

Important Concepts and Elements of an Adequate State Watershed  
Monitoring and Assessment Program

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prepared by

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## Important Concepts and Elements of an Adequate State Watershed Monitoring and Assessment Program

### I. INTRODUCTION

Watershed-based approaches are gaining widespread acceptance as a conceptual framework from within which water quality management programs should function. However, overall reductions and inequities in State ambient monitoring and assessment programs jeopardize the scientific integrity of watershed-based approaches. This also has had the undesirable effect of failing to properly equip the States and EPA to adequately meet the challenges posed by recently emerging issues such as cumulative effects, nonpoint sources, habitat degradation, and interdisciplinary issues (*e.g.*, TMDLs) in general. Unfortunately, the chronic shortfall in ambient monitoring and assessment resources is not new - the ITFM (1995) reported that of the funding allocated by state and federal agencies to water quality management activities, only 0.2% was devoted to ambient monitoring. As the need for adequate supplies of clean water increases, concerns about public health and the environment escalate, and geographically targeted watershed-based approaches increase, the demands on the water quality monitoring "infrastructure" will likewise increase. These demands cannot be met effectively nor economically without fundamentally changing our attitudes towards ambient monitoring (ITFM 1995). An adequate ambient monitoring and assessment framework is needed to ensure not only a good science-based foundation for watershed-based approaches, but water quality management in general. This paper attempts to describe the important elements, processes, and frameworks which need to be included as part of an adequate State monitoring and assessment program and how this should be used to support the overall water quality management process. Furthermore, it is a goal of this effort to highlight the need to revitalize monitoring, assessment, and environmental indicators as an integral part of the overall water quality management process.

Monitoring and assessment information, when based on a sufficiently comprehensive and rigorous system of environmental indicators, is integral to protecting human health, preserving and restoring ecosystem integrity, and sustaining a viable economy. Such a strategy is intended to achieve a better return on public and private investments in environmental protection and natural resources management. In short, more and better monitoring and assessment information is needed to answer the fundamental questions that have been repeatedly asked about the condition of our water resources and shape the strategies needed to deal with both existing and emerging problems within the context of watershed-based management.

The long-term vision is to develop a process for the comprehensive assessment of the waters of each State by producing and implementing a multi-year monitoring and assessment framework at relevant geographic scales to support all water quality management objectives (including risk-based decision making). Some of the key elements of this approach are:

- development and implementation of a statewide monitoring strategy.
- publishing existing monitoring and assessment results from all relevant sources (*e.g.*, Watershed specific reports, State 305[b] reports).
- performance of data storage, retrieval, and management.
- taking appropriate regulatory and management actions based on those results.

These efforts would fall short if a linkage between program management and monitoring and assessment were not made part of the overall water quality management process (Figure 1). This, too, is part of the long range vision for revitalizing the role of water quality monitoring nationwide.

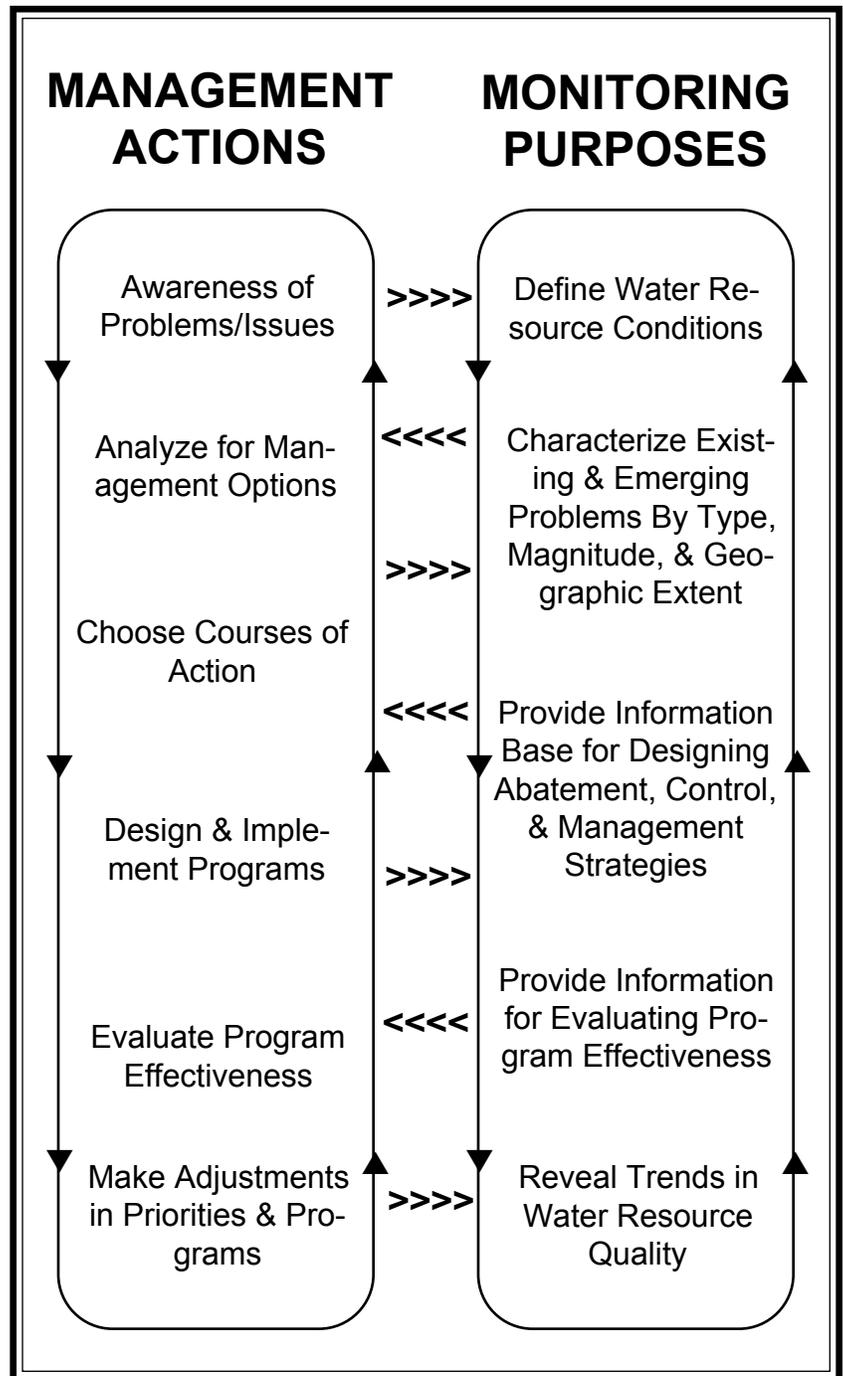
## II. GOALS OF AN ADEQUATE STATE MONITORING AND ASSESSMENT PROGRAM

The following is a compilation of the major program goals that should shape the design of an adequate State monitoring and assessment program and thus become the identifiable characteristics. While much of this is patterned after the major monitoring and assessment compendia and program guidance that has recently been developed (ITFM 1995; U.S. EPA 106 Program Guidance), the specifics of implementation lie within the custodial responsibilities of State water quality management programs.

1. The **18 national water indicators** and the goals each measures (U.S. EPA 1995a; see inset p. 3) are employed as the core indicators with additional area and/or resource specific goals and indicators as needed to fulfill the following purposes:

- conserve and enhance public health.
- conserve and enhance ecosystems.
- support uses designated by States/Tribes in Water Quality Standards (WQS).
- conserve and improve ambient conditions.
- reduce or prevent loadings and other stressors (*e.g.*, habitat degradation).

Taken together, all of the above should lead to achieving healthy watersheds.



*Figure 1. The relationship between management actions and the purposes monitoring and assessment (after ITFM 1995).*

2. **Assess all water resource types** within an organized time frame (*e.g.*, rotating basin approach) by employing the following approaches:

***The U.S. EPA National Indicators for Water and the Goals Each Supports***

***Conserve & Enhance Public Health:***

1. Population served by drinking water systems in compliance with health-based standards.
2. Population served by drinking water systems at risk from microbial contamination.
3. Population served by drinking water systems exceeding lead action levels.
4. Number of drinking water systems with source water protection.
5. Percentage of waters with fish consumption advisories.
6. Percentage of estuarine and shellfish waters approved for harvest for human consumption.

***Conserve & Enhance Ecosystems:***

7. Percentage of waters with healthy aquatic communities (*i.e.*, biological integrity).
8. Percentage of imperiled aquatic species.
9. Rate of wetland acreage loss.

***Support Designated Uses:***

10. Percentage of waters meeting designated uses:
  - a. Drinking water supply
  - b. Fish and shellfish consumption
  - c. Recreational
  - d. Aquatic life

***Conserve & Improve Ambient Conditions:***

11. Population exposed to chemical pollutants in ground water.
12. Trends in surface water pollutants.
13. Concentrations of selected pollutants in shellfish.
14. Trends in estuarine eutrophication.
15. Percentage of waters with chemically contaminated sediments.

***Reduce Loadings & Prevent Other Stressors:***

16. Point source loadings to surface and ground water.
17. Nonpoint source loadings to surface and ground water.
18. Marine debris.

- achieve virtually 100% coverage through a mix of different spatial schemes, *i.e.*, targeted sites, rotating basin cycles, and/or probabilistic design.
- utilize appropriate and robust techniques for extrapolation and stratification of monitoring and assessment results (*i.e.*, every mile of every stream need not be monitored to achieve the 100% coverage goal).
- maximize interagency and inter-organizational cooperation and collaboration.
- when appropriate, make use of volunteer organization results.

3. Produce a **“better” 305b report:**

- national statistics are currently biased by wide differences between State approaches to monitoring & assessment including indicators usage and calibration - one result is widely divergent state estimates of impaired waters (generally overly optimistic estimates of the full attainment of aquatic life uses).
- assignment of impairment (or lack thereof) to associated causes and sources also reveals the inconsistent usage of indicators and indicator frameworks - *e.g.*, habitat has been under reported by most states (almost one-half of states reported *zero* impaired miles for rivers & streams in 1992).

4. Support the emerging **watershed approaches:**

- reductions in State monitoring & assessment programs jeopardize the science basis for successfully implementing watershed-based approaches which are ostensibly based (in part) on addressing previously overlooked or under-emphasized problems.
- management applications most commonly take place at the watershed level thus

monitoring & assessment must be relevant to this level of management and be capable of detecting impairments and characterizing aquatic resources at this scale.

5. **Satisfy basic questions** that are frequently encountered by water quality program managers:

- what is the condition of surface, ground, estuarine, and coastal waters?
- how and why are conditions changing over time?
- what are the associated causes and sources of impairment?
- are water quality management programs producing the desired results?
- are state and national water quality goals being attained?

Each of the above can be subdivided into issue specific questions that are commonly encountered by water quality managers (see inset at right).

6. **Integrate the water resource integrity concepts** that have been developed during the past 10-15 years into monitoring and assessment approaches, environmental indicators, and watershed-based programs:

- the five factors that determine the integrity of water resources (Figure 2; Karr *et al.* 1986) should be used to guide the development of environmental indicators - indicators which both represent or extend to each major factor *and* which reflect the integrity of the water resource as a whole (*e.g.*, composite measures, indices) are needed.
- follow the stressor, exposure, response paradigm for determining the most appropriate roles for individual indicators - *avoid the inappropriate substitution of stressor and exposure indicators for response indicators.*
- utilize appropriate regionalization schemes (*e.g.*, ecoregions, subregions) to stratify and partition natural variability for ambient indicators.
- incorporate tiered and refined use designations in the State WQS as appropriate.
- use the water indicators hierarchy (Figure 3) as an operational framework for State water quality management programs - make linkages between administrative activities and indicators of stress, exposure, and response.

III. STATE MONITORING & ASSESSMENT PROGRAM OBJECTIVES

***Water Quality-Based Decisions  
Which Would Benefit From  
Better Monitoring & Assessment  
Information***

***Water Quality Standards:***

- Refined and stratified designated uses and criteria
- Biological criteria
- Site-specific applications (*e.g.*, dissolved metals translators, design temperature & pH, hardness)
- Water effect ratios
- Anitdegradation
- Ground truthing revisions to water quality criteria

***TMDLs:***

- Delineating impaired segments and associated causes & sources
- Wasteload allocation (model calibration & verification)

***NPDES Permits:***

- Impact assessment
- Toxicity assessment (*i.e.*, WET testing)
- Overall permit program effectiveness

***Nonpoint Sources:***

- Delineating impaired segments and prioritization of watersheds
- Database for State Nonpoint Source Assessments

***404/401 Dredge & Fill:***

- Improved site-specific review and approval criteria
- Minimize exemptions via nationwide permits

***Ground Water:***

- Development of ambient background characteristics

***Wetlands:***

- Improved wetlands classification and delineation criteria

The following are some of the major objectives that State monitoring & assessment programs should have as priorities. Fully meeting some of these objectives will require time to acquire and develop

the necessary database, indicators, and staff expertise. However, this will be partly dependent on the status of existing and past State monitoring and assessment efforts. Nevertheless, using the following objectives provides a basis for determining the adequacy of a given State program. A well rounded approach to indicators and monitoring design utilizing a core set of chemical, physical, and biological indicators should provide the information needed to simultaneously meet these objectives without the need to redesign the approach for each different objective.

### 1. Baseline characterizations of surface water resources:

- status and trends information.
- aquatic resource characterization.

### 2. Identification and characterization of existing and emerging problems:

- selection of indicators and the overall indicator framework will strongly influence the adequacy of problem identification and characterization (we cannot address problems that we do not know about or adequately understand).
- the indicator framework and monitoring design must be prepared to provide information and insights to problems that may not yet be understood or even recognized.
- there will be a need to go beyond point source paradigms.
- make better linkages between designated uses and indicators.

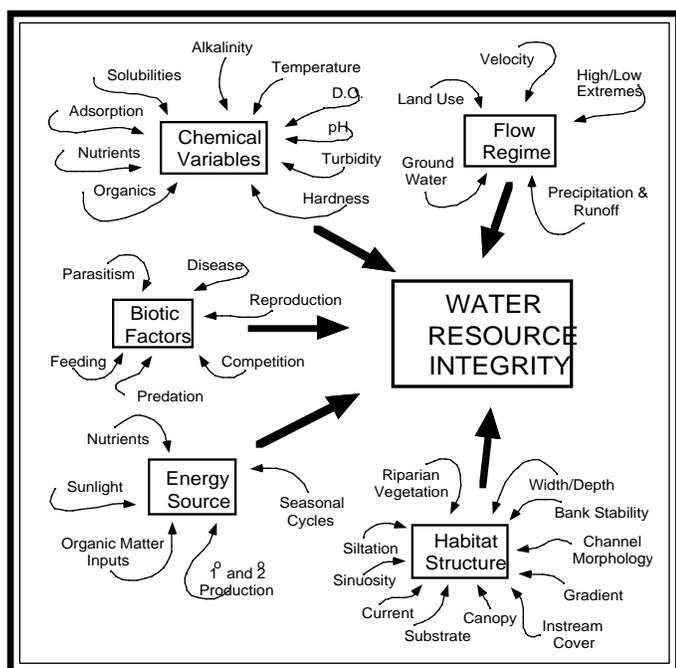


Figure 2. The five major factors which determine the integrity of the water resource (modified after Karr et al. 1986).

### 3. Guide and evaluate the water quality management and regulatory process:

- monitoring & assessment information should drive the regulatory and management processes from problem identification to assessing the effectiveness of these efforts.
- the 305[b] process (*i.e.*, Water Body System) should be the central reporting mechanism for State programs - this will further benefit the national assessments compiled by EPA, other federal agencies, and private organizations.
- support the development and refinement of aquatic life and other designated uses in State WQS.
- examples of other regulatory and management programs that can be influenced include 303[d] listing, TMDLs, water quality-based permitting, compliance and enforcement, prioritizing grants and other financial assistance, the State nonpoint source assessment (319 program), etc.
- monitoring and assessment information should provide the impetus for “new” regulatory or program management directions (*e.g.*, initiatives to restore and protect riparian habitat, nutrient criteria, sediment criteria, stream protection, antidegradation) and enhance existing efforts (CSOs, stormwater, 404/401 program, chemical criteria validation, biological criteria).

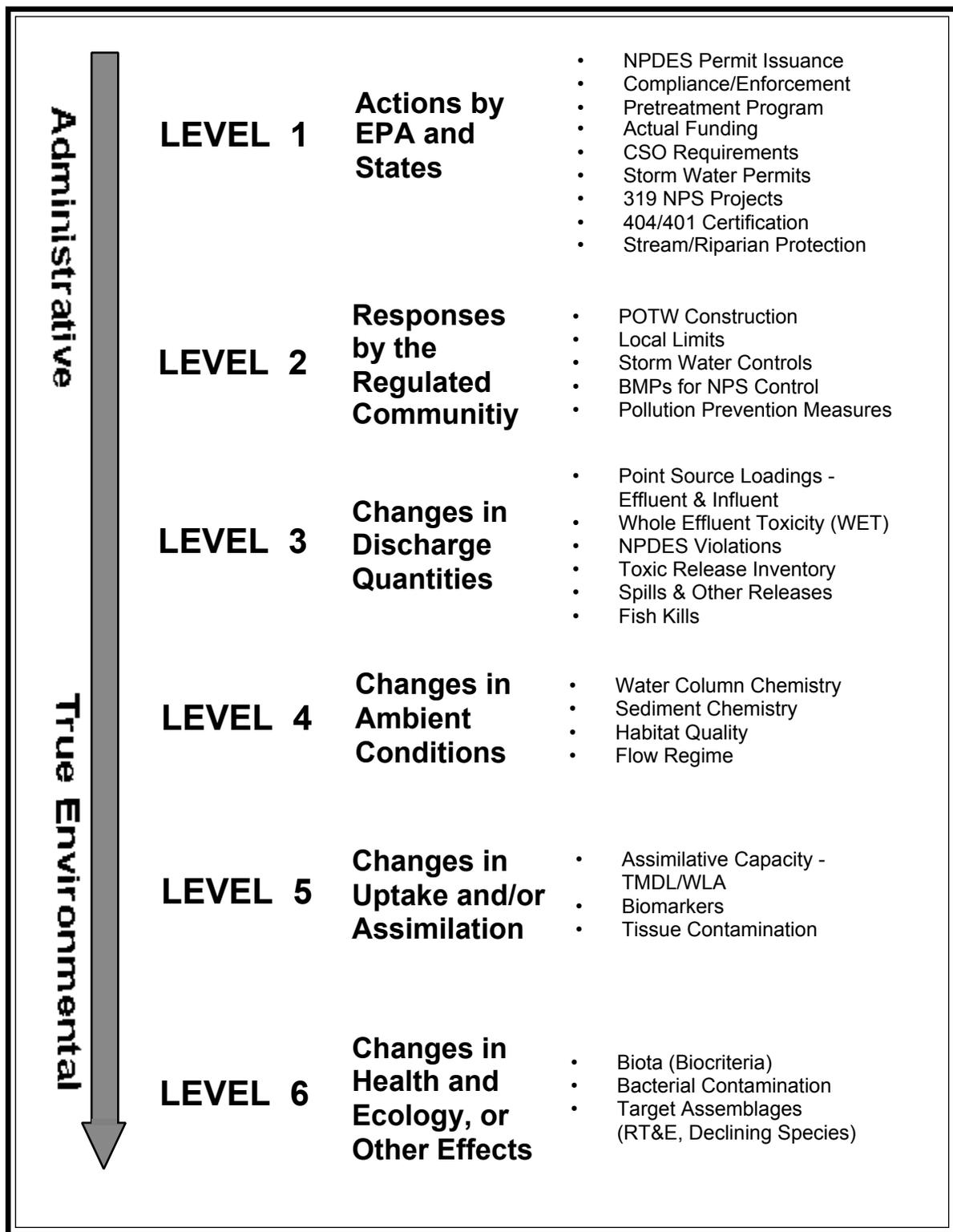


Figure 3. Hierarchy of administrative and environmental indicators which can be used by States for monitoring and assessment, reporting, and evaluating overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995b).

4. Evaluation of overall water quality management program effectiveness:

- demonstrate the effectiveness of 25+ years of CWA program implementation.
- establish linkages between administrative activities (*i.e.*, “bean counts” ) and environmental results (*i.e.*, ambient chemical, physical, and biological indicators).
- which actions worked and which ones did not? - provide insights on why and suggest what specific program and/or resource adjustments might be needed.

5. Responding to emergencies, complaint investigations:

- quantify environmental damages on a spatial and/or temporal basis.
- characterize resources at risk.
- define the magnitude of apparent problems.

6. Identify and characterize reference conditions:

- baseline for development of indicator benchmarks for evaluating designated use attainment/non-attainment (*e.g.*, biological criteria) and other management objectives.
- this functions as a long term data source for characterizing ambient biological, chemical, and physical conditions through time.

#### IV. MONITORING & ASSESSMENT PROGRAM DESIGN ISSUES

Monitoring and assessment program design includes the different types of indicators and the frameworks within which each is developed and used. This in turn determines the different types of data that will need to be collected and synthesized into information in order to successfully realize the previously stated goals and objectives. Spatial considerations about the basic design of the monitoring program are also included and will be most influenced by the overall program goals and objectives of each State. State monitoring and assessment programs serve multiple needs and must function across multiple scales (*i.e.*, local watershed, basin/subbasin, statewide), thus consideration of more than one approach will likely be needed.

##### ***Environmental Indicators for Surface Waters***

1. The most appropriate roles of indicators are defined as follows:

- Stressor Indicator - measures of activities which have the potential to impact the environment (*e.g.*, pollutant loadings, land use characteristics, habitat changes).
- Exposure Indicator - measures of change in environmental variables which suggest a degree (magnitude and duration) of exposure to a stressor (*e.g.*, chemical pollutant levels in water and sediment, toxicity response levels, habitat quality indices, biomarkers).
- Response Indicator - usually a composite measure or other expression of an integrated or cumulative response to exposure and stress (*e.g.*, biological community indices, status of a target species, etc.).
- The problem nationally with inconsistent 305[b] statistics (and by extension inconsistent 303[d] and 304[I] lists, etc.) is usually the result of the inappropriate substitution of stressor and/or exposure indicators in the place of response indicators - this is commonly due to the lack of

information about response indicators.

- The exclusion of response indicators and the inappropriate substitution with exposure and/or stressor indicators ultimately influences what States report in terms of waters meeting designated uses. An example of this is illustrated in Figure 4 where some State estimates of aquatic life use attainment based on surrogate approaches are much different than estimates based primarily on biological assessments (U.S. EPA 1996).

2. Use the EPA hierarchy of indicators (U.S. EPA 1995b; Figure 3) as a template to improve the integration of administrative actions and measures with environmental indicators within the State water quality management process:

- The EPA hierarchy of surface water indicators links traditional administrative approaches (permitting, funding, compliance, enforcement) with environmental indicators which simultaneously sequences stressor, exposure and response indicators - six levels (Figure 3).
- The six level hierarchy can become an operational template for implementing environmental indicators and monitoring information within a State water quality management process via a watershed approach. This will facilitate the development of case histories about what works and what does not, showing where information gaps exist, and providing opportunities for feedback throughout the process. An example from the Ohio pilot water indicators demonstration project is included in the selected examples (Part IX.).

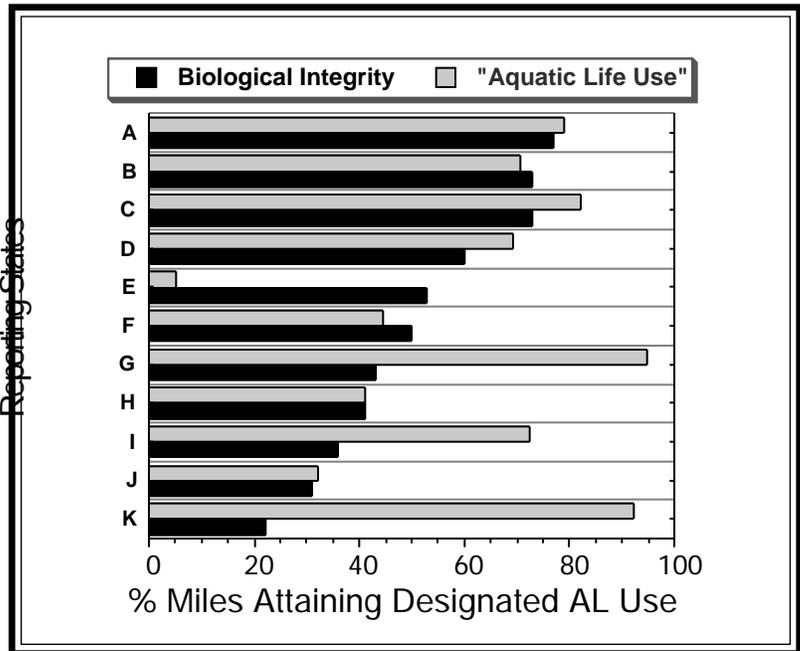


Figure 4. Miles of rivers and streams reported as fully supporting designated aquatic life uses based on varying methods used by 11 states in their 305[b] reports (light shading) compared to that based on biological assessments (after U.S. EPA 1996).

### Monitoring Design Approaches

A key issue facing the States and EPA is selection of an appropriate monitoring design. It has been recognized for some time that the traditional fixed station design (e.g., NAWQMN, NASQAN) common to many State monitoring networks is alone insufficient to meet the above stated objectives. However, State monitoring and assessment resources even under the best of circumstances have been limited and therefore must be prioritized. Thus, selection of the most cost and information effective spatial design is a critical step in the process. Two approaches, a synoptic, targeted design commonly referred to as a rotating basin approach and the probabilistic design developed by the U.S. EPA EMAP program are summarized here. The strengths and weaknesses of each are indicated with respect to the multiple issues that State monitoring and assessment programs must address. A case example from the Ohio portion of the E. Corn Belt Plains ecoregion Regional EMAP project is included in Part IX.

### *Rotating Basin Approach*

#### 1. Strengths:

- organized, systematic approach based on accumulating assessment information at a local scale over a fixed period of time, usually 5 or 10 years.
- coincides with various management programs which are supported by the monitoring & assessment information (*i.e.*, NPDES permit reissuance, basin-wide water quality planning, proposed 5-year 305b reporting cycle).
- provides monitoring & assessment information at a local or reach specific scale so that the many issues which occur at this level can be addressed while providing the opportunity to aggregate upwards to a watershed, regional, statewide, or national scale once sufficient data exists.
- there is more opportunity to define gradients of specific human disturbances with assessment information (*e.g.*, Karr's human activity "dose" - ecological response curve).
- develop and maintain tabs on reference condition in a predictable and standardized time frame.

#### 2. Weaknesses:

- visiting a basin/segment/watershed only once in 5 or 10 years may not be sufficient to satisfy all needs.
- larger scale assessment information (*i.e.*, in support of a valid statewide assessment) is generally not available for 5-10 years.

### *Probabilistic Design*

#### 1. Strengths:

- statistically robust design.
- "faster" route to a statewide assessment - aggregate to national scale.
- transcends State boundary limitations - can facilitate collaborative monitoring between States.

#### 2. Weaknesses:

- lacks site-specific/issue-specific resolution.
- logistics are potentially more difficult (*i.e.*, more difficult access to remote monitoring sites).
- reference condition may be more difficult to define on probability basis alone.
- local scale issues may be overlooked.

## V. AQUATIC RESOURCE CHARACTERIZATION

Defining the different aquatic resource types that a State program must address is a critical step in the process. This includes the major aquatic ecosystem types such as flowing waters (*i.e.*, rivers and streams), lakes and reservoirs, coastal waters, great lakes, estuaries, or wetlands. Further stratification within each is possible (*e.g.*, headwater streams, wadable streams, large rivers, depressional wetlands, riparian wetlands, etc.) and may be accounted for *a priori* or as part of the indicator development and calibration process. Other stratification elements, which includes watershed driving factors (*e.g.*, ecoregions) and other physical vectors, are incorporated as well. Designated aquatic life uses provide an additional layer of stratification. Taken together all of these processes should result in more finely tuned indicator expectations or benchmarks against which management program success will ultimately be judged.

## VI. STATE MONITORING & ASSESSMENT COMPONENTS AND RESOURCES

State monitoring and assessment programs need to include the appropriate ambient measurements in order to adequately meet the previously stated goals and objectives. The Intergovernmental Task Force on Monitoring Water Quality (ITFM 1995) recommended the minimum elements of an adequate monitoring and assessment program that will support meeting the previously stated goals and objectives (Table 1). This also represents the elements essential to implementing the hierarchy of water indicators framework (Figure 3) which, in turn, is needed to not only demonstrate program effectiveness, but provide opportunities for feedback resulting in future program improvements.

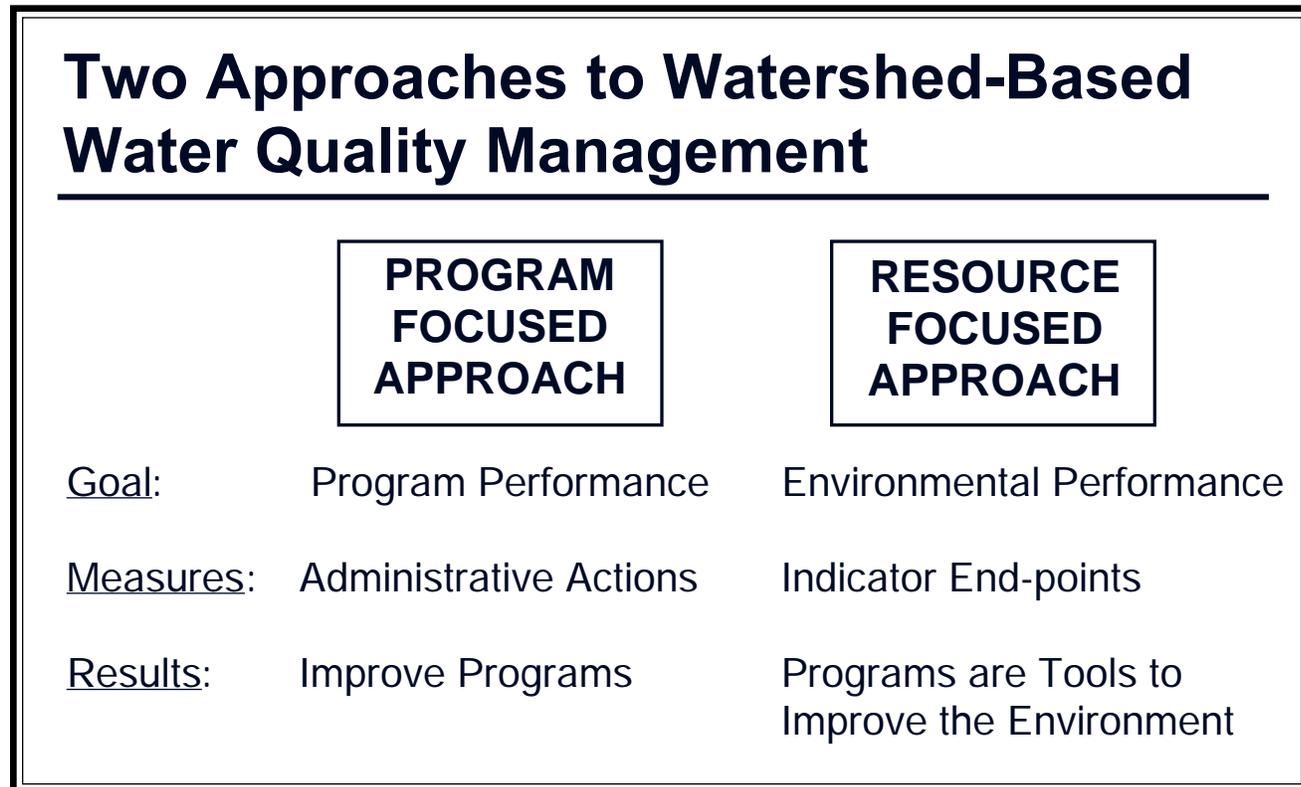
The ITFM (1995) concluded that the implementation of the ITFM recommendations and strategy would result in an adequate information base to achieve the environmental protection and natural resource management goals and objectives established for the nation's aquatic resources. However, it was also recognized that full implementation of the strategy could not be achieved "overnight" and that the necessary capacity and resources (*i.e.*, the monitoring and assessment "infrastructure") will need to be acquired over a reasonable period of time. Nevertheless, monitoring organizations, including States, will need to review, update, and/or revise their monitoring strategies in a series of deliberate steps. The demands that are increasingly being placed on our water resources at all scales require that past approaches to monitoring be significantly improved both in terms of quality and quantity. Some of the steps towards a more comprehensive and effective approach to ambient monitoring include the following which also summarizes the major points of this document:

1. Develop a goal oriented approach to monitoring, assessment, and indicators development where indicators are sufficiently specific so as to explicitly measure the identified national goals and those relevant to State WQS.
2. Evaluate information priorities and identify existing information gaps.
3. Develop a comprehensive and flexible approach that addresses all relevant scales and aquatic resource types.
4. Take advantage of inter-organizational collaboration whenever appropriate.
5. Link traditional compliance monitoring with watershed-based ambient monitoring.
6. Deal effectively with methods comparability to maximize the flexibility in monitoring and assessment approaches while producing data and information of known quality and power of assessment.
7. Automate and streamline data and information management including data entry, storage, and retrieval.
8. Develop better assessment and reporting at all relevant scales; publish results on a regular basis.
9. Promote the development of incentives and the elimination of disincentives to the development of better State ambient monitoring programs and indicators.

Table 1. Summary matrix of recommended environmental indicators for meeting management objectives for status and trends of surface waters (shaded boxes with **X** are recommended as a primary indicator after ITFM 1995; other recommended indicators are indicated by **↓**). The corresponding EPA indicator hierarchy level is also listed between indicator groups.

Indicator Group	Categories of Management Objectives					
	Human Health	Ecological Health		Economic Concerns		
	Consumption of Fish /Shellfish	Public Water Supply	Recreation (swimming, fishing, boating)	Aquatic/ Semi-aquatic Life	Industry/ Energy/ Transportation	Agriculture/ Forestry
<b>Biological Response Indicator (Level 6)</b>						
Macroinvertebrates		X	X	X		X
Fish	X		X	X		X
Semiaquatic Animals	X		X	X		X
Pathogens	X		X			X
Phytoplankton	X	X	X	X	X	
Periphyton				X		
Aquatic Plants		X	X	X	X	X
Zooplankton		X	X	X		X
<b>Chemical Exposure Indicator (Level 4&amp;5)</b>						
Water chemistry	X	X	X	X	X	X
Odor/Taste	X	X	X			
Sediment Chemistry	X	X	X	X	X	X
Tissue Chemistry	X	X	↓	X	X	
Biochemical Markers	↓	↓	↓	↓		↓
<b>Physical Habitat/Hydrologic Indicator (Levels 3&amp;4)</b>						
Hydrological Measures	X	X	X	X	X	X
Temperature	X	X	X	X	X	↓
Geomorphology	X	X	X	X	X	X
Riparian/shoreline	X	X	↓	X	X	X
Ambient Habitat Quality	↓	↓	↓	↓	↓	↓
<b>Watershed Scale Stressor Indicators (Levels 3,4&amp;5)</b>						
Land Use Patterns	X	X	X	X	X	X
Human Alterations	X	X	X	X	X	↓
Watershed Impermeability	↓	↓	↓	↓	↓	↓
<b>Pollutant Loadings Stressors (Level 3)</b>						
Point Source Loadings	↓	↓	↓	↓	↓	↓
Nonpoint Source Loadings	↓	↓	↓	↓	↓	↓
Spills/Other Releases	↓	↓	↓	↓	↓	↓

Simply upgrading the monitoring program to include more and better measurements and the better conversion of data to information, while important, is alone insufficient. To achieve the overall goal of improving the use of monitoring and assessment information in the emerging watershed approach, water quality management must mature to focus primarily on the condition of the environment as the overall measure of program success (Figure 5). Whereas the performance of the "program" was



*Figure 5. The goals, measures, and results of program based and resource based approaches to water quality management. State programs will evolve towards a resource based approach by developing and using a sufficiently comprehensive and rigorous system of environmental indicators.*

once the principal measure of effectiveness, the program must be viewed as a tool to be used alongside monitoring and assessment and environmental indicators to improve the quality of the environment.

### VIII. REFERENCES

- ITFM (Intergovernmental Task Force on Monitoring Water Quality). 1995. The strategy for improving water-quality monitoring in the United States. Final report of the Intergovernmental Task Force on Monitoring Water Quality. Interagency Advisory Committee on Water Data, Washington, D.C. + Appendices.
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- U.S. Environmental Protection Agency. 1996. Summary of state biological assessment programs for streams and rivers. EPA 230-R-96-007. U. S. EPA, Office of Policy, Planning, & Evaluation, Washington, DC 20460.
- U.S. Environmental Protection Agency. 1995a. Environmental indicators of water quality in the United States. EPA 841-R-96-002. Office of Water, Washington, DC 20460. 25 pp.
- U.S. Environmental Protection Agency. 1995b. A conceptual framework to support development and use of environmental information in decision-making. EPA 239-R-95 012. Office of Policy, Planning, and Evaluation, Washington, DC 20460. 43 pp.

**IX. INDICATORS & PARAMETERS FOR ADEQUATE STATE MONITORING & ASSESSMENT PROGRAMS**

The following supplemental figure shows core and supplemental indicators and parameters that are used in an adequate State monitoring and assessment program. This is patterned after the recommendations of the Intergovernmental Task Force on Monitoring Water Quality (ITFM 1995). The core indicators are measured everywhere and are supplemented by a variety of chemical and physical measurements depending on the applicable designated use(s) and watershed-specific needs.

<b>CORE INDICATORS/PARAMETERS</b>	
<ul style="list-style-type: none"> <li>• <b>Fish Assemblage</b> • <b>Macroinvertebrates</b> • <b>Periphyton</b></li> </ul> <p style="text-align: center;"><i>(Use Community Level Data From At Least Two)</i></p>	
<p><b>Physical Habitat Indicators</b></p> <ul style="list-style-type: none"> <li>• Channel morphology • Flow</li> <li>• Substrate Quality • Riparian</li> </ul>	<p><b>Chemical Quality Indicators</b></p> <ul style="list-style-type: none"> <li>• pH • Temperature</li> <li>• Conductivity • Dissolved O<sub>2</sub></li> </ul>

**For Specific Designated Uses Add the Following Parameters:**

<p><b>AQUATIC LIFE</b> <i>Base List</i></p> <ul style="list-style-type: none"> <li>• Ionic strength :</li> <li>• Nutrients, sediment</li> </ul> <p><i>Supplemental List</i></p> <ul style="list-style-type: none"> <li>• Metals (water/sediment)</li> <li>• Organics (water/sediment)</li> </ul>
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<p><b>RECREATIONAL</b> <i>Base List</i></p> <ul style="list-style-type: none"> <li>• Fecal bacteria:</li> <li>• Ionic strength</li> </ul> <p><i>Supplemental List</i></p> <ul style="list-style-type: none"> <li>• Other pathogens</li> <li>• Organics (water/sediment)</li> </ul>
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<p><b>WATER SUPPLY</b> <i>Base List</i></p> <ul style="list-style-type: none"> <li>• Fecal bacteria</li> <li>• Ionic strength :</li> <li>• Nutrients, sediment</li> </ul> <p><i>Supplemental List</i></p> <ul style="list-style-type: none"> <li>• Metals (water/sediment)</li> <li>• Organics (water/sediment)</li> <li>• Other pathogens</li> </ul>
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<p><b>HUMAN/WILDLIFE CONSUMPTION</b> <i>Base List:</i></p> <ul style="list-style-type: none"> <li>• Metals (in tissues)</li> <li>• Organics (in tissues)</li> </ul>
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*Supplemental Figure 1. Core indicators and parameters for an adequate State watershed monitoring and assessment program with supplemental chemical parameters according to the applicable designated use(s). Parameters are added based on site and watershed-specific needs and overall water quality management objectives.*

## X. CASE EXAMPLES (ASIWPCA Meeting Version)

Case examples of how monitoring and assessment information based on an integrated water indicators framework can be used to address some of the key goals and objectives of this guidance document are appended. These examples provide tangible evidence of how good monitoring and assessment information can be used to not only support specific program areas, but the overall water quality management process in general.

### A. *Pennsylvania DEP*

The Pennsylvania examples show how the DEP is responding to the settlement of a TMDL suit by committing to increased monitoring and assessment (biological monitoring in particular) statewide.

### B. *Tennessee Valley Authority (TVA)*

The TVA has traditionally been a leader in using ambient monitoring information to meet their water quality management obligations. The examples appended here portray the types of monitoring and assessment, the spatial design, and how this has fostered a better approach to inter-organizational collaboration.

### C. *Wisconsin DNR*

A published paper from the Wisconsin DNR shows how biological and habitat information was used to determine the effects of nonpoint sources and land use on the integrity of Wisconsin streams. This should begin to point out how this type of information can be used in the TMDL process.

### D. *Ohio EPA*

A number of examples from the Ohio EPA surface water monitoring and assessment program are presented and include:

- fact sheets from the 1996 Ohio Water Resource Inventory (305b report);
- watershed profiles from two basin survey areas.
- preliminary results from the E. Corn Belt Plains Ecoregion REMAP project;
- a synopsis of figures from the pilot water indicators project; and,
- three examples of how ambient monitoring data can be used to validate and/or derive chemical water quality criteria.

### E. *U.S. EPA, Office of Water*

The most recent version of the U.S. EPA Section 106 monitoring guidance attempts to foster helping States to achieve the many goals and objectives stated herein.

## XI. OHIO EPA CASE EXAMPLES:

### I. 1996 Ohio Water Resource Inventory (305[b] Report) Fact Sheets:

- Streams and Rivers Status
- Causes and Sources of Impairment
- Streams and Rivers: Siltation & Habitat Destruction
- Impaired Waters in Ohio: What Does This Mean?

### II. An Evaluation of Spatial Monitoring & Assessment Design: Preliminary Results from the E. Corn Belt Plains REMAP Project

### III. Ammonia Fact Sheets

- Associations Between the Index of Biotic Integrity and Unionized Ammonia in Ohio Rivers and Streams: A Preliminary Analysis
- Associations Between the Index of Biotic Integrity and Total Ammonia in Ohio Rivers and Streams: A Preliminary Analysis

### IV. Ohio EPA Pilot Indicators Project figures

### V. Watershed Profile Summaries

- Sandy Creek
- Little Miami River

# 1996 Ohio Water Resource Inventory Fact Sheet: Streams & Rivers Status



The short-term goal is for 75% of the stream and river miles to fully attain the applicable aquatic life standards (called "uses") by the year 2000. The most recent Ohio Water Resource Inventory (Ohio EPA 1996) reported that **49.3%** of streams and rivers were fully supporting the applicable aquatic life "uses". This means that nearly one-half of Ohio's streams, other than a small proportion of waters maintained as

ditches or other physically limited waters, and rivers harbor **good** or **exceptional** quality fish and/or aquatic invertebrate assemblages. Streams that are considered as "partially" supporting aquatic life means that while either the fish or aquatic insects are good or excellent, the other group is only in **fair** condition.

In such cases certain sensitive species may be absent or there are too many pollution tolerant species (e.g., carp) than in a comparable stream where there is less pollution. "Non-attaining" streams and rivers are waterbodies in which the fish and aquatic invertebrates are both fair or one group is in **poor** or **very poor** condition. Examples of such streams and rivers include a warmwater stream where we should expect to find **good** fish and aquatic invertebrate communities, but both groups are rated as **fair**; or an exceptional stream, where we expect to find **exceptional** fish and invertebrates, but where both groups are **good**. As sum-

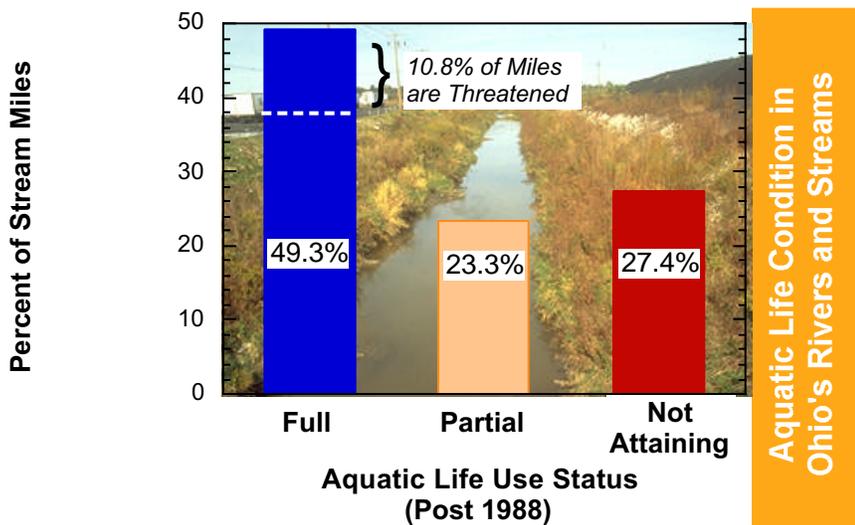
Ohio is a water-rich state with more than 25,000 miles of named and designated streams and rivers and a 451-mile border on the Ohio River. The suitability of these waters to support human uses (e.g., recreation and drinking water) and to maintain healthy ecological conditions or "biological integrity" is critical to the sustainable future of Ohio's economy and standard of living.

Ohio uses the fish and invertebrate communities found in streams to assess the health and well-being of Ohio's flowing waters. Aquatic animals are generally the most sensitive indica-

tors of pollution because they inhabit the water all of the time and because of the direct contact of their gills with the water. A healthy stream community is also associated with high qual-

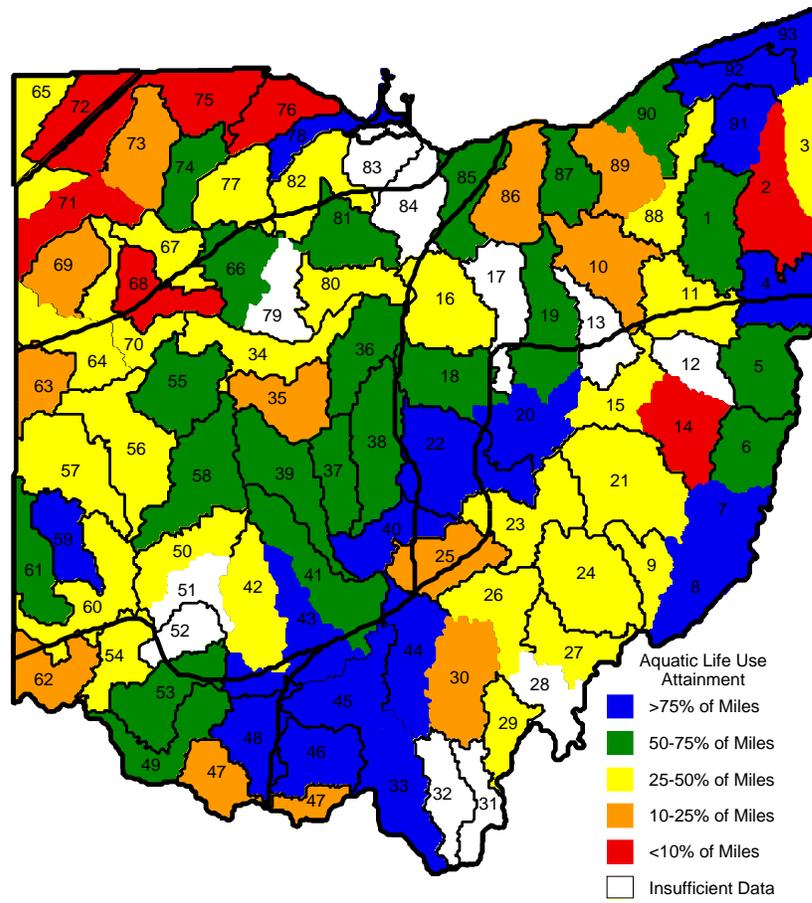


ity recreational opportunities (e.g., fishing and other outdoor-related activities).

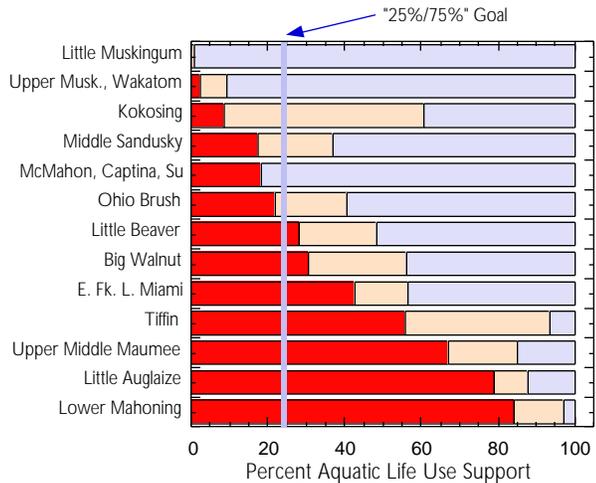


marized in the pie chart below, the non-attainment designation does not mean that the stream is "dead," but rather represents varying degrees of unacceptable impairment.

It is also helpful to look at stream and river quality from a regional perspective. The map on this page (upper right) summarizes the condition for each of 93 watersheds ("subbasins") in Ohio. Some areas of the state generally have a higher proportion of high quality streams and rivers (central and southern Ohio) than other areas (northwest Ohio). By using this perspective, we can see which watersheds are currently meeting or exceeding the Ohio 2000 goal. These will be priorities for protection. For watersheds that are far below the Ohio 2000 goal, there will be a need to evaluate the "restorability" potential and future restoration efforts prioritized. It is clear that a watershed approach, that includes efforts to restore habitat and decrease sedimentation (two of the leading causes of impairment), needs to be central to any strategy to reach the Ohio 2000 goal.

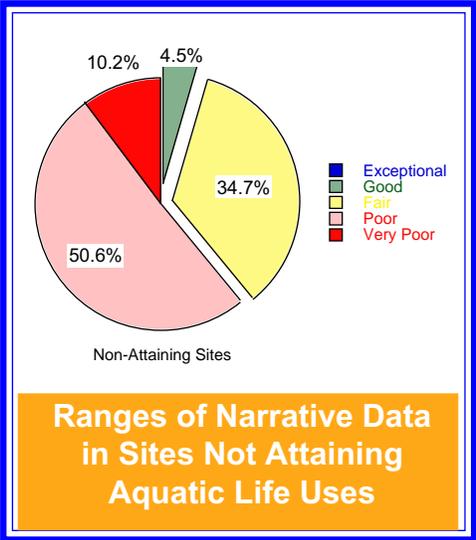


**Map of Aquatic Life Use Attainment By Subbasin**



**Column Chart of Aquatic Life Use Attainment For Selected Subbasins**

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# 1996 Ohio Water Resource Inventory Fact Sheet: Streams & Rivers Causes & Sources of Impairment



water, sediment and effluents; data on the contaminants in fish flesh; and data on the physical nature of streams (*i.e.*, aquatic habitat, siltation). This data is essential to identify the factors that are limiting or impair aquatic life and which constitute threats to human health.

**Causes** of impairment are the "agents" that actually damage or impair the aquatic life in a stream, such as the toxic effects of heavy metals or acidic water. **Sources** of impairment are the origin of the agent. For example, an industry may discharge a heavy metal or a coal mine may be the source of acid water leaching into a stream.

The leading **causes** of impairment to aquatic life in Ohio streams are listed in the adjacent figure (bottom left). The leading cause is **organic enrichment**, which includes low dissolved oxygen and excessive organic pollutants. This largely originates from the inadequate treatment of municipal wastewater (a "point source") and is the most rapidly *declining* cause of impairment. **Habitat alterations** and **siltation** are the second and third leading causes and will likely emerge as the leading causes in two or three years. These causes are termed "nonpoint source" in origin because they do not emanate from pipes, but instead are a result of

Ohio's streams and rivers have seen a substantial improvement in quality over the past 10-15 years. The majority of this improvement has been a result of investments and improvements in municipal wastewater treatment plants across Ohio.

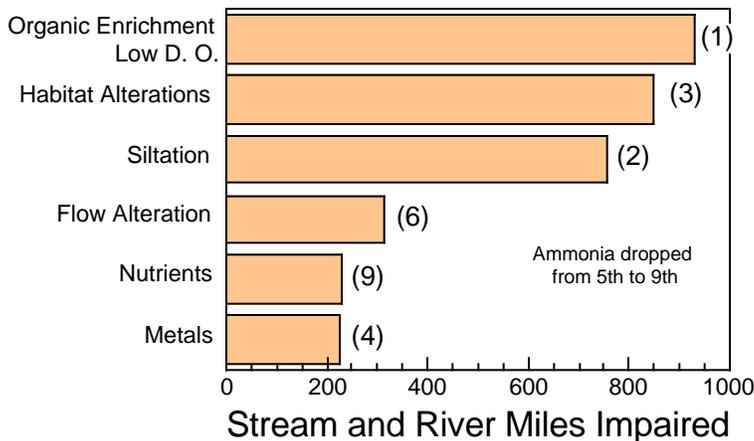
Ohio uses the fish and invertebrate communities found in streams to assess conditions in Ohio's flowing waters. Aquatic animals are generally more sensitive to pollutants compared to other animals because they inhabit the water all of the time. A healthy stream community is also associated

with higher quality recreation opportunities (e.g., fishing, canoeing, and other outdoor-related activities).



In addition to the biological data, Ohio EPA also collects information on the chemical quality of the

Six Leading Causes of Aquatic Life Use Impairment

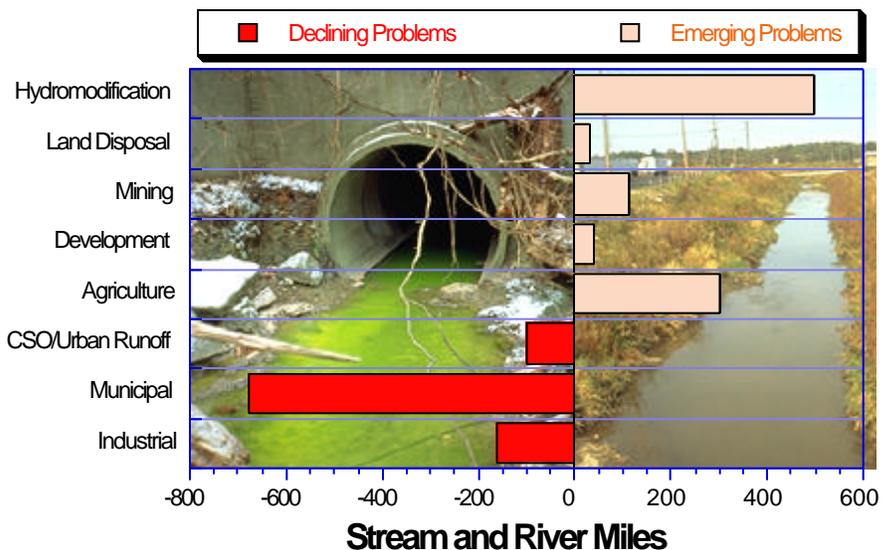


Causes of Impairment in Ohio's Rivers and Streams

land use activities or direct disturbance of stream ecosystems (e.g., by dredging, urbanization, riparian vegetation removal).

Other point source-related **causes** of aquatic life impairment have also declined in importance (see top right figure). Impacts from heavy **metals** (e.g., copper, cadmium, lead, etc.) have declined from the third leading cause to the sixth since 1988. **Ammonia**, a toxic component of municipal wastewater, has dropped from the second leading cause in 1988 to ninth. This dramatic improvement resulted from the construction of new sewage treatment plants in the 1980s at a cost of approximately \$6 billion throughout Ohio.

The leading **sources** of impairment are listed in the figure below. **Point sources** of impairment are the most rapidly declining source. The importance of **hydromodification** (activities that result in habitat degradation) as a leading source of impairment will likely increase over the

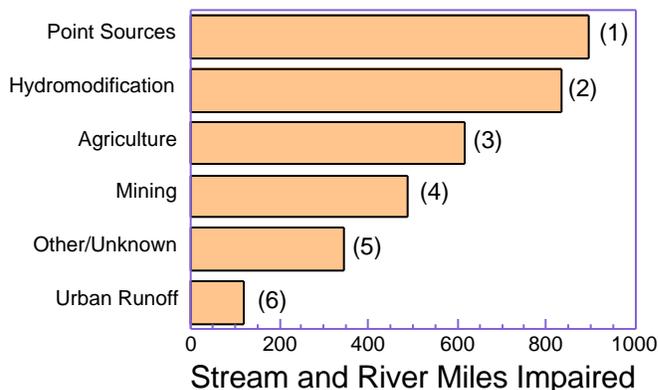


**Identification of declining and emerging sources of aquatic life impairment**

next several years. This trend is illustrated in the figure (see above) that compares declining and emerging sources of impairment over the past 15 years. Such impacts are termed "emerging" problems because while always present, they were frequently masked by the more severe point source impacts of the past.

The information and knowledge illustrated in this fact sheet will be incorporated into the Ohio EPA strategic planning process, which will direct future efforts to protect and restore the water resources of Ohio in a cost-effective and scientifically sound manner.

**Six Leading Sources of Aquatic Life Use Impairment**



**Sources of Impairment in Ohio's Rivers and Streams**



The aquatic life in a stream is a sensitive measure of the overall quality of the resource.

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# 1996 Ohio Water Resource Inventory Fact Sheet: Streams and Rivers Siltation & Habitat Destruction

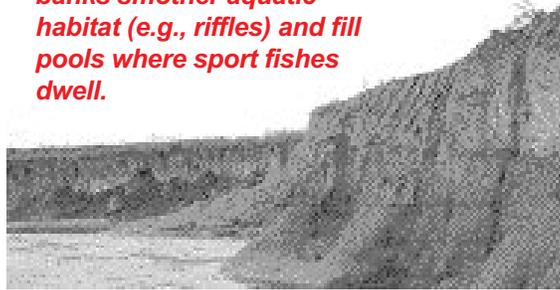


accelerate the rate of erosion into streams faster than the streams can export sediment downstream or expel it onto the floodplain. The impacts to aquatic life arise largely due to the smothering of living and spawning areas. Stream surveys on Ohio have documented the loss of sensitive aquatic species, including sport species such as smallmouth bass where siltation and sedimentation is high.<sup>1</sup>

Ohio's streams and rivers have seen a substantial improvement in their quality over the past 10-15 years generally a result of improvements in "point sources" of pollution across Ohio. As a result of this, much of the remaining impairment to aquatic life is the result of impacts that are termed "nonpoint" sources (see Fact Sheet FS\DSW-EAS-97-3). The leading nonpoint causes that impair aquatic life are siltation and habitat modification. The causes are the result of many different nonpoint sources, especially suburban and urban development, agriculture, and flood control.

*What Is "Siltation/Sedimentation?"*  
Siltation and sedimentation is the erosion of small particles of soil from the land surface or stream banks into the channel of a

**Sediments from eroding banks smother aquatic habitat (e.g., riffles) and fill pools where sport fishes dwell.**



stream or river. Erosion is a natural process, however, certain human activities can greatly

*What Is "Habitat?"*

Most aquatic species live in specific types of stream habitat. For example, sensitive species such as darters are typically found in riffles, while large predators (e.g., smallmouth bass) spend much time in pools or other deep areas (see photo in lower left hand corner of this

page). Most natural streams and rivers in Ohio have a diverse array of habitats characterized by a meandering form with numerous riffles, runs, pool, islands, gravel bars, backwaters, etc. In such natural streams that are not impacted by "point sources", stream surveys result in many species of fish (up to 40 or more) and macroinvertebrates (up to 100) in a single sample!

*Habitat and Siltation Impacts*  
Most habitat and sediment impacts result from direct modification to a stream or land uses that encroach on the riparian forests along a stream. The miles of aquatic life impairment caused by habitat modification, siltation and flow alteration are listed in

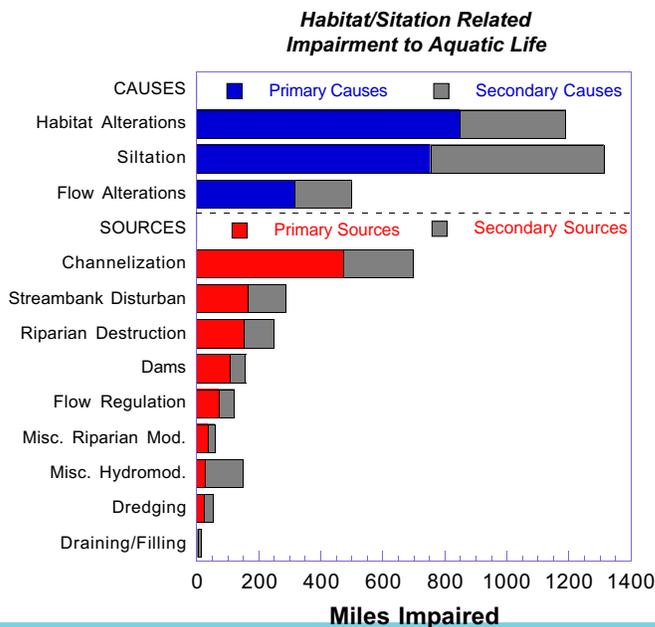


Stream Habitat Types



the top of the figure below. The origin of causes include activities such as agriculture, urban/sub-urban runoff, and development related construction. Situations where the the source of the impact is directly attributed to specific hydromofication activities are listed on the figure below.

Channelization of streams for agricultural drainage or flood control is the most frequent activity that degrades habitat (see photo right). The key for protecting and restoring aquatic habitat in Ohio is eliminating stream modifications where they are not absolutely needed and protecting stream riparian areas from encroachment or conversion to inappropriate land uses. It is the most serious type of impact because it is essentially irretrievable, especially for our highest quality streams (Exceptional Warmwater Habitat). ODNR has experience with habitat restoration and enhancement, through an understanding of the self-stabilizing tendencies of streams, that often can serve both the environment and the need to reduce erosion and costs associated with

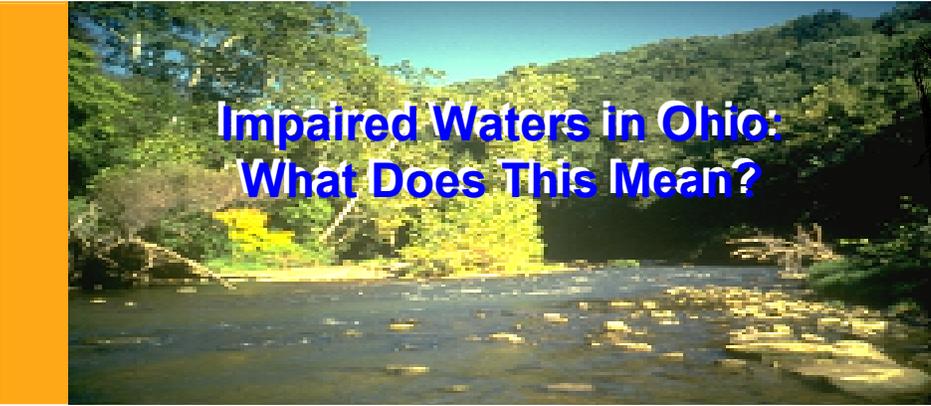


Sources of Impairment in Ohio's Rivers and Streams

maintaining streams in an "altered" condition. Those interested can contact the Division of Soil and Water or the Division of Wildlife at ODNR

The information illustrated in this fact sheet will be incorporated into the Ohio EPA strategic planning process. This process will direct future efforts (i.e., monitoring, assessment, education and regulation) to protect and restore the waters of Ohio in a cost-effective and scientifically sound manner. Protecting stream and riparian habitat in Ohio is a key to maintaining a quality of life that Ohioians expect into the next Century.

<sup>1</sup>Source: Ohio WATER Resource Inventory: 1996. Ohio EPA, Division of Surface Water, 1800 WaterMark Drive, Cols., Ohio 43216



## Impaired Waters in Ohio: What Does This Mean?

Positive progress has been made in improving the quality of Ohio rivers and streams. More river and stream miles meet water quality standards today (49.3%) than eight years ago (34%). This improvement is largely due to the effectiveness of efforts in reducing point sources of chemical pollution. While this progress is encouraging, one-half of river and stream miles do not meet standards. However, this does not mean that 50% of our streams and rivers are "unsafe" or "dead". It is the purpose of this fact sheet to explain what these facts really mean.

Ohio EPA devotes considerable resources to the monitoring of surface water resources such as streams, rivers, lakes, and wetlands. A systematic framework termed the Five-Year Basin Approach is used. Our goal is to intensively monitor all major watersheds on a rotating cycle of 5-10 years. This includes most of our major rivers, streams, and lakes. By emphasizing biological indicators, such as the fish and invertebrate communities found in streams and rivers, a comprehensive and long term assessment of water resource quality is gained. Aquatic animals are the most consistent and sensitive indicators of environmental quality because they inhabit the water all of the time and respond to all impacts, both

chemical and physical. Healthy and flourishing biological communities are also a good indicator that high quality recreational opportunities (e.g., fishing and other outdoor-related activities) are available. By focusing our protection efforts on aquatic life many other important uses (i.e., water supply, recreation) are also covered.

Compared to some States, Ohio uses a comparatively sophisticated and scientifically robust system to determine if rivers and streams meet standards. Because of the variability among States in how this is determined, the information reported nationally by U.S. EPA frequently results in statistics that appear "better" than Ohio's. This problem is discussed in detail in the 1996 Ohio Water Resource Inventory, Executive Summary. Recently, U.S. EPA has followed Ohio EPA's lead by developing new guidelines for States to follow. The goal of this effort is to have more comparable and reliable statistics reported by all States in the future.

Ohio EPA uses biological criteria to rate the quality of our waters. These criteria are used to determine the degree to which standards are exceeded, met, or missed. For communication purposes a rating system has been established. **Exceptional** is the highest quality rating. This rat-



ing is given to those sites with the highest species diversity and frequently includes populations of rare, threatened, or endangered species. These waters also support the best sport fisheries. **Good** is assigned to sites with a diversity and quality of aquatic species typical of reference streams and rivers. This varies by ecoregion of which Ohio has five. Streams and rivers that do not meet these standards are considered impaired and are placed into one of two categories, partial attainment and non-attainment. An impaired condition does not mean that the stream or river is "dead" or "unsafe", but rather represents varying degrees of unacceptable condition.

Just as exceptional and good are used to indicate the degree to which Ohio's standards are met or exceeded, three additional ratings are used to indicate the degree to which these standards are missed. **Fair** means that certain characteristics are missing which reflect an "imbalance" in the aquatic community. While many fish, invertebrates, and other forms of aquatic life are generally present, overall diversity is in decline, and species tolerant to nutrients, habitat destruction, and low levels of dissolved oxygen predominate. Placement in the fair category does not mean that the water is unsafe or recreational opportunities do not exist. However, the quality of such opportunities is diminished compared to exceptional and good. **Poor** means that desirable attributes are altogether absent and environmental conditions have wors-

ened. Toxic effects are more prevalent and include declines in species diversity, fewer and smaller fish, fewer invertebrates, and a higher rate of anomalies (lesions, eroded fins, tumors, deformities) on fish. **Very poor** means that environmental conditions have worsened further and that extreme reductions in diversity and abundance have occurred. Other symptoms may include acutely toxic levels of chemicals, complete destruction of habitat, and generally unsafe conditions. Waters rated as **poor** and **very poor** are likely not to support uses important to Ohioans and some of the problems may pose serious health risks.

Nearly one-half (49.3%) of Ohio rivers and streams exhibit **good** or **exceptional** quality. This means that biological communities like those found at background reference sites occur. As such, these waters are also likely to support many other uses important to Ohioans. Partial attainment means that at least one of the biological indicators (fish or invertebrates) exhibits only **fair** quality. In such cases certain sensitive species may be absent or there are too many pollution tolerant species (e.g., carp). Non-attainment means that *all* of the biological indicators are no better than **fair** or one or both groups exhibit **poor** or **very poor** quality. As illustrated by Figure 1, 23.3% of river and stream miles are in partial attainment and 27.7% in non-attainment. When these two categories were separated by major causes of impairment, the partial category (which corresponds to fair quality) was mostly affected by habitat (49.5%) and nutrient enrichment (41.1%), with only a minor fraction (9.4%) caused by toxic pollutants. Non-attainment (which corresponds mostly to poor and very poor

quality) was also predominated by habitat (48.6%) and nutrient enrichment (25.8%), but toxic pollution was a larger contributor (25.5%). The presence of toxic pollution as a major cause is an indication that these waters are less safe for other uses than are those affected by habitat and nutrient enrichment. Based on these statistics less than one-tenth (9.2%) of Ohio's rivers and streams are seriously impaired by toxics.

The protection and restoration of aquatic ecosystem quality using

evidence that we are attempting to use areas that are more susceptible to flood damage. The degradation of habitat in small, headwater streams makes water quality less suitable for "downstream" uses (e.g., drinking water) and contributes to increased flooding. Thus, a failure to meet aquatic life standards suggests that we may experience "environmental infrastructure" problems in the future.

#### Human Health Risks

Our assessments include two other indicators that relate di-

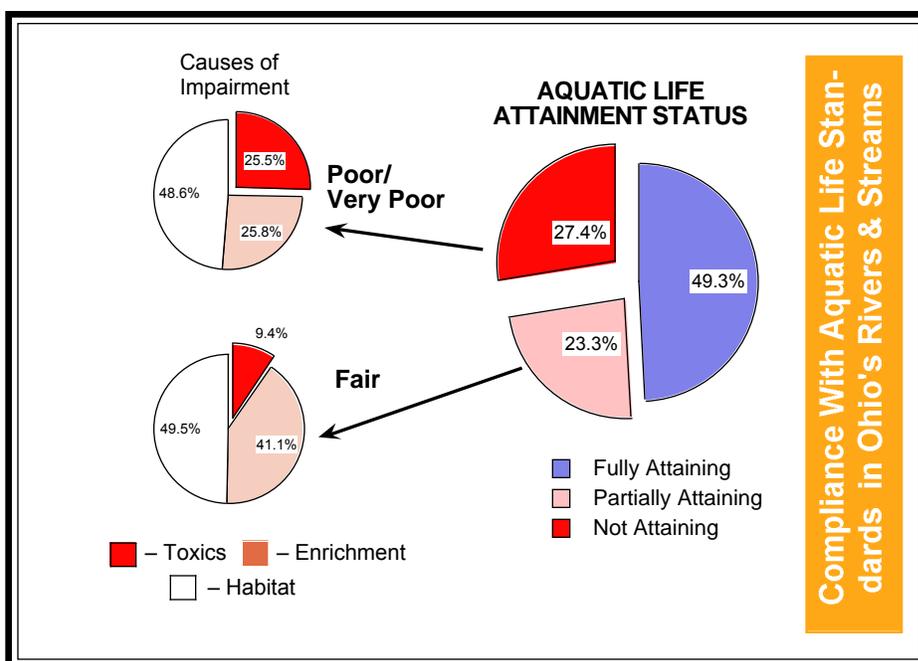


Figure 1. Percentage of river and stream miles that fully, partially, or do not attain Ohio standards for aquatic life (right) with the major causes of impairment (toxics, habitat, nutrient enrichment) listed for the partial (lower left) and non-attainment categories (upper left).

Ohio's biological standards has both realized and potential benefits for Ohio. The long-term recreational and economic quality of our waters is strongly linked to that required by aquatic life. For example, the failure to meet these standards due to excessive nutrients and sediment from runoff is frequently correlated with the unacceptable loss of our soil resources via erosion. Habitat destruction such as the clear-cutting of trees along streams is

directly to human health, fecal bacteria and toxic chemicals in fish tissue. More than one-half (56.9%) of Ohio's rivers and streams are free from bacterial contamination. The remaining waters (43.1%) show levels that indicate varying degrees of risk for human uses such as swimming, canoeing, boating, and wading. The period of greatest risk is usually immediately following rainfall and increased runoff. Bacteria contamination usually reaches streams and rivers via

storm sewers or combined sewer overflows, the effluent of which may contain diluted raw sewage. This problem occurs mainly in the larger urban areas of Ohio, there may be similar problems in unsewered communities. Bacterial contamination can also affect inland lakes and Lake Erie. If public beaches are present, advisories are posted by the Ohio Department of Health when bacterial levels exceed safe thresholds.

Data on the levels of chemicals in fish tissue are used to establish consumption advisories. The monitoring program was expanded in 1993 to include nearly 300 sites sampled each year. In addition, new criteria for consumption advisories recently became available. Four advisory levels establish restrictions on fish consumption as follows: 1) one meal a week, 2) one meal per month, 3) six meals per year, and 4) do not eat. These are based on the levels of certain chemicals (e.g., PCBs, mercury) found in fish with the advisory becoming more restrictive at higher levels. The Ohio Department of Health recently released updated advisories based on the data collected since 1993. Advisories for frequencies of less than once per week were listed for 23 Ohio streams, rivers, and lakes. All of the advisories are specific to individual fish species. For example, the consumption of channel catfish may be restricted to one meal per month in a given water, but all other species may have no or lesser restrictions. A statewide advisory for mercury of one meal per week applies to the more sensitive parts of the human population such as women of child-bearing age and young children. Outside of this precautionary statewide advisory for mercury, 18.4% of the stream and river miles monitored had highly or extremely elevated lev-

els of chemicals (one meal per week or six meals per year) for at least one fish species; only 3.8% have a consumption advisory that extends to all species.

Furthermore, these problems tend to be concentrated in the larger urban areas (Figure 2) and are frequently the result of past activities which occurred prior to

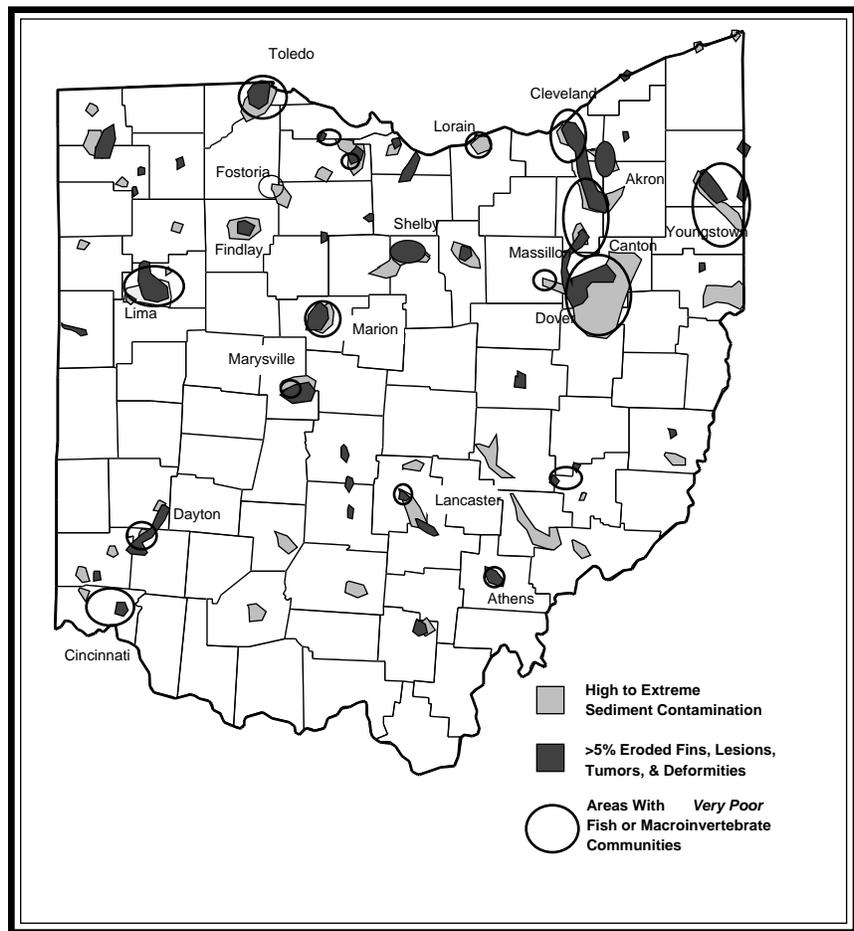


Figure 2. Areas of Ohio with high to extreme sediment contamination, elevated levels of anomalies on fish, and very poor biological communities. The occurrence of two or more generally indicates toxic pollution and an increased risk to human health.

#### Are Ohio's Waters Safe?

Based on the information available to Ohio EPA, the majority of our rivers and streams are safe for activities such as fishing, boating, canoeing, swimming, and wading, even though not all meet standards. However, in a small proportion of rivers and streams, activities such as swimming and eating fish should be restricted to varying degrees. The greatest risks will occur in waters where severe toxic effects are evident (Figure 2). This includes less than 10% of Ohio's river and stream miles.

recent environmental regulations. Remediating these problems presents a significant challenge. More detailed information about these and other problems is described in the 1996 Ohio Water Resource Inventory, Volume I and other Ohio EPA publications.

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## Fact Sheet

### An Evaluation of Spatial Monitoring & Assessment Design: Preliminary Results from the E. Corn Belt Plains REMAP Project

Ohio EPA employs a targeted, synoptic watershed design for monitoring the chemical, physical, and biological water quality of the State's rivers and streams. This approach is implemented through the Five-Year Basin Approach and is targeted to assess all water quality issues within each targeted watershed or study area. A criticism of this approach is that it may produce biased assessments of the spatial extent of water quality

conditions. Furthermore, there is a perception that the five-year basin



design inherently targets waters where problems are either suspected or known to exist with a further bias towards point sources of pollution. As such, the aggregated results of the Ohio EPA basin surveys may not truly represent the spatial extent of water quality conditions across Ohio. It is further presumed that the aggregate condition of Ohio's waters are better than that reported in the biennial Ohio Water Resource Inventory (305b report).

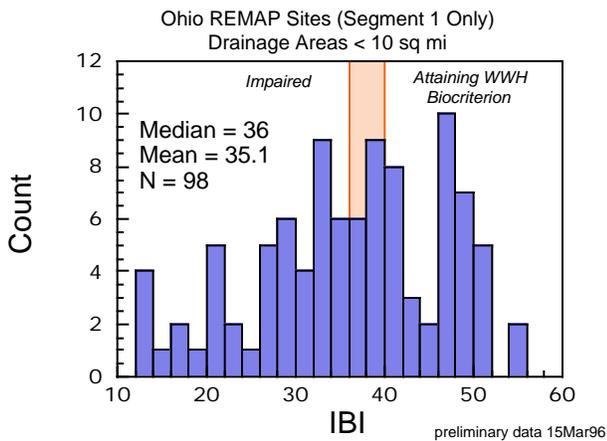


Figure P-1. Frequency histogram of IBI scores from 98 REMAP stations in Ohio with drainage areas < 10 sq mi. Samples collected from June-October 1995.

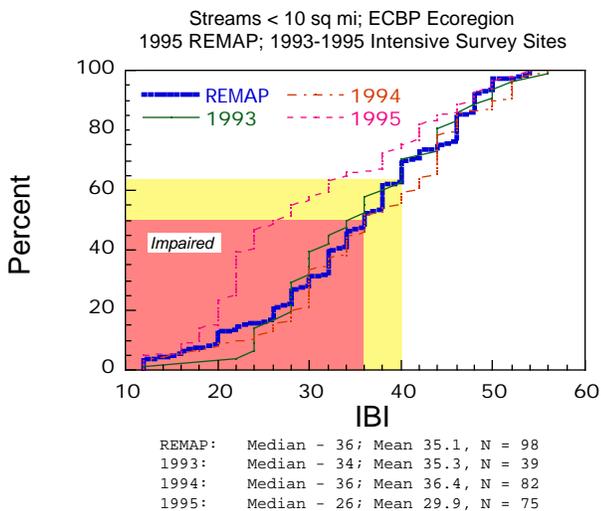


Figure P-2. Cumulative frequency histogram of IBI scores from REMAP stations in the ECBP ecoregion of Ohio during 1995 and intensive survey sites from the same ecoregion in 1993, 1994, and 1995. All sites had drainage areas < 10 sq mi.

Recently, U. S. EPA, Region V, and the States of Ohio, Indiana, and Michigan collaborated on a project that was designed to provide a spatially unbiased estimate of aquatic life conditions in the small streams of the Eastern Corn Belt ecoregion within each of these three states (REMAP - Regional Environmental Monitoring and Assessment Program). The estimates of stream quality resulting from this effort are considered to be unbiased because sampling sites were selected using a probabilistic (*i.e.*, random) design. Fish communities (Index of Biotic Integrity, etc.), habitat quality (QHEI), and basic chemical/physical field parameters were collected at each site one time during the period July-early October, 1995.

The Ohio EPA has intensively sampled the State's rivers and streams since the late 1970s and, as such, has developed an extensive database consisting of more than 5,000 sampling sites. Of the river and stream sizes included in this database, small

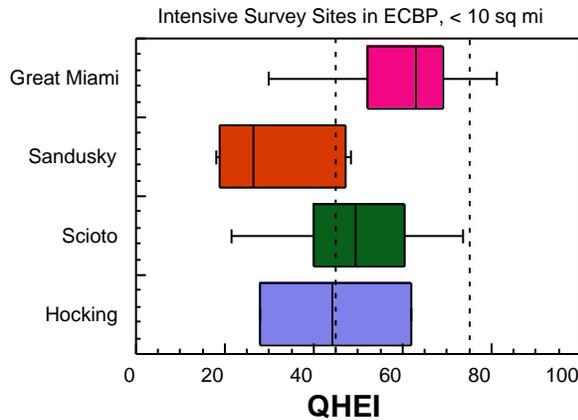


Figure P-2. Cumulative frequency histogram of IBI scores from REMAP stations in the ECBP ecoregion of Ohio during 1995 and intensive survey sites from the same ecoregion in 1993, 1994, and 1995. All sites had drainage areas < 10 sq mi.

streams draining less than 10-20 square miles represent the least sampled in terms of the proportion of stream miles assessed. Approximately 10-15% of the small stream miles have been assessed over this time period compared to more than 50% of streams and rivers draining more than 50 square miles and nearly 100% of those draining more than 1000 square miles. The ECBP REMAP project presented a good opportunity to compare the results of two different spatial sampling designs. This fact sheet is a summary of some preliminary findings for Ohio streams draining less than 10 square miles and to address questions of potential bias in our basin survey data (i.e., how different are synoptic vs. probability

estimates of aquatic life condition).

The distribution of IBI scores from the 98 REMAP sites located in Ohio are illustrated in Figure P-1. The median IBI score for these sites was 36 (i.e., the minimum IBI score considered to attain the Warmwater Habitat use designation) which means that 50 percent of the sites are impaired. The distribution also shows a skewness towards lower IBI scores (Figure P-1). This estimate of the

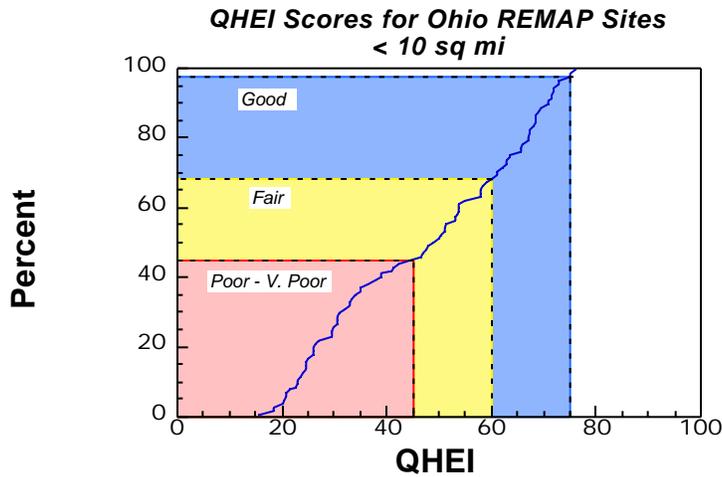


Figure P-4. Cumulative frequency histogram of QHEI scores from REMAP stations in the ECBP ecoregion of Ohio during 1995. All sites had drainage areas < 10 sq mi.

proportion of impaired small streams agrees well with the statewide basin survey estimate of stream quality in both the 1994 and 1996 305b assessment cycles for small ECBP ecoregion streams with drainage areas < 10 square miles (50% impaired based on 85.2 miles assessed). Thus the unbiased REMAP design and the spatially biased basin survey designs produced similar estimates of the proportion of impaired small streams in the Ohio portion of the ECBP ecoregion.

A more direct comparison was made by comparing all IBI scores from the

ECBP ecoregion for small streams, by basin survey year, as a cumulative frequency distribution versus the 1995 REMAP results (Figure P-2). The REMAP results were not appreciably different from the basin survey IBI scores in 1993 or 1994, but were different from the 1995 results. The 1995 results were most from the "Clayey, High Lime Till Plains" subregion of the ECBP ecoregion which is characterized by extensive channel modification and impacts from row crop agriculture. The poorer habitat quality of these sites was largely responsible for the much lower median IBI

scores in 1995 (Figure P-3). The highest IBI scores were from the comparatively higher quality Twin Creek subbasin. Thus for any given basin year there can be some differences in aggregated use attainment estimates between a randomized and targeted basin survey design. However, when averaged over multiple years the estimates produced by either design were in much closer agreement. Furthermore, these results indicate that the basin survey design employed by Ohio EPA produces an essentially unbiased estimate of small stream quality. The major difference between the REMAP and basin survey design is that the former requires one year to produce a reliable estimate whereas the latter appears to require 4-5 years.

The Ohio EPA basin survey results have increasingly highlighted habitat degradation and sedimentation as major causes of impairment to aquatic life in Ohio's streams. Habitat data (QHEI scores) were collected during the REMAP project, thus an estimate of the extent of habitat degradation can be obtained. Previous work has shown a strong relationship between the condition of fish communities (*i.e.*, IBI scores) and habitat quality in Ohio as measured by the QHEI (Rankin 1995). The 1996 Ohio Water Resource Inventory (305b report) identified habitat degradation and sedimentation as the second and third leading causes of impairment, respectively, statewide. The REMAP data indicated that 45% of the sampling sites had poor or very poor habitat quality and that less than 35% had what is considered to be good quality habitat. This, too, is confirmation of the prevalence of habitat degradation as a major cause of impairment of small streams in Ohio.



**The aquatic life in a stream is a sensitive measure of the overall quality of the resource**

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## Fact Sheet

## Associations Between the Index of Biotic Integrity and Unionized Ammonia in Ohio Rivers and Streams: A Preliminary Analysis

The main purpose of an aquatic life-based chemical criterion is to protect the aquatic life of a stream, river, or lake in accordance with the goal of the designated use. Biocriteria are a direct measure of the aquatic community and as such represent a direct measure of designated aquatic life use attainment status. Having biocriteria provides the Ohio EPA with a unique method to examine whether existing and proposed chemical criteria are over or under-protective of designated aquatic life uses. Previous studies have attempted to evaluate chemical water quality criteria for certain parameters, such as heavy metals, by comparing instream concentrations with different measures of aquatic community health and well-being. However, no study yet has utilized a fully calibrated and standardized system of biological criteria and a statewide chemical water quality and biological database for this purpose.

Many studies have shown the toxic effects of unionized ammonia on aquatic macroinvertebrates and fish. In many instances in Ohio, negative effects to aquatic life have been strongly associated with exceedances of the Ohio EPA water quality criteria for unionized ammonia. Reductions in loadings of ammonia discharged from point sources has been observed throughout Ohio to be a key in the recovery of previously impaired aquatic life uses. While ammonia was a major cause of impairment in more than 1100 miles of rivers and streams in the 1988 Ohio Water Resource Inventory (305[b] report), this figure had shrunk to 150 miles by 1996.

The purpose of this fact sheet is to examine the association between one of the biological indices which comprises the Ohio EPA biological criteria, the IBI, and unionized ammonia to determine above which ammonia concentrations is aquatic life at risk. A scatter plot of unionized ammonia based on grab samples collected from Ohio rivers and streams versus the IBI yields a "wedge" of data points (Figure 1). The outer, sloped surface of points approximates the maximum concentrations that have been observed to coincide with a given level of aquatic community performance as portrayed by the IBI. A line drawn on the outer surface of the data points so that 95% of the points fall to the left or beneath the line is referred to as the "95% line of best fit. In the IBI and unionized ammonia example this represents the typically occurring maximum unionized ammonia concentrations at which a corresponding IBI value exists in the statewide database. Chi-square tests of independence were used to test whether or not the occurrence of IBI scores are independent of unionized ammonia concentrations at the same sites. If the IBI is independent of the ammonia concentrations, then we can conclude that ambient concentrations of ammonia are not strongly affecting the IBI or the relationship is obscured by other environmental factors. If however, IBI and ammonia are statistically correlated, further analysis to determine the concentrations of unionized ammonia at which a reasonable risk of harm to aquatic life exists should take place.

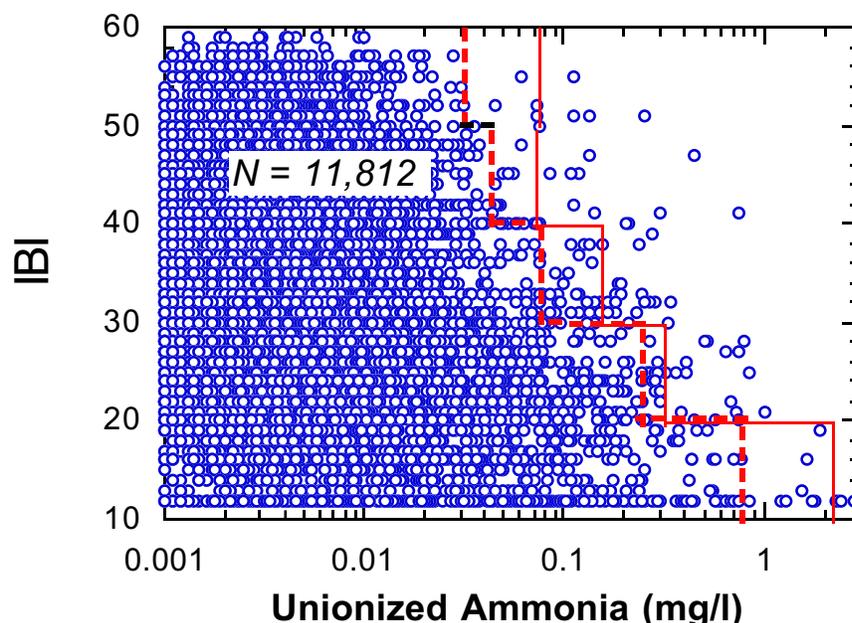


Figure 1. The IBI versus unionized ammonia from streams and rivers monitored by Ohio EPA between 1982 and 1994.

An alternative to generating a "continuous" 95th percentile regression line is to focus more on identifying outliers and extreme values (extreme percentiles) that represent an unacceptable risk to aquatic life. The method to identify outliers and extremes in the data is to cluster the distribution of the independent variable by ranges of IBI scores that correspond to narrative ratings of quality (*e.g.*, exceptional, good, fair, poor, very poor) and the tiered system of aquatic life use designations employed by Ohio EPA. The upper tenth percentile of the parameter concentration in each IBI category is used to identify the outliers and extremes in each distribution because the biological results at these sites are most likely affected by concentrations of that parameter. Box-and-whisker plots and percentile plots are then used to illustrate the

Table 1. Chi-square test of association between the IBI and un-ionized ammonia based on data collected in Ohio streams between 1982 and 1994 showing actual and expected (in parentheses) observations.

IBI Range	Un-Ionized Ammonia (mg/l)				
	<0.01	0.01-0.05	0.05-0.10	0.10-0.50	> 0.5
50-60	944 (815)	60 (148)	4 (22)	4 (23)	0 (3.3)
40-49	2464 (2203)	251 (401)	12 (61)	9 (63)	1 (9.0)
30-39	2912 (2765)	449 (504)	38 (76)	36 (79)	0 (11.3)
20-29	2377 (2583)	609 (471)	108 (71)	105 (73)	10 (10.6)
12-19	812 (1142)	363 (208)	100 (31)	116 (32)	28 (4.7)

$\chi^2 = 1135; P < 0.0001$

Table 2 can be used in a risk management approach for establishing water quality criteria, NPDES permit limits, or other water quality management objectives. Water quality criteria which result in ambient unionized ammonia concentrations in the range of the maximum value, excluding outliers (upper whisker on the plot), and the 99.5th percentile values would be considered to pose an unacceptably high risk to aquatic life and, thus, a lower value should be chosen.

The scatterplot of unionized ammo-

upper, empirically observed values for the independent variable compared to the narrative ranges of the IBI. Outliers in the data are those points that are greater than the upper quartile (UQ: 75th percentile) plus 1.5 times the interquartile range (distance between the 25th and 75th percentiles: UQ - LQ). The other statistic used to describe extreme values is the 99.5th percentile of all the data in an IBI category (illustrated as the 95th percentile of the upper 10 percent of the data in Figure 2). Where such data is strongly skewed the 99.5th percentile can be greater than the "maximum" value where outliers are excluded.

The ranges described above and illustrated in Figure 1 and

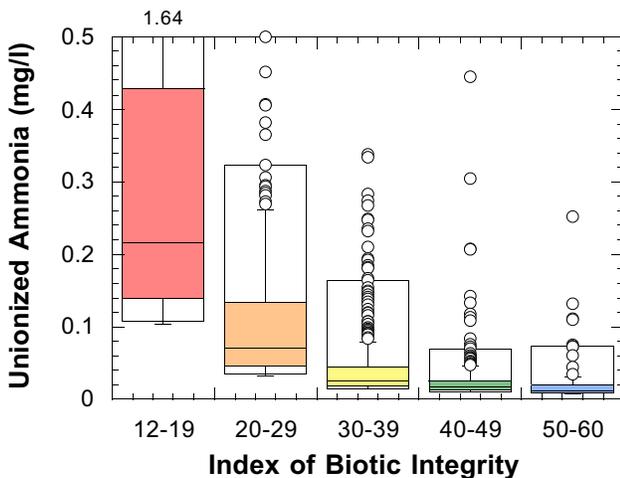


Figure 2. Box-and-whisker and percentile plot of the IBI versus unionized ammonia from streams and rivers monitored by Ohio EPA between 1982 and 1994. Data represent the upper ten percent of the unionized ammonia values within each IBI range. Shaded boxes represent the 25th, median, and 75th percentiles; open boxes the 5th and 95th percentiles; whiskers are the maximum and minimum values excluding outliers which are values greater than the upper (or lower) quartile plus (or minus) 1.5 times the interquartile range.

Table 2. Maximum unionized ammonia concentrations (excluding outliers) and 99.5th percentile unionized ammonia values by IBI narrative ranges and corresponding aquatic life uses.

Narrative Range	IBI Range	99.5th %tile Un-ionized Ammonia	Max. Un-ionized Ammonia
Exceptional (EWH)	50-60	0.073	0.031
Good (WWH <sup>1</sup> )	40-49	0.070	0.045
Fair (WWH <sup>2</sup> )	30-39	0.162	0.080
Poor (MWH)	20-29	0.321	0.262

1 excluding the Huron/Erie Lake Plain (HELP) ecoregion.  
2 applies only within the HELP ecoregion.

nia showed a well defined outer boundary of data points which suggests a strong association with the IBI. The chi-square analysis confirms this association as highly significant (Table 1). There were fewer sites that had IBI values >40 (good or WWH) and unionized ammonia concentrations >0.05 than expected (if there were no association) and more sites with low IBI values <30 (fair, reflects impairment) and unionized ammonia concentrations >0.05 than expected. The values listed in Table 2 can be used to validate water quality criteria derived by the traditional toxicological approaches. Tiered water quality criteria which correspond to the aquatic life uses developed by Ohio EPA have already been established. Other uses of the results presented here could include site-specific applications of the ammonia criteria in combination with the biological criteria. This would be most applicable where instream concentrations exceed the values in Table 2.

## Fact Sheet

### Associations Between the Index of Biotic Integrity and Total Ammonia-Nitrogen in Ohio Rivers and Streams: A Preliminary Analysis

The main purpose of an aquatic life-based chemical criterion is to protect the aquatic life of a water body in accordance with the goals and objectives of the designated use. Biological criteria are based on measurable attributes of an aquatic community and as such represent a direct measure of designated aquatic life use attainment status. Having biological criteria provides the Ohio EPA with a unique method to examine whether existing and proposed chemical criteria are potentially over or under-protective of designated aquatic life uses. Previous studies have attempted to evaluate chemical water quality criteria for selected parameters, such as heavy metals, by comparing instream concentrations with different measures of aquatic community health and well-being. However, no study yet has utilized a fully calibrated and standardized system of biological criteria and a paired, statewide chemical water quality and biological database for this purpose. This fact sheet describes the observed relationship between a measure of the health and well-being of stream and riverine fish assemblages and total ammonia-nitrogen (N) concentrations based on data collected between 1982 and 1992 throughout Ohio. This parallels a similar analysis conducted for unionized ammonia-N.

The toxic effects of unionized ammonia-N on aquatic macroinvertebrates and fish are well known. In many instances in Ohio, negative effects to aquatic life have been strongly associated with exceedences of the unionized ammonia-N water quality criterion. Recently, reductions in loadings of

total ammonia-N discharged by point sources has been associated with the restoration of previously impaired aquatic life uses in a number of Ohio rivers and streams (Ohio EPA 1997). While ammonia was a major associated cause of impairment in more than 1100 miles (23.9%) of assessed rivers and streams in the 1988 Ohio Water Resource Inventory (305[b] report), this had shrunk to 150 miles (4.5%) by 1996. While the principal deleterious effect of unionized ammonia on fish is toxic, the effect of total ammonia-N on aquatic life reflects both the toxic effects of the unionized fraction of the ammonium ion and the enrichment effect as total ammonia is converted to nitrate. We examined the association between one of the biological indices which comprises the Ohio EPA biological criteria, the Index of Biotic Integrity (IBI), and total ammonia-N to determine whether any relationship is evident. We also examined for the same between total ammonia-N and the number of sensitive fish species. The total ammonia-N data was collected primarily during the summer and early fall months (June - early October), thus the results are most applicable to this time period. Even though the influence of winter ammonia-N levels is implicitly addressed by the biological assessment data, safe levels of winter ammonia-N cannot be derived from this database.

A scatter plot of total ammonia-N based on grab samples collected from Ohio rivers and streams versus the IBI yields a "wedge" of data points (Figure 1) similar in shape to that previously observed for unionized ammonia-N. The outer

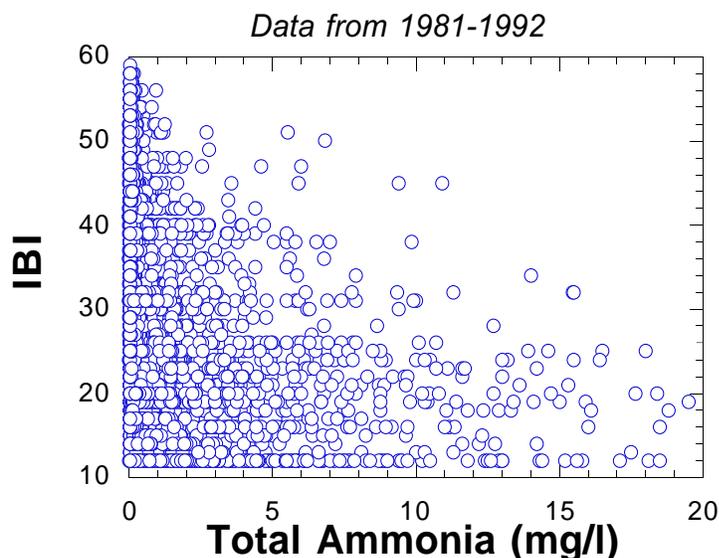


Figure 1. The IBI versus total ammonia-N from streams and rivers monitored by Ohio EPA between 1982 and 1992.

sloped surface of points approximates the maximum concentrations that have been observed to coincide with a given level of aquatic community performance as portrayed by the IBI. A line drawn on the outer surface of the data points so that 95% of the points fall to the left or beneath the line is referred to as the "95% line of best fit". In the IBI vs. total ammonia-N example this represents the typically occurring maximum ammonia concentrations at which a corresponding IBI value exists in the statewide database. Chi-square tests of independence were used to test whether or not the occurrence of IBI scores are independent of total ammonia-N concentrations at the same sites. If the IBI is independent of the total ammonia-N concentrations, then we can conclude that ambient concentrations of ammonia are not significantly affecting the

Table 1. Chi-square test of association between the IBI and total ammonia based on data collected in Ohio streams between 1982 and 1992 showing actual and expected (in parentheses) observations.

IBI Range	Total Ammonia (mg/l)					
	≤ 1.0	1.1-2.0	2.1-5.0	5.0-10.0	10.0-15.0	> 15.0
50-60	790 (705)	230 (89)	1 (34.6)	2 (13.3)	0 (4.1)	0 (3.0)
40-49	2671 (2416)	207 (172)	19 (119)	3 (45.6)	1 (14.1)	0 (10.1)
30-39	3118 (3933)	103 (156)	65 (144)	27 (55.4)	3 (17.1)	2 (12.3)
20-29	3162 (3233)	609 (471)	187 (159)	71 (61)	22 (18.9)	9 (13.6)
12-19	1217 (1671)	363 (208)	267 (82)	104 (31.6)	38 (9.8)	35 (7.0)

$\chi^2 = \text{????}; P < 0.0001$

outliers and extremes in the data is to cluster the distribution of the independent variable (total ammonia-N) by ranges of IBI scores that correspond to narrative ratings of quality (e.g., exceptional, good, fair, poor, very poor) and the tiered system of aquatic life use designations currently employed by Ohio EPA. The upper tenth percentile of the parameter concentration in each IBI range was used to identify the outliers and extremes in each distribution. Box-and-whisker plots and percentile plots were used to illustrate the upper, empirically ob-

IBI or the relationship is obscured by other environmental factors (e.g., proportion of total ammonia that is unionized). If, however, IBI and total ammonia-N are statistically correlated, further analysis to determine the concentrations of total ammonia-N at which a reasonable risk of harm to aquatic life can exist should take place. This does not necessarily indicate direct causality, but rather these relationships can be used to estimate "concentrations of concern".

An alternative to generating a continuous 95th percentile regression line is to focus more on identifying outliers and extreme values (extreme percentiles) that clearly represent an unacceptable risk to aquatic life. The method to identify

Table 2. Maximum total ammonia (mg/l) concentrations (excluding outliers) and 99.5th percentile unionized ammonia values by IBI narrative ranges and corresponding aquatic life uses.

Narrative Range	IBI Range	99.5th %tile Total Ammonia	Max. Total Ammonia
Exceptional (EWH)	50-60	1.24	0.87
Good (WWH <sup>1</sup> )	40-49	2.8	2.04
Fair (WWH <sup>2</sup> )	30-39	6.9	4.8
Poor (MWH)	20-29	12.7	10.8

1 excluding the Huron/Erie Lake Plain (HELP) ecoregion.  
2 applies only within the HELP ecoregion.

served values for the independent variable compared to the five narrative ranges of the IBI. Outliers in the data are statistically defined as those points that are greater than the upper quartile (UQ: 75th percentile) plus 1.5 times the interquartile range (distance between the 25th and 75th percentiles: UQ - LQ). The other statistic used to describe extreme values is the 99.5th percentile of all the data in an IBI category (illustrated as the 95th percentile of the upper 10 percent of the points in Figure 2). Where such data is strongly skewed, the 99.5th percentile can be greater than the "maximum" value where outliers are excluded.

The ranges described above and illustrated in Figure 1 and Table 2 can be used in a risk management approach for establishing and modifying water quality criteria, NPDES permit limits, and for other water quality management objectives. Water quality criteria which result in ambient total

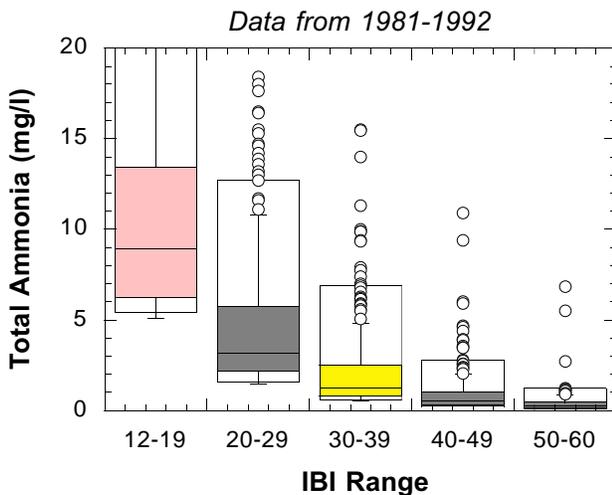


Figure 2. Box-and-whisker and percentile plot of the IBI versus total ammonia (mg/l) from streams and rivers monitored by Ohio EPA between 1982 and 1992. Data represent the upper ten percent of the unionized ammonia values within each IBI range. Shaded boxes represent the 25th, median, and 75th percentiles; open boxes the 5th and 95th percentiles; whiskers are the maximum and minimum values excluding outliers which are values greater than the upper (or lower) quartile plus (or minus) 1.5 times the interquartile range.

ammonia-N concentrations in the range of the maximum value, excluding outliers (upper whisker of the box-and whisker plots), and the 99.5th percentile values would be considered to pose an unacceptable risk to aquatic life.

The scatterplot of total ammonia-N showed a well defined outer boundary of data points which suggests a strong association with the IBI. The chi-square analysis confirmed this association as being highly significant (Table 1). There were fewer sites that had IBI values >40 (good - meets the WWH use) and total ammonia-N concentrations >1.0 mg/l, than what would have been expected if there were no significant relationship. Conversely, there were more sites with IBI values <30 (poor - reflects impairment of the WWH use) and total ammonia-N concentrations >1.0 mg/l than what would have been expected if there were no significant relationship. The values listed in Table 2 can be used to ground truth water quality criteria derived by the more traditional toxicological approaches. Tiered water quality criteria, which correspond to the aquatic life uses developed by Ohio EPA, have already been estab-

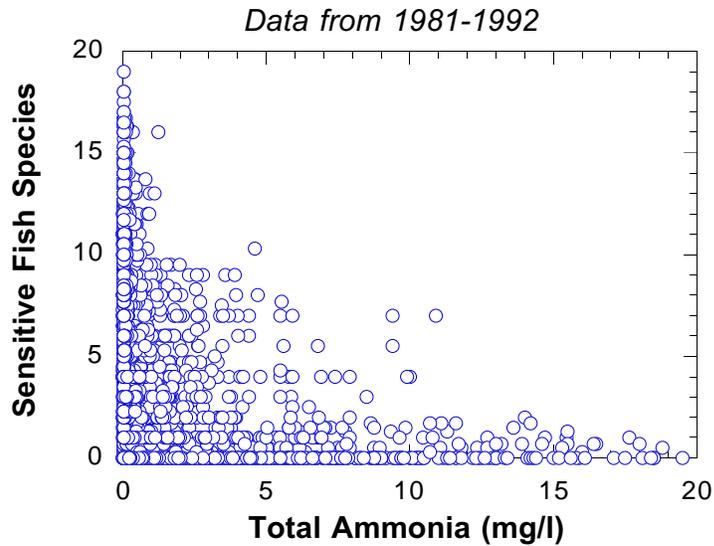


Figure 3. The number of sensitive fish species versus total ammonia from streams and rivers monitored by Ohio EPA between 1982 and 1992.

lished for ammonia-N. Another use of the results presented here would include validating site-specific applications or modifications of the ammonia-N criteria.

Figure 3 illustrates the relationship between the number of sensitive fish species and total ammonia-N. The distinct decline in the number of sensitive species along an increasing continuum of total ammonia-N (especially >10 sensitive species) reflects the level of sensitivity of the Ohio's highest quality waters. The fish species in these streams and rivers are sensitive not only to toxic effects of ammonia, but also to more subtle shifts in the trophic dynamics of these ecosystems caused by increasing nutrient enrichment. Rivers and streams with more than 10 sensitive fish species usually have total ammonia-N concentrations less than 1.0 mg/l.

# Demonstrating Linkages Between Indicators: Scioto River Case Study

## ADMINISTRATIVE INDICATORS

**LEVEL 1:**  
Ohio EPA issues WQ based permits & awards funds for Columbus WWTPs

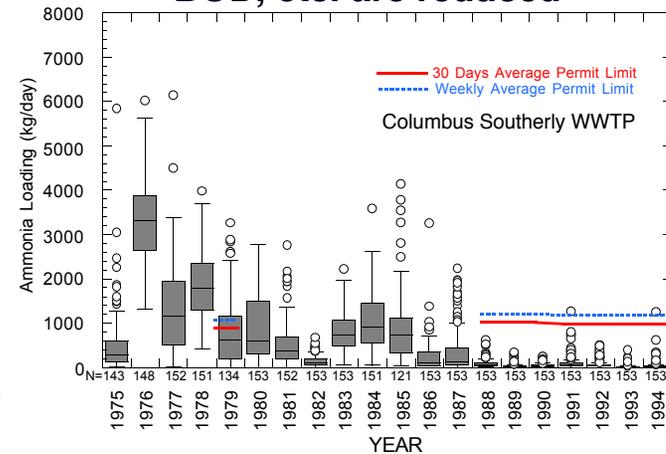


**LEVEL 2:**  
Columbus constructs AWT by July 1, 1988; permit conditions attained

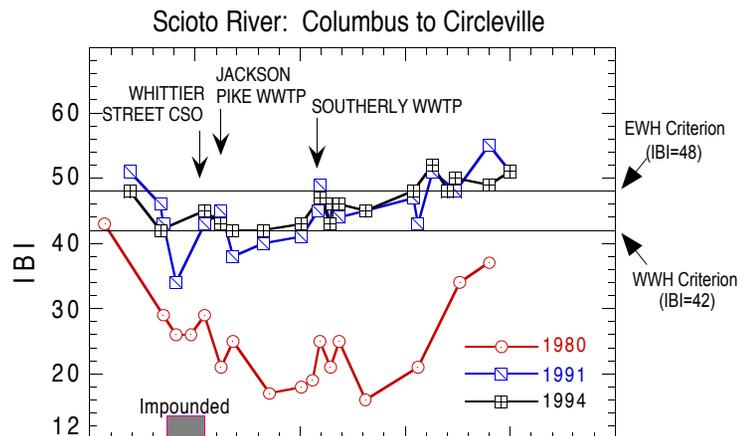


## STRESSORS

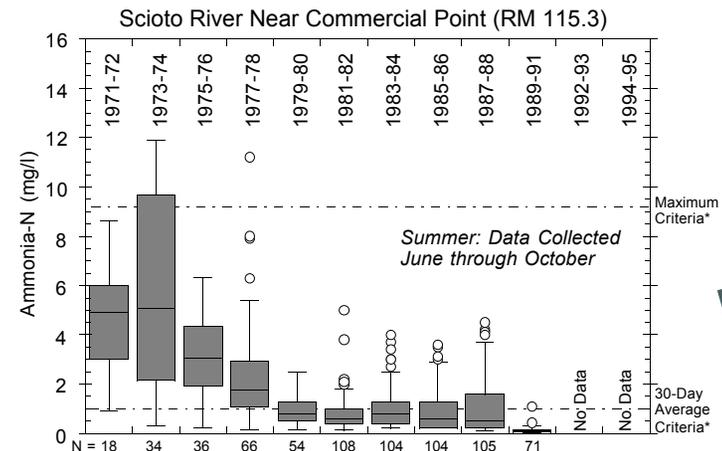
**LEVEL 3:** Loadings of ammonia, BOD, etc. are reduced



**LEVEL 6:** Biological recovery evidenced in biocriteria; 3 yrs. post AWT



**LEVELS 4&5:** Reduced instream pollutant levels; enhanced assimilation



## RESPONSE

## EXPOSURE

# Demonstrating Linkages Between Indicators: Ottawa River Case Study

## ADMINISTRATIVE INDICATORS

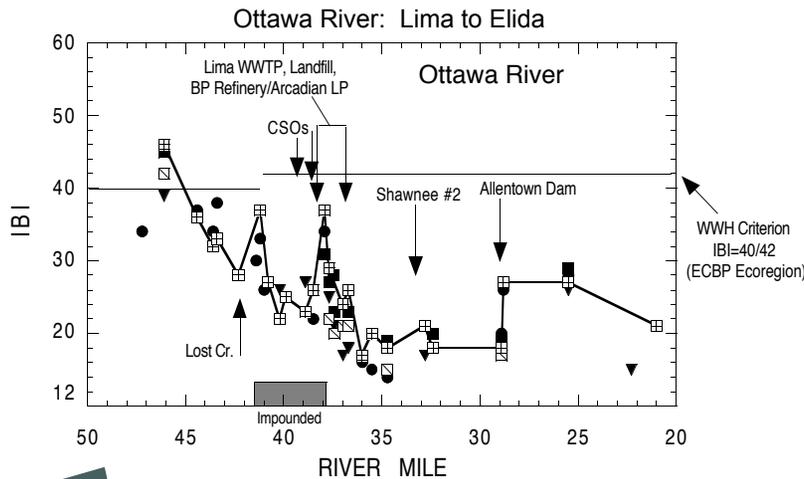
**LEVEL 1:**  
Ohio EPA issues WQ based permits & awards funds for the Lima WWTP



**LEVEL 2:**  
Lima constructs AWT by mid 1980s; permit conditions attained by 1990



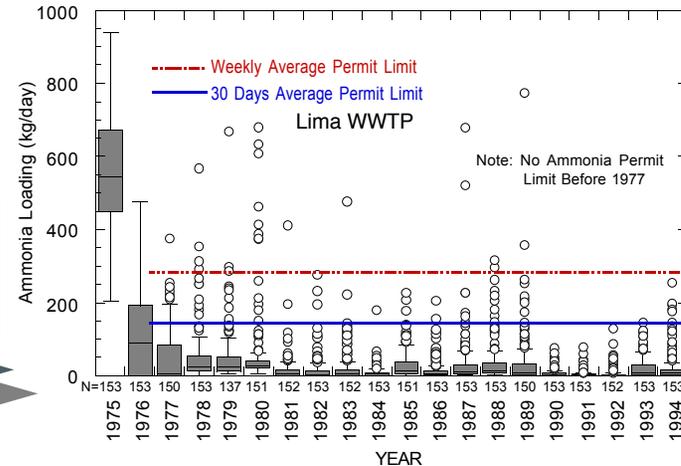
**LEVEL 6:** Biological recovery incomplete 6-8 yrs. post AWT; toxic response signatures



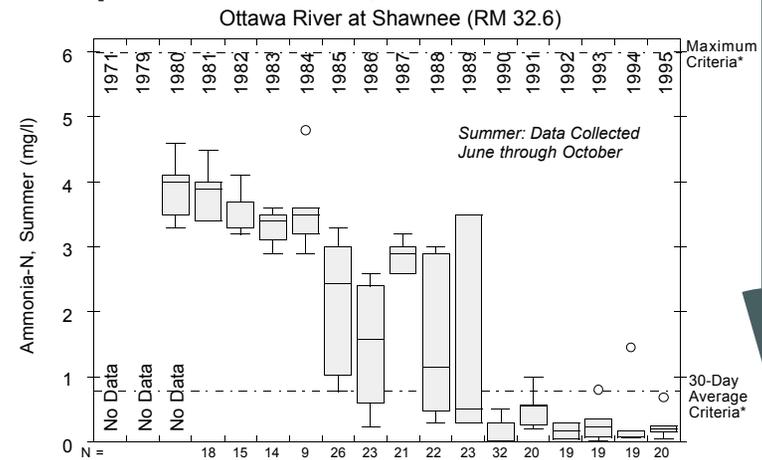
## RESPONSE

## STRESSORS

**LEVEL 3:** Loadings of ammonia, BOD, were reduced; other sources present



**LEVELS 4&5:** Reduced instream pollutant levels; toxics in sediment



## EXPOSURE

# SANDY CREEK

## Quick Facts - Sandy Creek

length:	41 miles
gradient:	10.0 feet / mile
river miles assessed:	12.3 miles
fish species:	36
aquatic insect species:	128
Ohio endangered species:	none
aquatic life use designation:	warmwater habitat
average river flow:	175,000,000 gallons/day
fish consumption advisories:	none

## STREAM HABITAT

The upper Sandy Creek is comprised of a good to excellent mixture of pool, riffle, and run habitats beneficial to supporting good to exceptional biological communities.

## FISH CONTAMINATION

Polychlorinated biphenyls (PCBs) were detected in a number of fish, with the highest values reported in common carp. Three carp samples collected upstream from Malvern had PCB concentrations exceeding Ohio water quality standards.

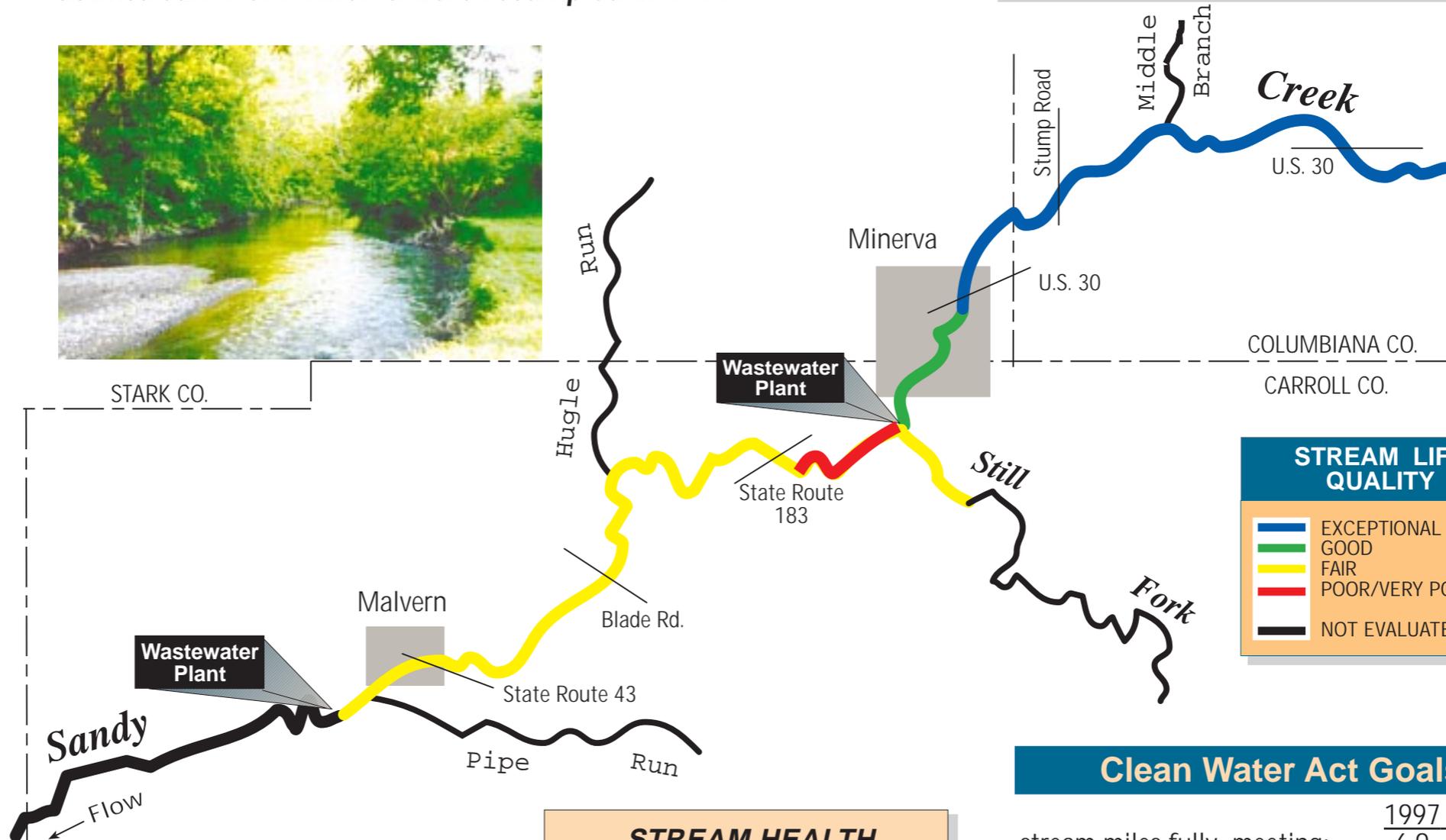
## WATER QUALITY

Chemical contaminants caused severely toxic conditions in Sandy Creek during 1996. Potential sources of chemicals include ammonia from the Minerva wastewater plant and unknown compounds spilled or released into the stream. Ammonia from the Minerva wastewater plant was significantly reduced in 1997.

## BIOLOGICAL TRENDS

In 1993, severe biological degradation occurred in Sandy Creek immediately downstream from the Minerva WWTP. Biological communities were severely degraded during 1996, but substantial improvement occurred in 1997.

The water and ecological quality of the upper Sandy Creek has been monitored and evaluated by the Ohio EPA during 1993, 1996, and 1997. The 1996 study included sampling of water quality, sediment quality, fish and aquatic insect communities, stream habitat quality, and fish tissue for contaminants. Three sites downstream from Minerva were resampled in 1997.

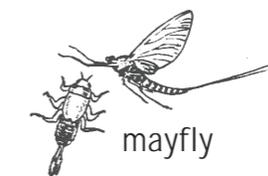


## STREAM LIFE QUALITY

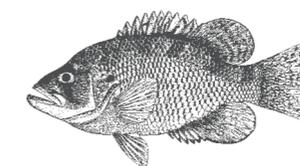
Blue	EXCEPTIONAL
Green	GOOD
Yellow	FAIR
Red	POOR/VERY POOR
Black	NOT EVALUATED

## Clean Water Act Goals

	1997	1996
stream miles fully meeting:	6.9	5.4
stream miles partially meeting:	5.0	0.3
stream miles not meeting:	0.4	6.6



mayfly



rockbass

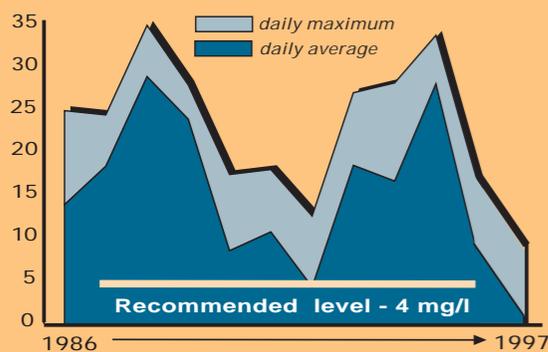


OhioEPA

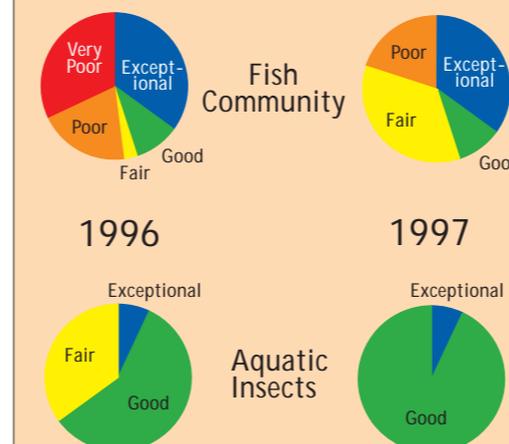
## AMMONIA

### A POLLUTANT

Ammonia discharged into Sandy Creek from the Minerva wastewater plant.



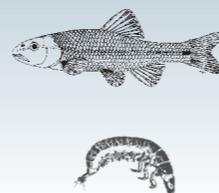
## STREAM HEALTH



## Pollution Sensitive Species

Some of the more common aquatic species in Sandy Creek which are indicative of clean water and good habitat.

river chub  
hornyhead chub  
rosyface shiner  
banded darter  
mayflies  
caddisflies





# Ohio Watersheds

## The Little Miami

### State and National Scenic River

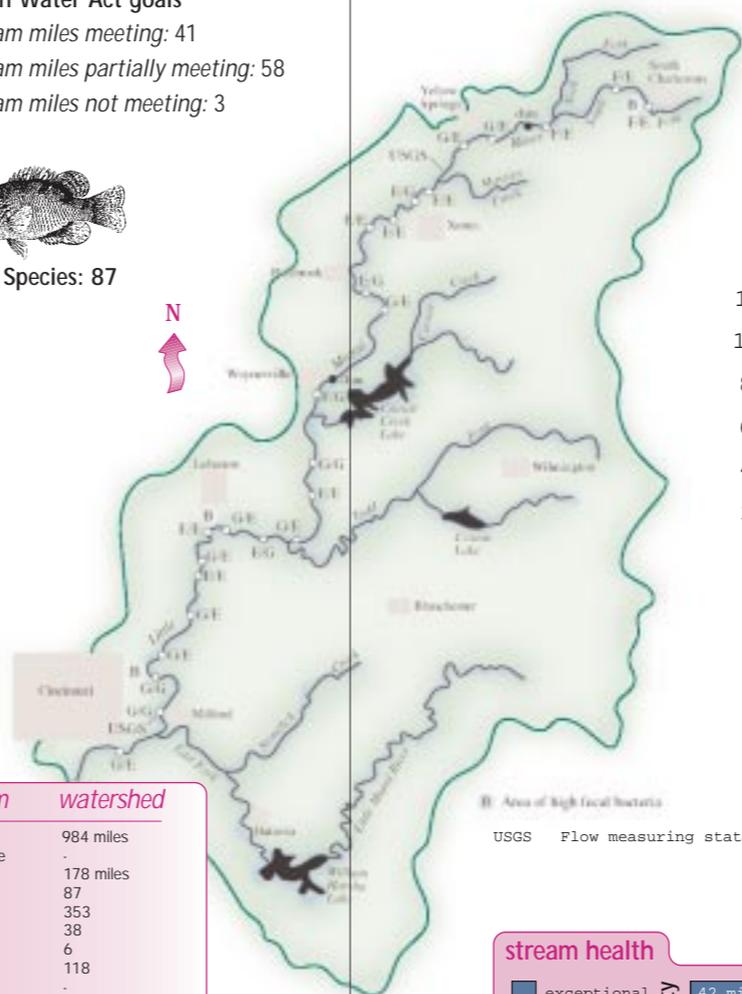
The Little Miami watershed occupies 1,757 square miles of ten southwestern Ohio counties. Originating near South Charleston, the mainstem flows in a southwesterly direction to its confluence with the Ohio River near Cincinnati. The watershed contains 133 named streams, some of Ohio's most scenic and diverse riverine habitats, and a high diversity of aquatic organisms (including six Ohio endangered species). With canoe liveries, bike trails, parks, and healthy populations of sport fish at many locations, it is easy to understand why the Little Miami River is a popular recreational retreat for Ohioans.



Clean Water Act goals  
 stream miles meeting: 41  
 stream miles partially meeting: 58  
 stream miles not meeting: 3



Fish Species: 87



#### water quality

##### major problems

organic/nutrient enrichment

fish abnormalities

siltation

river bacteria

##### major sources

municipal sewage  
 suburbanization  
 row crop agriculture,  
 new construction, eroding  
 streambanks  
 municipal sewage, sewer  
 overflows to the river, urban  
 runoff, livestock

#### Water quality trends

The Little Miami River has shown a significant improvement in water quality since the 1980's. Sewage containing organic material has been substantially reduced from most wastewater plants - a direct result of improved treatment. However, the total amount of pollutants still exceeds the capacity of the Little Miami River to adequately assimilate the waste.

#### quick facts

	mainstem	watershed
length:	105.5 mile	984 miles
gradient:	6.5 feet / mile	-
river miles assessed:	102 miles	178 miles
fish species:	83	87
aquatic macroinvertebrate taxa:	268	353
(mussel species):	36	38
Ohio endangered species:	6	6
scenic river miles:	105	118
aquatic life use designation:	EWB	-
wastewater dischargers:	5	24
wastewater volume:	12 MGD	50 MGD
average river flow:	811 MGD	-
public access sites:	13	-
canoe liveries:	7	-
number of dams:	2	3 major reservoirs
fish consumption advisories:	none	none

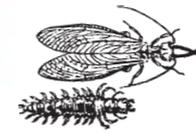
## A guide to Ohio's Streams

#### Recreational Opportunities

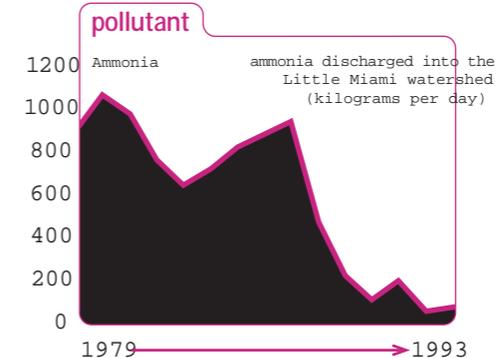
sport fishing: smallmouth bass, rockbass flathead catfish, sauger  
 canoeing: 250,000 people per year  
 biking & hiking trails: 50+ miles  
 parks & wildlife areas & preserves: 12?

#### Stream Habitat

The Little Miami River is comprised of a good mixture of pool, riffle and run habitats. The river channel has been little modified by man, with less than four percent affected by dam impoundments or channelization. The Little Miami River and its tributaries contain some of the highest quality river habitat in Ohio.



Macroinvertebrate Taxa: 353



#### pollution sensitive species

Some of the more common aquatic species in the Little Miami River which are indicative of clean water conditions and good habitat:

black redhorse  
 slenderhead darter  
 stoneflies



shorthead redhorse  
 rainbow mussel  
 mayflies



#### stream health

