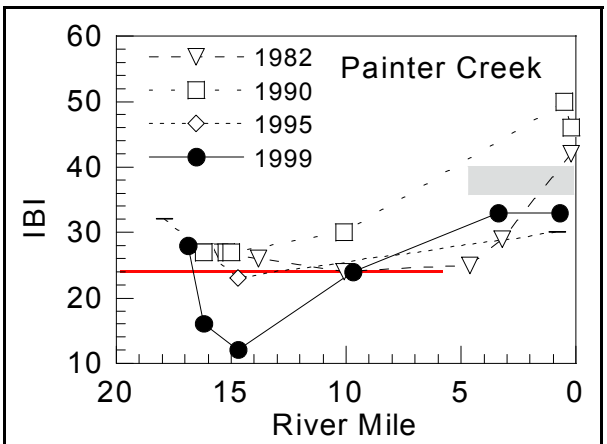


Figure 107. Plots of IBI scores by river mile for locations sampled in Painter Creek, 1982 - 1999. The Village of Arcanum CSOs and WWTP discharge between river mile 15.0 and 16.5.

Ludlow Creek, Brush Creek and Hog Run

Like the Stillwater River, the headwaters of Ludlow Creek have been modified for improved agricultural drainage, and effects from that habitat degradation are exported downstream. Consequently, although the fish community does improve with improving habitat quality in the lower reaches, and does meet WWH, it under-performs the excellent habitat present. Most notably, the number of sucker and intolerant species were much lower than expected, a direct result of the magnitude of historic habitat degradation in the headwaters, and the natural barrier to recolonization imposed by Ludlow Falls. A slight improvement in 1999 over 1982 was noted, and could be due to improved sewage treatment by the Village of Laura. An unnamed tributary to Ludlow Creek (confluence at RM 11.8 of Ludlow) was impacted beyond habitat degradation by organic enrichment (Figure 108).

Brush Creek has recovered from impacts by an electroplating industry in Phillipsburg. The stream channel in Hog Run, at the location sampled, had recovered from historic channelization. The fish community sampled there rated very good.

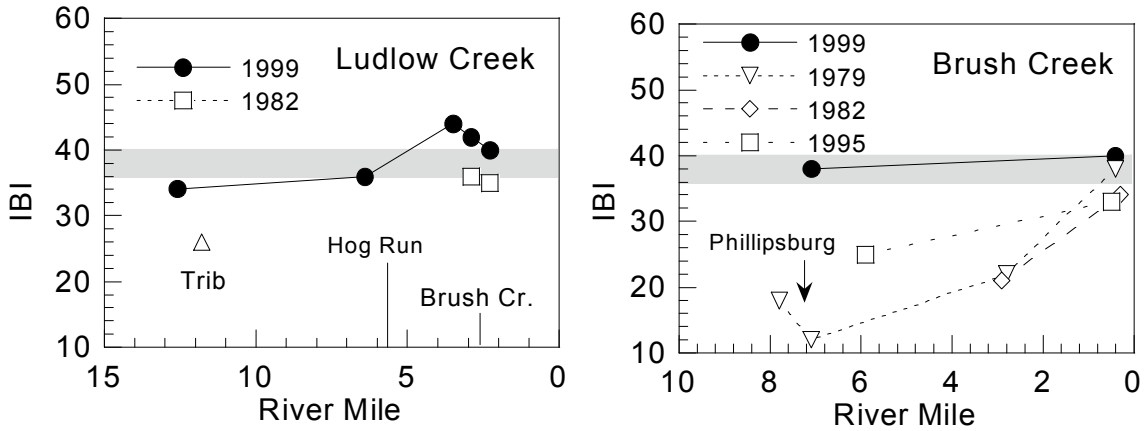


Figure 108. Plots of IBI scores for Ludlow Creek (left panel) and Brush Creek (right panel) for the years indicated. The unnamed tributary to Ludlow Creek referenced in the text is plotted as a triangle in the left panel.

Harris Run and Ballinger Run

CSO discharges from the Village of Bradford, and nonpoint agricultural pollution affect both Harris Run and Ballinger Run. The Village of Bradford discharges to Ballinger Run between RM 1.0 and 1.75, and Ballinger Run is a tributary to Harris Run at RM 2.5. In 1982, Ballinger Run was essentially dead as a result of the Bradford CSOs. The stream, though still impaired, has recovered from the gross CSO impact as the result of control measures (Figure 109). However, the impact from the CSOs remains and is limiting the performance of the fish community downstream from the WWTP that otherwise would likely be meeting WWH. The impact from organic enrichment

(and possible D.O. sag from the WWTP) also affects Harris Run. Harris Run upstream from Ballinger Run was grossly impaired by sedimentation due to channelization and the absence of riparian buffers upstream.

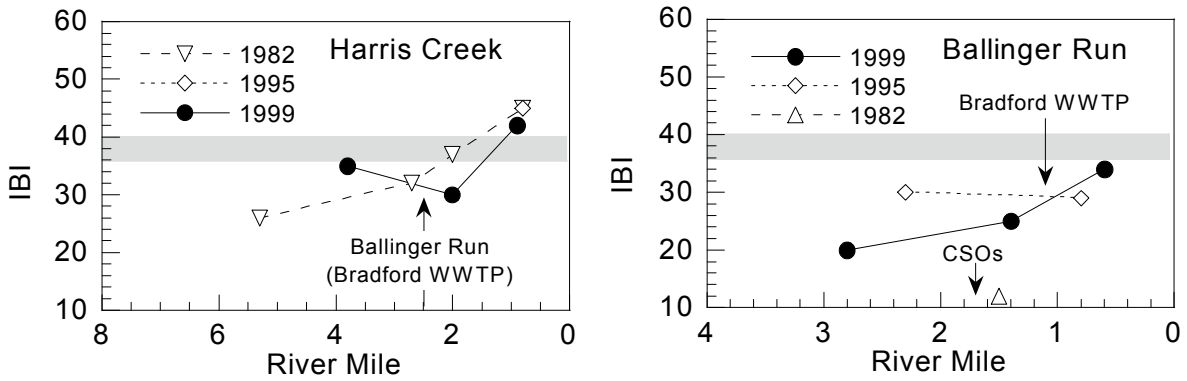


Figure 109. Plots of IBI scores for locations sampled in Harris Creek and Ballinger Run, 1999, 1995 and 1982.

Mill Creek (Dayton Airport)

The issues with Mill Creek and the Cox-Dayton Airport have been discussed extensively (Ohio EPA 1995, 1996). The pattern of impact and recovery from airport deicing chemicals is the same as that documented in 1994 and 1995 (Figure 110), but the impact at RM 1.2 was less in 1999 than previously.

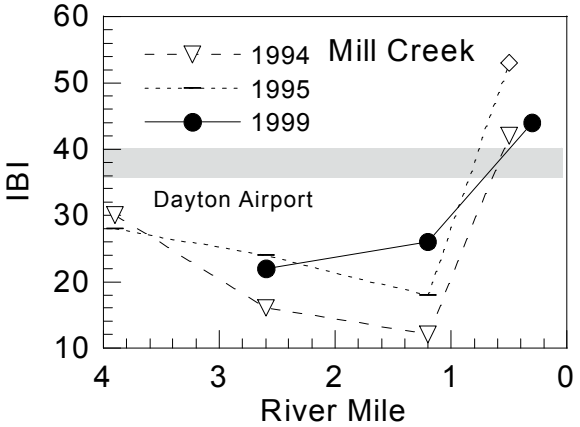


Figure 110. Plots of IBI score from Mill Creek in relation to the Cox-Dayton Airport, 1999, 1995 and 1994.

References

Ankley, G. T., S. A. Collyard, P. D. Monson, and P. A. Kosian, 1994. Influence of Ultraviolet Light on the Toxicity of Sediments Contaminated with Polycyclic Aromatic Hydrocarbons. Environmental Toxicology ans Chemistry, Vol 13, No. 11, pp. 1791-1796, 1994

Anonymous. 1992. Wastewater treatment/disposal for small communities, manual, EPA/625/R-92/005

Fausch, D.O., J.R. Karr and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River. Tech. Report No. 86. Purdue University. Water Resources Research Center, West Lafayette, Indiana. 73 pp.

Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. pp. 307-324. In: Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 703, J.M. Bates and C.I. Weber (eds.). Philadelphia, PA.

Gaugin, A.R. and C.M. Tarzwell. 1952. Aquatic invertebrates as indicators of stream pollution. Public Health Reports 67(1):57-64.

Gordon, N.D., T.A. McMahon, B.L. Finlayson. 1992. Stream Hydrology: An introduction for ecologists. John Wiley & Sons, Ltd. Chicheler, West Susex, England. 526 pp.

Hoggarth, M.A. 1992. A study of the Unionidae of the Little Miami River system. Division of Natural Areas and Preserves, Department of Natural Resources, Columbus, OH 105 pp.

Hughes, R.M., D.P. Larsen, and J.M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. Env. Mgmt. 10(5): 629-635.

Ireland, D.S., G. A. Burton, and G. G. Hess.1995. In Situ Evaluations of Turbidity and Photoinduction of Polycyclic Aromatic Hydrocarbons. Environmental Toxicology ans Chemistry, Vol 15, No. 4, pp. 574-581, 1996

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21-27.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55-68.

Keeney, D. R. (1973). The nitrogen cycle in sediment-water systems. J. Environ. Quality, 2:15-29.

Kelly, M.H., R. L.Hite. 1984. Evaluation of Illinois stream sediment data: 1974-1980. Illinois Environmental Protection Agency, Division of Water Pollution Control. Springfield, Illinois.

Leonard , P.M. and D.J. Orth. 1986. Application and testing of an Index of Biotic Integrity in small, cool water streams. Trans. Am. Fish. Soc. 115: 401-414.

Miltner, R. J. and E. T. Rankin (1998). Primary nutrients and the biotic integrity of rivers and streams. Freshwater Biology 40: 145-158.

Ohio Department of Natural Resources. 1960. Gazetteer of Ohio Streams, Report No. 12, Ohio Water Plan Inventory . Columbus, Ohio.

Ohio EPA (1996). Interim report on the Black River TMDL Project. Ohio EPA, Division of Surface Water. Columbus, Ohio. 46 pp.

Ohio EPA (1994). Biological and water quality study of the Black river (with selectedtributaries) and Beaver Creek. OEPA Technical Report EAS/1993-12-8. Ohio EPA Division of Surface Water. 128 pp.

Ohio EPA (1987). Comprehensive water Quality report for the Black River: Amendments tothe Ohio Water Quality Management Plan. Ohio EPA, Division of Water Quality Planning and Assessment. 160 pp.

1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

1988a. Ohio nonpoint source assessment. Division of Water Quality Monitoring and Assessment, Nonpoint Source Management Section Columbus, Ohio.

1988b. Biological and Water Quality Study of the Little Scioto River Watershed - Marion County , Ohio. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

1989a. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological

field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

1989c. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

1990a. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

1990b. Compendium of biological results from Ohio rivers, streams and lakes: 1989 edition. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1990c. State of Ohio Nonpoint Source Assessment. Volume 5. Lake Erie West Region. Division of Surface Water, Nonpoint Source Program Management Section, Columbus, Ohio.

___ 1993. State of Ohio Water Quality Standards. Chapter 3745-1 of the Ohio Administrative Code.

____ 1994. Biological, Sediment and Water Quality Study of the Little Scioto River, Marion, Ohio. Division of Surface Water, Columbus, Ohio.

Ollivon, D., M. Blanchard, and B.Garban. 1998. PAH Fluctuations in Rivers in the Paris Region (France): Impact of Floods and Rainy Events. Water, Air, and Soil Pollution 115:429-444, 1999

Omernik, J.M. 1988. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Paller, M. H. 1995. Relationships among number of fish species sampled, reach length surveyed, and sampling effort in South Carolina Coastal Plain streams. North American Journal of Fisheries Management 15: 110 - 120.

Persaud, D., J. Jaagumayi, and A. Hayton. 1994. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ministry of the Environment, Public Information Centre, Toronto, Ontario.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Rankin, E.T.and C.O. Yoder. 1991. Calculation and uses of the area of degradation value (ADV).

Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

Reash R.J. and T.M. Berra. 1989. Incidence of fin erosion and anomalous fishes in a polluted stream and a nearby clean stream. Water, Air, Soil Pollution. 47: 47-63.

Reash R.J. and T.M. Berra. 1987. Comparison of fish communities in a clean-water stream and an adjacent polluted stream. Am. Midl. Nat. 118: 301-322.

Reash R.J. and T.M. Berra. 1986. Fecundity and trace-metal content of creek chubs from a metal contaminated stream. Trans. Am. Fish. Soc. 115: 346-351.

Simpson, K.W. and R.W. Bode. 1980. Common larvae of Chironomidae (Diptera) from New York State streams and rivers. Bull. No. 439, New York State Education Dept., Albany. 105 p.

Thurston, R. V., R. C. Russo, and K. Emerson. 1979. Aqueous ammonia equilibrium - Tabulation of percent un-ionized ammonia. U.S. EPA Environmental Research Laboratory, Duluth, MN. EPA-600/3-79-091.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Washington, D.C.

Warren, C. E. 1971. Biology and Water Pollution Control. W. B. Saunders Co., Philadelphia, Pa. 434 pp.

Yoder, C. O. and E. T. Rankin. 1996. Assessing the condition and status of aquatic life designated uses in urban and suburban watersheds. Pages 201-227 *in* Effects of Watershed Development and Management on Aquatic Ecosystems, L. A Rosner, editor. American Society of Civil Engineers, New York, NY.