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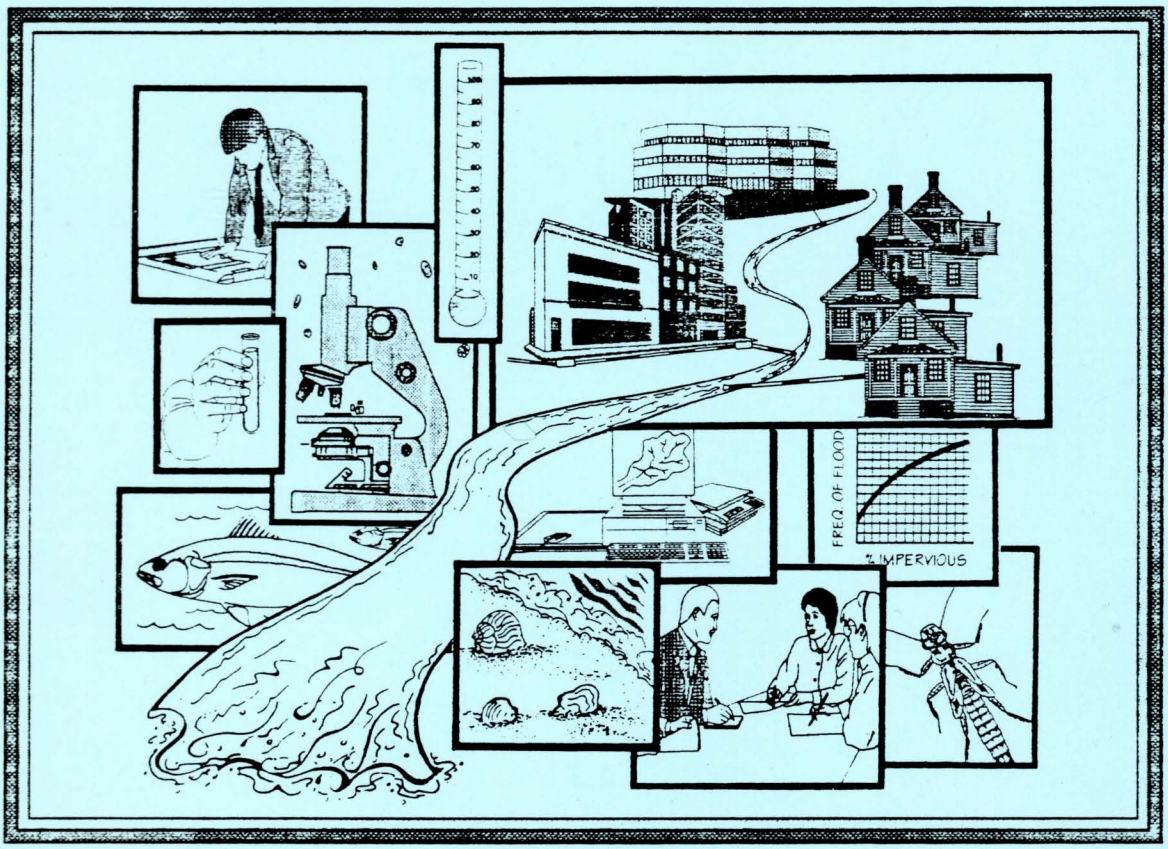
# Environmental Indicators
## to Assess Stormwater Control Programs and Practices

## Final Report




**Center for Watershed Protection**
Richard A. Claytor and Whitney E. Brown

**July 1996**

CENTER FOR WATERSHED PROTECTION

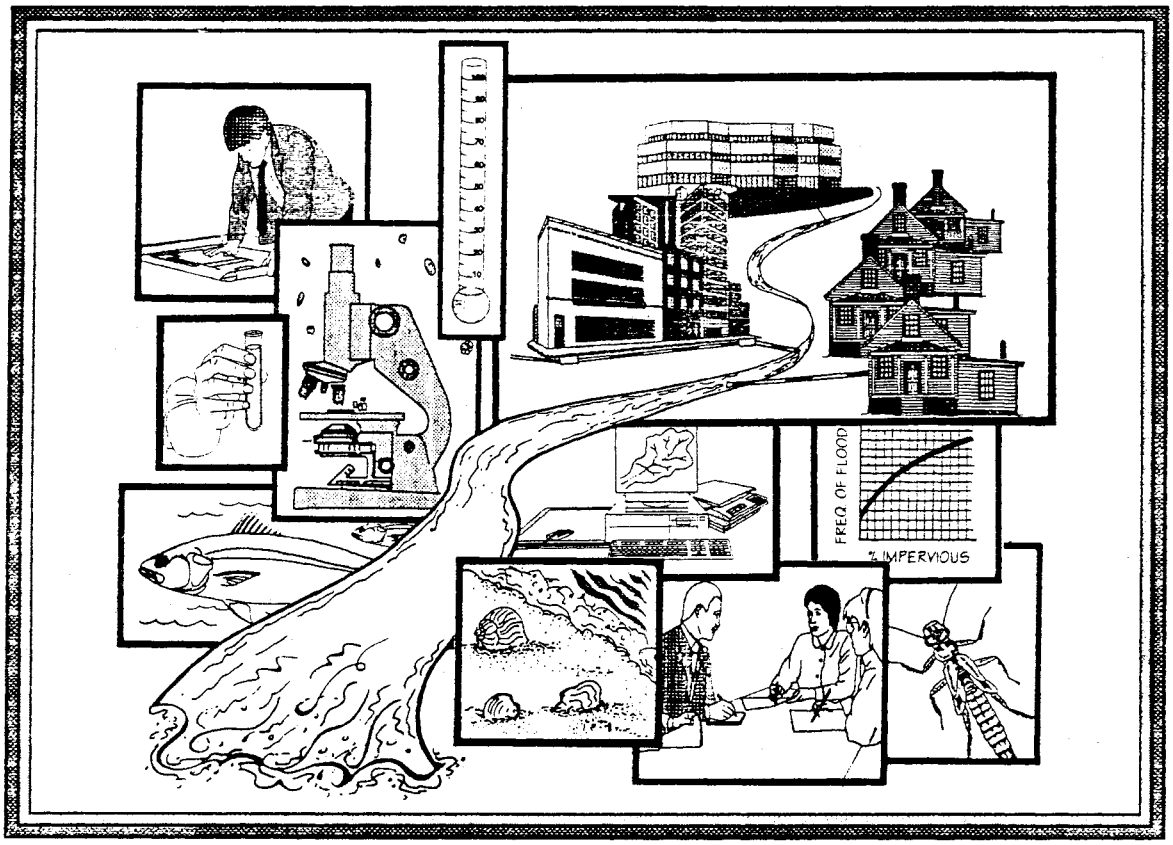
1100.005

# ENVIRONMENTAL INDICATORS

to Assess

Stormwater Control Programs and Practices

## FINAL REPORT

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## Abstract

Title: Environmental Indicators to Assess Stormwater Control Programs and Practices

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Abstract: The document presents a series of alternate stormwater monitoring techniques which rely on indicators, or surrogates of chemical, biological, physical, social, and programmatic conditions to assess stormwater program and practice success. Twenty-six "environmental indicator" profile, or fact sheets are presented which describe the indicator, explain advantages and disadvantages for use, review indicator utility, present a case example, and cite references for further investigation. A framework for using indicators is presented, along with a potential methodology for crafting an indicator based monitoring program for municipal and industrial site managers. Three theoretical case examples are presented applying the principles of environmental indicator based stormwater monitoring programs.

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# *EXECUTIVE SUMMARY*

In response to National Pollutant Discharge Elimination System (NPDES) stormwater regulations, many municipalities and industrial facilities have invested significant time, money, and manpower towards stormwater monitoring. Traditionally, the focus of these efforts have been end-of-pipe conditions and chemical and physical water quality criteria. However, many stormwater management professionals have begun to question the ability of traditional monitoring to accurately describe existing conditions in receiving waters, evaluate the overall integrity of aquatic communities, and assess the degree of improvement in stream systems. Environmental indicators have become popular as regulators, resource protection managers, and others look to alternative techniques to assess stormwater management efforts and environmental health.

Environmental indicators are select parameters and indices which can be used to characterize overall conditions in the receiving water and provide benchmarks for assessing the success of stormwater management efforts.

This report represents a component of a larger project call the Environmental Indicators/Measures of Success Project, funded by the U.S. Environmental Protection Agency (EPA) under the Clean Water Act, Section 104(B)(3). The first phase of this project, conducted by The Center for Watershed Protection, consisted of a review of approximately 500 research papers and studies. The results of the review were summarized in an annotated bibliography of environmental indicator resources. The second phase, performed by The Rensselaerville Institute, involved soliciting stakeholder input on the selection of appropriate indicators and on development of a flexible methodology for using indicators. The final phase of the project will focus on local and/or state demonstration projects testing the use of indicators. This effort will be performed by the Water Environment Research Federation. Case studies will be prepared on the outcome of the demonstration projects.

This report is intended for municipal stormwater managers, regulatory agencies, and industrial site managers. A framework for identifying appropriate indicators based on reference and baseline conditions, regional considerations, and available resources is provided (Chapter II). The applicability and usefulness of twenty-six environmental indicators for stormwater monitoring are summarized in a series of Profile Sheets (Chapter III). A suggested methodology for development of a comprehensive stormwater monitoring program, based on environmental indicators, is provided (Chapter IV). Lastly, three theoretical scenarios are presented to illustrate the potential application of stormwater indicators in real world situations (Chapter 5). A summary of the key findings in this report is presented below.

## STORMWATER ENVIRONMENTAL INDICATORS

Environmental indicators are measurements of environmental conditions or trends in environmental quality which can be used by managers to evaluate resource protection programs and assess the general state of the environment. Environmental indicators can be viewed as analogous to economic indicators such as housing starts, new construction gains, and the Dow Jones index which, although based on diverse measurements, when examined in combination, give a general indication of improvements or downturns in the economy and the success of various economic strategies. Similarly, environmental indicators provide a general assessment of improvements (or downturns) in the environment and of the effectiveness (or success) of resource

management strategies.

Environmental indicators are comprehensive and include a vast array of monitoring parameters applicable to a variety of management goals (i.e., water supply, point source) and environmental resources (i.e., forests, wetlands, groundwater). The term "stormwater indicator" applies to the select few environmental indicators which specifically focus on urban stormwater runoff impacts and can be evaluated to assess the success (or failure) of stormwater management efforts. These indicators are designed to be used by municipal stormwater managers, regulatory agencies, or industrial site managers to track general improvements or downturns in overall aquatic health due to implementation of various stormwater management practices and programs.

Twenty-six stormwater indicator categories were compiled through joint work sessions with EPA and Center for Watershed Protection staff and review of comments received from the stakeholders group (Table E.1). The indicators, organized into six categories, represent both traditional and less frequently used assessment methods. The stormwater indicators are described in indicator profile sheets which include descriptions of indicator applications, advantages and disadvantages, brief case studies and method references (Chapter III).

TABLE E.1

STORMWATER INDICATOR PROFILE CATEGORIES

| | INDICATOR NAME | PROFILE NO. |
|---|---|---|
| **Water Quality Indicators** | Water quality pollutant constituent monitoring | 1 |
| | Toxicity testing | 2 |
| | Non-point source loadings | 3 |
| | Exceedance frequencies of water quality standards | 4 |
| | Sediment contamination | 5 |
| | Human health criteria | 6 |
| **Physical and Hydrological Indicators** | Stream widening/downcutting | 7 |
| | Physical habitat monitoring | 8 |
| | Impacted dry weather flows | 9 |
| | Increased flooding frequency | 10 |
| | Stream temperature monitoring | 11 |
| **Biological Indicators** | Fish assemblage | 12 |
| | Macro-invertebrate assemblage | 13 |
| | Single species indicator | 14 |
| | Composite indicators | 15 |
| | Other biological indicators | 16 |
| **Social Indicators** | Public attitude surveys | 17 |
| | Industrial/commercial pollution prevention | 18 |
| | Public involvement and monitoring | 19 |
| | User perception | 20 |
| **Programmatic Indicators** | No. of illicit connections identified/corrected | 21 |
| | No. of BMPs installed, inspected, and maintained | 22 |
| | Permitting and compliance | 23 |
| | Growth and development | 24 |
| **Site Indicators** | BMP performance monitoring | 25 |
| | Industrial site compliance monitoring | 26 |

## INDICATOR USEFULNESS AND ADVANTAGES

Potential indicator usefulness and advantages were qualitatively analyzed (Chapter III). To complete this analysis, two lists of questions were developed which provide some insight on the types of questions which should be considered when developing a successful stormwater management program.

The usefulness analysis focused on the ability of each indicator to adequately document stormwater impacts and/or the efficacy of management efforts in the following six areas:

- aquatic integrity of lakes, streams and estuaries;
- land use impacts;
- stormwater management programs;
- whole watershed quality;
- industrial sites; and
- municipal programs.

The analysis of indicator advantages concentrated on the applicability of the indicators with respect to the following nine areas:

- multiple geographic regions;
- establishment of baseline conditions;
- wide range of stormwater applications;
- identification of the health or quality of an aquatic system;
- cost effectiveness;
- varying environmental and geographical conditions over a long time period;
- site, subwatershed, watershed and river basin scales;
- acceptance and familiarity to professionals involved in urban runoff management; and
- inexpensive, rapid and relative easy personnel training.

Comparisons of the overall usefulness of each indicator category and of indicator advantages is presented in Tables E.2 and E.3. An overall effectiveness category is included in both tables. An indicator which receives the highest ranking for overall effectiveness in both the Usefulness and Advantages Matrices, is likely to be a very useful tool for stormwater program managers.

## COST ANALYSIS

Cost estimates were developed for each indicator based on data collected through a telephone survey of stormwater practitioners, a literature review, the authors' experience, and general industry information (Chapter III). The cost basis for each indicator is identified in a concise format in a series of tables in Chapter III. Whenever possible, the cost data represents a unit basis of cost per station, per sample.

## TABLE E.2
## USEFULNESS QUICK REFERENCE GUIDE
## OVERALL INDICATOR SUMMARY

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| Water Quality Indicators | ● | ◖ | ● | ◖ | ◖ | ○ | ● | ◖ | ◖ |
| Physical and Hydrological Indicators | ○ | ● | ○ | ● | ● | ◖ | ○ | ● | ◖ |
| Biological Indicators | ● | ● | ◖ | ● | ● | ◖ | ◖ | ● | ● |
| Social Indicators | ○ | ○ | ○ | ○ | ● | ◖ | ○ | ◖ | ○ |
| Programmatic Indicators | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ● | ◖ |
| Site Indicators | ◖ | ◖ | ○ | ◖ | ● | ○ | ● | ◖ | ◖ |

*Key*
*Yes (Very Useful)* ● *Partially (Moderately Useful)* ◖ *No (Not Useful)* ○

## TABLE E.2
## ADVANTAGES QUICK REFERENCE GUIDE
## WATER QUALITY INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) Water Quality Monitoring | ● | ◖ | ○ | ◖ | ○ | ◖ | ● | ◖ | ○ | ◖ |
| (2) Toxicity Testing | ● | ○ | ◖ | ◖ | ○ | ◖ | ◖ | ◖ | ○ | ○ |
| (3) Nonpoint Source Loading | ● | ○ | ◖ | ◖ | ○ | ● | ◖ | ◖ | ○ | ◖ |
| (4) Exceedance Frequencies | ● | ● | ◖ | ◖ | ○ | ● | ◖ | ● | ● | ● |
| (5) Sediment Contamination | ◖ | ◖ | ◖ | ◖ | ○ | ◖ | ○ | ● | ◖ | ◖ |
| (6) Human Health Criteria | ○ | ◖ | ◖ | ◖ | ◖ | ● | ○ | ● | ◖ | ◖ |

*Key*
*Yes (Very Advantageous)* ● *Partially (Moderately Advantageous)* ◖ *No (Not Advantageous)* ○

The indicator costs are planning level estimates and are not all-encompassing. There are many different methodologies that can be used to perform indicator monitoring, and implementation costs can vary significantly in different regions of the country. Program managers should use these estimate for comparison purposes only and verify all costs with other sources, before implementing program monitoring strategies.

## FRAMEWORK FOR USING INDICATORS

Identification of appropriate stormwater indicators for monitoring programs should be conducted within a framework based upon regional and site-specific considerations. This framework, which acknowledges the impacts of urbanization on water resources, represents reference and baseline conditions, regional considerations, and available resources.

Reference conditions are used to establish a benchmark for assessing existing conditions or to measure trends in conditions. A reference site should be selected to represent a least or minimally impacted condition. Ecoregions, representing regions of homogeneity in land surface, form, soils, natural vegetation, and general land use, should be utilized in the establishment of reference sites. A variety of reference sites can be established in each ecoregion to represent a variety of gradients, substrates, and water body types.

Regional considerations provide a framework for the selection of appropriate indicators based on specific land use, climate and local geology and geography. Stormwater indicators require regional adaptation to be utilized in different regions of the country.

## TOOLS FOR INDICATOR USE

Several "tools" can be used over a broad range of physical, chemical, and biological conditions to measure environmental indicators including:

- Watershed Simulation Modeling
- Geographic Information Systems (GIS)
- Paired Subwatershed Monitoring
- Comparison to Reference Conditions
- Photographic Records

Watershed simulation modeling has been used to assess various land uses and development scenarios to calculate pollutant load wash off Watershed simulation modeling can also be applied to predict changes in stormwater runoff quantity and stream dry weather flow impacts caused by changes in watershed imperviousness. Changes in peak stormwater flows can be related to the potential for stream channel erosion, channel widening and downcutting and related habitat damage.

Geographic Information Systems are used to assemble and compile watershed characteristics and other information into a graphical and/or tabular format for assessment of various conditions. GIS and watershed simulation modeling can be used in combination to calculate various land use/BMP combinations and their impacts on downstream water quality.

Paired subwatershed studies involve comparing the response of two physiographically similar watersheds when subjected to different management practices. A control watershed is established to account for climatic, seasonal, and other natural variations, while a treatment watershed

measures the affects of implementation of management practices.

Photographic and video records can be used to document many different indicators, but are perhaps most suited to assessing changes in physical conditions. The use of digital cameras to document conditions can be integrated with GIS watershed mapping to convey this information to a wide range of potential viewers.

## CRAFTING AN INDICATOR MONITORING PROGRAM - A METHODOLOGY

Stormwater indicator monitoring programs can be tailored to address the specific information needs of individual municipalities and industrial sites. When selected correctly, stormwater indicators can assess the long-term effectiveness of stormwater management programs as well as provide required baseline data. A two-level methodology for development of stormwater monitoring programs was developed based on general considerations common to all monitoring efforts (Chapter IV). This methodology is presented as a flexible tool which can be adapted to a particular jurisdiction's or industrial site situation. The Level I methodology targets assessment of baseline conditions; the Level II methodology is for assessing program management efforts. The two-level methodology for crafting a stormwater indicator monitoring program is outlined in Figures E.1 and E.2.

**FIGURE E.1**
**STORMWATER INDICATOR METHODOLOGY**
**LEVEL I, PROBLEM IDENTIFICATION**

**① ESTABLISH MANAGEMENT SPHERE**

*Who will be responsible for implementation? A government agency (municipality, county, or state) or a site-specific industry? What other programs are being implemented within the watershed? Can this program be developed and implemented on a watershed-wide or basin basis?*

⇓

**② GATHER/REVIEW HISTORICAL DATA**

*Identify what programs and studies have already been implemented in the watershed.*
*Determine what problems associated with stormwater have already been identified.*
*Assess the effectiveness of earlier efforts and programs.*

⇓

**③ IDENTIFY POTENTIAL RECEIVING WATER IMPACTS**

*Identify uses and characteristics which may be impacted by stormwater runoff.*

Hydrology and Hydrodynamics (Flooding, Drainage)
Biological Integrity (Fish Diversity, Macro. Community)
Non-contact Recreation (Sports Fishing)
Supply (Potable Water)
Contact Recreation (Swimming)
Aqua-culture (Shellfish Harvesting, Food Fishing)

⇓

**④ INVENTORY RESOURCES AND IDENTIFY CONSTRAINTS**

*Determine manpower and funding limitations.*
*Identify regulatory-mandated deadlines and programs.*

Staffing
Scheduling Constraints
Funding
Regulatory Compliance

⇓

**⑤ ASSESS BASELINE CONDITIONS**

*Use rapid (qualitative) assessment methods versus detailed quantitative techniques to assess baseline conditions.*

Indicator Options by Receiving Water Use

| Concern: | Hydrology & Hydrodynamics | Biological Integrity | Non-contact Recreation | Water Supply | Contact Recreation | Aqua-culture |
|---|---|---|---|---|---|---|
| Type of Indicator to be Considered: | *Physical*<br>*Social*<br>*Programmatic*<br>*Site* | *Biological*<br>*Water Quality*<br>*Social*<br>*Programmatic*<br>*Site* | *Water Quality*<br>*Physical*<br>*Biological*<br>*Social*<br>*Programmatic*<br>*Site* | *Water Quality*<br>*Biological*<br>*Social*<br>*Programmatic*<br>*Site* | *Biological*<br>*Water Quality*<br>*Physical*<br>*Social*<br>*Programmatic*<br>*Site* | *Biological*<br>*Water Quality*<br>*Physical*<br>*Social*<br>*Programmatic*<br>*Site* |

FIGURE E.2
STORMWATER INDICATOR METHODOLOGY
LEVEL II, ASSESSMENT OF MANAGEMENT PROGRAM

**① STATE GOALS FOR PROGRAM**

*Based on baseline conditions, resources, and constraints, articulate goals for stormwater management program in terms of measurable achievements.*

**Example:** We want to increase the level and diversity of the fish population in the next 5 years.

To accomplish this, we must improve biological integrity, water quality, and physical conditions.

↓

**② INVENTORY PRIOR AND ONGOING EFFORTS**

*Identify prior stormwater management efforts and assess success of prior efforts.*
*Identify current stormwater management efforts both within the municipal boundaries and the larger watershed.*
*Assess success of ongoing efforts.*
*Incorporate complementary programs and goals.*
*Identify potential conflicts.*

↓

**③ DEVELOP AND IMPLEMENT MANAGEMENT PROGRAM**

*Identify and implement specific program facets in order to achieve goal.*

**Example:** In order to increase the fish population, we will retrofit BMPs, require stormwater BMPs all new development, remove fish barriers, and re-introduce some aquatic species.

↓

**④ DEVELOP AND IMPLEMENT MONITORING PROGRAM**

*Based on goals, program structure, resources and constraints, select indicators to be used to assess success of stormwater management program. Level II indicators will likely be more quantitative in comparison to Level I techniques. Quantitative analysis is required to identify pollutant sources and assess success of program.*

**Example:** macro-invertebrate assemblage, fish assemblage, public opinion surveys, toxicity testing.

↓

**⑤ ASSESS INDICATOR RESULTS**

*Analyze indicator monitoring results.*

What do the monitoring results indicate about the success of the stormwater management program?
Have the indicators accurately reflected the effectiveness of the management program?
What do the indicators suggest about the ability of the stormwater indicator monitoring program to measure of overall watershed health?

↓

**⑥ RE-EVALUATE MANAGEMENT PROGRAM**

*Re-evaluate resources and constraints.*
*Update (if necessary) assessment of baseline conditions.*
*Review and revise program goals.*
*Review and revise indicator monitoring program.*
*Implement revised management program.*

## SCENARIOS FOR INDICATOR USE

The potential application of stormwater indicators in real world situations is illustrated in three theoretical scenarios (Chapter V). The scenarios represent different regions of the country, while facing different resource management challenges. Scenario 1 focuses on a moderately sized, rapidly growing suburban municipality in the Southeast United States. The theoretical situation involves development of a watershed management program targeting non-point source control as well as water supply protection. Level I methodology (resource problem identification) and Level II methodology (management efforts assessment) is used to develop the comprehensive monitoring program. The scenario also demonstrates how costs associated with preparation and implementation of the watershed management plan and monitoring program must be weighed against available resources.

Scenario 2 illustrates efforts required to implement a resource restoration and protection management strategy for an older industrial municipality in the Great Lakes region of the county. This theoretical example identifies a five task management strategy, including: industrial runoff controls, residential runoff controls, combined sewer overflow (CSO) reductions, habitat and water quality assessments and public involvement initiatives. A monitoring program is identified and program costs are specified.

Scenario 3 illustrates management strategies for a smaller industrial park located on the Southwest United States. The theoretical situation involves an industrial park which has been identified as a significant source of non-point source pollutants being exported to a tidal estuary. Storm monitoring and toxicity testing have shown that dissolved metals are the principal pollutants leaving the site. A management strategy employing construction of structural BMPs and pollution prevention efforts is proposed. The costs of constructing the BMPs, implementing the pollution prevention efforts, and post-implementation monitoring are compared to the available budget.

All three scenarios demonstrate the impact of urbanization on aquatic quality and the necessity to utilize stormwater indicators within a watershed-wide context. Recent studies throughout North America and elsewhere have shown a consistent relationship between the impacts of urbanization and degraded water resource quality, even with the widespread use of BMPs. The increased frequency and magnitude of runoff and the increased pollutant load associated with urban stormwater, can dramatically degrade critical stream systems by destroying habitat, eroding channel bottoms and banks, and by producing an influx of toxic runoff and sediments. Stormwater managers must recognize this when using stormwater indicators to evaluate how effectively these mitigation measures are working.

It is also important to implement stormwater indicator monitoring strategies on a watershed-wide basis. At this scale, managers will be able to better differentiate between water resource impacts associated with land use changes, as opposed to poor performance of BMPs or poor stormwater management program implementation.

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# CHAPTER I INTRODUCTION

## OVERVIEW

Stormwater runoff management has traditionally focused on end-of-pipe controls and compliance with chemical and physical criteria, usually set by Environmental Protection Agency (EPA) or state environmental protection agencies. In part, due to EPA stormwater permit requirements, many municipalities and industries have invested significant time, money, and manpower towards characterization of stormwater runoff and collection of chemical and physical data for receiving streams (or water bodies). Recently, however, many stormwater management professionals have questioned the applicability and usefulness of these data to accurately describe existing conditions in the receiving water, evaluate the overall integrity of the aquatic community, and assess the degree of improvement in the stream system (Swietlik et al 1994). EPA is now re-assessing stormwater monitoring parameters and goals with an eye towards development of comprehensive monitoring programs which characterize overall conditions in the receiving water and provide benchmarks for assessing the success of stormwater management efforts.

Many municipalities and industries are required to implement monitoring and management programs in compliance with National Pollutant Discharge Elimination System (NPDES) stormwater regulations. Stormwater indicators can be used by the municipalities and industries as alternatives to traditional end-of-pipe monitoring, to assess the effectiveness of their stormwater management programs and to focus these programs so that generally limited resources are used effectively.

## BACKGROUND

EPA identified national environmental goals in the draft report "Proposed Environmental Goals for America with Benchmarks for the Year 2005: Summary (EPA 1995). These goals outline a commitment to continued restoration of the environment (including land, air, and water resources), enhancement of environmental resources, and full usage of the environment in ways that ensure sustainable development.

Following the overall agency lead, the EPA Office of Water (EPA/OW) outlined its commitment to protection and maintenance of healthy and clean waters and designated water uses. In order to measure their success in attainment of this goal, EPA/OW, in conjunction with other EPA, Federal, State, and tribal agencies, developed a list of environmental indicators. Environmental indicators are measurements and indices which can be used to assess existing environmental conditions, provide insight into general environmental trends over time, and measure the effectiveness of existing environmental monitoring and management programs. Environmental indicators are analogous to economic indicators such as housing starts, new construction gains, and the Dow Jones index which, although based on diverse measurements, when examined in combination, give a general indication of improvements or downturns in the economy and the success of various economic strategies. The environmental indicators will provide water resource managers with insight into the state of their aquatic environment and the effectiveness of current resource management strategies.

## STORMWATER INDICATORS

The overall thrust of the EPA/OW effort is reduction or prevention of pollutant loadings and other stressors. One of the most significant sources of pollutant loads to receiving waters in this country is stormwater runoff. The significance of stormwater pollutants, especially from urban areas, was examined in the early 1980's as part of the National Urban Runoff Program (NURP). In recognition of the impacts associated with stormwater runoff, Congress required, in the 1987 amendments to the Clean Water Act, that EPA expand the NPDES program to include a stormwater component.

NPDES stormwater regulations focus on reduction of pollutants from large and medium-sized municipalities, as well as select industries. During Phase I of the NPDES stormwater program, participating municipalities and industries conducted "characterization" monitoring of stormwater runoff. The purpose of this monitoring was to characterize the stormwater runoff from separate land uses (industrial, commercial and residential), identify significant pollutant sources (i.e., illicit connections, outside material storage, etc.), and provide a basis for development of future monitoring and stormwater management programs as outlined in permit requirements.

A next step in assessing the effects of urban stormwater runoff on the environment is through the use of comprehensive monitoring practices. The comprehensive approach provides information on the health of receiving waters (as opposed to an end-of-pipe focus) and tracks improvements in overall aquatic integrity as various management programs are implemented. Comprehensive monitoring of all environmental parameters would be required to assess the total aquatic health of a particular waterway, given the vast array of environmental conditions and management practices. Since it is not practical nor cost effective to evaluate all biological, chemical, and physical parameters, a few select environmental indicators, focusing specifically on urban stormwater runoff impacts, can be evaluated to tell the story of the whole system.

"Stormwater indicators" will be used to track general improvements or downturns in the overall aquatic health of the receiving water and to assess the effectiveness of various management practices and programs. These indicators are designed to be used by municipal stormwater managers, regulatory agencies, or industrial site managers. EPA/OW has undertaken an effort to develop a list of stormwater indicators and to assess the usefulness of these indicators as predictors of effective stormwater management practices and programs.

Twenty-six stormwater indicator categories were compiled through joint work sessions with EPA and Center for Watershed Protection staff and review of comments received from the stakeholders group. (The stakeholders represent a cross-section of stormwater management professionals including administrators, scientists, and engineers.) The list of 26 indicator categories has been reduced from an original list of 33. These indicators have been evaluated with respect to the following considerations:

- Do the indicators provide an accurate representation of environmental conditions?
- Are they relatively easy to use and inexpensive?
- Do the indicators work (in a scientific sense) and how?
- What indicator or combination of indicators can be used to evaluate a stormwater management program?
- What aquatic uses do the indicators assess?

- How comparable are the indicators in different geographic locations (are they equally effective throughout the country and equally effective in different water bodies; i.e., lakes, streams, rivers, estuaries)?
- At what watershed scale are the indicators most effective (over the whole watershed, only in headwater streams, or only within the ultimate receiving water)?

Although the indicators are designed to focus on the success (or failure) of individual municipal, jurisdictional, or industrial site efforts, comprehensive monitoring results must also be examined in a watershed-wide context. Urban stormwater runoff represents only one potential impact to water systems. Other potential non-point source impacts include agricultural runoff and atmospheric deposition. Point sources are also of concern. Successful design and implementation of stormwater management programs for a particular catchment, drainage area, or subwatershed can depend upon more than implementation of effective BMPs, pollution prevention measures, aquatic restoration strategies, and public involvement. Land use management in the larger watershed, implementation of complementary stormwater management programs in upstream drainage areas, attention to other non-point sources of pollution, and a general watershed-wide commitment to minimize and alleviate stormwater impacts is required. Thus, a comprehensive monitoring program may reveal that although the selected stormwater management strategies are effective on a subwatershed scale, the overall aquatic environment may continue to degrade due to upstream influences not within the jurisdiction's control. Conversely, monitoring results may indicate that only limited additional measures are required because watershed-wide growth management controls have been implemented.

## REPORT OUTLINE

This report presents the results of the review of stormwater indicators, their applicability, and their usefulness for measuring the success of stormwater management programs. Developed for use by municipal stormwater managers, regulatory agencies, and industrial site managers, this report provides a framework for identifying appropriate indicators based on reference and baseline conditions, regional considerations, and available resources (Chapter II). Profile sheets which describe the various stormwater indicators; summarize application, advantages and disadvantages, and costs; and provide brief case studies and method references are presented in Chapter III. Draft versions of the profile sheets were previously published as Environmental Indicators to Assess the Effectiveness of Municipal and Industrial Stormwater Control Programs (Claytor, R. and R. Ohrel 1995a). The profile sheets have been revised to reflect stakeholder comments. Also presented in this report is a suggested methodology (decision matrix) for development of comprehensive monitoring programs based on stormwater indicators (Chapter IV). Lastly, three scenarios are presented to illustrate and further examine the potential benefits associated with use of stormwater indicators (Chapter V).

This study is part of a larger project called the Storm Water Program-Environmental Indicators/Measures of Success Project. The first phase of this effort, Step I: Research and Information Gathering, focussed on compilation and review of currently used indicators and development of a methodology for applying these indicators. An annotated bibliography of environmental indicators was developed and is presented in the Annotated Bibliography of Environmental Indicators to Assess the Effectiveness of Municipal and Industrial Stormwater Control Programs (Claytor, R. and R. Ohrel 1995b). This report presents the stormwater indicators and describes a methodology implementation.

During the second phase of the project, Step II: Stakeholder Input, stakeholders were convened to provide input on selection of appropriate indicators and development of a flexible methodology for use of the indicators. Step II was conducted by the Rennselaerville Institute and is summarized in Appendix A.

Appendix B presents an example of a recently issued NPDES municipal stormwater discharge permit. The permit is included as an example because it incorporates many of the environmental indicators presented in this document as part of a watershed based monitoring and management program.

During the final phase of the study, a series of grants will be awarded for development of comprehensive monitoring programs using stormwater indicators to assess stormwater management program effectiveness. The results of these demonstration projects will be reported under separate cover by the grantees.

## REFERENCES

Claytor, R. and R. Ohrel. 1995a. Environmental Indicators to Assess the Effectiveness of Municipal and Industrial Stormwater Control Programs. Prepared by the Center for Watershed Protection for the United States Environmental Protection Agency, Office of Wastewater Management. March 1995.

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# *CHAPTER II FRAMEWORK FOR USING INDICATORS*

## URBANIZATION AND WATER RESOURCE QUALITY

Water resource quality is influenced by many different parameters, however, human induced alterations are probably the single biggest contributor to degraded conditions. The ability of streams, lakes, rivers, and estuaries to sustain healthy ecosystems is often a function of how much or how little humans have altered the natural conditions.

One primary way aquatic ecosystems are altered by human influences is through physical, chemical, and biological impacts associated with urban stormwater runoff. The increased frequency and magnitude of runoff and the increased pollutant load associated with urban stormwater, can dramatically degrade critical stream systems by destroying habitat, eroding channel bottoms and banks, and by producing an influx of toxic runoff and sediments. Stormwater management programs and practices are designed to mitigate these adverse impacts. Stormwater monitoring allows managers to evaluate how effectively these mitigation measures are working. Environmental indicators can provide managers with alternative monitoring tools to evaluate program success.

Environmental indicators have the utility and applicability to be extremely versatile tools for analyzing stormwater program and best management practice (BMP) effectiveness. However, before reviewing these tools in detail, a cautionary note is worth emphasizing. Too often local officials, planners, engineers, landscape architects, and others involved in urban stormwater management utilize best available technologies to attempt to solve complex ecological alterations of the natural environment. These professionals may mistakenly assume that the impacts of urbanization can be prevented through the use of BMPs. However, recent studies throughout North America and elsewhere have shown a consistent relationship between the impacts of urbanization and degraded water resource quality, even with the widespread use of BMPs (Schueler 1994).

Urbanization is often measured in terms of impervious area, population, or number of building permits issued. Water resource quality can be measured in terms of physical, chemical, and biological parameters, using many of the indicators examined in this document. One conclusion appears consistently throughout the several studies referenced above, which is, as the amount of urbanization surpasses certain thresholds, water resource quality and aquatic life diversity shows increasing signs of degradation. Even at relatively low levels of imperviousness, the most sensitive aquatic species tend to disappear from examined systems (Schueler 1995).

This presents a challenge for urban watershed managers attempting to evaluate the effectiveness of their stormwater management programs and practices. Officials must realize that even the most successful programs may have indicators which show partially degraded conditions. One benefit of utilizing a comprehensive monitoring program, relying on multiple indicators, is that managers are likely to be able to assess those components of a program which work, and those that may need further development. For these reasons, it is important to utilize environmental indicator monitoring strategies on a watershed-wide basis. At this scale, managers will be able to better differentiate between water resource impacts associated with land use changes, as opposed to poor performance of BMPs or poor stormwater management program implementation.

Another significant hurdle for program managers will be to identify, or more accurately, to eliminate confounding sources influencing water body health. This is necessary to be able to target control strategies for particular sources of pollutants. While some indicators will be useful for documenting that there are problems with water body health, a more significant value should be in the identification of pollutant sources and assessing whether or not management practices are working. It is important to recognize that indicators will be of limited value if there are multiple sources of pollutants influencing water body health. Non-point source pollution, by definition, is coming from locations and activities which are not easily identifiable.

In order to establish environmental indicators as effective tools to address this difficult problem, it is first useful to understand the typical pollution sources and pathways affecting water quality. Several non-point sources affecting water quality in urban areas are identified in Table 2.1, below:

TABLE 2.1

TYPICAL NON-POINT SOURCE PATHWAYS AND POLLUTANTS

| ACTIVITY | POLLUTANT PATHWAY | PRINCIPLE POLLUTANTS |
|---|---|---|
| Agricultural runoff | Runoff and leachate | Nutrients<br>Sediment<br>Pesticides/herbicides |
| Atmospheric deposition | Fallout of pollutants in rainfall and dry deposition | Nutrients<br>Metals |
| Combined sewage overflows and sanitary sewage overflows | Piped directly in drainage system | Pathogens (bacteria)<br>Metals |
| Urban stormwater runoff | Drainage network | Whole host of "conventional pollutants" |
| Forestry | Overland runoff | Sediment |
| Septic discharges | Leachate through ground water | Bacteria |
| Boating activities | Direct discharge | Hydrocarbons<br>Oil/grease<br>Metals |
| Resuspension of previously settled solids | Thermal turn-over<br>Bottom feeding fish activity<br>Microbial activity | Phosphorus release<br>Metals<br>Other pollutants bound to sediments |

To be effective, a monitoring program must be set up to isolate these confounding sources. For example, it is difficult to evaluate and analyze the confounding sources of larger rivers which flow through urban areas, if they first flow through large agricultural areas and/or other varied land uses. Similarly, it is difficult to assess the contribution of urban runoff for large drainage areas to larger lakes and estuaries which receive input from several sources. Therefore, a monitoring program

should specify a drainage area which can be realistically identified and quantified. For example, stormwater runoff, draining a mostly residential and commercial subwatershed, is most likely to be the primary source of pollutants and hydrologic impacts to first or second order streams (commonly referred to as headwater streams).

Management strategies concentrating on reducing urban stormwater pollutants and hydrologic impacts can be evaluated by measuring changes within these smaller headwater streams. Once the drainage area gets significantly larger and industrial, agricultural, and other inputs are included in the non-point source load, it is more and more difficult to measure the effectiveness of stormwater management programs on water body health. Municipalities and industrial sites which concentrate on managing the smaller headwater streams, and which focus their urban stormwater monitoring efforts at this level, are more likely to be able to assess program and practice success and corresponding improvements in water resource quality.

## IMPORTANCE OF REFERENCE CONDITIONS AND ESTABLISHMENT OF ECOREGIONS

Successful water resource management programs have traditionally focussed on efforts which reduce chemical or microbial pollutant loads or concentrations below a pre-determined numerical limit (Hughes and Larsen, 1988). These standards and criteria, developed under the auspices of the Federal Water Pollution Control Act, are intended to restore, protect, and maintain the biological, chemical, and physical quality of the Nation's aquatic environments. This management approach has resulted in significant reductions in point source discharges of conventional and toxic pollutants. However, the resultant benefits to the biological aquatic community have fallen below expectations. Chemical and physical criteria are often either under protective or inappropriate (e.g., the acceptable mercury standard is toxic to the resident fish population). In addition, quantitative biological criteria and standards have generally not been developed to the same degree as chemical and physical standards.

Comprehensive stormwater monitoring programs must focus on indicators which provide a realistic assessment of the total aquatic health of the system. Compliance with national standards will not necessarily ensure attainment of the best possible or most realistic level of aquatic protection which can be obtained in a specific watershed or water body. Traditional water quality and biological standards are generally not applicable across the broad range of diverse geological, ecological, and water quality conditions to which they are applied. These standards, therefore, have limited usefulness as benchmarks for success.

In order to realistically assess present conditions (including biological diversity and aquatic habitat), set achievable stormwater management goals, and accommodate diverse geology and ecology, reference conditions must be identified. Reference conditions are established through identification of watersheds (or water bodies) where human impacts are minimal. Existing conditions in the reference watershed are then determined through review of existing records or monitoring results. Stormwater management goals based on these reference conditions, (with consideration accorded for existing anthropogenetic influences) are then used as a benchmark for assessing the success of the stormwater management effort.

It is not always possible nor desirable to identify reference conditions which represent all possible geologic, habitat, and water quality conditions for each water body of concern. In order to minimize the number of reference watersheds required, a geographically based ecological region (ecoregion) approach may be used. Ecoregions are mapped regions of homogeneity in land surface

form, soil, potential natural vegetation, and general land use (Hughes and Larsen 1988). They group water bodies together that would be naturally similar in the absence of human influences. Based on the work of Omernik, Hughes, and Griffith, and others, ecoregions are now considered a more appropriate framework for assessment of aquatic health. Seventy-six ecoregions in the United States were defined in 1987 by Omernik using regional patterns in climate, geology, and land use (Omernik 1987).

A variety of reference sites can be identified within each ecoregion to represent the variety of gradients, substrates, water quality, and body types in each ecoregion. The ecoregion approach allows stormwater managers to develop estimates of water quality conditions or organisms likely to be observed in a body of water. Stormwater mangers can then assess the success of their program in context of both the potential for restoration as represented by the reference watershed and the relative condition of the watershed as compared to other watersheds in the ecoregion.

## REGIONAL CONSIDERATIONS

Ecoregions provide a framework for assessment of stormwater indicator results. Similarly, regional considerations provide a framework for selection of appropriate indicators based on specific land usage, climate, and local geology and geography. Selection of an indicator such as number of illicit connections detected would be more appropriate for an industrialized watershed versus an agricultural watershed. Similarly, selection of an indicator assessing changes in dry weather flows would be more appropriate for a perennial stream system in the semi-humid mid-Atlantic coastal plain than for an ephemeral stream system in the semi-arid high plains of Colorado.

Regional considerations also provide a framework for modification of stormwater indicators to more accurately represent local conditions. Biological and physical stormwater indicators can be used to assess stormwater management programs throughout the country. However, in order to establish realistic restoration goals, these indicators will need to be modified to more appropriately represent regional conditions. For example, Miller and others reported that the Index of Biotic Integrity (an indicator of biological diversity) has been modified in various states to reflect native species, thus providing an indicator of greater utility and applicability (Miller et al. 1988).

Upfront consideration of regional differences is required to ensure selection of appropriate stormwater indicators which accurately represent local conditions. Development of an appropriate framework for selection of stormwater indicators and establishment of restoration goals can only be achieved by taking into account regional considerations as well as reference conditions and ecoregional concerns.

## TOOLS FOR INDICATOR USE

As has been discussed, one goal of this environmental indicator project is to recommend and analyze a group of indirect measurements of environmental conditions to assess water body health and stormwater management practice and program effectiveness. During the course of this project, the "indicators" used to measure environmental conditions have evolved. Several topics were originally categorized as Whole Watershed Indicators which were initially envisioned as measurements of "whole watershed" health. These included watershed simulation modeling, watershed geographic information systems (GIS), comparison to reference watersheds, paired

watershed analysis, and watershed imperviousness studies. What became apparent through the Stakeholder meetings and through various comments received, was that these "indicators" were really "tools" used to measure other indicators. With the exception of watershed impervious studies, which has been renamed and incorporated into a the indicator topic called "Growth and Development," these other tools can all be applied over a broad range of physical, chemical, and biological indicators as identified in Chapter III.

Although the tools discussed here can be used to estimate specific water resource impacts, the emphasis for monitoring programs to be structured on a watershed-wide basis cannot be overstated. For it is at the watershed or subwatershed scale, that it is most obvious to differentiate between land use management strategies and other BMP implementation strategies.

The following discussion identifies some of the common "tools" watershed managers and stormwater practitioners can use to measure a range of environmental indicators, specifically:

- Watershed Simulation Modeling
- Geographic Information Systems
- Paired Subwatershed Monitoring
- Comparison to Reference Conditions
- Photographic Records

Not discussed are tools used to measure specific indicators, such as the Index of Biotic Integrity to measure fish assemblages (Karr et al. 1986). These specific tools are reviewed and discussed for each relevant indicator topic, in Chapter III - "Environmental Indicator Profile Sheets."

### Watershed Simulation Modeling and Geographic Information Systems (GIS)

Watershed simulation modeling is a tool that can be used to characterize pollutant constituent load wash-off from various land surfaces, or to estimate the hydrologic and hydraulic affects upon receiving waters. Several computer models have been developed to assess the quality and quantity of stormwater runoff. These models must usually be calibrated to properly estimate watershed responses to various land use development patterns. Geographic information systems (GIS) are tools that can be used to compile watershed characteristics in a graphic and tabular format for use in examining the effects of various land use/land cover conditions.

Recent efforts to combine the capabilities of water quality/quantity simulation models with GIS have yielded powerful new tools for watershed analysis. The pollutant load estimation, transport, and flow rate computational capabilities of simulation models complement the database and spatial graphic capabilities of GIS. Combined, these tools provide a quick and efficient method to assess different watershed development scenarios and their impacts on receiving water quality. GIS is used to compile watershed parameters such as land use/land cover, soils, vegetative cover, drainage networks, topography, hydrologic data, watershed, and political boundaries. This data is linked spatially using the graphic capabilities of the software, and/or tabularly using database capabilities. In addition, GIS can compile data on pollutant sources such as on-site sewage disposal systems (OSDS), nutrient contributions for agricultural land uses, BMP effectiveness, and sediment loading.

The GIS/simulation model combination can be used to calculate pollutant loads and flow rates for various locations within the watershed. Different management strategies or land use scenarios

can be evaluated for their impact on downstream water quality. Physical conditions can also be modeled. For example, streambank erosion and depositional areas can be estimated based on land use, channel geometry, and soil particle size characteristics. Flooding potential and frequency has traditionally been modeled using several computer models. These models are now being combined with GIS databases to quickly assess the physical flooding potential of alternative management efforts or land development patterns.

GIS to can also be used to assemble biological monitoring data into a spatial database. This information can then be used to compare biological integrity across various land use/land cover situations and locations to evaluate and assess conditions leading to biological degradation. Although little literature is available on this application, utilization of the GIS tool in this area is likely to be expanded in the future.

Kasi (1993) reported on the use of GIS to compute pollution potential indices. This approach compiles pollution load estimates for different land uses and then combines this data into a single quantifiable number. Watersheds, subwatersheds, or portions of watersheds can be prioritized for management based on the potential pollutant contributions of the respective areas. This program can then be used to target resources for protection and/or remediation.

GIS and simulation models are extremely versatile for evaluating different watershed development and restoration alternatives. By using these combined tools, stormwater runoff problems and alternative control measures can be rapidly evaluated. Analysis of watershed scenarios can be evaluated at a variety of scales including analysis of different structural BMPs at the micro-scale; evaluation of comprehensive planning and growth management options at the macro-scale; and assessment of alternative land use "location" (as opposed to just type and quantity).

Watershed simulation models and GIS are limited by the input data and require calibration to be truly effective. Calibration can be very costly and time consuming. Actual monitoring data is necessary to compare simulation modeling results against actual field measurements. Furthermore, the results of simulation modeling are dependent on the resolution of the database input. The source and precision of the data must be matched with the anticipated results. Databases must be continually updated to remain current with changing development activity and other watershed changes.

Perhaps the biggest complaint made by stormwater managers regarding GIS development is the cost and resources required to input the raw data into digital format. Much of this data may be less than desirable. For example, one watershed study, in Delaware, utilized zoning maps for inputting land use data, only to find that the agricultural zone had available more than half a dozen different land development options. In addition, the data storage requirements for topography alone required a completely new computer system to accommodate the millions of bytes of data (Shaver 1995). Data from digital sources is rapidly becoming the preferred data format for most GIS because input is quicker and usually cheaper (Griffin 1995). As national, state, and local databases become more common, the data input problem will likely become more manageable.

The following references can be used to obtain additional information for a few widely used simulation models and GIS software packages:

HSPF: Hydrologic Simulation Program-Fortran. Barnwell, T.O. and R. Johanson. 1981.

HSPF: A Comprehensive Package for Simulation of Water Hydrology and Water Quality, Nonpoint Pollution Control: Tools and Techniques for the Future. Interstate Commission on the Potomac River Basin.

ANSWERS Areal Nonpoint Source Watershed Environmental Response Simulation. Beasley, D. and Huggins, L. 1982.

ANSWERS: Users Manual (EPA-905/9-82-001). Environmental Protection Agency Great Lakes National Program Office.

SLAMM Source Loading and Management Model (SLAMM), A Water Quality Management Planning Model for Urban Stormwater Runoff, Volume 1: Model Development and Summary. Pitt, R. 1991.

SWMM: Storm Water Management Model, Version 4: User's Manual (EPA/600/3-88/001, NTIS PB88-236641/AS. Environmental Protection Agency. 1988.

ARC/INFO Understanding GIS, The Arc/Info Method. Environmental Systems Research Institute, Inc. 1990.

**Paired Subwatershed Monitoring and Comparison to Reference Conditions**

The use of paired watershed studies and comparison to reference conditions is becoming an increasingly important tool for watershed research and monitoring. The paired watershed study approach involves comparing the response of two watersheds when subjected to different management practices (Clausen and Spooner 1993). The approach requires two physiographically similar watersheds which are treated identically over a calibration period to establish a quantifiable relationship between the paired data. Then one watershed, the "treatment watershed," is actively subjected to management strategies. The other (control) watershed continues to be exposed to the same conditions as during the calibration period. The control watershed accounts for climatic, seasonal, and other natural variations, while the treatment watershed measures the affects of implementation of the management programs. The same process can also be used to measure impacts associated with the lack of management or to reflect the impacts of developing watersheds.

The comparison to reference conditions involves the same approach, except a reference watershed or water body, judged to be in a natural or a "least impacted" condition, serves as the control area. Responses to management strategies or impacts from land use changes are compared with the best attainable condition (as represented by the reference condition). The reference condition may be an isolated site or may encompass an entire subwatershed. This minimally impacted site should be selected to be as typical of the natural ecoregion condition as possible. Hughes (1989) recommends the following selection criteria for ecoregional reference sites:

- Minimal impacts from stressors, common elsewhere in the ecoregion
- Within close proximity to biological refuge areas

- Few natural or man made barriers to migration
- Water body, channel type, and basin size typical of ecoregion
- Contains data of historical conditions

The reference site may be hard to initially select, since the habitat and biological characteristics should be based on the aquatic life uses to be analyzed in the study watershed or site. This reference site may be representative of the best attainable conditions of a particular watershed or may be part of a regional reference station system to evaluate conditions on a larger scale (Plafkin et al. 1989).

Comparison between paired watersheds can be used as an assessment tool to estimate a wide range of biological, physical, and chemical environmental conditions. An example might include comparing flooding frequencies between two watersheds. As one watershed experiences development, growth in the control watershed remains reasonably constant. The frequency of flood events can be documented for each watershed over a period of time and then compared to assess the impact of urbanization. An important component to this analysis is establishing the control condition through a calibration process. A variation of this type of study was reported by Weiss, in a paper entitled "Effects of Urbanization on Peak Streamflows in Four Connecticut Communities, 1980-84" (Weiss 1990).

**Photographic Records**

Another tool which is not technical in nature, but may provide valuable information, is a simple photographic or video record. Photographs can be used to document many types of indicators, but perhaps most effectively, they can be used to record physical conditions. Examples include: flood damage, channel erosion and sediment deposition, trash and debris accumulation, visible water clarity impairment, and habitat loss (both instream and riparian cover).

Photographic or video records are easy to do, require little special training, are inexpensive, and are easily understood by a wide audience. Photographs are particularly useful in documenting changing conditions over time. Application of digital camera technology can be particularly effective in linking photographic evidence of aquatic conditions at specific sites directly to a GIS watershed map. Photographs can be combined with other tools, such as watershed models, to document the complete conditions of a waterbody.

Photographs can sometimes be misleading, usually implying an un-impacted status. For instance, a water body can appear very clean, have plentiful habitat cover and other appearances of physical quality, but contain a degraded biological community due to severe water chemistry contamination. It should be emphasized that this tool is most valuable as a supporting role, and not as a stand alone measurement of a particular indicator topic.

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# CHAPTER III STORMWATER INDICATOR PROFILE SHEETS

## OVERVIEW

The twenty-six environmental indicators for stormwater monitoring are organized into six categories representing both traditional monitoring practices such as water quality monitoring, and less frequently used methods such as programmatic analyses. The indicator categories include:

- Water Quality Indicators;
- Physical and Hydrological Indicators;
- Biological Indicators;
- Social Indicators;
- Programmatic Indicators; and
- Site Indicators.

An Environmental Indicator Profile Sheet has been prepared for each indicator. The Profile Sheets provide a concise and analytical compilation of information gathered during a literature review (published separately as an Annotated Bibliography of Environmental Indicators). Each Profile Sheet contains a description of the indicator; a list of applications, advantages and disadvantages; a brief case study; and method references. The Profile Sheets are intended to function as a quick reference and provide stormwater program managers with a general introduction to various monitoring techniques. The Profile Sheets are designed to function as a guide for obtaining more information on specific indicator protocols and implementation. The Profile Sheets are only short guidance "fact sheets," therefore, they will likely best serve program managers when used to compare the applicability and utility of the various indicators.

A qualitative analysis of indicator usefulness and advantages, as well as a cost analysis, has been completed for each stormwater indicator. The analysis methodology and results are described below. The individual Profile Sheets are presented later in this chapter.

## INDICATOR USEFULNESS AND ADVANTAGES

The results of a qualitative analysis of potential indicator usefulness and advantages are presented as a concise visual guide in the Profile Sheets. This guide can be used to ascertain the usefulness of an indicator for a particular application and to determine what advantages one indicator might have over another method. To complete this analysis, two lists of questions were developed which are intended to provide some insight on the types of questions which should be considered when developing a successful stormwater management program. The questions can be answered either yes, no, or partially. The key identified below corresponds with the characters used in the Profile Sheets.

### Usefulness Matrix: Questions for Usefulness Assessors

1. Aquatic Integrity of Lakes, Streams and Estuaries: Can the indicator assist in adequately documenting changes in overall aquatic health for lakes, streams and/or estuaries?

2. Land Use Impacts: Can the indicator be useful for identifying impacts of different urban and suburban land uses on aquatic systems?
3. Stormwater Management Programs: Does the indicator measure the overall effectiveness of a stormwater management program or a component of a stormwater management program?
4. Whole Watershed Quality: Can the indicator assess the complete range of long term change/impacts in aquatic health or quality over an entire watershed?
5. Industrial Sites: Is the indicator applicable for assessing industrial site stormwater management practices and programs?
6. Municipal Programs: Is the indicator applicable for assessing municipal stormwater management practices and programs?

Key: Yes (Very Useful) ●
Partially (Moderately Useful) ◖
No (Not Useful) ○

**Advantages Matrix** **Questions for Advantages Assessors**

1. Geographic Range: Can the indicator be applied over multiple geographic regions, assuming moderate changes are made in measuring techniques?
2. Baseline Control: Can the indicator be applied to various conditions (including geographic locations) without requiring re-establishment of baseline conditions against which change is measured?
3. Reliable: Can the indicator be considered a dependable measure of aquatic system health over a wide range of stormwater applications?
4. Accuracy: Can the indicator identify the health or quality of an aquatic system with reasonable confidence?
5. Low Cost: Is the indicator cost effective in obtaining the useful and meaningful results?
6. Repeatable: Can different investigators use the same indicator and get consistently similar results under varying environmental and geographical conditions, and over a long time period?
7. All Watershed Scale: Does the indicator provide useful information across site, subwatershed, watershed and river basin scales?
8. Familiar to Practitioners: Is the indicator commonly accepted and familiar to professionals involved in urban runoff management?
9. Easy to Use and Low Training: Can personnel be trained to apply the indicator inexpensively, rapidly and with relative ease?

Key: Yes (Very Advantageous) ●
Partially (Moderately Advantageous) ◖
No (Not Advantageous) ○

The results of the indicator usefulness analysis are presented in Tables 3.1A through 3.1G (Usefulness Quick Reference Guide). The first six tables correspond to the six indicator categories. The seventh table presents a comparison of the overall usefulness of each indicator category. Similarly, the results of the analysis of indicator advantages (Tables 3.2A through 3.2G, Advantages Quick Reference Guide) are presented in six tables organized by category and one table for the overall comparison.

An overall effectiveness category has been included in both the Usefulness Guides and the Advantages Guides. Overall effectiveness was estimated based on the cumulative responses to the questions identified above. An indicator which receives a solid circle ( ● ) for both the Usefulness and Advantages Matrices and is reasonably cost efficient, is likely to be a very useful tool for stormwater program managers.

**TABLE 3.1A**
**USEFULNESS-QUICK REFERENCE GUIDE**
**WATER QUALITY INDICATORS**

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| (1) Water Quality Monitoring | ● | ● | ◖ | ◖ | ◖ | ◖ | ● | ◖ | ◖ |
| (2) Toxicity Testing | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ● | ● | ◖ |
| (3) Nonpoint Source Loading | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ |
| (4) Exceedance Frequencies | ● | ● | ● | ◖ | ◖ | ◖ | ● | ◖ | ◖ |
| (5) Sediment Contamination | ● | ◖ | ● | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ |
| (6) Human Health Criteria | ● | ○ | ● | ◖ | ◖ | ○ | ○ | ◖ | ○ |

| *Key* | |
|---|---|
| *Yes (Very Useful)* | ● |
| *Partially (Moderately Useful)* | ◖ |
| *No (Not Useful)* | ○ |

## TABLE 3.1B
## USEFULNESS QUICK REFERENCE GUIDE
## PHYSICAL AND HYDROLOGICAL INDICATORS

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| (7) Stream Widening/Downcutting | ○ | ● | ○ | ● | ◖ | ● | ◖ | ● | ◖ |
| (8) Physical Habitat Monitoring | ◖ | ● | ◖ | ● | ◖ | ● | ○ | ◖ | ◖ |
| (9) Impacted Dry Weather Flows | ○ | ● | ○ | ◖ | ◖ | ◖ | ○ | ◖ | ○ |
| (10) Increased Flooding Frequency | ○ | ● | ○ | ● | ● | ◖ | ◖ | ● | ◖ |
| (11) Stream Temperature Monitoring | ○ | ● | ○ | ● | ● | ◖ | ◖ | ● | ◖ |

## TABLE 3.1C
## USEFULNESS QUICK REFERENCE GUIDE
## BIOLOGICAL INDICATORS

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| (12) Fish Assemblage Analyses | ◖ | ● | ◖ | ● | ● | ● | ◖ | ● | ● |
| (13) Macro-invert. Assemblages | ● | ● | ◖ | ● | ● | ● | ◖ | ● | ● |
| (14) Single Species Indicator | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ |
| (15) Composite Indicators | ● | ● | ● | ● | ● | ● | ◖ | ● | ● |
| (16) Other Biological Indicators | ● | ◖ | ● | ◖ | ◖ | ○ | ◖ | ◖ | ◖ |

| *Key* | |
|---|---|
| *Yes (Very Useful)* | ● |
| *Partially (Moderately Useful)* | ◖ |
| *No (Not Useful)* | ○ |

## TABLE 3.1D
## USEFULNESS QUICK REFERENCE GUIDE
## SOCIAL INDICATORS

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| (17) Public Attitude Surveys | ○ | ○ | ○ | ○ | ● | ◖ | ○ | ◖ | ○ |
| (18) Industrial/commercial Pollution Prevention | ○ | ○ | ○ | ○ | ● | ○ | ● | ○ | ○ |
| (19) Public Involvement and Monitoring | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ○ | ◖ | ◖ |
| (20) User Perception | ◖ | ◖ | ◖ | ○ | ◖ | ◖ | ○ | ◖ | ○ |

## TABLE 3.1E
## USEFULNESS QUICK REFERENCE GUIDE
## PROGRAMMATIC INDICATORS

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| (21) No. of Illicit Connections Identified/Corrected | ● | ● | ● | ◖ | ◖ | ◖ | ● | ● | ● |
| (22) No. of BMPs Installed, Inspected, & Maintained | ○ | ○ | ○ | ◖ | ◖ | ◖ | ◖ | ● | ○ |
| (23) Permitting and Compliance | ○ | ○ | ○ | ◖ | ◖ | ◖ | ◖ | ● | ○ |
| (24) Growth and Development | ◖ | ● | ◖ | ● | ◖ | ● | ◖ | ● | ◖ |

| *Key* | |
|---|---|
| *Yes (Very Useful)* | ● |
| *Partially (Moderately Useful)* | ◖ |
| *No (Not Useful)* | ○ |

## TABLE 3.1F
## USEFULNESS QUICK REFERENCE GUIDE
## SITE INDICATORS

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| (25) BMP Performance Monitoring | ● | ● | ◖ | ◖ | ● | ◖ | ● | ● | ● |
| (26) Industrial Site Compliance Monitoring | ○ | ○ | ○ | ◖ | ● | ○ | ● | ○ | ○ |

## TABLE 3.1G
## USEFULNESS QUICK REFERENCE GUIDE
## OVERALL INDICATOR SUMMARY

| Indicators | Lakes | Streams | Estuaries | Land Use Impacts | Stormwater Management Programs | Whole Watershed Quality | Industrial Sites | Municipal Programs | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|
| Water Quality Indicators | ● | ◖ | ● | ◖ | ◖ | ○ | ● | ◖ | ◖ |
| Physical and Hydrological Indicators | ○ | ● | ○ | ● | ● | ◖ | ○ | ● | ◖ |
| Biological Indicators | ● | ● | ◖ | ● | ● | ◖ | ◖ | ● | ● |
| Social Indicators | ○ | ○ | ○ | ○ | ● | ◖ | ○ | ◖ | ○ |
| Programmatic Indicators | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ◖ | ● | ◖ |
| Site Indicators | ◖ | ◖ | ○ | ◖ | ● | ○ | ● | ◖ | ◖ |

| *Key* | |
|---|---|
| *Yes (Very Useful)* | ● |
| *Partially (Moderately Useful)* | ◖ |
| *No (Not Useful)* | ○ |

## TABLE 3.2A
## ADVANTAGES QUICK REFERENCE GUIDE
## WATER QUALITY INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) Water Quality Monitoring | ● | ◖ | ○ | ◖ | ○ | ◖ | ● | ◖ | ○ | ◖ |
| (2) Toxicity Testing | ● | ○ | ◖ | ◖ | ○ | ◖ | ◖ | ◖ | ○ | ○ |
| (3) Nonpoint Source Loading | ● | ○ | ◖ | ◖ | ○ | ● | ◖ | ◖ | ○ | ◖ |
| (4) Exceedance Frequencies | ● | ● | ◖ | ◖ | ○ | ● | ◖ | ● | ● | ● |
| (5) Sediment Contamination | ◖ | ◖ | ◖ | ◖ | ○ | ◖ | ○ | ● | ◖ | ◖ |
| (6) Human Health Criteria | ○ | ◖ | ◖ | ◖ | ◖ | ● | ○ | ● | ◖ | ◖ |

## TABLE 3.2B
## ADVANTAGES QUICK REFERENCE GUIDE
## PHYSICAL AND HYDROLOGICAL INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (7) Stream Widening/ Downcutting | ● | ● | ● | ● | ● | ● | ◖ | ● | ● | ● |
| (8) Physical Habitat Quality | ● | ● | ● | ◖ | ● | ● | ● | ● | ● | ● |
| (9) Impacted Dry Weather Flows | ◖ | ◖ | ◖ | ○ | ◖ | ◖ | ● | ◖ | ● | ◖ |
| (10) Increased Flooding Frequency | ● | ◖ | ● | ◖ | ◖ | ◖ | ● | ● | ◖ | ● |
| (11) Stream Temperature Monitoring | ● | ● | ◖ | ◖ | ◖ | ● | ● | ● | ● | ● |

*Key*

*Yes (Very Advantageous)* ●
*Partially (Moderately Advantageous)* ◖
*No (Not Advantageous)* ○

## TABLE 3.2C
## ADVANTAGES QUICK REFERENCE GUIDE
## BIOLOGICAL INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (12) Fish Assemblage Analyses | ● | ◖ | ● | ● | ◖ | ● | ◖ | ● | ◖ | ● |
| (13) Macro-invert. Assemblages | ● | ◖ | ● | ● | ● | ● | ● | ● | ◖ | ● |
| (14) Single Species Indicator | ● | ◖ | ○ | ◖ | ● | ◖ | ◖ | ◖ | ● | ◖ |
| (15) Composite Indicators | ● | ◖ | ● | ● | ○ | ● | ● | ● | ◖ | ● |
| (16) Other Biological Indicators | ● | ◖ | ○ | ◖ | ◖ | ● | ◖ | ○ | ○ | ◖ |

## TABLE 3.2D
## ADVANTAGES QUICK REFERENCE GUIDE
## SOCIAL INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (17) Public Attitude Surveys | ● | ◖ | ◖ | ◖ | ◖ | ● | ● | ◖ | ◖ | ◖ |
| (18) Indust./comm. Pollution Prevention | ● | ◖ | ◖ | ◖ | ◖ | ● | ● | ◖ | ◖ | ◖ |
| (19) Public Involvement & Monitoring | ● | ○ | ◖ | ◖ | ● | ○ | ● | ● | ● | ◖ |
| (20) User Perception | ● | ◖ | ◖ | ◖ | ◖ | ● | ● | ◖ | ◖ | ◖ |

*Key*

*Yes (Very Advantageous)* ●
*Partially (Moderately Advantageous)* ◖
*No (Not Advantageous)* ○

## TABLE 3.2E
## ADVANTAGES QUICK REFERENCE GUIDE
## PROGRAMMATIC INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (21) # Illicit Connections | ● | ○ | ◖ | ◖ | ◖ | ◖ | ◖ | ● | ◖ | ◖ |
| (22) #BMPs Installed | ● | ● | ◖ | ◖ | ○ | ● | ◖ | ◖ | ○ | ◖ |
| (23) Permitting and Compliance | ● | ● | ◖ | ◖ | ● | ● | ◖ | ◖ | ◖ | ● |
| (24) Growth and Development | ◖ | ◖ | ◖ | ◖ | ◖ | ● | ● | ◖ | ● | ◖ |

## TABLE 3.2F
## ADVANTAGES QUICK REFERENCE GUIDE
## SITE INDICATORS

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| (25) BMP Performance Monitoring | ◖ | ◖ | ◖ | ◖ | ○ | ● | ◖ | ◖ | ○ | ◖ |
| (26) Industrial Site Compliance Monitoring | ● | ● | ◖ | ◖ | ● | ◖ | ○ | ◖ | ● | ◖ |

*Key*

*Yes (Very Advantageous)* ●
*Partially (Moderately Advantageous)* ◖
*No (Not Advantageous)* ○

## TABLE 3.2G
## ADVANTAGES QUICK REFERENCE GUIDE
## OVERALL INDICATOR SUMMARY

| Indicators | Geographic Range | Baseline Control | Reliable | Accuracy | Low Cost | Repeatable | All Watershed Scale | Familiar to Practitioners | Easy to Use & Low Training | Overall Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|
| Water Quality Indicators | ● | ○ | ○ | ◖ | ○ | ● | ○ | ◖ | ○ | ◖ |
| Physical & Hydrological Indicators | ● | ● | ● | ◖ | ◖ | ● | ● | ● | ● | ● |
| Biological Indicators | ● | ◖ | ◖ | ● | ◖ | ● | ◖ | ◖ | ◖ | ● |
| Social Indicators | ● | ◖ | ◖ | ◖ | ◖ | ● | ● | ◖ | ◖ | ◖ |
| Programmatic Indicators | ● | ◖ | ◖ | ◖ | ◖ | ● | ◖ | ◖ | ◖ | ◖ |
| Site Indicators | ● | ● | ◖ | ◖ | ◖ | ● | ○ | ◖ | ◖ | ◖ |

| *Key* | |
|---|---|
| *Yes (Very Advantageous)* | ● |
| *Partially (Moderately Advantageous)* | ◖ |
| *No (Not Advantageous)* | ○ |

## COST ANALYSIS

Costs for each indicator are presented by category in Tables 3.3A through 3.3F. The costs are based on a review of available data collected through a telephone survey of stormwater practitioners, a literature review, the authors' experience, and general industry information. For example, the cost for Indicator No. 20, User Perception, is based on development and implementation of a telephone survey. According to the results of the data review, this is a common method for conducting user perception surveys.

The indicator costs should only be considered planning level estimates, and should not be relied upon as all encompassing. There are many different methodologies that can be used to perform the indicator monitoring and implementation costs can vary significantly in different regions of the country. (Examples which demonstrate how these costs comparisons may be used are presented in three case study scenarios in Chapter IV.) Program managers should verify all costs with other sources, before implementing program monitoring strategies.

TABLE 3.3A
WATER QUALITY INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COSTS | NOTES |
|---|---|---|
| (1) *Water Quality Constituent Pollutant Monitoring*<br>• Per site, one person at each site<br>• Sampling site accessible from land<br>• Conventional pollutants* and physical parameters (pH, temperature, conductivity) only<br>• Four hour sampling event<br>• Single composited sample provided for laboratory analysis<br>• Weir or flume used to establish stage-discharge relationship<br>• Stage recorded during monitoring event to determine flow<br>• Grabs sample collected manually<br>• Composite aliquots collected using automated sampler<br>• Compositing based on constant time-volume proportional to flow increment or rate relationship<br>• Cost includes analysis to compile and arrange data | $700 - $850 per station, per storm event | Cost to set-up station (installation and calibration of weir or flume; development of stage discharge relationship; acquisition of automated samplers and DO, temperature, conductivity, and pH meters; aquisition of reagents, sampling buckets, etc.) not included in cost estimate. Set up costs (based on the above-listed assumptions) will be on the average of $7,000 - $9,000 dollars per station. Cost may be reduced by using same sampler at different stations during different storm events and/or by using alternative methods to determine flow (i.e., USGS data).<br>*Conventional pollutants include those typically reported as pollutants of concern in "normal urban runoff"--(e.g., TKN, nitrate + nitrite, ammonia nitrogen, TP, ortho-phosphate, cadmium, copper, lead, zinc (both total and dissolved), TSS, $BOD_5$, COD)(Strecker 1995) |
| (2) *Toxicity Testing*<br>• Per sampling event test, assumes 10 replicate samples collected and analyized<br>• Short term, chronic 7 day toxicity test using *Ceriodaphnia dubia* or *Pimephales promelas* | $2,500 - $3,750 per sampling event | Cost estimate does not include sampling/collection costs. Cost is based on laboratory analysis only. In-situ and/or flow through testing involves sophisticated equipment and station set-up which can dramatically add to cost. |

TABLE 3.3A
WATER QUALITY INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COSTS | NOTES |
|---|---|---|
| (3) ***Nonpoint Source Loadings***<br>Method #1: Sub-watershed assessment with computer modeling<br>• Water quality data collection not included<br>• Land use/imperviousness data collection not included<br><br>Method #2: Simple method, EMC based on land use<br>• Land use/imperviousness data collection not included | **Method #1:**<br>$70,000 - $84,000 per sub-watershed<br><br>**Method #2:**<br>$500 - $1,000 per sub-watershed | Estimates for water quality data collection costs can be based on Water Quality Constituent Pollutant Monitoring costs. In Sub-watershed assumed to be approximately 5 square miles. |
| (4) ***Exceedance Frequencies of Water Quality Standards*** | N/A | Costs associated with implementation of this indicator are assumed to be minimal. The most significant portion of the cost would be associated with data collection. The data required to implement this indicator is most likely collected as part of an ongoing baseflow and/or wet weather water quality monitoring program. |
| (5) ***Sediment Contamination***<br>• Per site<br>• Conventional pollutants only*<br>• Single sample collected and laboratory analysis<br>• Interpretation of results not included | $450 - $550 per sample | Cost estimate does not include sampling collection costs.<br>*Conventional pollutants include those typically reported as pollutants of concern in "normal urban runoff"--(e.g., TKN, nitrate + nitrite, ammonia nitrogen, TP, ortho-phosphate, cadmium, copper, lead, zinc (both total and dissolved), TSS, $BOD_5$, COD)(Strecker 1995) |
| (6) ***Human Health Criteria***<br>• Annual cost<br>• Based on shellfish bed or beach closures<br>• Per growing area or beach, average 5 samples per year<br>• Fifteen to twenty locations within each growing area<br>• Two people monitoring, 8 hours per monitoring event | $5,250 - $6,500 per area (beach) | Cost based on analysis of f. coli or E. coli samples. |

TABLE 3.3B
PHYSICAL AND HYDROLOGICAL INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COST | NOTES |
|---|---|---|
| (7) ***Stream Widening/Downcutting***<br>• Per reach cost<br>• Reach defined as approximately 2000', 10 measurements per reach<br>• Two staff members required per site<br>• Stream cross-sections measured with taped surveys, not traditional field survey equipment<br>• Field cross-sections established and recorded with flagged steel reinforcing bar<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $575 to $700 per 2000 foot reach | Cost is based on surveying first and second order headwater streams, in semi-humid to humid climates.<br>For start-up add:<br>steel reinforcing bars, flagging, hip chain, 50' tape, wading rod, notebooks, clinometer, and computer(s). |
| (8) ***Physical Habitat Quality***<br>• Per reach cost<br>• Reach defined as approximately 275' (75 meters), 10 observations per reach.<br>• Quantitative assessments of natural habitat structures (such as fallen trees, large rocks, etc.), channel alterations, recently deposited sediments, riffle/pool sequences, and length of erosional areas.<br>• Qualitative assessment of presence of trash and debris, and stream character (morphology, dominate substrate, etc.).<br>• Substrate composition measured at 3 stations per reach using modified Wolman pebble count. Percent embeddedness, wetted width, bank height, gradient, and canopy coverage measured at all stations.<br>• Two staff members required per site<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $400 to $490 per 275 foot reach | Cost is based on a series of discrete measurements using quantitative and semi-quantitative descriptive parameters.<br>For start-up costs add:<br>50' tape (or walktax), clinometer, notebooks, and computer(s). |

TABLE 3.3B
PHYSICAL AND HYDROLOGICAL INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COST | NOTES |
|---|---|---|
| (9) ***Impacted Dry Weather Flows***<br>• Per study cost<br>• Study cost assumes long term (≥ 10 years) stream flow gaging data is available<br>• Study involves comparing data from one or more gaging station(s) undergoing changed land use with gaging station data from an unchanged (control) area.<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $4,500 to $5,500 per study area | Based on long term data (≥ 10 years) availability.<br>For start-up costs add:<br>Long term stream flow monitoring data and computer(s).<br>Study area assumed to include data from five stations or less. |
| (10) ***Increased Flooding Frequency***<br>• Per study cost<br>• Study cost assumes long term (≥ 10 years) stream flow gaging data is available<br>• Study involves comparing data from one or more gaging station(s) undergoing changed land use with gaging station data from an unchanged (control) area.<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $4,500 to $5,500 per study area | Based on long term data (≥ 10 years) availability.<br>For start-up costs add:<br>Long term stream flow monitoring data and computer(s).<br>Study area assumed to include data from five stations or less. |
| (11) ***Stream Temperature Monitoring***<br>• Per monitoring station cost, per year<br>• Cost includes automated samplers, recording temperature hourly, requiring downloading every six months<br>• Automated samplers are downloaded in office (laboratory), not at site<br>• Analysis of data includes computing daily mean, maximum and minimum temperature<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, printing, and equipment) | $400 to $500 per station per year | Based on yearly monitoring costs, temperature meters deployed once, data downloaded twice per year. Data is automatically downloaded into a desktop computer, additional data analysis required to compute daily mean, maximum and minimum temperatures. |

TABLE 3.3C
BIOLOGICAL INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COST | NOTES |
|---|---|---|
| (12) *Fish Assemblage Analyses*<br>• Per sample, per site cost<br>• Three staff members per site (one intern)<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, computers, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $400 to $475 per sample, per site | Based on methodology of Karr's IBI (1986).<br>Cost for first or second order stream (only one electofishing shocker required)<br>For start-up costs add:<br>electrofishing equipment, computer(s), and basic field gear (e.g., hip waders, fish holding buckets, etc.). |
| (13) *Macro-Invertebrate Assemblage*<br>• Per sample, per site cost<br>• Two staff members required per site<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, computers, printing, and equipment)<br>• Includes sub-sample analysis, identification to genus level, and preparation of summary report | $500 to $600 per sample, per site | Based on RBP protocol III, and sampling to genus level.<br>Cost for 200 individual sub-sample count<br>For start-up costs add:<br>Microscope, kick-screen sampler(s), glassware, preservative, and computer(s). |
| (14) *Single Species Indicator*<br>• Per sample, per site cost<br>• Two field staff members required per site<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, computers, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $375 to $425 per sample, per site | Based on fish electro-shocking surveys of trout or salmon.<br>For start-up costs add:<br>Electrofishing equipment, computer(s) and basic field gear. |
| (15) *Composite Indicators*<br>• Per sample, per site cost<br>• Two field staff members required per site<br>• assumes at least two biological indicators investigated per site<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, computers, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $900 to $1,075 per sample, per site. | Based on combining fish and macro-invertebrate sampling at one site.<br>For start-up costs add:<br>Equipment referenced under fish and macro-invertebrates. |

TABLE 3.3C
BIOLOGICAL INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COST | NOTES |
|---|---|---|
| (16) *Other Biological Indicators*<br>• Per sample cost, lake site<br>• Two staff members required per sample<br>• Phytoplankton community sampling costs<br>• Incudes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent, printing, and equipment)<br>• Includes data analysis and preparation of summary report | $340 - $420 per sample, per lake | Based on single index sampling for phytoplnkton only. Multi-metric protocols, incorporating habitat assessments (requiring at least two trips per sample and two or more sample locations) cost between $1,800 to $2,200 per assessment (excluding start-up costs). |

TABLE 3.3D
SOCIAL INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COSTS | NOTES |
|---|---|---|
| (17) ***Public Attitude Surveys***<br>• Per survey cost per 1,000 households contacted (implementation costs)<br>• Interviews conducted over telephone<br>• Includes survey implementation, data analysis, and summary of findings | $14,500 - $17,750 per 1,000 households | Generally, 50% of those households contacted respond to survey. |
| (18) ***Industrial/Commercial Pollution Prevention***<br>• Per survey cost per 1,000 industrial facilities contacted (implementation costs)<br>• Interviews conducted over telephone<br>• Includes survey implementation, data analysis, and summary of findings | $14,500 - $17,750 per 1,000 facilities | Generally, 50% of those industrial facilities contacted respond to survey. |
| (19) ***Public Involvement and Monitoring***<br>• Per 100,000 people<br>• Substantial in-kind support required from citizens' groups such as Save Our Streams, Trout Unlimited, Izaak Walton League<br>• Major costs associated with development and printing of educational materials training of volunteer monitors | $8,000 - $10,000 per 100,000 persons | No additional comments |
| (20) ***User Perception***<br>• Per survey cost per 1,000 households contacted (implementation costs)<br>• Interviews conducted over telephone<br>• Includes survey implementation, data analysis, and summary of findings | $14,500 - $17,750 per 1,000 households | Generally, 50% of those households contacted respond to survey. |

TABLE 3.3E
PROGRAMMATIC INDICATORS
COST COMPARISON

| INDICATOR/BASIS FOR COST | IMPLEMENTATION COSTS | NOTES |
|---|---|---|
| (21) ***No. of Illicit Connections Identified/Corrected***<br>• Per illicit connection identification survey<br>• Assumes survey will be conducted visually; smoke, dye, or other methods will not be used<br>• Illicitness of dry-weather flows will be determined by tracing source upstream in system and through use of field test kits | $1,250 - $1,750 per $mi^2$ | Cost does not include costs associated with correction of illicit connections. Nationally, approximately 15 to 20 percent of storm drain outfalls carry illicit discharges (Lalor, 1995). |
| (22) ***No. of BMPs Installed, Inspected, and Maintained***<br>• Per survey cost<br>• Includes data reporting and summary report of findings<br>• Assumes telephone survey and on-site visit to records office will be required<br>• Assumes municipalities maintain records of BMP installation and inspection<br>• No field inspections performed | $15,000 - $20,000 per survey | Cost does not include field inspecton of each facility. For file inspection program, add $80 to $100 per BMP inspected (assumes one trip per year) |
| (23) ***Permitting and Compliance*** | N/A | No cost data provided since methods and procedures to conduct surveys of permits and compliance will vary depending on the type of permit, whether or not a jurisdiction already has existing data, the means with which data is recorded, and the capability to retrieve data. |
| (24) ***Growth and Development***<br>• Annual cost<br>• Based on use of GIS database for multiple sub-watersheds<br>• Assumes growth will be tracked through imperviousness or other land use variable | $26,000 - $21,250 per sub-watershed | Initial capital expense not included in cost estimate. Costs for collection of data not included. Instead, cost is based on updating GIS system using already digitized land use or imperviousness data. Sub-watershed assumed to be approximately 5 square miles. |

TABLE 3.3F
SITE INDICATORS
COST COMPARISON

| INDICATOR/ BASIS FOR COST | IMPLEMENTATION COST | NOTES |
|---|---|---|
| (25) ***BMP Performance Monitoring***<br>• Per site, annual cost<br>• Two automated samplers collecting composite aliquots, one inflow, and one outflow<br>• Flow/stage relationship established using hydraulic capacity of inflow pipe<br>• Conventional pollutants* and physical parameters only (PH, temperature, and conductivity)<br>• 10 storms per station collected, and analyzed per year<br>• Compositing based on constant time-volume proportional to flow increment or rate relationship<br>• Includes overhead expenses<br>• Includes bi-weekly equipment maintenance and inspections<br>• Includes data analysis and preparation of summary report | $22,000 to $26,000 per site, per year | Cost to set-up stations not included in cost estimate. For set-up costs add: $14,000 to $18,000 per site (two stations)<br>*Conventional pollutants include those typically reported as pollutants of concern in "normal urban runoff"--(e.g., TKN, nitrate + nitrite, ammonia nitrogen, TP, ortho-phosphate, cadmium, copper, lead, zinc (both total and dissolved), TSS, $BOD_5$, COD) |
| (26) ***Industrial Site Compliance Monitoring***<br>• Per Industrial site (based on 5 acre site)<br>• Light industrial land use<br>• Visual inspections of compliance with pollution prevention plans<br>• One technical inspector per site<br>• Includes overhead expenses (supplies, vehicles, travel, utilities, maintenance, rent printing, and equipment)<br>• Includes preparation of summary report | $290 to $350 per 5 acre site | Based on visual inspections only, for pollutant constituent monitoring refer to Table 3.3A.<br>For start-up costs add:<br>Notepads, computer(s), camera. |

### Water Quality Indicators

The costs comparison for the water quality indicators is presented in Table 3.3A. Costs for Water Quality Constituent Pollutant Monitoring, Toxicity Testing, Sediment Contamination, and Human Health Criteria are based on sampling considerations and/or laboratory analyses. The cost comparison for Nonpoint Source Loadings, however, does not include sampling or analytical costs. Instead, the cost comparison for Nonpoint Source Loadings focuses on costs associated with model development and data manipulation.

No cost comparison is provided for Exceedance Frequencies of Water Quality Standards. Labor and capital costs associated with this indicator are most likely already incorporated into existing monitoring efforts.

### Physical and Hydrological Indicators

The cost comparison for physical indicators are computed on the basis of reach length for stream assessment techniques (e.g., physical habitat quality), study area for watershed-wide assessment techniques (e.g., increased flooding frequency), and station-year for time based monitoring techniques (e.g., stream temperature monitoring). The assumptions for the cost comparison are included in Table 3.3B. Since the costs are closely tied to the assessment methodologies, and since these methodologies can vary from study to study, the specific assessment methodology is depicted for each indicator. Other alternative methodologies may be used, but the cost assumptions will need to be verified.

### Biological Indicators

The cost comparison for biological indicators are, in general, computed on a per sample, per site basis. The assumptions for the cost comparison are included in Table 3.3C. These include the number of staff required, overhead expenses, the methodology used to conduct the monitoring, and items needed to compute start-up costs. The cost data was obtained from a brief survey of stormwater practitioners, the authors' experience and general industry information.

The data is reported on unit cost to aid stormwater program managers in planning monitoring programs. For implementation of a state-wide or large municipality program, add administrative and management staff costs. The cost is reported as a range, which encompasses the average of costs obtained from the survey results. Programs which have a large number of monitoring stations will undoubtably receive the rewards of economy of scale, whereas programs with a small number of stations can expect to pay more per station.

### Social Indicators

The costs comparison for the social indicators is presented in Table 3.3D. Costs for Public Attitude Surveys, Industrial/Commercial Pollution Prevention, and User Perception are based on the same assumptions regarding development costs, implementation costs (via telephone), and analysis costs. Although these indicators represent different methods for assessing the social aspect of stormwater management, the tools used to measure the indicators are similar. The costs for these indicators are presented on a per 1,000 households (or industrial facilities) contacted basis.

Costs for Public Involvement and Monitoring are based on a survey of various citizen groups and local watershed protection and nonpoint source government agencies. These costs are

presented on a per 100,000 person basis.

**Programmatic Indicators**

Table 3.3E presents the costs comparison for the programmatic indicators. The major portion of the costs for Permitting and Compliance; Number of BMPs Installed, Inspected, and Maintained; and Number of Illicit Connections Identified/Corrected are labor costs. Implementation of these indicators will probably require a significant man-hour investment. However, little, if any, capital costs will be expended.

Growth and Development costs, on the other hand, include significant capital costs for computers and workstations, as well as labor costs associated with development, maintenance, and updating of a GIS database.

**Site Indicators**

The cost comparison for site indicators are computed on the basis of each BMP monitored for BMP performance monitoring and each site for industrial site compliance monitoring. The assumptions for the cost comparison are included in Table 3.3F. The specific assessment methodology is depicted for each indicator. Other alternative methodologies may be used, but the cost assumptions will need to be verified.

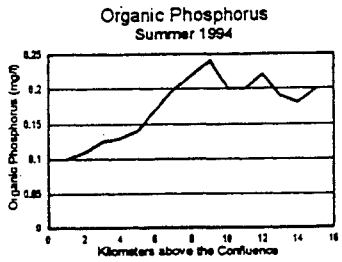
## INDICATOR PROFILE SHEETS

The twenty-six Environmental Indicator Profile Sheet are listed by category in Table 3.4. Each Profile Sheet contains a brief description of the indicator; a discussion of indicator utility; a review of indicator advantages and disadvantages; a case study; and method references. In addition, the results of the analysis of indicator usefulness and advantages are presented in the sidebar on the right side of each Profile Sheet.

TABLE 3.4
ENVIRONMENTAL INDICATOR PROFILE SHEETS

| | INDICATOR NAME | PROFILE NO. |
|---|---|---|
| **Water Quality Indicators** | Water quality pollutant constituent monitoring | 1 |
| | Toxicity testing | 2 |
| | Non-point source loadings | 3 |
| | Exceedance frequencies of water quality standards | 4 |
| | Sediment contamination | 5 |
| | Human health criteria | 6 |
| **Physical and Hydrological Indicators** | Stream widening/downcutting | 7 |
| | Physical habitat monitoring | 8 |
| | Impacted dry weather flows | 9 |
| | Increased flooding frequency | 10 |
| | Stream temperature monitoring | 11 |
| **Biological Indicators** | Fish assemblage | 12 |
| | Macro-invertebrate assemblage | 13 |
| | Single species indicator | 14 |
| | Composite indicators | 15 |
| | Other biological indicators | 16 |
| **Social Indicators** | Public attitude surveys | 17 |
| | Industrial/commercial pollution prevention | 18 |
| | Public involvement and monitoring | 19 |
| | User perception | 20 |
| **Programmatic Indicators** | No. of illicit connections identified/corrected | 21 |
| | No. of BMPs installed, inspected, and maintained | 22 |
| | Permitting and compliance | 23 |
| | Growth and development | 24 |
| **Site Indicators** | BMP performance monitoring | 25 |
| | Industrial site compliance monitoring | 26 |

# *Environmental Indicator Profile Sheet*




**Indicator Profile No. 1**

## Water Quality Pollutant Constituent Monitoring

Category: **Water Quality**

**Tools Used to Measure Indicator:**

- Pollutant Concentrations
- Event Mean Concentrations
- Spatial and Temporal Trend Analysis

### Description:

Water quality monitoring has traditionally focussed on examination of chemical parameters such as oxygen demand, nutrients, and metals, and physical parameters such as pH and temperature. Stormwater monitoring usually requires collection of water samples from stormwater detention and retention facilities, structural and non-structural conveyance channels, stormwater outfalls, and receiving waters during storm events. Evaluation of the parameters may be conducted in the laboratory (e.g. for chemical parameters) or in the field (e.g. pH).

Depending upon the geographic and temporal scope of the monitoring effort, monitoring results may be used to assess current water quality conditions at a specific location; evaluate changes in water quality throughout different seasons or over a period of years; or identify longitudinal or spatial trends in water quality along a river or within a lake. The monitoring results may also be used to identify significant sources of pollution or times of the year when water quality noticeably worsens.

### Utility of Indicator to Assess Stormwater Impacts:

- Monitoring results from long-term efforts (five years or more) can be examined to identify trends in water quality conditions over time.
- Monitoring results from urban stormwater studies can be compared to pollutant concentrations in reference rural or "least impacted" watersheds to assess the relative degree of impairment.
- Trends may correlate with land use changes or watershed restoration efforts, helping watershed managers determine priorities for problem sources and pollutants.
- Monitoring results can be used to identify pollution problems and identify potential sources of degradation.
- Monitoring can be implemented on both a regional and local level.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ● |
| Estuaries | ◖ |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ● |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ○ |
| * Accuracy | ◖ |
| * Low cost | ○ |
| * Repeatable | ◖ |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ○ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3A

**Advantages of Method:**

- Reasonably well standardized, generally accepted sampling methods and protocols are already established in many jurisdictions.
- Many jurisdictions have an extensive historical database which may be examined to determine whether water quality degradation has occurred over a specified period of time.
- Monitoring results are easily presented in graphic form.
- Violations of regulatory standards may be quantified and, therefore; are more likely to be legally defensible.
- Large existing databases on urban and highway stormwater runoff quality allows comparison between local and national concentrations.

**Disadvantages of Method:**

- Generally, samples must be collected during representative storm event (i.e., volume and duration of rain varies by less than 50 percent from average) to provide accurate characterization of event mean concentrations.
- Multiple sampling events over an extensive period of time are usually required to identify statistically defensible trends in water quality due to the tremendous variability seen in urban runoff data.
- This method is essentially a derivation of traditional, baseflow water quality monitoring using primarily chemical parameters. The applicability of this method to stormwater characterization has been questioned by many municipal stormwater managers.
- Requires accurate measurement of storm flow and automated sampling

**Case Study:** Wright, R.M.; Roy Chaudhury, R.; Makam, S. 1995
**Experiences from the Blackstone River Wet Weather Initiative**
*In: Stormwater NPDES-Related Monitoring Needs. Conference Proceedings. American Society of Civil Engineers. Mt. Crested Butte, CO. Aug. 7-12, 1994*

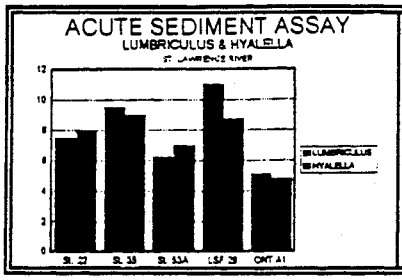
A program, initiated by the U.S. EPA, to study the Blackstone River under dry and wet weather conditions was conducted to pinpoint and rank major sources degrading water quality. The river was monitored at 13 locations along 48 miles, in addition to, six tributaries and five point sources. Three storms were monitored for 23 constituents with at least ten samples at each of the stations. Methods of interpreting the water quality data and isolating the sources into dry and wet weather sources are presented. The wet weather component is studied to establish loadings from point sources, new materials (runoff related) and old materials (bottom sediment re-suspension). A procedure to estimate annual loading rates is presented.

Total suspended soils and lead concentrations in the river generally increased during wet weather conditions. Copper concentrations also increased. This is attributed to re-suspension of copper from the sediments on the bottom. The original source of the copper is probably dry weather discharges from a wastewater treatment plant. Calcium and magnesium concentrations decreased during wet weather due to dilution. Overall, fluctuations in wet weather concentrations are attributable to pollutant loadings from runoff and re-suspension of pollutants in the sediment.

**Method References:**

- Chemical Monitoring: Taylor, G.F. 1990. *Quantity and Quality of Stormwater Runoff from Western Daytona Beach, Florida, and Adjacent Areas.* USGS Water-Resources Investigations Report 90-4002.
- Stormwater Sampling: EPA. 1992. *NPDES Storm Water Sampling Guidance Document.* EPA/833/B-92-001.
- Toxicity testing: Peltier, W.H.; C.I. Weber. 1985. *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms.* EPA/600/4-85/013. Environmental Monitoring Laboratory, Cincinnati, OH.

# *Environmental Indicator Profile Sheet*




**Indicator Profile No. 2**

## Toxicity Testing

Category: **Water Quality**

**Tools Used to:**
**Measure Indicator:**

- Acute, Chronic, and In-Situ Toxicity Testing
- Microtox
- Toxicity Identification Evaluation (TIE)

### Description:

Toxicity testing is used to assess the impact of stormwater pollutants on the overall quality of aquatic systems. Toxicity testing is usually conducted in a laboratory setting using sample water (e.g. stormwater runoff) and test organisms such as *Ceriodaphnia dubia* or *Pimephales promelas*. A single species or microcosm is exposed to collected stormwater runoff for a period of time. The organisms are analyzed for evidence indicating that exposure to pollutants in the stormwater produced lethal or sublethal effects such as mortality, limited reproduction, or stunted growth. Negative physiological and behavioral changes in response to stormwater exposure may also indicate the presence of pollutants in toxic concentrations.

Acute toxicity testing focuses on effects which become apparent over a relatively short interval (i.e., usually 24 to 96 hours). Chronic toxicity tests are used to identify effects which become apparent only after long periods of exposure, usually ten percent of the test organism's life span or longer. Chronic toxicity tests are commonly conducted over a seven-day period; longer periods of exposure are also used.

In-situ or flow through toxicity testing may also be conducted. Test organisms are transported to the site and placed in submerged exposure chambers designed to allow water flow in and out of the chamber. After the exposure period, the organisms are collected and analyzed in the laboratory for evidence of lethal or sublethal effects. Both acute (short-term) and chronic (long-term) toxicity testing can be conducted in-situ.

In order to identify the probable agent of the observed toxicity, toxic identification evaluation (TIEs) procedures may be performed. TIE is a step-wise procedure which first identifies the probable class of toxicant (e.g., metals, nonpolar organics) and then the specific toxicant (e.g., mercury, creosote). Once the probable toxicant has been identified, control measures may be developed and implemented.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◖ |
| Streams | ◖ |
| Estuaries | ◖ |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ● |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ○ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ○ |
| * Repeatable | ◖ |
| * All Watershed Scale | ◖ |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ○ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3A

**Utility of Indicator to Assess Stormwater Impacts:**

- Various species with specific levels of sensitivity can be used to evaluate the severity and identify the potential causes of degradation (i.e., pollutants).
- Toxicity testing can be used to evaluate the effectiveness of stormwater BMPs and other stormwater pollution reduction measures.
- Species-specific toxicity testing can be used as a rallying point for aquatic system restoration, especially if a particularly sensitive, well-known, and economically significant species is used.
- Applicable on both local and regional levels.
- Results of toxicity testing can be used by watershed managers to identify areas of high concern and to establish restoration priorities.
- Phase I, II, and III TIE procedures can be used to help identify specifc pollutant sources.

**Advantages of Method:**

- A great deal of data is available describing acute and chronic toxicity limits for various species.
- Toxicity testing can easily be incorporated into tiered stormwater monitoring programs. First tier indicators such as fish and macroinvertebrates assemblages and water quality monitoring can be examined to determine if the system is degraded. Toxicity testing, a second tier indicator, can then be used to identify the probable cause and source of the degradation.
- Watershed managers can identify potential severity of water quality degradation by using species with differing levels of sensitivity to environmental parameters.
- Different species sensitivity assists watershed managers' ability to distinguish between potential causes of existing water quality problems.
- The obvious visual impacts on species (e.g., tumors, stunted growth, and discoloration) can generate public concern and motivate involvement with restoration efforts.

**Disadvantages of Method:**

- Several possible factors influence toxicity for a given species, including concentration of the contaminant, concentrations of other substances, temperature, the organism's environmental conditioning and acclimation, toxicant interactions, and duration of exposure.
- Toxicity testing has historically focused on short term and lethal effects. Sublethal effects, which may not become apparent for years and which can include impacts to reproductive behavior, migration patterns, and predator avoidance, have not been as thoroughly studied.
- The same species may exhibit varying tolerance levels for different pollutants or combination of pollutants.
- Toxicity testing often occurs in a laboratory setting where conditions may not simulate exactly those found in the natural environment.
- There is some disagreement among practitioners about what constitutes acceptable and unacceptable aquatic impacts.
- Organisms' actual exposure to pollutants in stormwater is generally limited. Many toxicants in runoff are usually in biologically less available forms. Standard toxicity limits (generally developed under simulated baseflow conditions) are therefore, not wholly representative of stormwater toxicity response.
- A large quantity of the test organisms must be available quickly and the health of these organisms must be established through reference or control conditions.
- Reliance on single species tests or using only one species may not provide an accurate assessment of ambient toxicity.

**Case Study:** Hall, K.J.; B.C. Anderson. 1988
**The Toxicity and Chemical Composition of Urban Stormwater Runoff**
*Canadian Journal of Civil Engineering, Vol. 15, pp. 98-106 (1988)*

The authors studied the effects of land use on the chemical composition of urban stormwater runoff and its subsequent acute toxicity to the aquatic invertebrate *Daphnia pulex* in a drainage basin in British Columbia. It was determined that both land use and interval between rainfall events influenced the chemical composition and toxicity of the stormwater. Six of the twelve sites studied produced stormwater that was toxic to some degree. Stormwater from all open and/or green space areas was nontoxic to *Daphnia* in static 96-h tests. The frequency of occurrence of toxicity in stormwater, in relation to land use, appeared to be commercial > industrial > residential > open space.

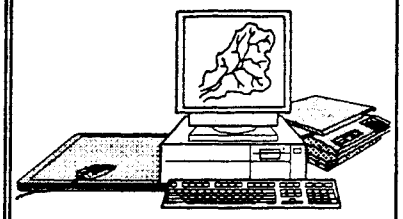
An examination of the pattern of toxicity in the watershed showed higher toxicity in the upper and lower reaches of the basin; those sites in the middle of the basin all had runoff that was nontoxic. In general, these middle reaches of the basin are at the lower, gently sloping elevations, close to the main water bodies and have been predominantly used for residential and open and/or green space land uses.

In laboratory bioassays with *Daphnia*, toxicity of iron was low and it reduced the toxicity of other metals. Lead increased the toxicity of copper and zinc. There was an increase in metal toxicity as pH decreased and suspended solids concentrations increased. The laboratory experiments begin to explain the variable nature of stormwater toxicity and provide an understanding of why field measurements of toxicity in stormwater can change rapidly, as a storm flushes particulate and soluble materials from the watershed.

**Method References:**


- Acute and chronic toxicity testing: Sayre, P.G.; D.M. Spoon, D.G. Loveland. 1986. Use of Heliophrya sp., a Sessile Suctorian Protozoan, as a Biomonitor of Urban Runoff. In: *Aquatic Toxicology and Environmental Fate: Ninth Volume*. Philadelphia, April 14-16, 1985. ASTM Special Technical Publication 921.
- Microtox: Morrison, G.M. et al. 1993. Variations of Environmental Parameters and Ecological Response in an Urban River. *Water Science and Technology*, 27(12):191-194.
- Long-term in-situ testing: Day. K.E. et al. 1990. Changes in Intracellular Free Amino Acids in Tissues of the Caged Mussel, *Elliptio complanata*, Exposed to Contaminated Environments. In: *Archives of Environmental Contamination and Toxicology*. New York. Vol 19, No. 6, pp 816-827.
- Toxicity identification evaluation (TIE) procedures: S.R. Hansen and Associates. 1994. *Identification and Control of Toxicity in Storm Water Discharges to Urban Areas: Final Report*.
- Marsh, J.M. 1993. Assessment of Nonpoint Source Pollution in Louisville, (Jefferson County), Kentucky. In: *Archives of Environmental Contamination and Toxicology*. New York. Vol 25, No. 4, pp. 446-455.
- U.S. Environmental Protection Agency. 1992. A Pilot Study for Ambient Toxicity Testing in Chesapeake Bay. Annapolis, MD. U.S. EPA Contract No. 68-WQ-00-43.
- Weber, C. I. (ed). 1991. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (Fourth Edition). EPA/600/4-90/027 Environmental Monitoring Stystems Laboratory, Cincinnati, OH.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 3**

## Nonpoint Source Loadings

Category: **Water Quality**

**Tools Used to Measure Indicators:**

- Computer Simulation Models (HSPF, SWMM, SLAMM, ILLUDAS, WASP)

### Description:

Nonpoint source (NPS) pollutant loadings represent the amount of pollutant in stormwater runoff from various land uses. NPS loadings are not directly measured, but instead are estimated based on empirical monitoring data, land use imperviousness and cover, area, and rainfall volume. NPS loadings can be used to estimate baseline water quality or to determine the relative decrease or increase in NPS pollutant loads due to changes in land use or implementation of restoration efforts.

NPS loading estimates can be calculated using the simple method or simulation models. The simple method is appropriate for small-scale studies. Comprehensive NPS loading estimates may be obtained with simulation models such as HSPF, SLAMM, or SWMM. Changes in NPS pollutant loadings in response to changes in watershed land use (typically pre-developed, existing, and anticipated future conditions) can be estimated using simulation models. Estimates may be reported on an average annual or seasonal mass basis or for a single storm event.

### Utility of Indicator to Assess Stormwater Impacts:

- Trends in NPS pollutant loadings can be compared with land use changes or implementation of BMPs to assess potential increases or reduction in NPS pollution.
- Can be used to help identify major land uses which are significant sources of NPS pollution.
- Can be used as a planning tool to evaluate loads associated with different development options.
- Can be used to help identify portions of a watershed where loadings may be concentrated and pollutant accumulation is likely.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◐ |
| Streams | ◐ |
| Estuaries | ◐ |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ◐ |
| * Municipal Programs | ◐ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ○ |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ○ |
| * Repeatable | ● |
| * All Watershed Scale | ◐ |
| * Familiar to Practitioners | ◐ |
| * Easy to use & Low training | ○ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3A

**Advantages of Method:**

- Calibrated NPS loading models can quickly and efficiently evaluate many different land use development options.
- Good method for evaluating pollutant load distribution throughout a watershed with respect to various land uses and restoration strategies.
- Allows for geographic analysis of watersheds and priority ranking of possible nonpoint sources.
- Identifies which NPS pollutants are most prevalent, allowing for programs targeted at reducing those specific pollutants.
- Calibrated NPS loading models partially alleviate the need for additional water quality monitoring.

**Disadvantages of Method:**

- Accuracy in estimating NPS pollutant load may vary from method to method and model to model.
- Development and calibration of watershed NPS loading models can be relatively expensive and time consuming. It may take several years to accurately evaluate trends in NPS loads.
- Accurate modeling requires fairly sophisticated data collection conducted over several years and a reasonably in-depth personnel training program.
- BMP pollutant removal efficiencies used in modeling may substantially differ from actual removal rates.
- Focus on urban stormwater loading and in-stream pollutant concentrations can be misleading in assessing land use impacts since these indicators do not address critical hydrological impacts and effects.

**Case Study:** Wulliman, J.T., 1994

**Application of Nonpoint Source Loading Relationships to Lake Protection Studies in Denver, Colorado**

*Pawlukiewicz, J.; et. al. (eds.), 1994. Proceedings from Watershed '93: A National Conference on Watershed Management., Alexandria, VA., Mar 21-24, 1993., USEPA No. 840-R-94-002*

The paper evaluates various approaches to estimate nonpoint source loads from watershed areas to help assist watershed managers in selecting alternative options. Ten loading estimation options, consisting of 4 basic methods are presented. They consist of various levels of analysis ranging from simple calculations to complex approaches which require hydrologic modeling and site-specific monitoring. The four methods are: the Unit Load Method, where loads are calculated based on a unit loading rate multiplied by the upstream drainage area; the EMC Method, where loads are expressed as the product of the constituent concentration and the runoff volume; the Regression Method, where watershed loads are estimated using regression relationships developed from local, regional, or national stormwater monitoring data; the Sediment Method, where loads are expressed as the product of the constituent concentration and the sediment volume. A number of these options have been used effectively in lake protection studies in the Denver area. In selecting which option to use, it is important to keep in mind the accuracy required and the budgetary limits. In general, there is a direct relationship between the accuracy and the level of complexity of the method. The Unit Load Method, for example is relatively quick and simple to calculate loads but does not incorporate physical hydrologic processes or site specific data and therefore may yield highly uncertain results. The other methods may be much more accurate but require a more sophisticated approach and are more difficult and costly to perform.

**Method References:**


- Simulation models (HSPF): Dinicola, R.S., 1990. *Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington State.* 55 pp.
- Simulation models (HSPF, ILLUDAS, SWMM): Dendrou, S.A., 1982. Overview of Urban Stormwater Models., *In: Urban Stormwater Hydrology*, American Geophysical Union, Washington, DC. Water Resources Monograph 7, 1982. p. 219-247
- Simulation models (WASP): DiToro, D.M.; J.J. Fitzpatrick; R.V. Thomann, 1983. *Documentation for Water Quality Analysis Simulation Program (WASP) and Model Verification Program (MVP).* Westwood, New Jersey. Hydroscience, Inc. EPA600381044.
- Simulation models (SLAMM): Pitt, R.; J. McLean, 1986. *Toronto Area Watershed Management Strategy Study - Humber River Pilot Watershed Project.* Toronto, Canada. Ontario Ministry of the Environment, June 1986.
- Simulation models (general): Hoos, A.B.; J.K. Sisolak, 1993. *Procedures for Adjusting Regional Regression Models of Urban-Runoff Quality using Local Data.* USGS, Open File Report 93-39, 1993, 39p.
- Simple method: Schueler, T.R., 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's.* Metropolitan Washington Council of Governments, Publication No. 87703

**Case Study:** Cooke, T.; Drury, D.; Katznelson, R.; Lee, C.; Mangarella, P.; Whitman, K. 1995
**Storm Water NPDES Monitoring in Santa Clara Valley**
*Stormwater NPDES-Related Monitoring Needs.* Conference Proceedings. 1995.

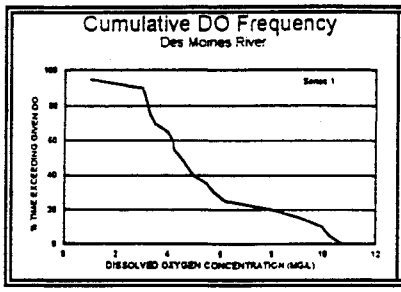
The authors compared metals monitoring data from four years of sampling with water quality objectives contained in the April 1991 California Inland Surface Waters Plan. Dissolved concentrations seldom exceeded objectives, whereas total metal concentrations exceeded the objectives with greater frequency. Most exceedances occurred at stations whose watersheds were smaller and more highly urbanized. Exceedances of objectives by dissolved metal concentrations were considered better indicators of potential toxicity problems than exceedances by total metals concentrations because dissolved metals are more bioavailable.

The duration of exceedance was also measured at one station. The duration of exceedance of acute water quality objectives for total copper, lead and zinc was always less than the duration of the storm runoff event. The frequency of exceedance varied depending on the metal, and was greatest for copper, followed by zinc and lead. For those cases where an exceedance was measured, the average duration of exceedances, expressed as a percent of the storm duration, was approximately 60% for copper, 40% for zinc, and about 20% for lead.

**Method References:**

- Frequency Exceedances: Yamane, C.M.; M.G. Lum, 1985. *Quality of Storm-Water Runoff, Mililani, Oahu, Hawaii, 1980-1984.* USGS Water-Resources Investigations Report 85-4265.

# *Environmental Indicator Profile Sheet*




**Indicator Profile No. 4**

## Exceedance Frequencies of Water Quality Standards

Category: **Water Quality**

**Tools Used to Measure Indicator:**

- Chemical Monitoring
- Trend Analysis

### Description:

Water quality standards have been established by federal, state, and local governments for various pollutants and receiving water classifications. The frequency with which a particular standard is exceeded or the percentage of water bodies, river-miles, or lake-acres failing to meet designated uses may be indicative of the relative success or failure of stormwater management efforts.

While physical characteristics (e.g., downcutting, flooding) and biological parameters (e.g., assemblage or diversity) could be evaluated by this method, few jurisdictions have standards for such parameters. Consequently, current use of this indicator is based primarily on chemical standards.

The frequency analysis can incorporate data already collected by local and State agencies as part of the 305(b) reporting process. Section 305(b) of the Federal Water Pollution Control Act requires States to prepare a biennial report including analyses of the extent to which pollution reduction; maintenance of specified levels of water quality; and protection of aquatic habitat, wildlife, and recreational usage has been achieved.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to evaluate the performance of stormwater BMPs with respect to various storm frequencies.
- Can be used to identify long-term and seasonal trends in regional water quality.
- Can be used to characterize water quality impacts due to urban runoff with respect to various storm categories (frequent storms, flood events).
- Can be used to document periods of poor water quality (e.g., following large storm events, during low-flow summer months).

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ● |
| Estuaries | ● |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ● |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ○ |
| * Repeatable | ● |
| * All Watershed Scale | ◖ |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3A

**Advantages of Method:**

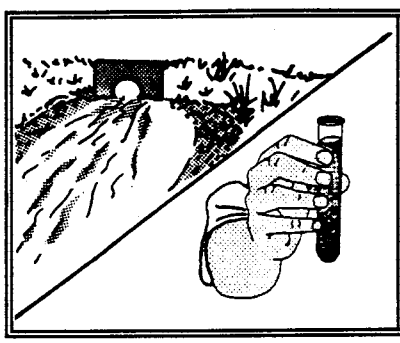
- Many jurisdictions already have long-term databases which may be examined to determine if standard exceedances are increasing in frequency (trend analysis).
- Required sampling and parameter determination for this indicator are already incorporated into regular monitoring programs and the 305(b) reporting process in many jurisdictions.
- Results are easy to interpret, making the method a good tool for initiating policy actions, securing funding sources, etc.
- Provides a reliable and legally defensible benchmark for enforcement actions.

**Disadvantages of Method:**

Exceedance frequencies are developed on a constituent by constituent basis. Comprehensive assessment of a particular water body or stormwater management effort requires identification and evaluation of several parameters and standards.

- Several sample locations are required within a relatively small area to determine the actual cause or source of the standard exceedance.
- Exceedance frequencies alone may not identify the causes and sources of observed degradation. Additional long-term and/or longitudinal monitoring may be required, especially if in-stream samples are used.
- Most criteria and standards are based on a few chemical water quality parameters that present indirect measure of the presence or absence of aquatic life.
- There are almost none that are based on physical or biological parameters that reflect the actual versus inferred presence or absence or aquatic species.
- Exceedance frequency may be an artifact of monitoring effort as much as water quality degradation. The more frequently monitoring is conducted, the more likely exceedances will be detected.
- Exceedance of a water quality standard or criteria may only occur briefly during storm events. Exceedance of the standard may not be reflected in the sample collected, and actual long-term impacts on the aquatic community are difficult to predict.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 5**

## Sediment Contamination

(Constitutent/toxicity analysis)

Category: **Water Quality**

**Tools Used to Measure Indicator:**

- Constituent Concentrations
- Sediment Quality Assessment Guidelines
- Spectrophotometry
- Chromatography

### Description:

Many pollutants found in stormwater runoff, such as metals, organic toxins, and aromatic compounds, become attached to sediments and settle to the bottom in slower receiving waters, wetlands, and stormwater retention and detention basins. The presence and mass concentration of pollutants can be determined through spectrometric and chromatographic analyses of sediment samples.

Sampling may be conducted in natural water bodies (e.g. streams, lakes, estuaries) or artificial basins (e.g. detention ponds). To determine whether sediments are contaminated by anthropogenic sources, samples are often compared to a reference water body where human impacts are minimal or nonexistent. The mass of contaminant is often cross-referenced with the distance from the suspected pollutant discharge location (e.g., stormwater outfall) or source (e.g., urban area).

Sediment may adversely impact the aquatic community. Benthic organisms feed and dwell in the bottom sediments. Nonbenthic organisms are potentially exposed to sediment contaminants through re-suspension, ingested benthic organisms, and exposure to the sediment as it settles to the bottom.

In order to identify potential ecological effects, contaminant concentrations may be compared to sediment quality assessment guidelines. Ecological impacts may also be assessed through analysis of the associated interstitial (pore) water and water immediately overlying the sediment. This water can be collected and analyzed for conventional pollutants. Acute and chronic toxicity testing of the water immediately overlying the sediment may be conducted either in the field or in the laboratory. Toxicity testing of the interstitial water and the sediment elutriates (recreated sediment suspensions) are performed in the laboratory.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ◖ |
| Estuaries | ● |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ◖ |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ◖ |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ○ |
| * Repeatable | ◖ |
| * All Watershed Scale | ○ |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3A

**Utility of Indicator to Assess Stormwater Impacts:**

- Analysis of the sediment within urban embayments can provide an indication of the level of contamination and, by proximity, the probable source of contamination in the drainage area.
- Analysis of samples taken within and/or immediately upstream and downstream of stormwater management facilities can be used to evaluate the performance of BMPs.
- Trends in sediment pollutant levels over time can reveal long-term changes in pollutant loadings.
- Can be used to evaluate local stormwater management efforts for the control of particular pollutant sources over the long term.

**Advantages of Method:**

- The relatively static nature of this indicator may increase public interest and involvement in stormwater issues.
- The likelihood that sediment pollutants come from nearby sources promotes local accountability thereby reducing the potential for jurisdictions to blame problems on others and instead encouraging them to assume responsibility for restoration.

**Disadvantages of Method:**

- There are few criteria or standards against which ambient sediment pollutant concentrations may be compared.
- Levels of concern and the long-term impact of sediment pollutant concentrations with respect to ecological impacts are still being studied and are not clearly defined.
- The method requires numerous samples (both spatially and at various depths) to determine whether pollutants come from anthropogenic sources.
- The method is useful only for pollutants that become adsorbed to dense particulates.
- Since sedimentation occurs primarily in low-energy embayments, the indicator is less appropriate for use in free-flowing channels.
- The usefulness of this indicator for "real-time" assessment of current pollutant reduction measures is limited due to resuspension of sediments, dredging, and other activities which inhibit the short-term settlement of pollutants.
- Several decades may be necessary to accumulate sufficient data for trend analysis.
- Industrial spills, wastewater discharges, illicit connections, atmospheric deposition and runoff from agricultural and industry sources can all deliver pollutants to sediments, making it very difficult to trace the actual source.
- While suspended in the water column, pollutants may undergo differential chemical behavior, microbial degradation, and photo-degradation. Correlation of the original pollutant source to pollutants identified in the sediment may, therefore, be difficult.

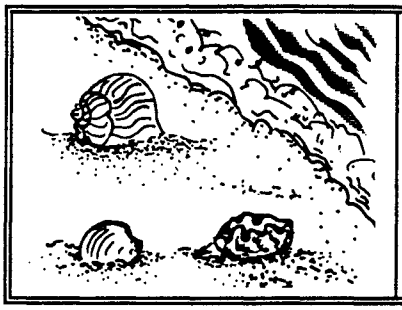
**Case Study:** Byrne, C.J.; DeLeon, I.R. 1987
**Contributions of Heavy Metals from Municipal Runoff to the Sediments of Lake Pontchartrain, Louisiana**
*Chemosphere, Vol. 16, Nos. 10-12: 2579-2583, 1987.*

The authors analyzed sediment samples from eight stations along the northern and southern shorelines of Lake Pontchartrain to determine the distribution and sources of heavy metal pollutants. Sampling sites were at stormwater runoff canals, the mouth of a highly industrialized canal, and the mouths of two lake tributaries. The authors used atomic absorption spectrometry to determine sediment concentrations of barium, copper, nickel, lead, and zinc. Metal concentrations tended to increase with increasing population densities, with the most highly impacted areas being adjacent to the metropolitan area of New Orleans. Lower metal concentrations were found in suburban/residential areas, with the lowest levels observed at the rural, low-density station.

**Method References:**


- Chemical Monitoring: Taylor, G.F. 1990. *Quantity and Quality of Stormwater Runoff from Western Daytona Beach, Florida, and Adjacent Areas.* USGS Water-Resources Investigations Report 90-4002.
- Toxicity testing: ASTM. 1995. Standard Guide for Collection, Storage, Characterization and Manipulation of (Freshwater/Saltwater) Sediments for Toxicological Testing. in Annual Book of ASTM Standards, Section II. Water and Environmental Technology. Vol 11.05.
- Biological monitoring/bioassays: Dermott, R.; M. Munawar. 1992. A Simple and Sensitive Assay for Evaluation of Sediment Toxicity Using *Lumbriculus variegatus* (Mueller). In: Hart, B.T.; Sly, P.G. (eds). *Sediment-Water Interactions.* Vol. 235-6, pp. 407-414.
- Contaminated sediment: U.S. EPA. 1994. EPA's Contminated Sediment Management Strategy-Reinventing Bovernment to Streamline Dicision-making. Washington, DC 151p. EPA/823/R-94/001

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 6**

## Human Health Criteria

Category: **Water Quality**

**Tools Used to Measure Indicator:**

- Bacteria concentrations
- Shellfish Bed Closures
- Fishing Restrictions
- Beach Closures

### Description:

Bacteria (usually fecal coliform, *Escherichia coli*, or *enterococci)* are often used as indicators of human pathogens in the water column. Large bacterial concentrations are assumed to be indicative of harmful levels of pathogens. Pathogens are of special concern in shellfish harvesting and recreational contact waters. Water quality criteria for these uses are among the strictest of all water use classifications.

Contact recreation such as water-skiing and swimming potentially expose humans to harmful pathogens; when bacterial levels exceed established standards, beaches may be closed. Since shellfish are filter feeders, they tend to accumulate pathogens in their tissues. When bacteria concentrations exceed the acceptable standard, it is assumed that shellfish taken from the area are unfit for human consumption. Consequently, the shellfish beds are closed to recreational and commercial harvesting.

Because bacteria concentrations tend to sharply increase following storm events, it is strongly suspected that stormwater runoff contributes significantly to elevated bacteria levels. A change in the frequency of shellfish bed closures or beach restrictions, therefore, can provide an early indication of degradation and may be used to assess the effectiveness of stormwater management programs.

Increases in fishing restrictions may also indicate degradation due to urban runoff. Similar to shellfish, fish tend to accumulate pathogens in their tissue. It should be noted that not all fishing restrictions are due to elevated bacterial concentrations. Restrictions may also be implemented in response to high toxic metal, or other pollutant concentrations.

### Utility of Indicator to Assess Stormwater Impacts:

- The tendency for many shellfish beds to be closed immediately following a storm event suggests that it can be used as an indicator of short term stormwater impacts.
- Consistent, long-term shellfish bed closures and beach restrictions can be used to detect early stages of water quality degradation.
- Can be used to assess the relative effectiveness of stormwater BMPs or watershed restoration efforts.
- Can be used as a motivational tool for initiating public support for stormwater management efforts.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ○ |
| Estuaries | ● |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ○ |
| * Industrial Sites | ○ |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ○ |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ○ |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3A

**Advantages of Method:**

- Provides an early indication of water quality degradation and allows managers to address the problem before it becomes substantial.
- Since no shellfish may be harvested near areas with wastewater treatment plants, bed closures located away from such areas are more likely to indicate problems resulting from stormwater runoff.
- Long-term data is usually available for trend determination.
- The public is generally knowledgeable about this issue; consequently, this indicator may generate public pressure on officials to initiate cleanup efforts.
- Beach closures and shellfish bed closures impact the local economy which increases the likelihood that government officials and the business community will support pollution reduction efforts.

**Disadvantages of Method:**

- Many of the bacterial species used in human health criteria are common in soil, in other warm-blooded animals, and on the surface of plants, making it difficult to ascertain whether water quality problems are human-induced.
- There is some debate about which bacteria best correlates with presence of human pathogens.
- There are several anthropogenic sources of indicator bacteria (e.g. industrial wastewater, septic systems, agricultural and stormwater runoff), making it somewhat difficult to determine which specific source or sources require management measures.
- Application is limited only to areas where bacteria is regularly monitored, usually shellfish harvesting areas and recreational waters.
- Coliform dies off rapidly when introduced to surface waters and high concentrations can return to normal levels in a matter of days. This makes it difficult to determine whether stormwater runoff causes a chronic water quality problem.
- Relatively little is known about the capability of stormwater BMP's to actually remove bacteria from urban runoff.

**Case Study:** Barber, R; Ohrel, R.; Fowler, P.; Gilbert, G.
**Why We Are Convinced That Traditional Strategies for Wastewater Management Are Not Working**
*Symposium Proceedings: Integrated Coastal Wastewater Management in North Carolina.* 1994.

In the North Carolina coastal region from Cedar Island to the South Carolina border, there have been increases and decreases in the acreage of shellfish beds closed to harvesting during the period 1980-1992. A large net annual decrease in prohibited area occurred once (1983/1984) in the Cape Fear River and the New River. This decrease in prohibited area resulted from both improvements in and elimination of point source discharges. When Cape Fear River and New River areas are excluded from the analysis, the remaining coastal region is shown to have increases in prohibited areas which have been steady and small, but numerous and widespread. The pattern of steady, widespread, and small annual increases in prohibited area does not match the pattern of agricultural or forestry activities; instead, the observed pattern suggests that expanding coastal development, with its associated increase in land disturbance, drainage, and urban runoff, is responsible for the observed pattern of degradation.

North Carolina's anti-degradation policy that protects existing uses of public trust waters. The evidence of shellfish bed closures indicates that State procedures for permitting development adjacent to shellfish waters do not protect the existing uses in those waters; that is, the permit process consistently violates North Carolina's anti-degradation policy.

**Method References:**

- Closure trends: North Carolina Division of Health Services, Shellfish Sanitation Program. 1988. *An Overview of Shellfish Growing Areas Since 1980.*
- Bacterial measurements: American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1989. *Standard Methods for the Examination of Water and Wastewater, 17th ed.* American Public Health Association, Washington, D.C.
- Bacterial measurements: Water Environment Federation. 1992. *The Detection of Pathogens in Storm-Generated Flows.* Alexandria, Virginia.

# *Environmental Indicator Profile Sheet*

**Indicator Profile No. 7**

## Stream Widening/Downcutting

Category: **Physical and Hydrological**

**Tools Used to Measure Indicator:**

- Stream cross-sectional geometry measurements
- Prevalence of stream bank erosion
- Sediment embeddedness

### Description:

The change in stream geometry is measured over time to determine the extent of channel widening/downcutting in response to changes in the magnitude and frequency of stormflows. Stream channel and bank erosion can be documented by measuring channel cross-sections at monumented locations, by measuring channel bankfull width and depth of representative reaches or by measuring the percent of channel-bank scour within specified channel reach lengths. Measurements should be conducted over a period of time in response to upstream land use changes.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to help document stream segments which are susceptible to channel erosion (by comparison to other stream systems with similar channel slopes and geologic materials).
- Can help provide documentation regarding the rate of stream channel erosion as a function of increased urbanization.
- Can be useful to estimate BMP quantity effectiveness, and in documenting locations where additional controls are needed to protect the stream.
- Can be useful in estimating habitat quality and therefore provide information regarding whether water quality or excessive flow discharges are limiting factors in a stream with respect to overall aquatic health.
- Can help a municipality develop better storm event management criteria to reduce streambank erosion.

### Advantages of Method:

- Reasonably easy to measure. Requires little specialized equipment and only minor training.
- Can provide similar results regardless of the experience or preferences of the investigator, very repeatable.
- Inexpensive and conducive to rapid assessment techniques.
- Valuable in assessing impacts over time as a result of upstream land use changes.
- Can help relate post-development changes in stream hydrology to changes in stream habitat.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ● |
| Estuaries | ○ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ● |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ● |
| * Accuracy | ● |
| * Low cost | ● |
| * Repeatable | ● |
| * All Watershed Scale | ◖ |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3B

**Disadvantages of Method:**

- Many stream networks may have already been substantially modified by channelization or storm drain enclosure.
- May not accurately assess aquatic habitat impacts in the absence of stream channel erosion.
- Is not by itself a predictive indicator. Once stream widening and downcutting are observed, degradation associated with upstream land uses is already occurring. The absence of erosive conditions may lead to false conclusions regarding future disturbances.
- May not adequately evaluate current land use impacts where past erosion and sedimentation has modified natural stream morphological processes (e.g., in urbanizing areas with past intensive agricultural land uses).
- May not be applicable for larger streams and rivers.

**Case Study:** Krug, W.R.; G.L. Goddard, 1986
**Effect of Urbanization on Streamflow, Sediment Loads, and Channel Morphology in Pheasant Branch Basin Near Middleton, Wisconsin**
*USGS Water-Resources Investigations Report 85-4068*

A five year monitoring and modeling study was conducted on Pheasant Branch basin near Middleton, WI. The study analyzed the effects of urbanization on streamflow characteristics, sediment loads and channel morphology and took steps to predict the future effects associated with urbanization. The results of the study showed significant increases in sedimentation downstream from highly urbanized areas. Stream beds were lowered an average of two feet and significant stream widening occurred over the five year period downstream from the fully urbanized portion of the basin. Storm runoff modeling of full urban buildout revealed that simulated mean annual flood peaks would increase by more than a factor of 2 and stream widening would increase another 40 to 50% over current conditions.

**Method References:**


- Stream cross-sectional area measurements: Booth, D.B. 1994. *A Protocol for Rapid Channel Assessment*, Unpublished Report, Available from King County, Washington, Surface Water Management Division, Water Resources Section.

- Prevalence of stream bank erosion: MacRae, C.R.; A.C. Rowney, 1992. The Role of Moderate Flow Events and Bank Structure in the Determination of Channel Response to Urbanization. In: *Proceedings: Canadian Water Resources Association, Kingston, Ontario., 45th Annual Conference Resolving Conflict and Uncertainty in Water Management, June 1992.*

- Sediment embeddedness: Plafkin, J.L.; M.T. Barbour, K.D. Porter, S.K. Gross, R.M. Hughes, 1989. *Rapid Bioassessment Protocols for use in Streams and Rivers Benthic Macroinvertebrates and Fish.* Report No. EPA/440/4-89/001.

# *Environmental Indicator Profile Sheet*

**Indicator Profile No. 8**

## Physical Habitat Quality

Category: **Physical and Hydrological**

**Tools Used to Measure Indicator:**

- Rapid Bioassessment Protocols (Habitat Assess.)
- Rapid Stream Assess. Technique (RSAT)
- Lake Habitat Quality Index

### Description:

Physical habitat evaluations are conducted to determine the potential of waterbodies to sustain aquatically healthy systems. Degradation is evaluated to assess whether or not habitat or water quality is the limiting factor to aquatic biodiversity. Specific measurements of streams include channel stability, channel cover, instream sediment embeddedness and substrate condition, riffle, run, pool structure, and riparian habitat. Lake and estuary measurements include: prevalence of submerged aquatic vegetation, percent littoral dominance, depth variation, substrate condition, shoreline development, and submerged structure.

### Utility of Indicator to Assess Stormwater Impacts:

- Can help isolate and assess whether water quality or habitat is the limiting factor for aquatic biological health by evaluating what aquatic community might be expected to be present based on habitat alone.
- Can evaluate restoration potential based on the presence or absence of habitat characteristics.
- Can be used as the basis to enhance physical structure of a stream system to increase or maintain available habitat.
- Can help identify causes of degraded habitat (e.g., uncontrolled stormwater runoff).

### Advantages of Method:

- Reasonably inexpensive and conducive to rapid assessment techniques.
- Reasonably easy to measure. Requires little specialized equipment and moderate training.
- Provides information on past, present, and potential future channel morphology when conducted over time.
- Useful in detecting the impacts of relatively low levels of development on stream habitat (e.g., trout streams).

### Disadvantages of Method:

- May not accurately assess water quality impacts where habitat is in good condition but biological integrity is impaired.
- May be difficult to identify the sources of degraded habitat.
- Results may vary depending on the preferences and experience of the investigator.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◐ |
| Streams | ● |
| Estuaries | ◐ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ● |
| * Industrial Sites | ○ |
| * Municipal Programs | ◐ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ● |
| * Accuracy | ◐ |
| * Low cost | ● |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3B

**Case Study:** Maxted, J.R.; E.L. Dickey, G.M. Mitchell, 1994
**Habitat Quality of Delaware Nontidal Streams**
From Delaware Section 305(b) Report, 1994, Appendix D

Habitat assessments were conducted at 189 sites throughout the state of Delaware during the fall of 1991 and 1993. Sampling stations were selected randomly to provide results which could be statistically extrapolated to the entire state. 87% of all nontidal streams in Kent and New Castle Counties and 78% of all perennial streams throughout the state were found to have degraded physical habitat. The majority of the degraded sites were severely degraded compared to reference conditions. In the Northern Piedmont region, the habitat degradation was caused primarily by urbanization and stormwater. Peak stormwater flows with erosive velocities have caused stream bank failure and channel substrate sedimentation. Management implications are presented. They include the need for aggressive compliance with the state's Sediment and Stormwater Control Regulations.

**Method References:**

- Rapid Bioassessment Protocols (Habitat Assessment): Plafkin, J.L.; M.T. Barbour, K.D. Porter, S.K. Gross, R.M Hughes., *1989. Rapid Bioassessment Protocols for use in Streams and Rivers Benthic Macroinvertebrates and Fish*. Report No. EPA/440/4--89/001.

- Rapid Stream Assessment Technique (RSAT): Galli, J. Unpublished Notes, Available through the Metropolitan Washington Council of Governments. 777 North Capitol Street, NE, Washington, D.C. 20002.

- Qualitative Habitat Quality Index (QHEI): Rankin, E. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application. State of Ohio, Environmental Protection Agency. Columbus Ohio.

# *Environmental Indicator Profile Sheet*

**Indicator Profile No. 9**

## Impacted Dry Weather Flows

Category: **Physical and Hydrological**

**Tools Used to Measure Indicator:**

- Monitoring stream low flow data over time as land use changes.
- Comparing urban stream low flows with nearby rural stream low flows.

### Description:

Dry weather flows are measured over a period of time to assess the effects of urbanization on stream base flow. An alternative approach is to analyze streamflow data for various urban streams and compare this data with streamflow data from nearby rural areas (within the same physiographic ecoregion). This alternative approach may require further partitioning for valid comparisons (e.g., within the same physiographic/geologic regime).

In more humid climates, the indicator is reduced dry weather flows (as urbanization increases) as a result of decreased groundwater recharge. In more arid climates, the indicator is increased dry weather flows (as urbanization increases) as a result of increased irrigation/domestic water use.

Dry weather water chemistry, as a result of illicit connections or other discharges, may degrade with increasing urbanization (reviewed as part of pollutant constituent monitoring, Indicator Profile No. 1).

### Utility of Indicator to Assess Stormwater Impacts:

- Can assess the low flow quantity effects of increased urbanization.
- Can help assess the causes of reduced low flows in streams by evaluating effects associated with sanitary sewer and storm drainage pipe installation and by evaluating effects of increased impervious surfaces (humid climates).
- Can be used to help watershed managers to institute practices which encourage groundwater recharge and minimize impervious areas.
- Can help assess the causes of increased low flows in streams by evaluating domestic water usage and behavior patterns (arid climates).
- Degraded water chemistry, during low flow conditions can help identify pollutant causes and sources.
- Extremely useful when done in conjunction with stream widening/downcutting studies.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ● |
| Estuaries | ○ |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ○ |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ◖ |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ○ |
| * Low cost | ◖ |
| * Repeatable | ◖ |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3B

**Advantages of Method:**

- Provides a direct indicator of low flow quantity as related to watershed urbanization.
- Relatively easy to monitor flows and report results.
- Reduced stream low flow is easily understood by the general public who can apply pressure on decision makers to make appropriate land use decisions (humid climates).
- Most useful in assessing the impact of development on headwater streams.

**Disadvantages of Method:**

- May take several years to obtain statistically valid results showing trends in flow data with increasing urbanization.
- May not adequately address varying geologic or climatic conditions where other influences (such as irrigation, well drawdown, public water supply use, sea water intrusion, long term drought, etc.) can affect results, unless method is partitioned to account for this variability.
- Areas with excessively poor natural infiltration rates may show inconclusive trends with changing land use.
- The handful of studies conducted have not shown consistent trends.
- Trends are hard to detect in larger streams or where long term hydrology records are not available.
- In arid climates, where low flow tends to increase with increasing urbanization, resultant condition may be perceived by some as more beneficial than natural conditions.

**Case Study:** Ferguson, B.K.; P.W. Suckling, 1990
**Changing Rainfall-Runoff Relationships in the Urbanizing Peachtree Creek Watershed, Atlanta, Georgia**
*Water Resources Bulletin, American Water Resources Association, Vol. 26, No. 2*

Peachtree Creek is a gaged watershed located in a rapidly urbanizing area. The relationships of runoff to rainfall were studied for total annual flow, low flows and peak flows. Flows were compared between a later, more urbanized condition and an earlier, less urbanized condition. An increase in total runoff in wet years was observed as urbanization increased, but a decrease occurred during dry years. A decrease in low flow was also observed during dry years.

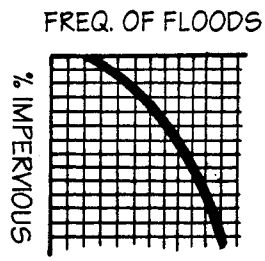
Increasing peak flows and declining low flows can be adequately explained by urban hydrologic theory. A decline in total runoff in dry years can be explained only by taking into account evapotranspiration. The concept of advectively assisted urban evapotranspiration is presented. Urban hydrologic theory must take into account vegetation and evapotranspiration, as well as impervious surfaces and their direct runoff, to explain the magnitude of total annual flows and low flows.

**Method References:**


- Low flow monitoring over time: Spinnello, A.F.; D.L. Simmons, 1992. *Base Flow of 10 South-Shore Streams, Long Island, New York, 1976-85, and the Effects of Urbanization on Base Flow and Flow Duration.* USGS Water-Resources Investigations Report 90-4205

- Comparing urban and rural low flow: Evett, J.B., 1994. *Effects of Urbanization and Land-Use Changes on Low Stream Flow.* Dept. of Civil Engineering, College of Engineering Univ. of North Carolina, UNC-WRRI-94-284

# *Environmental Indicator Profile Sheet*




**Indicator Profile No. 10**

## Increased Flooding Frequency

Category: **Physical and Hydrological**

**Tools Used to Measure Indicator:**

- Stream gaging data
- Computer modeling
- Stream channel obstruction assessments

### Description:

Flooding frequency (or flowrate magnitude change) is measured over time to determine the response to changing levels of urbanization. The number and magnitude of flooding events (in response to rainfall or snowmelt) for a particular location or specific stream segment is documented and compared with the relative changes in land use. Another method is to compare peak flows for different frequency events in urban watersheds and in rural watersheds with similar physiographic characteristics.

The amount of debris and obstructions identified and documented for a given stream reach also provides an indirect measure of flooding potential. Obstructions are identified through stream channel reconnaissance assessments.

The frequency of bankful storm events (in streams) and the corresponding amount of rainfall are essential in understanding stormwater impacts and planning restoration efforts.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to assess the frequency, duration, and quantity of flooding with increasing urbanization.
- Can be used to evaluate the effectiveness of structural BMPs in reducing flooding and streambank erosion potential.
- Can be used to evaluate flooding potential associated with different land use development patterns.
- Can help identify specific flood prone areas.
- Can indirectly predict potential for streambank erosion and habitat degradation.
- Frequently identified debris and obstructions can be an indicator of increased flooding potential which can underline the need for corrective actions.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ● |
| Estuaries | ○ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ● |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ◖ |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3B

**Advantages of Method:**

- Flooding is a well-known occurrence and is understood by the general public. Corrective measures are more readily addressed than less tangible water quality issues.
- Increased flooding is fairly easily documented and can be reasonably accurately modeled using several computer models.
- Can help focus public attention and support for urban stormwater programs. Can act as a catalyst in developing other watershed restoration initiatives.

**Disadvantages of Method:**

- May focus too much attention on structural solutions (such as levees, flood control channels, etc.) rather than more natural, biologically based alternatives.
- Increased flooding frequency may encourage jurisdictions to institute more stringent onsite stormwater regulations without evaluating the hydrologic/hydraulic implications within the watershed.
- Does not provide any data on changes in water quality.

**Case Study:** Weiss, L.A., 1990
**Effects of Urbanization on Peak Streamflows in Four Connecticut Communities, 1980-84**
USGS Water-Resources Investigations Report 89-4167

Peak stormwater flows for six urban streams in Connecticut were determined from rainfall and runoff data collected from 1981 to 1984 and from a computer rainfall-runoff model that simulated storm runoff for a period from 1951 to 1980. Recurrence intervals for these six streams and three other urban streams were estimated using the log-Pearson Type III method. These results were compared with peak flows for rural streams that were computed from regression equations.

Ratios of peak flows in urban basins to peak flows in rural basins are about 1.5 to 6.1 for the 2 year frequency event and 1.1 to 4.3 for the 100 year frequency event. The lower ratios, for each case, apply to areas where 30% of the basin is served by storm sewers. The higher ratios apply to areas where 90% of the basin is served by storm sewers.

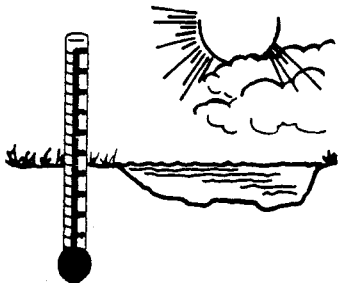
**Method References:**


- Stream gaging data: Bailey, J.F.; W.O. Thomas, K.L. Wetzel, T.J. Ross, 1989. Estimation of Flood-Frequency Characteristics and the Effects of Urbanization for Streams in the Philadelphia, Pennsylvania Area., In: *USGS Water-Resources Investigations* Report 87-4194, March 1989. 71p.

- Computer modeling: Richter, K.G.; G.A. Schultz, 1988. Aggravation of Flood Conditions Due to Increased Industrialization and Urbanization., In: *Hydrological Processes and Water Management in Urban Areas.* Proceedings of the International Symposium 24-29 April 1988, Duisburg, West Germany.

- Change in Flood Peaks: Kibler, D.F.; D.C. Froelich; G. Aron, 1981. Analyzing Urbanization Impacts on Pennsylvania Flood Peaks., In: *Water Resources Bulletin,* American Water Resources Association. Vol. 17, No. 2, April 1981.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 11**

## Stream Temperature Monitoring

Category: **Physical and Hydrological**

**Tool Used to Measure Indicator:**

- Stream Temperature Monitoring

### Description:

Stream temperature is monitored over time to assess changes in response to increasing urbanization. Alternatively, stream temperatures in urban areas may be compared with stream temperatures in nearby rural areas. Monitoring includes both storm events and low flow conditions. For a comparative analysis, streams should be located in close proximity and in the same physiographic province (subject to similar weather events or weather related stressors).

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to assess the effects of urbanization on stream temperature base flows and storm flows.
- Can be used to assess the effects of BMPs on stream temperatures and help in promoting practices which have less impacts.
- Can help identify stream reach lengths which may benefit from riparian buffer enhancement.
- Can be used as a watershed land use planning tool in protecting cool water stream systems.

### Advantages of Method:

- Provides a direct indicator of temperature impacts as related to watershed urbanization.
- Since stream temperature changes will likely affect the most sensitive organisms, can provide an early warning indicator of environmental stress which may make remediation easier.
- Reasonably easy to monitor temperatures and report results.
- Stream thermal pollution is easily understood by the general public, public officials, and decision makers who can use the information to make appropriate land use decisions.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ● |
| Estuaries | ○ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3B

**Disadvantages of Method:**

- May be of limited value in warm water systems.
- Results may be skewed due to natural conditions such as a prevalence of springs and seeps within a watershed or unusually hot summers.
- Changing climatic conditions could have more effect on stream temperatures than urbanization, over the long term.
- Provides only a single measure of the impact of urbanization on water quality.
- Once temperature increases are detected, few management measures are available to decrease them.

**Case Study:** Galli, J.; R. Dubose, 1990

**Thermal Impacts Associated with Urbanization and Stormwater Management Best Management Practices**

Produced by the Metropolitan Washington Council of Governments for The Maryland Department of the Environment.

The study consisted of a two part approach to evaluate thermal and dissolved oxygen impacts to aquatic life associated with urbanization and various stormwater management BMPs. Part one of the study involved water temperature monitoring and water quality grab sampling at six headwater streams and four stormwater management BMPs located in the Piedmont portion of the Anacostia River basin. The urban streams studied spanned the entire spectrum of watershed imperviousness from undeveloped to approximately 60% impervious cover.

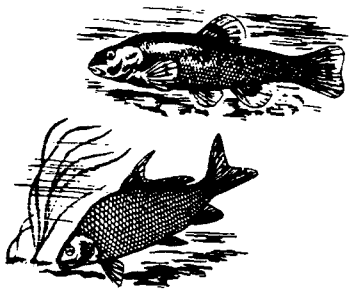
The four representative BMPs monitored in the study included: an infiltration facility, an artificial wetland, an extended detention dry pond and a wet pond. The second part of the study consisted of a comprehensive literature review to evaluate potential temperature and dissolved oxygen impacts at major levels of the aquatic food chain.

The major findings of the study are as follows: (1) Air temperature and other local meteorological conditions had a greater influence on stream temperature than stormflow for 90-95% of the time. Rainfall amount and intensity was second in importance. (2) Watershed imperviousness together with local meteorological conditions had the largest influence on urban streams. (3) Riparian canopy coverage played a key role in insulating small streams from warming. (4) Stream temperature increased with increasing order in a downstream direction. (5) All four BMPs had a positive average effect in increasing stream temperatures. Temperature increases were the most severe in the wet pond and the extended detention dry pond. The artificial wetland was next and the infiltration facility had the least effects on both stormflow and baseflow.

**Method Reference:**

- Stream Temperature Monitoring: Pluhowski, E.J., 1970. *Urbanization and its Effect on the Temperature of the Streams on Long Island, New York.* U.S. Geological Survey, Professional Paper 627-D, 110p.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 12**

## Fish Assemblage Analyses

Category: **Biological**

**Tools Used to Measure Indicator:**

- Index. of Biotic Integ., (IBI)
- Index. of Well Being, ($I_{WB}$)
- Rapid Bio. Assess., (RBP)
- Species Extinct./Reduction.
- Presence of fish with disease, tumors, fin damage, etc.

### Description:

Fish diversity, species richness, species pollutant tolerance, disease prevalence, and other metrics are used to evaluate the aquatic health of waterbodies as compared to a regional reference condition. This indicator, used by state and local governments, volunteer monitoring groups, and environmental organizations for measuring in-stream water resource quality, is widely regarded as one of the more reliable methods for assessing human-caused ecological impacts.

Fish are collected (usually by electrofishing or seining) and a biosurvey of the resident fish community is conducted. Stations for collection must be representative of the entire reach system in terms of habitat. Wherever possible, multiple habitats (i.e., riffle, run and pool) are sampled for each site.

Fish pathology, indicated by the presence of tumors, fin damage, parasite infestations, and discoloration, among other anomalies is also used in the designation of water body health.

### Utility of Indicator to Assess Stormwater Impacts:

- Can characterize the existence and severity of degradation and help identify causes and sources of degradation.
- Can be used to evaluate the effectiveness of restoration programs and help prioritize sites for future evaluation.
- Can be used to help evaluate the effectiveness of BMP controls (both structural and non-structural).
- Can be used on both a regional and local level.
- Can help identify barriers to fish migration.
- Can be used to mobilize public support when popular species are impacted.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◖ |
| Streams | ● |
| Estuaries | ◖ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ● |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ● |
| * Accuracy | ● |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ◖ |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3C

**Advantages of Method:**

- Because of a longer lifespan (3 to 4 years), fish exposed to years of impacts, provide a good assessment of long-term impacts.
- The fish assemblage represents a broad range of trophic levels and may be strongly influenced by lower trophic levels (i.e., algae, macroinvertebrates, etc.). Therefore, the fish assemblage provides an integrated view of the entire environmental system.
- Fish are relatively easy to collect and identify. The environmental requirements and life history of fish are fairly well documented.
- The general public is familiar with fishing for sport and food.
- Waterbody aquatic life uses are depicted in terms of fish.

**Disadvantages of Method:**

- Careful regional analysis is required to ensure that metrics and data are representative of ecoregion. This can require substantial calibration of metrics prior to application monitoring.
- Seasonal changes in fish populations and distribution are natural occurrences. Therefore, multiple sampling sessions are required to obtain representative results.
- Data collected after major flow events may not be representative of normal conditions.
- The relative health of a selected reference condition can skew the results of the system being evaluated.
- Monitoring must account for stream size and order as a factor in natural biological diversity and species density. Fish that spawn elsewhere may be impacted by degraded spawning grounds. Reduced richness in the study area may not be a true indicator of its water quality conditions.
- Lack of fish diversity can be due to confounding problems (poor habitat, low flow, channelization, fish barriers, fishing pressures, etc.), making impact source identification difficult.

**Case Study:** Schueler,T.R. 1994
**The Importance of Imperviousness**
*Watershed Protection Techniques, Vol.1, No. 3 Fall 1994*

Four streams in the Maryland Piedmont were monitored to identify the number of fish and number of sensitive fish present as related to watershed imperviousness. As the level of imperviousness increased the total number of fish species present decreased. For a watershed of less than 10% imperviousness, a total of 12 species were present (7 of which were sensitive). At a percent impervious between 10 and 12, two sensitive species (brown trout and sculpin) were no longer present. As the percent imperviousness rose to above 25, four more species were no longer identified. At 55% imperviousness only two, pollutant tolerant species existed.

This relatively simple study shows that as the intensity of development increases (as measured in terms of impervious area, the total number of fish species decreases. Those fish species which are the most sensitive are adversely affected in watersheds of relatively low impervious area.

**Method References:**

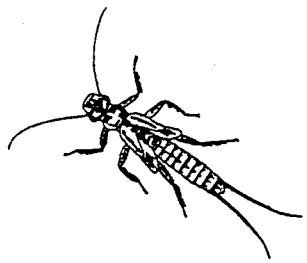
- Index of Biotic Integrity (IBI): Karr, J.R.; K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser., 1986. Assessing Biological Integrity in Running Waters: A Method and Its Rationale. *Special Publication 5. Illinois Natural History Survey*

- Index of Well Being ($I_{wb}$): Gammon, J.R. 1980. The use of community parameters derived for electrofishing catches of river fish as indicators of environmental quality,. In: *Seminar on Water Quality Management Tradeoffs.* Report No. EPA-905/9-80-009. U.S. EPA, Washington, D.C.

- Rapid Bioassessment Protocols (RBP): Plafkin, J.L.; M.T. Barbour, K.D. Porter, S.K. Gross, R.M. Hughes., 1989. *Rapid Bioassessment Protocols for use in Streams and Rivers Benthic Macroinvertebrates and Fish.* Report No. EPA/440/4-89/001. U.S. EPA, Office of Water

- Extinction/Reduction in Species: Klein, R.D. 1979. Urbanization and Stream Quality Impairment., In: *Water Resources Bulletin.* Vol. 15, No. 4, pp 948-963

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 13**

## Macro-Invertebrate Assemblage

Category: **Biological**

**Tools Used to Measure Indicator:**

- Hilsenhoff Biotic Index
- Rapid. Bioassess. (RBP)
- EPT Index
- Invertebrate Community Index (ICI)

### Description:

Benthic macro-invertebrates are used to evaluate the aquatic health of waterbodies. Several metrics (e.g. taxa richness, ratio of scrapers to filterers, ratio of sensitive to tolerant species, abundance, etc.) are used to assess the relative health of a given system. Aquatic systems are usually compared to a reference condition which is defined as the natural or "least impacted" habitat of a particular region. The maximum expectations for macro-invertebrate community structure and function are determined by monitoring the set of streams selected to establish reference conditions.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to depict the existence and severity of degradation.
- Can be used to help screen possible sources and causes of degradation.
- Can be used to help assess the performance of watershed restoration measures (particularly in-stream habitat restoration projects).
- Can be used to help evaluate the performance of stormwater BMPs (both structural and non-structural)
- Provides short term responses to changes in aquatic systems and therefore is a valuable tool to measure short term impacts (such as effects from construction projects).

### Advantages of Method:

- Macro-invertebrates have limited mobility, and therefore are good assessors of site specific impacts (mobility, however, may be affected by storm flows and drift).
- Aquatic insects have relatively short lifespans and respond quickly to stress. Therefore, they provide good short term monitoring results.
- Macro-invertebrates are relatively easy to identify, sampling is reasonably easy and does not effect the resident biota. It is relatively easy to identify degraded systems through casual observations.
- Macro-invertebrates are usually abundant in most small streams where few fish are present.
- Citizen volunteers can quickly learn insects to family level, more comprehensive training is required for other metrics.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ● |
| Estuaries | ◖ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ● |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ● |
| * Accuracy | ● |
| * Low cost | ● |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3C

**Disadvantages of Method:**

- Some regional modifications of metrics are required to ensure that data is representative of ecoregion.
- Seasonal changes in species composition and populations requires strict adherence to consistent sampling frequency.
- Data collected after major flow events is likely not to be representative of normal conditions due to habitat disruptions.
- The relative health of a selected reference condition can skew the results of the system being evaluated.
- Species identification may be time consuming and complex.
- Sensitive macro-invertebrate species seem to decline significantly at relatively low watershed imperviousness ($\leq$ 15%) and therefore are less effective as predictive tools for more densely urbanized areas.
- Paired sampling sites must have comparable habitat to produce valid results. Macro-invertebrate prevalence may be as much a function of habitat type as quality.

**Case Study:** Jones, R.C.; Clark, C.C. 1987
**Impact of Watershed Urbanization on Stream Insect Communities**
*Water Resources Bulletin, American Water Resources Association, Vol 23, No. 6*

The effects of urbanization on aquatic insects were analyzed for 22 sites in five watersheds in northern Virginia. The amount of urbanization was measured in terms of human population. Population densities ranged from near 0 in one watershed to nearly 20 individuals per hectare at one sampling site. Sampling sites were located so as to only collect data for non point source discharges. Three samples were obtained for each stream reach, each for a separate riffle. Organisms were collected using a modified circular Hess sampler. During sample collection other physio-chemical parameters were also measured: temperature, dissolved oxygen, conductivity, pH, alkalinity and hardness, and canopy coverage. Organisms were identified to genus using the method of Merrit and Cummins (1984).

Results of the study showed that abundance of Diptera was strongly correlated with increasing urbanization. The relative abundance of other groups was negatively correlated with urbanization. Trichoptera and Ephemeroptera as a percent of total organisms, each decreased with increasing urbanization. Coleoptera, Megaloptera, Plecoptera and Odonata were found almost exclusively at low to moderately urbanized stations. The 22 sites were placed into two groups; 9 sites were in watersheds that had population densities less than 10 per hectare and 13 sites were in watersheds with human populations greater than 10 per hectare. The less urbanized watersheds had significantly less Diptera and significantly more Ephemeroptera, Coleoptera, Megaloptera, Plecoptera and Odonata. The total number of insects was not significantly affected by urbanization. Trichoptera was the only group which did not vary significantly with increasing urbanization. Genus richness and diversity was also significantly higher in the less urbanized group. The result of the study indicates that the relative urbanization has a significant effect on aquatic insect community.

**Method References:**

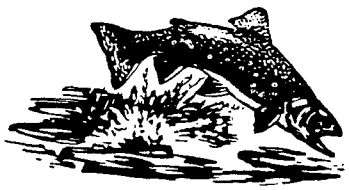

- Hilsenhoff Biotic Index: Hilsenhoff, W.L. 1982. Using a Biotic Index to Evaluate Water Quality in Streams., In: *Technical Bulletin No. 132.* Department of Natural Resources, Madison, Wisconsin.

- Hilsenhoff Improved Biotic Index: Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution., *Great Lakes Entomology.* 20:31-39

- Rapid Bioassessment Protocols (RBP): Plafkin, J.L.; M.T. Barbour, K.D. Porter, S.K. Gross, R.M. Hughes., 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers Benthic Macroinvertebrates and Fish.* Report No. EPA/440/4-89/001. U.S. EPA, Office of Water

- Invertebrate Community Index (ICI): Ohio Environmental Protection Agency, 1987. *Users Manual for Biological Field Assessment of Ohio Surface Waters. Vol. II of Biological Criteria for the Protection of Aquatic Life.* Div. Water Quality Monitor. and Assess. Surface Water Section, Columbus, OH0

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 14**

## Single Species Indicator

Category: **Biological**

**Tools Used to Measure Indicator:**

- Electrofishing Surveys
- Physical Habitat Assessments
- Bioassays

### Description:

The biological status of a carefully chosen single species is used as an assessment tool for representing the environmental health of an aquatic system. The presence, absence and/or trend in population of a particular environmentally sensitive species (such as trout, salmon or freshwater mussels) in a waterbody provides a measure of aquatic health. Single species reproduction rates and mortality rates are compiled to evaluate trends in aquatic system integrity. Species pathology, indicated by the presence of tumors, fin damage, parasite infestations, and discoloration, among other anomalies is also used to assess water body health.

### Utility of Indicator to Assess Stormwater Impacts:

- Useful in identifying degradation associated with land use for the single species and/or trophic level.
- Potential to act as a focal point for aquatic system protection and restoration. Can induce public education, support and activism.
- Can solicit political pressure and support regarding planning issues.

### Advantages of Method:

- Usually on a higher trophic level and therefore potentially representative of broader range of environmental quality.
- Easy to identify, sample and has low training costs.
- Single species monitoring is conducted relatively quickly.
- The general public is usually very familiar with the species being monitored (such as trout and salmon).
- The use of sensitive species as an indicator species identifies degradation in its early stages which may make remediation easier.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◐ |
| Streams | ◐ |
| Estuaries | ◐ |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ◐ |
| * Municipal Programs | ◐ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◐ |
| * Reliable | ○ |
| * Accuracy | ◐ |
| * Low cost | ● |
| * Repeatable | ◐ |
| All Watershed Scale | ◐ |
| * Familiar to Practitioners | ◐ |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3C

**Disadvantages of Method:**

- Management activities, such as fish stocking, can distort monitoring results.
- Habitat protection/restoration measures (based only on single species) may not adequately address other aquatic species needs.
- The natural variability and population fluctuations of the single species being measured may skew results. The advantage of multiple metrics to account for aberrations is not present.
- Species that migrate make it difficult to isolate whether the effect is occurring in the study area or somewhere else.
- If the species is not currently or historically present in the aquatic system, the method provides little useful data.

**Case Study:** Scott, J.B.; Steward, C.R.; Stober, Q.J.
**Effects of Urban Development on Fish Population Dynamics in Kelsey Creek, Washington**
*Transactions of the American Fisheries Society* 115:555-567, 1986

The authors presented a paper from a 30 month study comparing the relative fish dynamics for two small streams in Washington, one located within a predominately urban area and one located in a predominately rural area. Kelsey Creek is located in the City of Bellevue, Washington and has land uses consisting of mainly single-family and multi-family residential, but also has a significant commercial and industrial land use component. Nearby Bear Creek is in a predominantly rural area with only 15% of the land use occupied by single-family residential and the remaining land cover is in forest and pastureland.

According to historic studies Coho salmon *Oncorhynchus kisutch* and cutthroat trout *Salmo clarki* were the most abundant salmonids present in the early 1940's in both streams. Although there were no detailed lists of the other species inhabiting the study streams at that time, more recent investigations indicate that sculpins *Cottus* sp. were originally widely distributed in the area.

Study methods included conducting outmigrant netting and resident fish sampling. Netting of downstream migrants was conducted at the mouth of Kelsey Creek. Resident fish were sampled at five sites on Kelsey Creek and three sites on Bear Creek. Fish were sampled using a backpack electrofisher. Fork lengths of all salmonids were measured, scale samples were obtained and wet weights were determined. Nonsalmonid fish species were recorded as present or absent except for one sampling session when numbers and weights were recorded. Ages of the fish were determined, population of each species-age group at each study site was estimated by the removal method and the Seber-Jolly mark-recapture method. Population growth rates were calculated.

Impacts from urbanization appeared to have a greater affect on coho salmon and nonsalmonid fish species than on cutthroat trout. The total biomass of fish in each stream was determined to be about the same, but the composition of the fish assemblage differed substantially. The majority of fish in Kelsey Creek were cutthroat trout between age 0 and 1 year. Bear Creek had a much more diverse salmonid community of various ages and numerous non-salmonids were present.

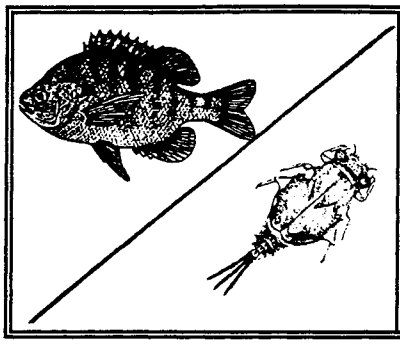
**Method References:**


- Electrofishing surveys: Tennessee Valley Authority, 1993. *Survey of Brook Trout (Salvelinus Fontinalis) Population in the Upper Little Tennessee River Watershed, Macon and Swain Counties, North Carolina.* TVAWM9320.

- Physical habitat assessments: Platts, W.S.; et. al., 1989. Changes in Salmon Spawning and Rearing Habitat from Increased Delivery of Fine Sediment to the South Fork Salmon River, Idaho. In: *Trans. Am. Fish. Soc.* Vol. 118, No. 3, pp. 274-283.

- Bioassays: Dermott, R.; M. Munawar. 1992. A Simple and Sensitive Assay for Evaluation of Sediment Toxicity Using Lumbriculus Variegatus (Mueller). In: Hart, B.T.; Sly, P.G. (eds). *Sediment-Water Interactions.* Vol. 235-6, pp. 407-414.

# *Environmental Indicator Profile Sheet*



**Indicator Profile 15**

## Composite Indicators

**Biological Indicators**

**Tools Used to Measure Indicator:**
Two or more of the following:
- Ind. of Bio. Integrity (IBI)
- Rapid Bioass. Pro. (RBP)
- Index of Well Being ($I_{wb}$)
- Invertebrate Community
- Index (ICI)

### Description:
Multiple groups of organisms and/or taxa (e.g., macroinvertebrates, fish, plankton, amphibians) are used to comprehensively portray the health of aquatic systems. A series of biological metrics, ranging from fish diversity indices, macro-invertebrate indices, algal communities, and/or other communities are evaluated to assess the effects of urban runoff on aquatic biota. Composite indicators require comparison to reference conditions as a measure of use attainability.

### Utility of Indicator to Assess Stormwater Impacts:
- Provides the same utility to assess stormwater impacts as both fish and macro-invertebrate sampling but may provide a more thorough and comprehensive evaluation.
- Can be used to prioritize further and more detailed monitoring, such as chemical characterizations or toxicity testing.

### Advantages of Method:
- Composite monitoring allows for both long-term trend analysis as well as short-term impact assessments.
- Composite monitoring provides more comprehensive information relative to pollutant source identification. Locations are more easily confirmed when multiple metrics are indicating degradation.
- Composite monitoring is useful for whole watershed assessments as well as site specific impact assessments.

### Disadvantages of Method:
- Regional modifications of metrics will be necessary over a fairly wide range of taxa.
- Seasonal changes in species composition will require strict adherence to consistent sampling frequency.
- Major flow events will affect data validity.
- Reference condition health can skew results.
- Cannot alone characterize the precise causes of degradation, this will usually involve other tools.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ● |
| Estuaries | ● |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ● |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ● |
| * Accuracy | ● |
| * Low cost | ○ |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3C

**Case Study:** Pitt, R.E.
**Effects of Urban Runoff on Aquatic Biota**
*Handbook of Ecotoxicology, Lewis Publishers, Inc. 1994; Chapter 30*

This case study analyzes the effects of urban runoff on the receiving waters of Coyote Creek, near San Jose, California. The study describes the changes to the aquatic environment as the creek passes from an upstream non-urban area through an urbanized area.

The Coyote Creek is a reasonably large waterway which drains an area of approximately 200,000 acres. The urban portion of San Jose is within the downstream one-third of the approximately 45 mile long watershed. Sampling was conducted during the period of March 1977 to August 1980. Several parameters were sampled during the study period, including; basic hydrologic conditions, water quality, sediment properties, general habitat characteristics, fish, benthic organisms, attached algae, and rooted aquatic vegetation. The use of the above array of indicators provided a broad picture of the impacts of urbanization on Coyote Creek. The results of the study showed that there were distinct differences in species diversity, composition and abundance between the urban and non-urban portions of the study area. The non-urban areas supported a more diverse aquatic community, more native fishes and many more benthic macroinvertebrate taxa. The urban portions of the study area were composed of an aquatic community of mainly the most pollutant-tolerant species of fish and macroinvertebrates. There were changes in the physical habitat between the non-urban and urban portions of the creek, however it is believed that these differences could not account for the magnitude of change to the aquatic community through the urban reach.

Due to a wide variety of possible factors affecting the biological community, it is impossible to directly identify all of effects as being attributed to urban runoff alone. In a system as large as the Coyote Creek other factors such as extreme flows, drought, stream gradient, effects of impoundments, etc. may contribute to biological degradation. The evidence presented in this case study indicates that urban runoff is responsible for a large portion of the impacts to biological organisms.

**Method References:**


- Index of Biotic Integrity (IBI): Karr, J.R.; Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser., 1986. Assessing Biological Integrity in Running Waters: A Method and Its Rationale. *Special Publication 5. Illinois Natural History Survey.*

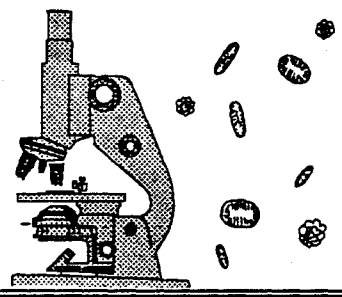
- Index of Well Being ($I_{wb}$): Gammon, J.R. 1980. The use of community parameters derived for electrofishing catches of river fish as indicators of environmental quality., In: *Seminar on Water Quality Management Tradeoffs.* Report No. EPA-905/9-80-009.

- Rapid Bioassessment Protocols (RBP): Plafkin, J.L.; et al. 1989. *Rapid Bioassessment Protocols for use in Streams and Rivers Benthic Macroinvertebrates and Fish.* Report No. EPA/440/4-89/001.

- Invertebrate Community Index (ICI): Ohio Environmental Protection Agency. 1987. *Biological Criteria for the Protection of Aquatic Life: Vol. II. User's Manual for Biological Assessment of Ohio Surface Waters.* Ohio Environmental Protection Agency, Columbus, OH.

- Biological Assessment: Davis, W.S., T.P. Simon (eds). 1995. Biological Assessment and Criteria-Tools for Water Resource Planning and Decision Making. Lewis Publishers. Boca Raton, FL.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 16**

## Other Biological Indicators

**Biological Indicators**

**Tools Used to Measure Indicator:**

- Phytoplankton Indices
- Zooplankton Indices
- Diatoms community measurments
- Periphyton Indices

### Description:

There are several additional biological monitoring methods that have been used to assess water quality. Examples of some of these include surveys of: plankton (phytoplankton, zoophankton, periphyton, diatoms) Bryozoans, algal microfossils, amphibians and bacteria. Some of these are more commonly used than others and some have been used for direct assessment of urban stormwater runoff while others are for different water quality evaluations (such as wastewater effluent monitoring, water treatment plant monitoring, CSOs, etc.). This profile is targeted primarily at the utility of plankton surveys as a biological indicator. Bryozoans are technically considered macro-invertebrates, algal microfossils are part of sediments and bacteria are addressed separately under the Human Health Criteria indicator profile.

### Utility of Indicator to Assess Stormwater Impacts:

- Plankton can be used to assess water quality through changes in community structure, patterns of distribution and relative proportions of sensitive and insensitive species.
- Plankton can be used to evaluate thermal pollution, presence of toxic pollutants, nutrients and excessive sedimentation.

### Advantages of Method:

- Valuable as a continuous monitoring tool because the nature of the cell structure allows for continuous integration of stresses that effect growth and reproduction. Good for assessing short term impacts.
- Phytoplankton (free floating algae) have distinct species which flourish in eutrophic conditions and distinct species which are indicitive of clean water. This is particularily useful in estuaries and freshwater lakes.
- Periphyton (attached forms of algae) are traditionally used in lotic systems as an indicator of water quality.
- Diatoms and other single-celled microscopic plants provide a quantifiable measure of water quality degradation over a wide geographic area.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ◖ |
| Estuaries | ● |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ○ |
| * Industrial Sites | ◖ |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ○ |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ◖ |
| * Familiar to Practitioners | ○ |
| * Easy to use & Low training | ○ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3C

**Disadvantages of Method:**

- May have limitations due to transient nature and variable distribution of species, and the influence of large storm events (washout).
- Requires fairly sophisicated sampling and laboratory work to quantify analysis and report results. Some methods and indices may over-simplify the ecological conditions by evaluating only species composition rather than community structure and dynamics.
- Short lifespans of organisms are not particularly suited for long term monitoring studies.
- Indicator populations are often highly seasonal in nature.
- Few stormwater managers have training or experience in interpreting sample data.

**Case Study:** Morgan, M.D., 1987
**Impact of Nutrient Enrichment and Alkalinization on Periphyton Communities in the New Jersey Pine Barrens.**
*Hydrobiologia, Vol. 144, No. 3, p 233-241*

Periphyton was used to evaluate impacts associated with urban residential and agricultural land uses in the New Jersey Pine Barrens. Communities of periphyton in three developed streams were compared with those of three undeveloped streams. 53 periphyton species were encountered in a sampling period of one year. Species richness was significantly greater in the disturbed streams. Species composition also varied between the two conditions. Elevated pH and nitrates in the disturbed conditions contributed to the effects of species composition.

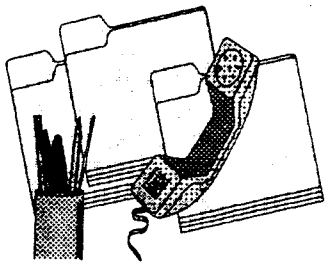
**Method References:**


- Phytoplankton and Zooplankton: Gast, H.F.; R.E.M. Suykerbuyk, R.M.M. Roijackers, 1990. Urban Storm Water Discharges: Effects Upon Plankton Communities., In: *Water Science Tech.*, Vol. 22, No. 10/11, pp. 155-162.

- Diatoms: Maples, R.S., 1987. Diatoms as Indicators of Water Quality in Three Bayous of the Calcasieu River/Lake Complex., In: *Ecosystem Analysis of the Calcasieu River/Lake Complex.* Report No. DOE/EP/31111-1 Vol. 2.

- Periphyton: Falter, C.M.; J. Kann, M. Beckwith, 1988. Attached Benthic Algae (periphyton) in the littoral of Lake Pend Oreille, Idaho. *8th Annual International Symposium on Lake and Watershed Management, 1988.*

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 17**

## Public Attitude Surveys

Category: **Social**

**Tools Used to Measure Indicator:**

- Direct mail to public
- Public workshops with citizens/citizen assoc.
- Interviews with targeted audience

### Description:

Public attitude surveys are directed at targeted groups to assess general awareness of key water quality problems and willingness to finance (via government spending) restoration efforts. A targeted group is solicited with a direct mailout, an interview or other mechanism of communication to gather information regarding an existing or potential program. The results of a survey are usually gathered into a summary report which may, for example, indicate that the public believes urban runoff to be the most significant source of pollution in the watershed or that funding for restoration efforts should be increased. This information is then used by decision makers in helping to formulate watershed management policy, develop restoration budgets and workplans, or implement stream restoration programs, for example.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to assess the public's perception of existing or proposed water quality programs (e.g., citizen volunteer monitoring, proposed waterbody restoration program, maintenance program implementation for BMP's, etc).
- Can be used as a foundation for political action to stress the relative value the public places on a particular water quality issue.
- Can be used as a mechanism for soliciting public or private funding for a particular water resource issue.
- Can be a major component of a public educational program which incorporates results of surveys into future programs.
- Helps managers develop more effective pollution prevention programs based on reported behaviors and targets scarce resources toward specific watersheds, population groups, or watershed interest groups.

### Advantages of Method:

- Effective way to obtain information regarding citizen attitudes/concerns for a particular issue or set of issues.
- Gives decision makers information on how proposed programs are likely to be received by the targeted audience.
- Generally is relatively easy to interpret results and therefore can be an effective tool for non technical applications.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ○ |
| Estuaries | ○ |
| * Land Use Impacts | ○ |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ○ |
| * Municipal Programs | ◖ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3D

**Disadvantages of Method:**

- Results of survey are dependent on the number of people who respond and the degree of importance people place on water quality issues.
- Results can be dependent on the socioeconomic status of the community being surveyed and the relative importance water quality plays in people's lives.
- Results of survey can be skewed by the relative knowledge of the target audience. Survey practitioners must consider target audience's understanding of topic in formulating questionnaires and be prepared to follow up with future surveys.
- Language barriers and lack of phone or address information may result in missing key population groups.
- Does not directly measure changes occurring in the receiving water.

**Case Study:** Blair, J., G. Slater, A. McLaughlin, 1994
**The Chesapeake Bay Attitudes Survey**
*Chesapeake Bay Program, Communications Subcommittee, Final Report, April 28, 1994.*

The Survey Research Center at the University of Maryland at College Park conducted a survey of residents in the Chesapeake Bay watershed. The goal of this study was to provide baseline data on the attitudes, behaviors, and opinions of residents about pollution, water quality, funding, and clean-up efforts in the Bay watershed. The survey was conducted from October 6, 1993 through January 27, 1994. A total of 2004 people were interviewed.

The study results indicated that 85% of all respondents were either very concerned or somewhat concerned about pollution in the Bay. This level of concern varied by distance from the Bay. Concern was greatest for people living closest to the Bay. Approximately one-third of the respondents thought that business and industry was the main cause of pollution in the Bay. About half of the respondents thought the Bay was more polluted today compared to ten years ago.

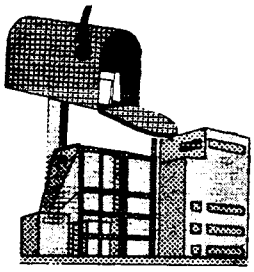
Seventy-eight percent of the respondents who reported being familiar with the Bay said that pollution had not interfered with any of the things they do for recreation on the Bay. Sixty-eight of these respondents thought that the water quality was unsafe for aquatic life; sixty percent thought water quality was unsafe for swimming, and fifty-three percent thought the water quality made seafood unsafe.

The major sources of pollution identified by respondents were business and industry, commercial shipping spills, recreational boating, landfills, construction, and farming. Sixty-one percent said efforts to clean-up the Bay were too little.

**Method References:**


- Direct Mail: Hampton Roads Municipal Communicators, 1992. *Environmental Attitudes Surveyed in Hampton Roads*, Hampton Roads Municipal Communicators
- Public Workshops: Hoffman, R.K., 1981. *The Public's Perspective on Nonpoint Sources. Nonpoint Pollution Control - Tools and Techniques for the Future*, Proceedings of a Technical Symposium, P 35-38
- Interviews with Target Audiences: Desvousges, W.H.; V.K. Smith, M.P. McGivney, 1983. *Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements.* Misc. Rep Ser. U.S. EPA. No. EPA/230/05-83/001

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 18**

## Industrial/Commercial Pollution Prevention

Category: **Social**

**Tools Used to Measure Indicator:**

- Direct mail out to industry
- Workshops with industry representative groups
- Interviews with individual industry personnel

### Description:

Surveys of pollution prevention efforts for industrial sites are conducted to assemble data regarding the costs and benefits associated with NPDES stormwater permit compliance. Site managers are surveyed to obtain information regarding permit implementation costs (e.g., BMP construction costs, spill prevention training costs), technical issues regarding implementation of structural and nonstructural BMPs, and potential benefits gained.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to assess industry's perception of effectiveness of stormwater BMPs and methods for improvement.
- Can be used to assemble cost information and compare implementation costs between different industries and different geographic locations.
- Can be a component of an industry stormwater educational program which incorporates results into future pollution prevention programs.
- Can foster partnerships with industry and help managers identify site conditions that they may be unaware of (e.g., illicit connections from floor drains).

### Advantages of Method:

- Effective way to obtain information regarding industry attitudes and perception of the importance of stormwater programs.
- Results of survey are based on industry input and therefore will likely be more directed at specific concerns/problems which affect industry operations which may lead to more cost effective ways of doing things.
- Generally is relatively easy to interpret results and therefore can be a useful tool for non-technical policy decisions.

### Disadvantages of Method:

- Results of survey are dependent on the information provided by industry personnel and may be skewed to industry's advantage
- Surveys are not usually based on highly technical information and may not adequately address complex water quality issues.
- Industry may be suspicious that participation in the surveys may lead to costly regulation.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ○ |
| Estuaries | ○ |
| * Land Use Impacts | ○ |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ○ |
| * Industrial Sites | ● |
| * Municipal Programs | ○ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ◖ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3D

**Case Study:** Beck, P.C.

**Stormwater Permit Program An Industrial Experience**

*Stormwater NPDES- Related Monitoring Needs. Conference Proceedings, American Society of Civil Engineers. MT. Crested Butte, CO August 7-12, 1994*

The Coors Brewing Company, located in the foothills of the Rocky Mountains west of Denver, is the third largest brewer in America and subject to the NPDES stormwater discharge permit. Coors' will be operating under four general stormwater permits. Coors has completed stormwater outfall sampling at more than twenty stormwater discharge locations. The results of the sampling showed that average concentrations fell within requirements for bottled water and RCRA Health Based Standards. Maximum values were in some cases substantially above the average values. Additional work is probably necessary to fully assess the normal distribution of data at any given outfall. Nutrients and suspended solids showed a wide range of variation among different samples and different results.

Coors has taken some corrective actions for areas with unusually high pollutant concentration values. For example, an outfall with a 3190 mg/l $BOD_5$ concentration was near a yeast drying facility and spilled yeast was responsible for the high value. Corrective actions were taken to reroute storm drains from the existing outfall to the process treatment plant. Other problems were also addressed: Roof drains on fermenting buildings were rerouted from a discharge into the adjacent creek to the process treatment plant. Storm drains in high traffic areas were modified to collect the five year storm and divert it to the sanitary system. Lean-to roof structures were installed over waste material collection bins and over above ground fuel storage facilities.

**Method References:**


- Workshop with industry group: Brosseau, G. 1992. *1992 Summary Report - Vehicle Service Facility Waste Minimization Program.*, Palto Alto Regional Water Quality Control Plant, Uribe & Associates

# *Environmental Indicator Profile Sheet*

**Indicator Profile No. 19**

## Public Involvement and Monitoring

Category: **Social**

**Tools Used to Measure Indicator:**

- Number and type of public involvement groups
- Quantity of volunteer monitoring performed
- Number of hotline reports
- Advisory council

### Description:

Public participation in stormwater programs is one measure of overall program effectiveness. Successful implementation of stormwater programs depends, in large part, upon the active support and participation of the public. Citizen monitoring programs, stream segments adopted, watershed stewardship groups, public education (including school curricula), participation in watershed education events are all components of public involvement programs. Other measures of public participation include participation in household hazardous waste recycling efforts, number of calls made to report illegal dumping into the storm sewer system or streams, and membership in citizen advisory groups.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to help modify citizen behaviors related to source controls.
- Can help reduce monitoring expenses and expand a jurisdiction's monitoring database.
- Can help identify pollutant sources through citizen watchdog actions.
- Can help prepare students to be knowledgeable about water pollution issues and respectful of existing water resources.
- Can generate political support for additional stormwater and watershed funding.
- Can foster acceptance of projects through close relationships with communities, and can provide input for adjacent residents on siting and aesthetic concerns

### Advantages of Method:

- Jurisdictions with active public involvement programs are more likely to have a population which is informed about water quality issues and therefore is more receptive to program initiatives, funding issues, and pollution prevention efforts.
- Programs can be initiated by local governments with relatively little expense.
- Provides decision makers with information on public perceptions which is useful in watershed management programs.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◐ |
| Streams | ◐ |
| Estuaries | ◐ |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ○ |
| * Municipal Programs | ◐ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ○ |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ● |
| * Repeatable | ○ |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3D

**Disadvantages of Method:**

- Monitoring may not always meet strict quality control protocols and, therefore, may not be scientifically useful for expanding databases.
- Citizen activists may not understand technical issues and may be less receptive to political and financial tradeoffs associated with particular projects.
- Educational efforts may take several years to affect citizen behavior.
- The lack of citizen involvement group participation may be a function of socioeconomic environment rather than actual program effectiveness.
- Does not measure or change the behavior/attitudes of residents that do not participate in the programs.

**Case Study:** Texas Natural Resource Conservation Commission
**Texas Watch: Volunteer Environmental Monitoring**
*Texas Natural Resource Conservation Commission, P.O. Box 13087, Austin, TX 78711*

This information packet describes Texas Watch, the statewide volunteer environmental monitoring program of the Texas Natural Conservation Commission. The program is one component of the agency's strategy to combat nonpoint source pollution. Texas Watch addresses nonpoint source pollution in two ways: it assists professional data gathering efforts by enlisting volunteers to monitor water quality in their communities and it provides an excellent tool with which to educate the public about nonpoint source pollution through teacher involvement and the media.

**Method References:**


- Number and type of public involvement groups: Fullmer, J., 1994. Successful Grass-Roots Strategies for Public Education and Participation In Watershed Protection Policy Making., In: Pawlukiewicz, J.; et.al. (eds.), 1994. Proceedings for *Watershed '93: A National Conference on Watershed Management.*, Alexandria, VA., Mar 21-24, 1993., USEPA No. 840-R-94-002
- Quantity of Monitoring: Ely, E (ed.); 1994. Volunteer Monitoring: Past, Present & Future., *The Volunteer Monitor.* Vol. 6, No. Spring 1994

# *Environmental Indicator Profile Sheet*

**Indicator Profile No. 20**

## User Perception

Category: **Social**

**Tools Used to Measure Indicator:**

- Direct mail to public
- On-site interviews
- User survey and counts

### Description:

Successful stormwater management efforts depend, in large part, on public support. Public support, in turn, depends upon its valuation of water resources. The public's valuation of a particular water body is usually based on more than water chemistry. Appearance, surroundings, ease of access, and apparent water quality are all considered by the average user. Trash, floatables, and turbidity will detract from the appearance of the water body. Surroundings are perceived as less than ideal when there is limited tree cover or other bank-side vegetation. Extremely dense vegetation, limited physical access, or remoteness may also detract from perceived value. Finally, oily waters, unusual colors and odors will also count against the water body.

It is possible that water bodies with generally good water quality may be perceived as being in poor condition by the public if access is limited or the water is turbid. On the other hand, biologically impaired waters may be perceived by the public as "clean" solely based on the lack of obvious pollution such as tires or bottles.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to assess the public's perception of existing conditions in the watershed.
- Can be used as a foundation for educating the public about the "hidden" impact of water quality pollution.
- Can be used as a platform for generating stewardship programs and public support for water restoration efforts.
- Can be a major component of a public educational program which incorporates results of surveys into future programs.

### Advantages of Method:

- Effective way to obtain information regarding citizen attitudes/concerns for a particular issue or set of issues.
- Gives decision makers information on what aspects of watershed restoration are most important to the public.
- Survey results are generally easy to interpret and therefore can be an effective tool for non-technical applications.
- Targets the portion of the public most likely to be knowledgeable about water quality issues and be supportive of watershed restoration efforts.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◐ |
| Streams | ◐ |
| Estuaries | ◐ |
| * Land Use Impacts | ○ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ○ |
| * Municipal Programs | ◐ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ◐ |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ◐ |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ◐ |
| * Easy to use & Low training | ◐ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3D

**Disadvantages of Method:**

- Results of survey are dependent on the number of people who respond and the degree of importance people place on water quality issues.
- Results can be dependent on the socioeconomic status of the community being surveyed, the proximity of the water body, and the designated recreational usage.
- Results of survey are site-specific. The survey results assess concerns about a specific water body, not the entire watershed.
- Language barriers and lack of phone or address information may result in missing key population groups.
- Does not directly measure changes occurring in water quality.
- Can be very costly to obtain a representative survey sample.

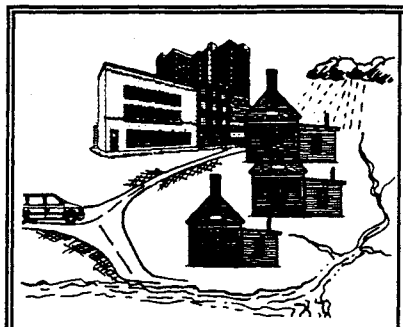
**Case Study:** Desvousges, W.H.; V.K. Smith, M.P. McGivney, 1983.
**Interviews with Target Audiences: Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements**
*Environmental Protection Agency, Misc. Rep Ser. U.S. EPA. No. EPA/230/05-83/001*

Pollution control policy can reduce the amount of effluents going into a particular river. In turn, this changes the water quality and ecological habitat. The public then may be able to use the river more for in-stream activities such as swimming, boating, and fishing and for withdrawal purposes such as drinking water, irrigation, and cooling. However, measuring change in use understates the total benefits of the pollution control if there are positive "intrinsic" benefits for preserving the potential for future use and vicarious consumption. This study compares three methods for measuring overall recreation and related benefits of improved water quality. These methods are travel cost, contingent calculation, and contingent ranking. The comparison is based on detailed interview data for 305 user and nonuser households in the Pennsylvania portion of the Monogahela River watershed. The benefits measurement approaches show consistent results for comparable changes in water quality. The results of this project strongly support the feasibility of measuring the recreation and related benefits of water quality improvement.

**Method References:**


- Direct Mail: Hampton Roads Municipal Communicators, 1992. *Environmental Attitudes Surveyed in Hampton Roads*, Hampton Roads Municipal Communicators
- Methodology: Interviews with Target Audiences: Brinkley, C. And W. Hanemann, 1978. *The Recreation Benefits of Water Quality Improvement: Analysis of Day Trips in an Urban Setting.* U.S. EPA

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 21**

## No. of Illicit Connections Identified/Corrected

Category: **Programmatic**

**Tools Used to Measure Indicator:**

- Investigative monitoring using wet and dry weather sampling, visual observations, GIS, dye testing, smoke testing, etc.

### Description:

This indicator involves the identification and correction of illegal and/or improper waste discharges into storm drainage systems and receiving waters. Dry weather flows potentially contribute substantial loadings to receiving waters. Jurisdictions have programs to identify, prioritize pollutants, and implement corrective actions to eliminate or minimize these non-stormwater entries.

### Utility of Indicator to Assess Stormwater Impacts:

- Since illicit connections can contribute substantially to pollutant loadings, the number identified and corrected can have a direct and immediate effect on water quality.
- Can be used as a measure to assess the effectiveness of a municipality's overall stormwater program.
- Sampling can help define the frequency and severity of illegal discharges to the storm sewer system (i.e., non sanitary system).

### Advantages of Method:

- Results are easily interpreted by politicians and administrative officials which help make programs sustainable and justify funding.
- Can be part of a citizen volunteer monitoring program.
- Helps many communities identify the locations and size of all storm and sanitary outfalls. Often many are "lost" over time due to poor record keeping.

### Disadvantages of Method:

- The number of illicit connections identified is not necessarily representative of the total number of illicit connections in existence.
- Programs to identify, prioritize, and correct illicit connections can be very costly to operate and personnel training can be expensive.
- Does not measure the hydrological impact of storm flows in the pipe system.
- Site-specific monitoring may be required to characterize volume of flow and pollutant constituents of illicit connection.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ● |
| Estuaries | ● |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ● |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ○ |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ◐ |
| * Repeatable | ◐ |
| * All Watershed Scale | ◐ |
| * Familiar to Practitioners | ● |
| * Easy to use & Low training | ◐ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3E

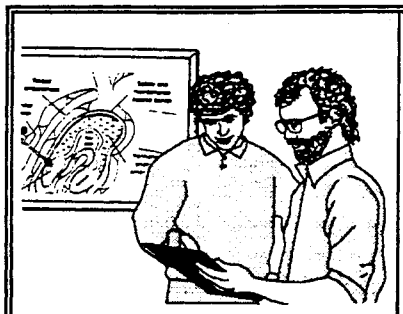
**Case Study:** Minor, J.D., 1995
**Finding Illicit Connections and Discharges with $P^2IL$**
Torno, J.C. (ed.) 1995. Stormwater NPDES-related monitoring needs. Conference proceedings. American Society of Civil Engineers. Mt Crested Butte, CO. August 7-12, 1994

Finding illicit connections for the City of Scarborough, Ontario, Canada, located on the north shore of Lake Ontario, requires dedicated *Programs* and *Procedures*, executed with *Intuition* and *Luck* ($P^2IL$). The City of Scarborough with a population of approximately 550,000, is about 85% developed. Sixteen per cent of the total area is within industrial districts. There are approximately 400 industrial/commercial/institutional (ICI) sites with stormwater discharges. The City has more than 800 storm drainage outfalls draining to three watercourses. Pollution prevention efforts occupy approximately 6000 manhours per year, equipment and lab costs are approximately $50,000 (CDN) and start up costs were approx. $200,000 CDN. The drainage system with outfalls has been mapped using GIS, waterways are monitored during wet and dry weather, and problem outfalls are identified with chemical, biological and visual techniques. Outfalls are further evaluated using flow meters, non-intrusive sensors, video cameras, dye testing, smoke testing, and pressure testing for the presence of illicit connections.

**Method References:**

- Identification of Illicit Connections: Pitt, R.; M. Lalor, D.D. Adrian, R. Field, D. Barbe, 1993. *Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems: A User's Guide.*, Alabama Univ. In Birmingham. Dept. of Civil Engineering. EPA-600-R-92-238.
- Discharge Characterization: Schmidt, S.D.; D.R. Spencer, 1986. Magnitude of Improper Waste Discharges in an Urban System. *In: Journal of the Water Pollution Control* Federation. Vol. 58, No. 7, July, 1986, pp. 744-748.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 22**

## No. of BMPs Installed, Inspected, and Maintained

Category: **Programmatic**

**Tools Used to Measure Indicator:**

- Development Site Plans
- Property Owner/Developer Interviews
- No. of Construction Permits Issued
- Local Inspection Programs

### Description:

By tracking the number of BMPs that are installed, inspected, and maintained in a given area, stormwater practitioners may be able to measure the progress and effectiveness of municipal programs. As more BMPs are installed, one may assume with reasonable confidence that progress in the stormwater arena is being made. Regular inspection and maintenance of BMPs will ensure that existing stormwater management resources are fully utilized, will help identify facilities which require retrofits, and will identify areas requiring additional management resources.

Program implementation can also be tracked through review of the maintenance backlog. Large BMP maintenance backlogs may indicate that additional monetary and manpower resources are required to ensure effective operation of existing BMPs.

### Utility of Indicator to Assess Stormwater Impacts:

- Inspections can expose weaknesses in BMP design, reveal maintenance needs, and determine needs for enforcement actions.
- Can be used to determine whether existing BMPs are sufficient in scope and size to adequately address a community's stormwater management needs.
- Helps a municipality improve the design criteria for future BMPs by determining which practices have more problems.
- Provides useful data when conducting stormwater retrofit inventories.

### Advantages of Method:

- Since BMPs are specifically designed to provide a particular level of performance, it is relatively easy to determine whether their functions are being achieved.
- Educational programs can be developed to involve private organizations in data collection. Such programs may also serve to educate the public about BMP usage, performance, and maintenance needs.
- Increased performance monitoring and reporting increases the likelihood that BMPs will be properly maintained.
- Can be combined with GIS and watershed simulation models to determine the cumulative watershed benefits of implementation of stormwater BMPs.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ○ |
| Estuaries | ○ |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ◐ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ○ |
| * Repeatable | ● |
| * All Watershed Scale | ◐ |
| * Familiar to Practitioners | ◐ |
| * Easy to use & Low training | ○ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3E

**Disadvantages of Method:**

- There is little standardization in place for reporting BMP performance, possibly resulting in conflicting inspection reports.
- Many watershed managers choose BMPs based on cost, with design performance a secondary consideration. As a result, even if a BMP performs according to design, it still may not adequately protect receiving water quality.
- BMP inspections and maintenance are costly and require extensive staff time.

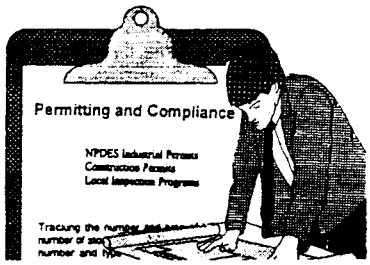
**Case Study:** Lindsey, G.; L. Roberts, and W. Page. 1992
**Maintenance of Stormwater BMPs in Four Maryland Counties: A Status Report**
*Journal of Soil and Water Conservation. 47(5): 417-422, Sept./Oct. 1992.*

Field inspections were made of more than 250 stormwater facilities in four Maryland counties. The types of facilities inspected included dry basins, wet and extended detention basins, infiltration basins and trenches, dry wells, underground storage facilities, and vegetated swales. Trained inspectors evaluated performance (inappropriate ponding of water, slow infiltration, incorrect flow patterns, clogging of facility, excessive sediment or debris, water bypassing facility, design shortcomings, structural failures, erosion at intake or outfall) and maintenance criteria (facility functioning as designed, quantity controlled as designed, quality benefits produced by ability, enforcement action needed, maintenance action needed) for each facility. While most (64%) of the facilities were found to be functioning as designed, many needed maintenance, especially to correct excessive sediment and debris problems. Inspectors believed that enforcement action was warranted at many sites. The condition of different types of facilities varied significantly. Several models were used to explain results, including a series of chi-square tests to determine the independence of facility status and objective and subjective variables. Overall, the investigations documented the need for improved inspection and maintenance by stormwater management regulatory authorities.

**Method References:**

- General: Galli, J.; 1992. *Analysis of Urban BMP Performance and Longevity in Prince George's County, Maryland.*, Metropolitan Washington Council of Governments. Publication No. 92711

# *Environmental Indicator Profile Sheet*




**Indicator Profile No. 23**

## Permitting and Compliance

Category: **Programmatic**

**Tools Used to Measure Indicators:**

- NPDES Industrial Permits
- Construction Permits
- Local Inspection Programs

### Description:

NPDES stormwater regulations require many municipal and industrial stormwater dischargers as well as construction site developers to obtain discharge permits. Permit requirements generally focus on identification and control of significant sources of nonpoint source pollution. Most permits also require implementation of pollutant reduction measures. These measures encompass structural BMPs such as sediment control basins and non-structural measures such as good housekeeping and personnel training.

Tracking the number and type of NPDES stormwater permits issued, the number of stormwater discharges in compliance with their permits, and the number and type of BMPs implemented in conjunction with the permits allows municipalities to gauge the relative impact of various pollutant sources (i.e., urban versus industrial versus construction), determine if regulatory baselines are being met, and identify the need for additional enforcement activities.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to identify potentially significant contributors of pollutants.
- Can be used to assess the level of industrial support for stormwater management efforts.
- Can be used by NPDES program managers to assess compliance with regulations and designate areas for improvement.
- Allows identification of uncontrolled sources of pollution to stormwater.

### Advantages of Method:

- Permitting is already required by many states.
- Comprehensive permitting structures have already been established.
- The majority of the cost and time burden associated with implementation and identification of pollutant control measures is borne by private sources.
- Fosters communications between developers, industry, and regulatory agencies responsible for developing and implementing stormwater management strategies.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ○ |
| Estuaries | ○ |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ◐ |
| * Whole Watershed Quality | ◐ |
| * Industrial Sites | ◐ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ● |
| * Repeatable | ● |
| * All Watershed Scale | ◐ |
| * Familiar to Practitioners | ◐ |
| * Easy to use & Low training | ◐ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3E

**Disadvantages of Method:**

- Some industrial sites are reluctant to identify the most effective measures, instead opting for less expensive measures with meet the minimal requirements.
- Processing permits and inspections to ensure compliance require significant staff time.
- Many permitting programs are conducted under the auspices of State or regional EPA programs. Local and municipal jurisdictions and watershed advisory bodies may have difficulty in obtaining permit

**Case Study:** Newport, R.G. and T.E. Davenport. 1988
**Stormwater Nonpoint Source Pollution Control**
*American Water Resources Association Technical Publication Series. TPS 88-4, p 183-193, 1988*

The Rouge Basin in Southeast Michigan is a significant example of a situation where stormwater is contributing to use impairment. To address urban stormwater problems, EPA and State pollution control agencies will issue discharge permits to the owner/operators of stormwater collection and conveyance systems and related outfalls. These permits will require data collection and reporting, and the development and implementation of pollution reduction programs. In some cases, these programs will require capital improvements, but in many instances, the cost-effective approach for solving the problems will be BMPs. These BMPs will reduce the introduction of pollutants to the storm sewer through management of nonpoint source (NPS) pollution. Requiring nonpoint source control components as part of stormwater permits will ensure (1) that the permits address all pollutants originating from nonpoint sources; (2) that the BMPs required under the permits will economically control the identified pollutants; and , (3) that the NPS control activities identified will be fully implemented.

**Method References:**


- Permitting: *Watershed Protection and Stormwater Permitting Seminar*, August 29 and 30, 1990. Sponsored by North Carolina Sections of AWWA/WPCA and APWA..
- Compliance: Brinigar, S.C. et al. 1992. Complying with Storm Water Permits. Pollution Engineering. February 15, 1992.

# *Environmental Indicator Profile Sheet*

**Indicator Profile No. 24**

## Growth and Development

Category: **Programmatic**

**Tools Used to Measure Indicator:**

- GIS Systems, land use mapping
- Other physical, biological or chemical monitoring techniques.

### Description:

As development in a watershed grows, imperviousness increases and the aquatic system is generally subjected to greater stress. This stress may include higher NPS pollutant loadings and increased stormwater runoff flows. Erosion within the stream system increases as the stream downcuts and widens to adjust to the new flow regime.

The relative health of a given system as measured through ecological impacts to the aquatic community (i.e., water quality, physical habitat, and biological diversity and health) can be correlated with the impervious percentage of the watershed. Zoning patterns in a watershed can be used to estimate existing and potential watershed imperviousness based on land use-imperviousness relationships.

The potential for continuing urbanization (and thus increased watershed imperviousness) can be tracked through review of building permits, environmental impact statements, and changes in population. Increases in the numbers of building permits issued and environmental impact statements completed and increased population are indicative of continuing urbanization.

### Utility of Indicator to Assess Stormwater Impacts:

- Can be used to evaluate existing and potential impacts to aquatic systems. Imperviousness can predict aquatic health degradation thresholds.
- Can be used to evaluate the effectiveness of BMPs in extending development thresholds (e.g., increasing impervious area limits without increasing aquatic health degradation).
- Can be used as a planning tool in making zoning and master planning decisions.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ◖ |
| Streams | ● |
| Estuaries | ◖ |
| * Land Use Impacts | ● |
| * Stormwater Mgmt Programs | ◖ |
| * Whole Watershed Quality | ● |
| * Industrial Sites | ◖ |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ◖ |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ◖ |
| * Repeatable | ● |
| * All Watershed Scale | ● |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3E

**Advantages of Method:**

- Easily measured using land use mapping or GIS technology.
- Easily understood by policy decision makers and politicians.
- Inexpensive to measure and report (however, development of a detailed GIS can be very expensive).
- Can provide a uniform method for measurement and assessment.
- Provides a comprehensive measure of the cumulative impact of land development on subwatersheds.
- Many of the indicator parameters are already tracked by local jurisdictions.

**Disadvantages of Method:**

- Measurement and use of growth indicators is not yet standardized.
- Assessment of stream quality has not been statistically correlated with impervious area.
- Does not precisely measure imperviousness, but rather estimates relative increases in imperviousness.
- Zoning changes, environmental impact statements, and building permits represent probable (not definite) changes in imperviousness.
- Does not take into account that development can increase without increasing aquatic health degradation.

**Case Study:** Booth, D.B.; L.E. Reinelt, 1994

**Consequences of Urbanization on Aquatic Systems - Measured Effects, Degradation Thresholds, and Corrective Strategies**

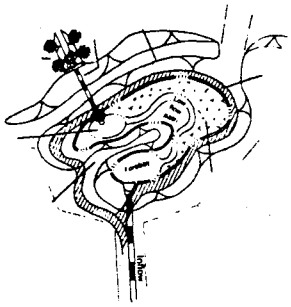
*Pawlukiewicz, J.; et. al., (eds.). 1994. Watershed '93: A National Conference on Watershed Management, USEPA 840-R-94-002*

Several watersheds in King County, Washington were evaluated to assess the effect of urbanization on stream and wetland system health. Watershed imperviousness was used as the unit of measure of urbanization. Stream structure (bankfull width, depth and fluctuations in water level) and biological function (species and population counts and rapid field assessments of habitat quality) were evaluated. Results indicated that aquatic system function (as measured by fish populations) was indirectly proportional to watershed impervious area. While there was no distinct threshold where population densities dropped, there was a measurable effect at reasonably low levels of imperviousness (10 - 15%). Habitat degradation was measured in terms of "degraded, good or excellent". There was marked degradation at imperviousness between 8 and 10%. Change in physical structure with increasing imperviousness was also measured. For example, stable channels, with little or no erosion, and unstable channels, where long continuous reaches of bare and eroding banks occur, were evaluated as impervious area increases. At impervious area percentages above 10%, stream channel instability is dominant.

**Method References:**


- Watershed Mapping: Sogona, F.J.; C.G. Phillips, 1994. Application of Watershed Index of Pollution Potential to Aerial Inventory of Land Uses and Nonpoint Pollution Sources., In: Pawlukiewicz, J., et. al., (eds.), *Watershed '93: A National Conference on Watershed Management.* USEPA 840-R-94-002
- Biological Monitoring: Mangun, W.R. 1989. A Comparison of Five Northern Virginia Watersheds in Contrasting Land Use Patterns., In: *J. Environmental Systems,* Vol. 18(2) 133-151
- General: Schueler, T.R., 1994. The Importance of Imperviousness., *In: Watershed Protection Techniques*, Vol. 1, No. 3 pp.100-111

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 25**

## BMP Performance Monitoring

Category: **Site Indicators**

**Tools Used to Measure Indicator:**

- Biological Monitoring
- Chemical Monitoring
- Physical Monitoring

### Description:

Stormwater BMPs are specifically designed to reduce pollutant loadings into natural water bodies. The evaluation of BMP performance can provide stormwater program managers with a more accurate assessment of pollutant removal capability.

BMP effectiveness is evaluated based on stormwater sampling of the mass and concentration of pollutants into and out of the facility. Alternatively, biological and/or physical indicators can be evaluated upstream and downstream of a facility to aid in assessing effectiveness of a specific practice or series of practices.

Controls are measured relative to design, cost, and other similar factors. Secondary characteristics which may be evaluated include habitat provisions, safety, aesthetics, groundwater recharge, and recreational opportunities.

### Utility of Indicator to Assess Stormwater Impacts:

- By comparing BMP performance data, stormwater managers may be able to select BMPs that provide the best pollutant removal effectiveness in the most cost-effective manner.
- Comparison of temporal data can be used to determine the need for BMP maintenance.
- Can be used in conjuction with biological and physical/hydrological indicators, to get a more accurate representation of the total aquatic community condition.
- Can be used to identify those BMPs which are not meeting pollutant removal expectations.
- Can be used as a basis to create, update, and enforce minimum design standards to meet target pollutant removal expectations.

### Indicator Useful for Assessing:

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ● |
| Streams | ● |
| Estuaries | ◖ |
| * Land Use Impacts | ◖ |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ◖ |
| * Industrial Sites | ● |
| * Municipal Programs | ● |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◖ |
| *Not Useful* | ○ |

### Indicator Advantages

| | |
|---|---|
| * Geographic Range | ◖ |
| * Baseline Control | ◖ |
| * Reliable | ◖ |
| * Accuracy | ◖ |
| * Low cost | ○ |
| * Repeatable | ● |
| * All Watershed Scale | ◖ |
| * Familiar to Practitioners | ◖ |
| * Easy to use & Low training | ○ |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◖ |
| *Not Advantageous* | ○ |

### Cost

See Table 3.3F

**Advantages of Method:**

- Since BMPs are specifically designed to provide a particular level of performance, it is relatively easy to determine whether their functions are being achieved.
- Educational programs can be developed to involve private organizations in data collection. Such programs may serve to educate the public about BMP usage, performance, and maintenance needs.
- Increased performance monitoring increases the likelihood that BMPs will be properly maintained.

**Disadvantages of Method:**

- There is little standardization in place for reporting BMP performance, resulting in a wide range of effectiveness being reported.
- Many watershed managers choose BMPs based on cost, with design performance a secondary consideration. As a result, even if a BMP performs according to design, it still may not adequately protect receiving water quality.
- Extensive monitoring is required to gain sufficient understanding of BMP effectiveness.
- A large number of paired samples must be collected to establish performance.
- Method requires extensive data interpretation and management.
- The performance of a monitored BMP may reflect site specific or watershed specific conditions, and may not always be generalized.

**Case Study:** Martin, E.H. 1988

**Effectiveness of an Urban Runoff Detention Pond-Wetlands System**

*Journal of Environmental Engineering, 114(4): 810-827. August 1988.*

An urban detention system, composed of a detention pond and wetlands in series (approximately 800 and 3000m$^2$, respectively), was analyzed to determine its effectiveness in reducing stormwater runoff constituent loads. The pond inlet, pond outlet/wetlands inlet, and wetlands outlet were monitored during eleven storm events. Samples were analyzed for concentrations of major ions, selected chemical and physical characteristics, metals, and nutrients. The system's efficiency was determined using three quantifying methods: event mean concentration, summation of loads, and regression of loads. For most pollutants, the three methods yielded similar results.

The detention pond was generally effective in removing 42-66% of suspended solids and suspended metals. Nutrient removal efficiencies were more variable due to changes in species and phase during transport through the pond.

The wetlands were effective in reducing both suspended and dissolved loads of solids and metals. Removal efficiencies for total nitrogen and phosphorus were 21 and 17%, respectively.

The full system, combining the pond and wetlands treatment, achieved appreciable reductions of most pollutants. The system was particularly effective in reducing solids, lead, and zinc, with efficiencies ranging between 55 and 83%. Total nitrogen and phosphorus efficiencies were somewhat lower: 36 and 43%, respectively.

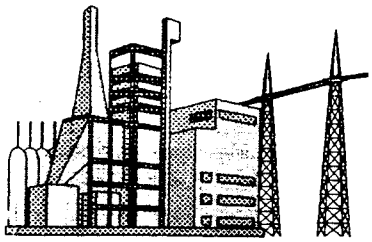
**Method References:**


- Biological monitoring: Plafkin, J.L.; M.T. Barbour, K.D. Porter, S.K. Gross, R.M. Hughes. 1989. *Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* Report No. EPA/440/4-89/001. U.S. EPA, Office of Water.

- Chemical monitoring: Taylor, G.F. 1990. *Quantity and Quality of Stormwater Runoff from Western Daytona Beach, Florida, and Adjacent Areas.* USGS Water-Resources Investigations Report 90-4002.

- Physical monitoring: MacRae, C.R.; A.C. Rowney, 1992. The Role of Moderate Flow Events and Bank Structure in the Determination of Channel Response to Urbanization., In: *45th Annual Conference Resolving Conflict and Uncertainty in Water Management.* Conference Proceedings. Canadian Water Resources Association, Kingston, Ontario. June 1992.

# *Environmental Indicator Profile Sheet*



**Indicator Profile No. 26**

## Industrial Site Compliance Monitoring

Category: **Site Indicators**

**Tools Used to Measure Indicator:**

- Visual inspections

**Description:**

NPDES permitting now requires most industrial sites to develop and implement pollution prevention plans and implementation of on-site best management practices. Compliance monitoring is conducted by either industry representatives, regulatory officials or certified inspectors. Monitoring may include pollutant constituent monitoring, as part of a permit condition, or visual inspections to check compliance with the approved and adopted pollution prevention plan.

While pollutant constituent data and compliance with pollution prevention plans documenting the success or failure of a program can be extremely useful, water quality managers may consider other information in assessing management efforts. Examples include: number of staff hours devoted to monitoring, public outreach efforts, pollution prevention training for employees, and documentation of pollution prevention teams.

**Utility of Indicator to Assess Stormwater Impacts:**

- Can be used to help evaluate the performance of structural and non-structural stormwater BMPs.
- Can help assess the contribution of industry to overall water quality degradation or improvement.
- Can induce public education, support and activism.
- Can solicit political pressure and support regarding planning issues.
- Can be used to determine industrial stormwater management needs, evaluate water quality trends, and target restoration efforts.
- Can help identify areas where technical support or research are needed to help address problems.

**Indicator Useful for Assessing:**

| | |
|---|---|
| * Aquatic Integrity of: | |
| Lakes | ○ |
| Streams | ○ |
| Estuaries | ○ |
| * Land Use Impacts | ◐ |
| * Stormwater Mgmt Programs | ● |
| * Whole Watershed Quality | ○ |
| * Industrial Sites | ● |
| * Municipal Programs | ○ |

| *Key:* | |
|---|---|
| *Very Useful* | ● |
| *Mod. Useful* | ◐ |
| *Not Useful* | ○ |

**Indicator Advantages**

| | |
|---|---|
| * Geographic Range | ● |
| * Baseline Control | ● |
| * Reliable | ◐ |
| * Accuracy | ◐ |
| * Low cost | ● |
| * Repeatable | ◐ |
| * All Watershed Scale | ○ |
| * Familiar to Practitioners | ◐ |
| * Easy to use & Low training | ● |

| *Key* | |
|---|---|
| *Very Advantageous* | ● |
| *Mod. Advantageous* | ◐ |
| *Not Advantageous* | ○ |

**Cost**

See Table 3.3F

**Advantages of Method:**

- Because the land areas involved are often small, few sampling stations are necessary.
- Several sites may combine efforts in the same area, resulting in the efficient use of monitoring resources.
- Several like industries may combine efforts, across a broad geographic area, to maximize efficiency of resources.
- Pollution reductions may show a correlation with various industrial efforts, enhancing the chances that runoff problems can be solved with relative ease.
- Can contribute significant understanding to pollutant source area problems.

**Disadvantages of Method:**

- Overall watershed health may be difficult to assess by this method.
- Industrial sites may be reluctant to employ the method for reasons such as cost, time, and concern about regulatory consequences resulting from data revelations.
- NPDES sampling requirements, to date, have not been stringently enforced by permitting agencies and quality assurance/quality control concerns may pose a problem for future compliance monitoring.
- The results and impacts of many techniques may be difficult to assess (e.g., BMPs, pollution prevention, public outreach), and may be a disincentive for industrial site managers to implement them.
- Very few industrial sites have streams, lakes or estuaries on-site.

**Case Study:** Settine, R.L.; K Burchfield. 1983
**Sampling and Analysis of Industrial Benthic Polynuclear Aromatic Hydrocarbons in Industrialized Urban Watersheds. Completion Rept. 1 Oct 82 - 31 Mar 83.**

A method is reported for the sampling and analysis that accurately describes the contour and distribution of benthic polynuclear aromatic hydrocarbons of Opossum Creek. The analytical methodology consisted of using fused silica capillary chromatography coupled with selected ion mass spectrometry to identify and quantify areas of high concentration of specific benthic compounds. It is apparent from the 'grid technique' herein reported that this model can be applied for future stream system analysis and would be an extremely reliable aid for engineering decisions with regard to cleanup.

**Method References:**

- Workshop with industry group: Brosseau, G. 1992. *1992 Summary Report - Vehicle Service Facility Waste Minimization Program.*, Palto Alto Regional Water Quality Control Plant, Uribe & Associates.

# CHAPTER IV CRAFTING AN INDICATOR MONITORING PROGRAM - A METHODOLOGY

Historically, stormwater monitoring programs were often "cookbook" efforts, regulatory-driven, and focused almost exclusively on end-of-pipe water chemistry. Although the data collected through such efforts could be used to determine baseline conditions, the monitoring results were generally unsuited for assessment of long-term stormwater management success. On the other hand, monitoring programs which incorporate stormwater indicators can be specifically tailored to address the information needs of individual municipalities and industrial sites. When selected correctly, stormwater indicators can assess the long-term effectiveness of stormwater management programs as well as provide the baseline data.

Stormwater indicator monitoring programs are based on specific data requirements, management goals, and resource constraints as determined by individual stormwater management authorities. Therefore, monitoring parameters and indicators will vary from municipality to municipality and from industrial site to industrial site. However, a common methodology can be used to develop stormwater indicator monitoring programs. This methodology is based on the general considerations which are common to all monitoring efforts.

- What is the overall purpose of the monitoring program? Is the purpose to assess baseline conditions, assess the effectiveness of the stormwater management program, or both?
- What resources are available? Is there historical data; complementary or conflicting efforts; sufficient staff, funding, and political support?
- Does the stormwater monitoring program have the ability to adequately assess the success of the stormwater management effort?

A comprehensive two-phase methodology (or protocol) for crafting a stormwater indicator monitoring program is outlined in Figures 4.1 and 4.2. The two phases correspond to the two overriding purposes for stormwater monitoring: Level 1, Problem Identification and Level 2, Assessment of Management Program. Municipalities and industrial sites with limited or no data available for characterization of baseline conditions will most likely begin at Level 1. When baseline conditions are known, a Level 2 monitoring program should be implemented.

This methodology is presented as a flexible, dynamic tool for development of an effective stormwater indicator monitoring program. Stormwater management officials do not have to begin with Step 1 of Level 1. Instead, stormwater managers are encouraged to review the methodology and determine which level most accurately represents their monitoring needs. Furthermore, because this assessment is an ongoing task, stormwater managers should frequently review their monitoring program. An effective stormwater indicator monitoring program will address current data requirements and provide an adequate basis for a long-term assessment of the management program.

FIGURE 4.1
STORMWATER INDICATOR METHODOLOGY
LEVEL I, PROBLEM IDENTIFICATION

**① ESTABLISH MANAGEMENT SPHERE**

*Who will be responsible for implementation? A government agency (municipality, county, or state) or a site-specific industry?*
*What other programs are being implemented within the watershed? Can this program be developed and implemented on a watershed-wide or basin basis?*

⇓

**② GATHER/REVIEW HISTORICAL DATA**

*Identify what programs and studies have already been implemented in the watershed.*
*Determine what problems associated with stormwater have already been identified.*
*Assess the effectiveness of earlier efforts and programs.*

⇓

**③ IDENTIFY POTENTIAL RECEIVING WATER IMPACTS**

*Identify uses and characteristics which may be impacted by stormwater runoff.*

Hydrology and Hydrodynamics (Flooding, Drainage)
Biological Integrity (Fish Diversity, Macro. Community)
Non-contact Recreation (Sports Fishing)
Supply (Potable Water)
Contact Recreation (Swimming)
Aqua-culture (Shellfish Harvesting, Food Fishing)

⇓

**④ INVENTORY RESOURCES AND IDENTIFY CONSTRAINTS**

*Determine manpower and funding limitations.*
*Identify regulatory-mandated deadlines and programs.*

Staffing
Scheduling Constraints
Funding
Regulatory Compliance

⇓

**⑤ ASSESS BASELINE CONDITIONS**

*Use rapid (qualitative) assessment methods versus detailed quantitative techniques to assess baseline conditions.*

Indicator Options by Receiving Water Use

| Concern: | Hydrology & Hydrodynamics | Biological Integrity | Non-contact Recreation | Water Supply | Contact Recreation | Aqua-culture |
|---|---|---|---|---|---|---|
| Type of Indicator to be Considered: | *Physical*<br>*Social*<br>*Programmatic*<br>*Site* | *Biological*<br>*Water Quality*<br>*Social*<br>*Programmatic*<br>*Site* | *Water Quality*<br>*Physical*<br>*Biological*<br>*Social*<br>*Programmatic*<br>*Site* | *Water Quality*<br>*Biological*<br>*Social*<br>*Programmatic*<br>*Site* | *Biological*<br>*Water Quality*<br>*Physical*<br>*Social*<br>*Programmatic*<br>*Site* | *Biological*<br>*Water Quality*<br>*Physical*<br>*Social*<br>*Programmatic*<br>*Site* |

FIGURE 4.2
STORMWATER INDICATOR METHODOLOGY
LEVEL II, ASSESSMENT OF MANAGEMENT PROGRAM

**① STATE GOALS FOR PROGRAM**

*Based on baseline conditions, resources, and constraints, articulate goals for stormwater management program in terms of measurable achievements.*

**Example:** We want to increase level and diversity of the fish population in the next 5 years.

To accomplish this, we must improve biological integrity, water quality, and physical conditions.

⇓

**② INVENTORY PRIOR AND ONGOING EFFORTS**

*Identify prior stormwater management efforts and assess success of prior efforts.*
*Identify current stormwater management efforts both within the municipal boundaries and the larger watershed.*
*Assess success of ongoing efforts.*
*Incorporate complementary programs and goals.*
*Identify potential conflicts.*

⇓

**③ DEVELOP AND IMPLEMENT MANAGEMENT PROGRAM**

*Identify and implement specific program facets in order to achieve goal.*

**Example:** In order to increase the fish population, we will retrofit BMPs, require stormwater BMPs all new development, remove fish barriers, and re-introduce some aquatic species.

⇓

**④ DEVELOP AND IMPLEMENT MONITORING PROGRAM**

*Based on goals, program structure, resources and constraints, select indicators to be used to assess success of stormwater management program. Level II indicators will likely be more quantitative in comparison to Level I techniques. Quantitative analysis is required to identify pollutant sources and assess success of program.*

**Example:** macro-invertebrate assemblage, fish assemblage, public opinion surveys, toxicity testing.

⇓

**⑤ ASSESS INDICATOR RESULTS**

*Analyze indicator monitoring results.*

What do the monitoring results indicate about the success of the stormwater management program?
Have the indicators accurately reflected the effectiveness of the management program?
What do the indicators suggest about the ability of the stormwater indicator monitoring program to measure of overall watershed health?

⇓

**⑥ RE-EVALUATE MANAGEMENT PROGRAM**

*Re-evaluate resources and constraints.*
*Update (if necessary) assessment of baseline conditions.*
*Review and revise program goals.*
*Review and revise indicator monitoring program.*
*Implement revised management program.*

# CHAPTER V THREE SCENARIOS FOR INDICATOR USE

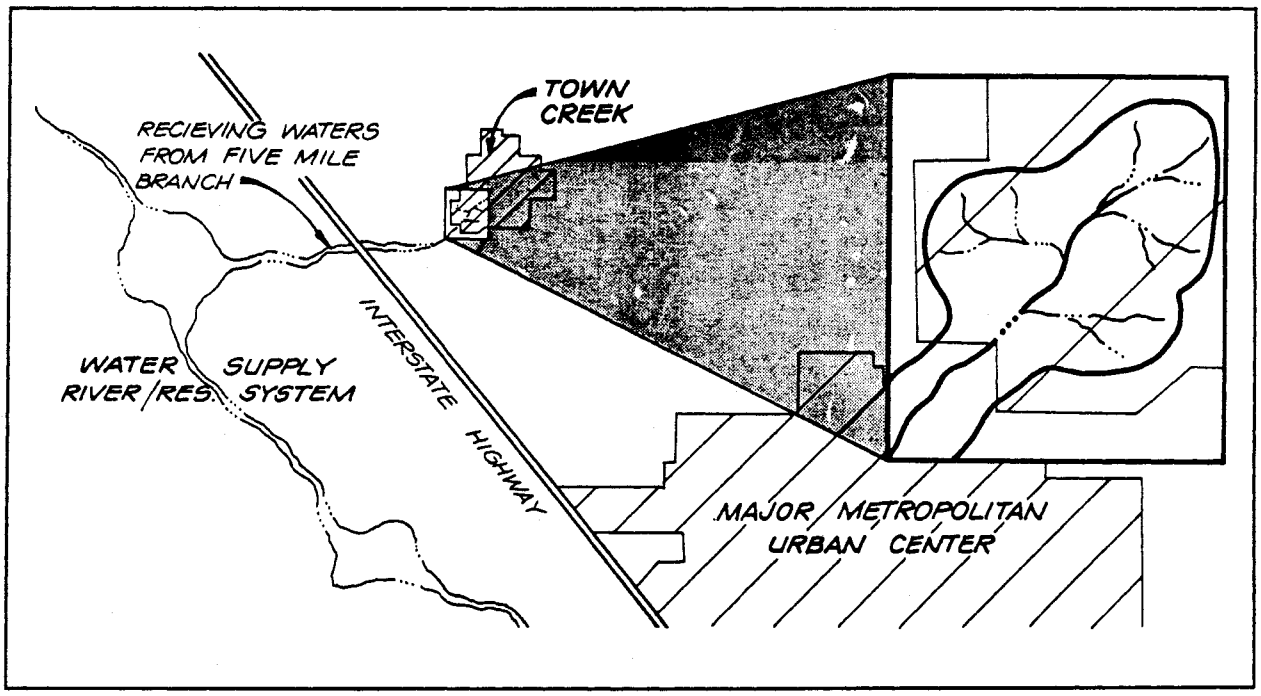
Three theoretical scenarios are described to illustrate the potential application of stormwater indicators in real world situations. The three scenarios are imaginary case studies, but are based on actual locations and conditions. Some of the baseline facts have been modified to more fully illustrate the utility of stormwater indicators as assessment tools for stormwater management program evaluation. The locations and scenarios were selected to represent different regions of the country and to test application of the indicators to different resource management situations.

The first scenario is an example of using both the Level I and Level II methodologies discussed in Chapter IV; the second scenario primarily focuses on Level II methodology; and the third scenario is intended to present a simplified Level I and Level II methodology for a small industrial park site.

## SCENARIO I - MODERATELY SIZED MUNICIPALITY - EXPERIENCING RAPID GROWTH

Five Mile Branch is a third order stream located in the Southern Piedmont region of the United States. The entire five-square mile Five Mile Branch Watershed lies within the medium-sized municipality of Town Creek. Town Creek is a rapidly growing, moderately sized town with a population of approximately 40,000 and is located 15 miles from an adjacent major urban center (Figure 5.1). A majority of the town citizenry seeks to protect the natural integrity of Five Mile Branch and its tributaries, while encouraging an atmosphere of sustainable development. The Five Mile Branch Watershed lies exclusively within the town boundaries and drains to a drinking water-supply river/reservoir system which serves the adjacent large metropolitan area. As part of

FIGURE 5.1 LOCATION AND CONTEXT OF TOWN CREEK AND FIVE MILE BRANCH



a state-initiated effort to protect source areas for drinking water-supply, the Town is being encouraged to prepare a watershed management plan to help reduce stormwater-borne pollutant loads to the receiving waters. A two year period is being allocated to develop and begin implementation of the watershed stormwater management plan. Every five to seven years the watershed stormwater management plan is reviewed and modified as necessary to reflect current and anticipated future conditions.

### Responsible Party Identification

One of the first recommended elements of preparing a watershed management plan is to identify the parties with authority to conduct and implement the plan. Since the Five Mile Branch Watershed falls completely within the boundaries of Town Creek, the Town will have complete authority to develop and implement the plan. The Town is the recipient of a $200,000 grant from the State, covering a two year period, to study the implementation of source controls within the watershed. The Town Creek Council has allocated an additional budget of $150,000 ($75,000 per year) to prepare and begin implementation of the Five Mile Branch Watershed management plan.

Portions of the Town drain to receiving waters outside its limits (outside of the Five Mile Branch Watershed). Even though these areas are not part of the Five Mile Branch Watershed management plan, they are under the town's overall management authority. A cooperative agreement, in the form of a Regional Water Quality Authority, between the region's municipalities and the State has been set up to coordinate watershed management efforts. The Town is a member of the Regional Water Quality Authority and contributes an annual fee to belong to the organization. In return, the organization provides technical staff and expertise for watershed and land use planning, enforces regionally adopted land use plans, and provides inter-local coordination for watershed management issues. The Five Mile Branch Watershed Management Plan is being prepared in compliance with the land use guidelines and recommendations of the Regional Water Quality Authority.

### Previously Collected Data

A comprehensive flood plain and flood management study was completed for the watershed within the last 10 years. This effort produced the original data-set of land use and topography, which is used to establish baseline conditions for the current work effort. The flood management report documented flood prone areas, identified potential flood control structures, and established a 100 year floodplain limit. Water quality analyses or impact assessments to the aquatic environment were not addressed in this report.

Although very little water quality data has been previously collected within the watershed, two separate studies have yielded some baseline information. First, as part of the State's 305(b) reporting and drinking water-supply source protection strategy, several chemical and some physical parameters were monitored at three locations in the watershed over a five year period. Grab samples were collected three times a year during both wet weather and dry weather periods. The monitoring data appears to indicate that in general, dry weather water quality is exceptionally good at the locations tested. Furthermore, only moderately high levels of TSS were present in three of five storm events sampled.

An additional set of data was recently collected by a citizen's stream stewardship organization, consisting of two years of data, collected at two separate locations, two times per year. This information consisted of biological monitoring data, using macro-invertebrates (identified to family level only) as an indicator species. The results indicate that at least one location, located downstream from an older large-lot residential area, appears to have a reasonably healthy biotic community. The biological community at the second location, located downstream from a regional shopping mall, shows indications of a moderately degraded system.

### Receiving Water Uses and Targeted Protection Areas

Five Mile Branch drains to a larger river/reservoir system which serves as a drinking water-supply to the adjacent large municipality. The control of nutrients, particularly phosphorous, is of primary concern to water-supply managers. In addition, a rare darter species has been found in the drainage basin, downstream of the Five Mile Branch basin. This rare darter species is considered a warm water fish and requires clean water and a sandy/gravely substrate for reproduction. The darter has been known to use the lower Five Mile Branch as refuge during the hot summer months of July and August. Over 10 miles of headwater streams (first and second order) flow through the Five Mile Branch Basin. The protection of these small streams from the impacts of urbanization, particularly with respect to controlling erosion and other physical disturbances, are of primary concern to many citizens of Town Creek.

### Town Creek Staff and Fiscal Resources

Town Creek has several full-time employees within the Department of Public Works (DPW), Division of Water Resources (DWR). Only one staff member has been assigned to the project with the understanding that the work effort will require approximately 50% of her time.

As discussed above, Town Creek has a annual budget of $175,000 for two years to prepare the watershed management plan, begin partial implementation of the plan, and provide one year of monitoring. The Town has retained an outside consultant to conduct baseline monitoring, assist in identification of program goals, develop implementation management strategies, prepare a long-term monitoring plan, and conduct monitoring to assess management efforts after the first year of implementation. The Town staff person is responsible for managing the consultant's contract. including contract management; helping the consultant with presentations to the Town Council; and providing input and reviews for issues related to Town goals, prioritizing Town citizen concerns, or providing direction in allocating future Town resources.

### Assessment of Baseline Conditions in Five Mile Branch Watershed

Since the primary objectives of the watershed management plan are to identity and control non-point source pollutants and protect the streams within Five Mile Branch Watershed, the following indicators are used to identify problems areas:

- Growth and development (Profile No. 24) is evaluated for all existing development and projected for all future development within the whole watershed.
- Biological monitoring (Profile No. 12 & No. 13) is conducted for the Five Mile Branch mainstem and tributaries for a total of 10 stations (Fish assemblage and macro-invertebrate assemblage).

- Physical assessments (Profile No. 7 & No. 8) are conducted for the mainstem and tributaries for a total stream length of approximately 3.5 miles (stream widening/downcutting, and habitat monitoring).
- Water quality monitoring (Profile No. 1) is conducted at one station at the confluence with the receiving water body (pollutant constituent monitoring of phosphorus, dissolved oxygen, TSS, and fecal coliform).
- Public attitudes (Profile No. 17) are surveyed once within a portion of the watershed.

The timetable to collect and assemble the baseline information is limited to one year. Growth and development is assessed over a two month period. Biological and physical assessments are conducted two times per year (in the spring and fall) and compared against a reference condition from a nearby watershed. Water quality monitoring is conducted for three storm events, using manually collected grab samples and a flume to establish the stage-discharge relationship. The public attitude survey is conducted within a portion of the watershed containing a mix of commercial, light industrial, and residential land uses, for a population of approximately 3,500 people.

Using the Town's already established geographic information system (GIS), existing development is measured in terms of impervious area. Based on current zoning, the ultimate impervious area is estimated and mapped. This effort yields valuable information on areas of the watershed which are at risk of degradation due to proposed levels of imperviousness.

Biological monitoring of the streams yielded the following results:

- The undeveloped areas are almost pristine, with a high abundance of species and high diversity.
- The residential land uses show moderate stream channel erosion, fair to poor aquatic habitat, and a moderately impacted aquatic community.
- The commercial/light industrial land uses show moderate to severe channel alterations, and a degraded aquatic biological community.
- The newly developed areas (constructed with BMPs) show light to moderate channel alterations and a moderately impacted aquatic community

The water quality pollutant constituent monitoring results indicate moderate nutrient levels, low fecal coliform levels and very low TSS levels for two of the three storm events. Data for one winter storm showed elevated TSS following several days of above average rainfall.

The public attitude survey results indicate that a majority of citizens are concerned with growth- related impacts to streams; consider water quality and biological integrity to be important; are willing to support moderate management efforts with money from the town's General Fund, realizing that other services may be slightly compromised; and are unwilling to increase taxes or pay user fees to provide for substantial protection of water resources.

The cost to conduct the baseline monitoring efforts discussed above, compile the results, and prepare a summary report is approximately $116,000. This figure includes the consultant fee plus the proportionate salary and overhead costs of the town staff person. Therefore approximately $234,000 is available to complete the management plan report, institute some implementation measures, and conduct one year of post-implementation monitoring.

## Watershed Management Plan - Implementation Program

*Identification of Watershed Management Goals for Five Mile Branch*

Based on the results of the baseline monitoring, the consultant, town staff and Town Creek Council have developed the following realistic goals as strategic elements of the watershed management plan.

- Protect, to the maximum extent possible, pristine streams in undeveloped areas by limiting development in those areas where the highest quality streams systems exist, instituting extensive and redundant BMP controls in areas already slated for development, and instituting land development techniques which minimize impervious area and maximize stream protection.
- Improve stream habitat and biological diversity for already degraded streams.
- Reduce nutrient and sediment loadings in receiving waters.
- Maintain or increase the habitat and population of the sensitive darter species within the lower reaches of Five Mile Branch.

*Prioritize Goals for Implementation Strategy*

The consultant, town staff and Town Council in conjunction with the general public (through a series of pubic meetings) have developed the follow priority for implementation of management strategies. This hierarchy will form the basis for allocating limited resources for implementation of management measures over the next several years.

1. Protection of most pristine resources
2. Increased protection for other undeveloped lands
3. Nutrient and sediment reduction to receiving water body
4. Protection of rare darter species
5. Enhancement of degraded streams

*Implementation of Management Strategies*

The implementation plan being developed by the consultant reflects the priority of achievable goals. The list of specific management measures include:

- Revisions to land use plans and zoning modifications to limit growth within the most pristine areas (may require innovative strategies, such as overlay zoning, transfer of development rights, conservation easements, etc.).
- Revisions to subdivision codes and stormwater management ordinance to require/encourage additional site planning techniques to reduce impervious areas and require more stringent BMPs for stream protection in developing areas.
- Public education and outreach program for nutrient reduction; investigate retrofit opportunities for existing residential areas.
- Revisions to erosion/sediment control regulations for areas draining directly to darter habitat to require additional redundant practices; additional inspections of construction sites for these areas; provide increased buffer requirements through the subdivision process for lower reaches of Five Mile Branch; provide instream habitat improvement projects for lower Five Mile Branch.

- Investigate retrofit opportunities upstream of degraded stream reach lengths; provide instream habitat enhancement and channel stabilization projects; replace or augment riparian cover along stream banks and buffers.

These measures will certainly not be implemented overnight; they require time and a change in public opinion to be fully implemented. Whether the management measures work or not is tested through post- implementation monitoring and assessment of results. A re-evaluation of these management strategies is likely as time passes.

As part of the consultant's scope of services, a management plan report is prepared which includes: a summary of baseline conditions, the goals and implementation strategy priority, a cost estimate, and a timetable for implementation of the management measures. The cost estimate is assessed on an annual basis with capitalization costs identified up front. The Town Creek Council reviews the cost analysis and determines whether sufficient funding is available within the General Fund to pursue implementation. Based on the current financial projections, only the last element (restoration of degraded streams) is likely to be beyond the budgetary means of the town. However, since this element has been prioritized as the last component of implementation, it is retained in the plan as a longer term goal when adequate funding is available.

It is projected that the town will expend approximately $135,000 to implement the first four elements of the management strategy in the first year of the plan. Therefore, approximately $99,000 will remain to conduct assessment monitoring and compile a summary report of results.

*Monitoring Program Development Strategy and Assessment of Results*

An indicator monitoring program will be used to assess the success of the management strategies. The consultant develops the monitoring program to directly measure the effects of management measures on the targeted resources with respect to protection and/or restoration. The following list of indicators is presented to the town staff and Council for review and approval:

- Biological and physical/hydrological indicators are proposed in areas experiencing growth to evaluate the effects of more stringent stormwater management controls and site planning techniques. These indicators are structured as a paired subwatershed analysis with one area being developed without modified stormwater and site planning controls and the other area being developed with the more stringent stormwater regulation and enhanced site planning techniques (Profile Nos 7, 8, 12, and 13).
- Water quality assessment at one station at the confluence with the receiving water body (pollutant constituent monitoring of phosphorus, dissolved oxygen, TSS, and fecal coliform - Profile No. 1)
- Public attitude survey of citizens within the watershed to evaluate the public's perception of how well management practices are working and to determine whether additional funding would be supported by the general populace (Profile No. 17).

The results of the first year of monitoring are compared directly with the management strategies to assess the effectiveness of the program. However, because nearly all of the management strategies will take several years to fully implement, several years of monitoring data will be required to completely assess the effectiveness of the program. A 5-year duration is recommended for re-assessment of the watershed management plan. As monitoring data is compiled over this 5-year period, sufficient data will emerge to enable assessment. At this end of the 5-year period, a re-evaluation of resource protection goals, management strategies, and implementation priority should be conducted.

## SCENARIO 2 OLDER INDUSTRIAL MUNICIPALITY - RESOURCE RESTORATION

The Town of Kelsey, an older industrial city, is developing a stormwater management program in compliance with NPDES regulations for medium-sized municipalities (current population is approximately 150,000). The Town lies on the shore of Hannah Bay, a shallow embayment to one of the Great Lakes (Figure 5.2). Most of the 25 square mile Bay watershed lies within city boundaries. The Town of Kelsey's stormwater management program will focus on the portion of the watershed within Town boundaries, including seven miles of stream which drain to Hannah Bay.

Within the Town, there is significant older residential development and some light industrial and commercial areas. Industrial and commercial development is also concentrated along the Bay waterfront. The area surrounding the Town of Kelsey is mostly agricultural, although there is some low density residential development.

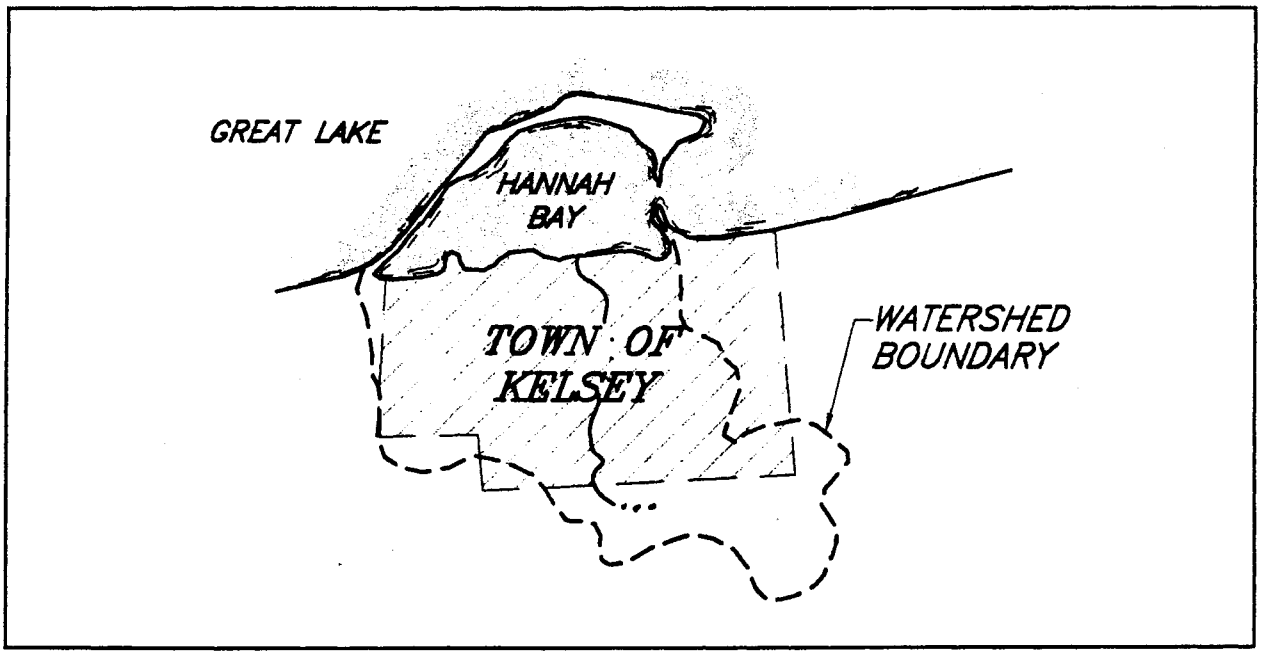
Almost all of Hannah Bay watershed is sewered and serviced by a wastewater treatment plant which discharges outside the Bay. The storm sewerage system contains both separate and combined sewers. Hannah Bay has designated water uses including warm water fisheries, potable water supply, and contact recreation (i.e., boating, fishing, and swimming).

The Town of Kelsey has completed NPDES Phase I stormwater monitoring. (NPDES regulations are enforced and regulated by the State.) The State has implemented a vigorous point source control program, but has not established stormwater quality standards.

### Program Objectives and Prior Efforts

The Town of Kelsey's stormwater management program will complement the Hannah Bay Remedial Action Plan (RAP). The RAP outlines strategies to restore and protect aquatic resources in the Hannah Bay watershed. The RAP was developed by the State in conjunction with EPA, the

FIGURE 5.2 THE TOWN OF KELSEY



International Joint Commission, and the Town of Kelsey and is based on guidance provided by the Great Lakes Water Quality Board.

Included in the RAP is a review of historical and current water quality data. Degraded water quality conditions have been reported since the 1970's. Problems include algal blooms, dissolved oxygen depletion, fish kills, malodorous conditions, reduced clarity, excessive growths of aquatic macrophytes, and high fecal coliform. Warm water fisheries have been impaired by polycyclic aromatic hydrocarbons (PAHs) and algal blooms. Contact recreation has been impacted by high fecal coliform concentrations. In addition, sediment dredging is restricted due to high heavy metals, nutrient, oil and grease, volatiles, and PAH concentrations. The most significant sources of these pollution problems are nonpoint source pollution from urban runoff and combined sewer overflows (CSOs).

The Town of Kelsey has two objectives for its stormwater management program: (1) protection of Hannah Bay fisheries and (2) minimization of impacts affecting recreational use of Hannah Bay.

**Responsible Parties and Resources**

The Town of Kelsey does not have the staff nor monetary resources needed to implement a full-scale stormwater management program. Growth in the Town is stagnant, and many factories have closed. Furthermore, there is little citizen support for allocating funds towards this effort. The Town has allocated $50,000 for stormwater management during this year. The stormwater management program will be implemented by the Town's Public Works Department which has assigned (part-time) one engineer and one technician to the stormwater effort.

The Town has entered into a partnership with the State and a nearby land grant university. The State has supplied a twelve-month, $150,000 grant and will provide technical support. Additional staff resources and technical support (including computers and research documents) will be provided by the university. Finally, because CSOs have been identified as a significant pollution source, the wastewater treatment plant authority has also been identified as a potential source of support.

**Management Program**

In a series of meetings with the State, the WWTP authority, and the university, the Town of Kelsey outlined a five task stormwater management program which includes:

- Task 1, Industrial Runoff Control;
- Task 2, Residential Runoff Control;
- Task 3, CSO Reduction;
- Task 4, Habitat and Water Quality Assessment; and
- Task 5, Public Involvement.

*Task 1, Industrial Runoff Control*

The focus of this effort is reduction of the toxicity and volume of runoff from industrial facilities. The Town, with assistance from the State, will ensure that all industrial facilities within the Town of Kelsey and subject to NPDES stormwater regulations have applied for, or are operating under, a valid NPDES stormwater permit. The Town will also work with the State to develop stormwater runoff guidelines; identify pollution prevention techniques (e.g., no exposure,

good housekeeping); and identify feasible pre-treatment and structural BMP options for industrial facilities. In conjunction with the WWTP authority, the Town will investigate possible diversions of runoff from industrial facilities to the treatment plant. Because there are a significant number of boating support and marina operations along the Hannah Bay waterfront, the Town will focus much of its NPDES compliance efforts on these facilities.

*Task 2, Residential Runoff Control*

The purpose of this task is to reduce the toxicity of runoff from residential areas. The Town will establish a household hazardous waste collection/recycling center, possibly in conjunction with local industries. The Town and the university will develop and conduct lawn care seminars to train homeowners in proper lawn care procedures including mowing regimes, types and amounts of products, and application procedures. Finally, a storm drain stenciling program will be started, possibly with the assistance of local Girl and Boy Scout Troops.

*Task 3, CSO Reduction*

This is a planning-level effort. This task will focus on identification of options for increasing sewer capacity, re-routing overflows, and/or providing treatment for the overflows (in cooperation with the WWTP authority). The relative cost of the various options will be determined. Potential funding options, including user fees, stormwater utility, and increased taxes, will also investigated. The Town will enlist the expertise of the WWTP authority. The university and State will be responsible for identifying reduction options and funding opportunities.

*Task 4, Habitat and Water Quality Assessment*

Shale sediment from eroding stream channels has been identified as a significant factor with respect to water quality problems in Hannah Bay. It has been speculated that the fine shale sediment encourages precipitation of pollutants in the water column. Prior to consideration and construction of streambank protection measures, the Town will assess current physical habitat and water quality conditions in the stream system. The focus of this effort is 3.5-mile Tate Creek, the largest tributary to Hannah Bay, which flows through a highly developed subwatershed. The assessment will be conducted in conjunction with the university and citizen monitoring groups.

*Task 5, Public Involvement*

Public involvement efforts are included in Task 2 (storm drain stenciling) and Task 4 (citizen monitoring). In addition, the Town and the university will develop and implement a series of seminars designed to educate the public regarding stormwater runoff, its environmental impacts, and management options. One of the primary purposes of this effort is to garner public support for current and future funding of the stormwater management effort.

## Monitoring Program

The success (or failure) of the Town of Kelsey's stormwater management program will be assessed within a long-term (i.e., 5 years or more) framework. Most of the management program is in the planning phase. Full implementation of structural BMPs, pollution prevention measures, and storm sewer modifications may not be achieved for many years. Some measures may be eliminated from consideration based on the results of the CSO reduction and habitat and water quality assessment efforts.

The Town of Kelsey monitoring program will focus on anticipated long-term benefits and is designed to assess the five management program tasks. Indicators included in the monitoring program include water quality pollutant constituent monitoring (Indicator No. 1), human health

criteria (No. 6), physical habitat monitoring (No. 8), fish assemblage (No. 12), public attitude surveys (No. 17), and permitting and compliance (No. 23). These indicators will be used to assess the program as follows:

*Task 1, Industrial Runoff Control:*

Permitting and compliance (No. 23): The State will provide the Town with a list of industries (within Town boundaries) subject to NPDES stormwater regulations; the number of permits issued; and copies of the permits. The Town will request copies of the Storm Water Pollution Prevention Plans from each permitted facility. An increase in the percentage of facilities subject to NPDES controls which have obtained permits is a potential indicator of success.

Water quality pollutant constituent monitoring (No. 1): The Town will select three locations in Hannah Bay and three locations in the stream system to monitor total phosphorus, total Kjedhal nitrogen, nitrate, dissolved oxygen, PAH, hydrocarbons, copper, lead, pesticides, and chemical oxygen demand. At least one site will be located upstream and at least one site downstream of major industrial development.

A total of 12 events will be monitored; 6 monthly baseflow events(April through September) and 6 storm events. The university will be responsible for collection and most analyses. A private laboratory will be contracted for the pesticides and PAH analyses. Long-term, general improvements in the monitored constituents is a potential indicator of success.

Fish assemblage (No. 12): The State (via the Department of the Environment) currently conducts fish pathology studies in Hannah Bay and its tributaries. The studies are used to track fishery health and focus on disease and poor health as evidenced by liver tumors, fin rot, and lesions. The State will continue these studies and will provide the Town of Kelsey with the monitoring results. The RAP linked fish tumors to elevated PAH levels in Hannah Bay. A reduction in the number of liver tumors is considered a potential indicator of success.

*Task 2, Residential Runoff Control*

Water quality pollutant constituent monitoring (No. 1): The water quality monitoring effort outlined in Task 1 will be used to assess the success of this effort. Monitoring sites will be located upstream and downstream of major residential development. Long-term, general reductions in pesticide concentrations have been identified as a potential indicator of success.

*Task 3, CSO Reductions*

Human health criteria (No. 6): The County (via the Health Department) conducts monthly fecal coliform surveys in Hannah Bay and immediately following storm events. During the swimming season, the maximum fecal coliform level is a geometric mean of 200 per 100 milliliters based on five samples. When fecal coliform levels exceed this level, the County closes beaches along Hannah Bay. Consumptive fishing is restricted whenever fecal coliform levels exceed 14 per 100 milliliters. The County has agreed to provide the Town of Kelsey with its survey results. The Town will use this information as baseline data.

*Task 4, Habitat and Water Quality Assessment*

Physical habitat monitoring (No. 8): Rapid Bioassessment Protocols will be used to evaluate physical habitat conditions in Tate Creek. University staff and students, citizen monitoring groups, and individual volunteers will be trained to conduct these surveys. The

survey results will be used to describe baseline conditions. It is anticipated that these surveys will be conducted on an annul basis. General improvements in the habitat scores is considered a potential indicator of success.

Water quality pollutant constituent monitoring (No. 1): The water quality monitoring effort outlined in Task 1 will also be used to assess water quality in the stream system. Two monitoring sites will be located in Tate Creek. Long-term reductions in pollutant concentrations (or increases in dissolved oxygen) have been identified as potential indicators of success.

*Task 5, Public Involvement*

Public attitude surveys (No. 17): The Town, in partnership with the university, will develop and conduct a public attitude survey. This survey will focus on the public's knowledge about problems associated with stormwater, CSOs, the cost of various solutions, habitat and water quality conditions in Hannah Bay, sources of pollution in the watershed, and willingness to fund stormwater management efforts. Approximately 2,000 households will be included in the survey.

The Town tentatively plans to conduct a similar survey in five years. Heightened awareness of stormwater issues and increased willingness to fund stormwater management have been identified as potential measures of success.

## Program Costs

The costs incurred by the Town of Kelsey for each phase of its stormwater management effort is outlined below.

| | | |
|---|---|---|
| **Task 1, Industrial Runoff Control** | | |
| Stormwater runoff guidelines | $ | 2,000.00 |
| Identification of industrial site options | $ | 5,000.00 |
| Review of potential runoff diversions to WWTP | $ | 5,000.00 |
| Permitting and compliance assessment | $ | 2,000.00 |
| Water quality pollutant constituent monitoring | $ | 70,000.00 [1] |
| Fish assemblage (fish pathology) studies | $ | 0.00 [2] |
| **subtotal** | **$** | **84,000.00** |
| **Task 2, Residential Runoff Control** | | |
| Household hazardous waste collection/recycling center | $ | 10,000.00 |
| Lawn care seminars | $ | 5,000.00 |
| Storm drain stenciling program | $ | 2,000.00 |
| Water quality pollutant constituent monitoring | $ | 0.00 [3] |
| **subtotal** | **$** | **17,000.00** |

[1] Cost for successive years will be approximately $45,000. This year's cost included $35,000 start-up costs.

[2] Conducted by State Department of the Environment.

[3] Costs included in Task 1.

| | | |
|---|---|---|
| **Task 3, CSO Reductions** | | |
| Review of options | $ | 5,000.00 |
| Human health criteria (fecal coliform) surveys | $ | 0.00 [4] |
| | **subtotal $** | **5,000.00** |
| **Task 4, Habitat and Water Quality Assessment** | | |
| Physical habitat monitoring (Rapid Bioassessment Protocol) | $ | 30,000.00 |
| Water quality pollutant constituent monitoring | $ | 0.00 [3] |
| | **subtotal $** | **30,000.00** |
| **Task 5, Public Involvement** | | |
| Public seminars | $ | 10,000.00 |
| Public attitude surveys | $ | 30,000.00 |
| | **subtotal $** | **40,000.00** |
| | **TOTAL $** | **176,000.00** |

[4] Conducted by County Health Department.

## SCENARIO 3 - SMALLER INDUSTRIAL PARK - SOURCE CONTROL FOCUS

Century Industrial Park is a 30-acre industrial park, located in a highly urbanized, southern west-coast municipality. Century consists of 16 properties of individually owned facilities. The major industrial uses are trucking related services, an auto salvage yard, and metal plating operations, in addition to several smaller, less intensive uses.

The site is located in a semi-arid region, which receives approximately 14 inches of rainfall per year, most of this during the fall and winter months. All stormwater runoff is collected by an on-site drainage system and piped to the property line. A small, off-site intermittent channel conveys stormwater runoff from the industrial park directly to a tidal estuary surrounded by a highly urban area (Figure 5.3).

Five years have elapsed since Century Industrial Park was originally issued a National Pollution Discharge Elimination System (NPDES) permit. During this period, a pollution prevention plan has been in effect which includes an intensive outreach program to assist site owners with methods for implementing source controls (good housekeeping measures). In addition, several structural best management practices (BMPs) were proposed for the most intensive activities. For one reason or another, only one on-site oil/water separator structure had been installed at the metal plating facility.

### Responsible Party Identification

The individual property owners were identified as regulated industries under the state's implementation of the Phase I NPDES permit process. The site owners pulled together their resources and filed a single joint application for an individual NPDES permit, instead of 16 separate ones. The state recognizes Century Industrial Park as the legal entity responsible for implementation and compliance with the NPDES permit conditions.

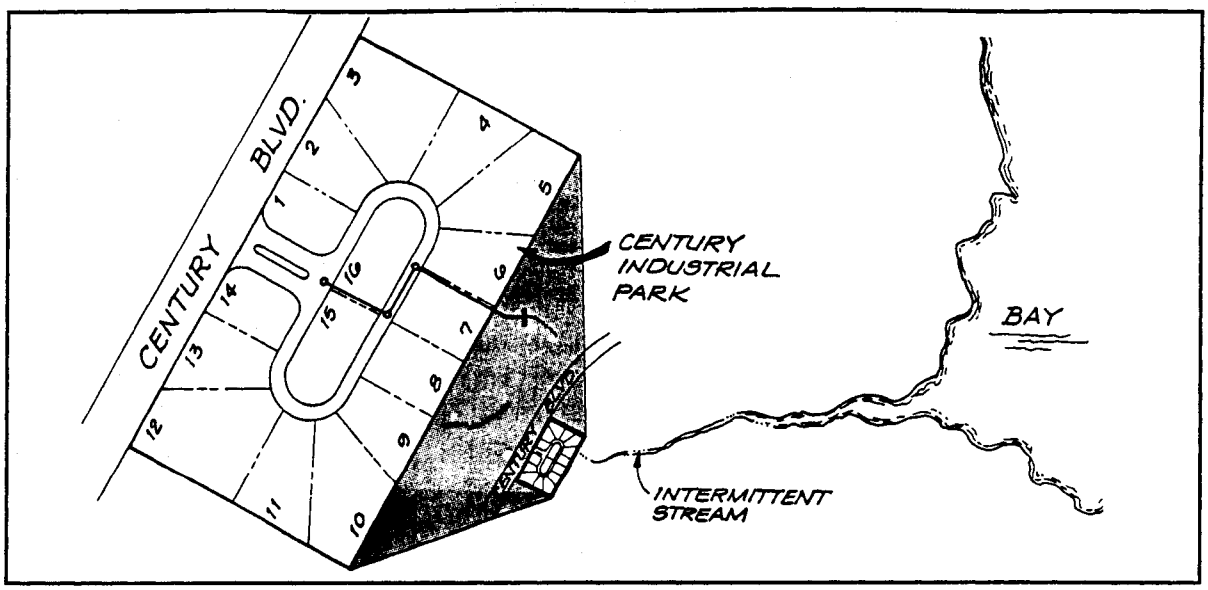



FIGURE 5.3 CENTURY INDUSTRIAL PARK

### Previously Collected Data and Assessment of Baseline Conditions

Data collected for the NPDES permit application and subsequent monitoring conducted as a condition of the permit contained end-of-pipe pollutant constituent data from five storm events. Rainfall from these events ranged in size from 0.12" to 1.96". The data confirmed that high levels of dissolved and total zinc, copper, and lead were being exported from the site during storm events. These levels were compared with the Water Quality Exceedance Frequencies (WQEFs) for total metals. All five storm samples exceeded the target water quality objectives.

Toxicity tests consisting of a two tiered approach were also conducted. Short-term, 7-day chronic toxicity tests were carried out on wet weather samples on *Ceriodaphnia Dubia* to establish the condition of consistent toxicity at the site. Next, a Toxicity Identification Evaluation (TIE) was performed to measure and identify chemical constituents responsible for the observed toxicity. This procedure involves both physical and chemical alterations of water samples to eliminate particular compounds or classes of compounds. The results of the TIE indicated that a large majority of toxicity was due to dissolved metal ions. Another conclusion appears to be that the WQEFs which are based on total metals, may be overly conservative. In many cases, particulate-bound metals are less toxic (based on the results of the TIE) and only the dissolved component is consistently causing toxicity.

### Receiving Water Uses and Target Protection Areas

As stated above the site drains to an urban estuary. This waterbody has been impacted by human influences for many years. It is believed that metals are the principal pollutant affecting aquatic health, particularly those particulate-bound metals within the bottom sediments. Other parameters, such as poly-aromatic hydrocarbons (PAHs), and nutrients are often cited as contributors to the degraded aquatic community.

The intermittent stream which drains the site has been armored over the years to stabilize the channel banks and bottom to reduce erosion, Since the channel is intermittent and reasonably well stabilized, the primary management strategy for this site is targeted towards reducing pollutant loadings being delivered to the bay.

**Resources**

The property owners pay an annual fee to fund the compliance measures of the NPDES permit. Each property owner pays a percentage of the total budget based on the amount of impervious surface and type of industry. The annual budget for the total 30 acre site is $20,000. Century Industrial Park has been identified as a significant contributor of non-point source pollutants to the receiving waters. A $100,000 grant has been appropriated by the State Water Conservation Board for this site to go towards addressing non-point source pollution control. A consultant has been hired to update the on-site pollution prevention plan, prepare a structural BMP implementation plan, and conduct monitoring for the term of the renewal permit.

**Management Plan Goals and Priority of Implementation**

The consultant in conjunction with the property owners and the State Water Conservation Board have developed the following goals and implementation priority for the term of the permit.

- Reduce total metal export from the site by 40% over existing levels by constructing structural BMPs to serve those properties with the greatest metal loading potential (i.e., auto salvage yard and metal plating facility).
- Reduce total pollutant loadings from the site to increase the percentage of *Ceriodaphnia* survival for a majority of storm events.
- Review and update pollution prevention plans for all on-site properties.
- Ensure compliance with pollution prevention plans.
- Increase the general public's awareness of the management efforts being implemented at Century Industrial Park for use as a platform for increased support for bay-wide stormwater non-point source controls.

**Implementation of Management Strategies**

The implementation of management efforts will involve the following basic steps to achieve the goals identified above. The approach must be carefully orchestrated since there is limited funding available and potential disruption of business operations must be avoided.

- Structural BMP locations are first identified and a feasibility analysis is conducted. Since the site is an industrial land use, little space is available for larger detention/retention facilities. Additionally, since downstream quantity controls are not warranted, the BMPs should be designed as quality-control facilities. A filtering BMP (such as a sand, compost or peat/sand filter) will probably be the most suitable given the site constraints. These facilities can be located along the edge of existing paved areas or even underground. Given the implementation budget constraints, and potential construction cost of approximately $3,500 per impervious acre (City of Austin, 1990), only about 15 acres can be realistically controlled by these facilities. The structural BMPs should be designed so as to control those portions of the site contributing the greatest pollutant loads (e.g., auto salvage yard, trucking services, and metal plating). Approximately $5,000 should be budgeted annually for the

maintenance of these facilities. An additional $1,000 per year should be budgeted for the cleanout and maintenance of the existing oil/water separator structure.

- The pollution prevention plan for each property is reviewed and evaluated to ensure that the good housekeeping and source control measures are incorporated into the plans. Some of these measures include: spill prevention and clean-up procedures; covered storage of materials; covered loading docks and/or cleanup procedures; covered vehicle maintenance and refueling areas; and floor drains connected to sanitary sewers. The cost to conduct this portion of the management plan is approximately $7,500. Construction costs for providing covered facilities will cost more. Each business may need to phase in these expenditures over a few years. Cleanup activities can be paid for, in part, out of the annual NPDES implementation expenses.
- Compliance monitoring is conducted to verify that all properties are following the measures outlined in the pollution prevention plans. Compliance monitoring is in the form of visual inspections only. Compliance monitoring will cost approximately $1,800 per inspection for the entire 30 acre site. This should be conducted at least once per year, but preferably twice.
- The public awareness element consists of distributing informational flyers; news releases; presentations at political forums, technical workshops and conferences; among other media. These elements are spaced over the term of the permit and should be incorporated into the annual budget. $5,000 should be budgeted to set up the program in the first year with $2,500 per year provided, thereafter.

The total cost to implement the above measures is approximately $75,000, not including engineering design costs. Given the $100,000 implementation grant, there should be sufficient funds available to cover the cost of design and construction inspection.

**Monitoring Program and Assessment of Results**

The monitoring program is developed to select indicators which will assess success of the management efforts in meeting the goals stated above. The following indicators are utilized:

- Pollutant constituent monitoring (Profile No. 1) at inflow and effluent of one structural BMP (for a minimum of three storm events per year).
- Pollutant constituent monitoring (Profile No. 1) at the outfall of the site to assess metal reduction success (for a minimum of three storm events per year).
- 7 day, chronic toxicity testing and TIEs (Profile No 2) at the outfall of the site to assess reduction in toxicity, conducted once per year during the term of the project.
- Industrial site compliance monitoring (Profile No 26), two times per year
- Public attitude survey (Profile No. 17) conducted in the vicinity of the site in year three of the program implementation, to assess the effectiveness of the public awareness efforts.

It is projected that the monitoring will cost $ 23,000 per year for the five year term of the permit. This number is slightly larger than the $20,000 budgeted for NPDES compliance, so some elements may need to be conducted on a bi-annual basis or the annual budget may need to be increased. As monitoring data is compiled over the duration of the permit term, data will emerge to be able to assess the success of the management strategies. After the five year term, a re-evaluation of the management efforts should be conducted and appropriate changes made.

# *APPENDIX A: REPORT ON STORMWATER INDICATORS MEETINGS*

Conducted April - June 1995
By The Rensselaerville Institute
as part of a cooperative agreement with
the U.S. Environmental Protection Agency

## INTRODUCTION

As part of a three-stage cooperative agreement with the U.S. EPA, and in conjunction with the Center for Watershed Protection (CWP) and the Water Environment Research Foundation (WERF), The Rensselaerville Institute convened and facilitated six stakeholder meetings which gathered storm water experts from throughout the U.S. The stakeholder groups represented at the meetings included: state and local regulators, EPA regional offices, industry, consultant engineers, and regulated municipalities.

The purpose of these meetings was to gain feedback on the Storm Water Indicator Profiles Document as prepared by the Center for Watershed Protection, and also examine the potential for identifying a core set of storm water indicators that could be used nationwide to track program effectiveness. Participants at these meetings were individuals who are recognized for their expertise in the area of storm water pollution prevention and control. Suggestions for participants were received from professional organizations including ASIWPCA, NAFSMA, APWA, and ACEC, as well as recommendations from EPA headquarters and regional offices, WERF and CWP. The list of participants at each meeting is appendixed to this report.

This report provides a short section describing the methods and approaches used for designing and implementing these six expert stakeholder meetings, and summarizes the key responses and recommendations made by the experts that seemed to become common "threads" throughout most or all of the meetings.

## METHODS

Six expert meetings were designed and organized by The Institute: the first three were designed to include mixed stakeholders representing a specific geographic area of the country. These three meetings were held in Denver, CO; Sacramento, CA; and Philadelphia, PA. The second three meetings were designed to gain feedback from single-constituent stakeholders representing various geographic regions of the country and, in one case, Canada. The stakeholder groups represented in these latter three meetings were: regulated municipalities, state regulators, and academia. All three of these latter meetings were conducted in Washington, DC.

The meeting format was designed to stimulate high interaction among participants. The basic guidelines set at each meeting were: experts were to speak their own opinions based on their personal expertise, not represent a corporate or agency "line" when responding to questions; participants were encouraged to ask questions to effectively probe areas of discussion rather than make assertions that tend to cut off interaction between participants; and issues beyond the scope of the defined area of discussion, i.e. selection and application of storm water indicators, and comments pertaining to the Profiles document, were off-limits, e.g. discussions on pending permit applications between permittees and regulators were inappropriate for these meetings.

All participants received the draft Indicator Profiles Document at least one week prior to their assigned meeting to familiarize themselves with the contents of the document and the format designed for meeting discussions. The key questions posed at each meeting were:

- Is there a core set of indicators that could be used nationwide to identify storm water problems?
- Is there similarly a core set of indicators that could be used consistently nationwide to assess storm water program effectiveness?
- What are the strengths and weaknesses of the Profiles document in its present draft form, and what information could be added or modified to improve its usefulness as a guidance tool for communities addressing storm water issues?
- Given certain conditions (as provided to the group in a simulated situation), how would participants approach the development of a storm water monitoring program for a given waterbody?

In each of the sessions, both small-group and whole-group discussions were used to engage participants. In each case of small group deliberations, highlights of those deliberations were presented to the plenary for further consideration and discussion. Consensus and divergent views were equally welcome from participants. The desired outcomes from these expert meetings were to determine:

- Which, if any, indicators that could be used nationwide to assess stormwater programs. If yes, what are the indicators, and what are the parameters of their use as national indicators.
- Those changes that could be made in the Profiles document draft to make it more user-friendly and useful to a wide range of community representatives in making rational and reasonable decisions for determining baseline conditions and selecting appropriate indicators to monitor change after implementation of BMPs.
- What approaches, steps, criteria or protocols would prove useful to communities starting or improving a storm water monitoring program, and the rationale behind using these approaches.
- What small pilots or tests could be tried by WERF or others to test the ability of these approaches to improve present storm water program monitoring efforts.

This report presents some of the key common responses and opinions expressed by participating experts on what they believed to be the most reasonable and cost-effective approaches to storm water monitoring, and what needed to be done to improve both understanding of storm water as a pollutant source and program performance.

## KEY RESPONSES AND RECOMMENDATIONS FOR IMPROVING STORM WATER PROGRAM MONITORING AND PERFORMANCE

Some of the key responses and recommendations made by the expert participants which seemed to "thread through" these six meetings were:

1. There are no specific storm water indicators that could be used nationwide comparably as a measure of program effectiveness. Most particularly, no indicator could be comparable in terms of its numerical (quantitative) standard. What experts did believe to be comparable nationwide were strategies and tactics that could be applied to select appropriate indicators

for any given watershed or sub-watershed. These would include strategies and tactics both for problem identification and determination of program effectiveness.

2. The availability of comparable baseline data is non-existent. Lack of standards and protocols for collection of data in the early promulgation of the regulations resulted in data which are not comparable from program to program and state to state. Further, the large expenditures for initial data collection that have no comparability strongly suggests that better guidance be provided to program developers and implementors on how to decide which data to collect that would be informative, useful and applicable to program improvement.

3. The Profiles document has excellent potential for providing such guidance both to communities starting a storm water monitoring program as well as those wishing to improve their present program. (Note: In each of the six expert meetings, staff from the Center for Watershed Protection received and carefully noted specific references to areas that could be improved for better document use and reference.) The overall conclusion was that the document did an excellent job in presenting key information in an understandable format; experts noted that the document needs to include approaches and protocols that could help bring consistency and common sense to the practice of program implementation and monitoring. Too often indicator selection is a result of what is known or comfortable, not what has been identified as needed to determine or deal with the problem. Basic decision-trees or decision strategies would be highly useful to laypeople referring to the document, as would guiding principles and questions that would help community members better identify and respond to problems.

4. Experts were clear: indicators have distinct roles in program assessment, and not all indicators can be used to serve the same role. Some indicators are used for problem identification; others are used to determine program effectiveness. Still others can only be used to look at program effectiveness over the long-term, while others can only effectively detect short-term gains in the program. Experts believe that problem identification is one of the biggest difficulties with the storm water program; municipalities in particular don't understand how to identify their storm water problems, and therefore often select the wrong indicators for the wrong reasons, thus generating useless data that provide no assessment of whether or not the problem is being solved.

5. One realistic approach to designing a monitoring program is to look first at those indicators that are easiest and least costly to use in order to determine the storm water problems being dealt with, e.g. indicators that are observational in nature are an excellent way to begin (example: walking a stream to assess physical and macro-biological indicators). Cost and time-intensity are two realistic constraints that must be considered in the development of any monitoring program. A third is time-appropriateness of using any given indicator: some indicators are appropriate for problem "screening" (earliest use) while others may need to be used later for finer identification of problems. Overall, experts feel that the indicators represent a toolbox from which the most appropriate tools for the job are selected at the time that they are needed. Not all indicators are used in all programs at all times...nor should they ever be required to be so used by a regulating agency.

6. Beneficial uses must be the target toward which any monitoring program is directed. There has to be a realistic understanding among all parties of what is trying to be achieved through the program. While it is clear that the program's purpose is to close the gap between present water quality conditions and what the desired beneficial uses are, it also has to be made clear

that different waterbodies have different designated uses; "pristine condition" cannot and should not be the goal for every waterbody. The storm water program, designed by a community, has to be based on what is realistically achievable for that given waterbody. All community representatives need to be part of the goal-setting process for the program to succeed; they need to be part of the decision-making on the trade-offs they are willing to make to achieve the goals they set.

7. Education is key to gain buy-in and active support from stakeholders. If a storm water program is to be effective, it must play to all the audiences of a given location. Helping people understand and commit to the program requires attending to their values and beliefs. These different audiences must not only be informed, but they must be persuaded to change their behavior.

## SUMMARY

At all six meetings, participant experts offered numerous suggestions for ways to make the Storm Water Indicator Profiles document more widely applicable and more user friendly. Staff at the Center For Watershed Protection made careful note and consideration of each of these suggestions, and many of the suggested changes are reflected in this final version. As more becomes known about storm water and effective approaches for dealing with pollutant sources, The Rensselaerville Institute is confident that this "living document" can grow and develop so that it continually meets community needs with accurate, helpful, up-to-date information and guidance.

The Rensselaerville Institute report ends with what we believe is probably the most important message received from the many experts involved: storm water programs will only be effective when a paradigm shift occurs in regard to our approaches to dealing with it as a pollutant source. Perception has to move from traditional, end-of-pipe, water chemistry, broad-spectrum pollutant monitoring, treatment and command-and-control enforcement, to a mindset focusing on receiving water body quality and the beneficial uses that the community desires for that waterbody. There needs to be strong emphasis on problem identification before a program is designed, and then there needs to be very judicial choice of appropriate indicators so that real progress toward return of the waterbody to beneficial uses can truly be measured. This new mindset must incorporate regulatory flexibility and emphasis on education and voluntary effort as key parts of the implementation plan. Government needs to move from the role of enforcer to be an enabler and technical advisor to communities that are putting forth best-faith efforts to deal with their storm water problems.

## *APPENDIX B: SAMPLE NPDES PERMIT - MONTGOMERY COUNTY, MD*

The enclosed NPDES permit for Montgomery County, Maryland, a large municipal separate storm sewer system jurisdiction, incorporates many of the indicators identified in this document. Several of the following elements are analogous to the Level 1 methodology described in Chapter IV:

- Watershed inventories (e.g., land use and impervious cover) are conducted and GIS mapping is utilized to help identify potential pollution source areas. This provides a quick assemblage of necessary databases, and supports watershed modeling efforts, among other applications.
- Pollutant constituent chemical monitoring is conducted to help characterize stormwater discharges as part of a pilot "pipe detectives" program (Profile No. 1).
- Physical and biological monitoring, on a watershed basis, is applied as a screening tool to identify water quality and habitat impairment (Profile No. 7, 8, 12, and 13).

A watershed-based management program is proposed that further supports the use of indicators in developing and assessing the county's stormwater program. Some elements of the Montgomery County stormwater management program include:

- Maintenance inspections of BMPs are being conducted (Profile No. 22).
- Stormwater waivers issued are incorporated into a tracking system (Profile No. 23).
- Commercial/industrial and residential pollution prevention and public outreach programs are established (Profile No. 18, 19, and 20).
- Illicit connections detection, correction, and enforcement programs are established (Profile No. 21).
- Watershed restoration action plans are being developed to define watershed protection goals, determine monitoring needs, incorporate public education and involvement elements, identify stormwater retrofit and stream restoration opportunities, and implement other projects needed to achieve these goals (Profile No's 1, 7, 8, 12, 13, 19, and 24).

In addition, Montgomery County's permit calls for assessing the effectiveness of controls in reducing pollutant loads. The non-point source loading indicator (Profile No. 3) and various watershed simulation model tools can be used to achieve this objective.

These are just a few of the indicator applications that are incorporated in the attached NPDES permit. A careful review of Montgomery County's permit can provide insights for other jurisdictions in either renewing a permit, carrying out permit conditions, or structuring a new permit.

We would like to acknowledge Mr. Cameron Wiegand of Montgomery County, Department of Environmental Protection, Division of Water Resources Management for his efforts in providing background information on Montgomery County's permit and for his invaluable insights on the application of environmental indicators in the NPDES permit arena.

# MARYLAND DEPARTMENT OF THE ENVIRONMENT

# NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

# MUNICIPAL SEPARATE STORM SEWER SYSTEM DISCHARGE PERMIT

## PART I. IDENTIFICATION

A. Permit Number: MS-MO-95-006

B. Permit Area

This permit covers stormwater discharges from the municipal separate storm sewer system in Montgomery County, Maryland.

C. Effective Date: March 15, 1996

D. Expiration Date: March 15, 2001

## PART II. STANDARD PERMIT CONDITIONS

A. Legal Authority

1. Montgomery County shall maintain adequate legal authority, in accordance with National Pollutant Discharge Elimination System (NPDES) regulations 40 CFR 122.26(d)(2)(i), throughout the term of this permit. In the event that any provision of its legal authority is found to be invalid, the County shall make the necessary changes to maintain adequate legal authority.

B. Source Identification

1. Montgomery County shall continue the development of its Geographic Information System (GIS) and submit appropriate topographic maps with a scale between 1:10,000 and 1:24,000 and their associated data layers to the Maryland Department of the Environment (MDE). GIS mapping shall include the location of the County's storm sewer system; each currently operating or closed municipal landfill or other treatment, storage or disposal facility for municipal waste; any known NPDES stormwater discharger; and major structural controls for stormwater discharges. Additionally, Montgomery County shall submit land use activities; an estimate of the average runoff coefficient for each land use type; estimates of population densities and projected growth for a ten year period; and the location of publicly owned parks, recreational areas, and other open lands.

2. Montgomery County shall complete GIS development according to the following schedule:

a) By 3/17/97, Little Falls watershed and Anacostia River drainage including the Sligo Creek, Northwest Branch, Paint Branch, and Little Paint Branch watersheds.

b) By 3/16/98, Potomac River drainage including the Cabin John Creek, Lower Rock Creek, and Upper Rock Creek watersheds.

c) By 3/15/99, Great Seneca Creek watershed and Potomac River drainage including the Watts Branch and Muddy Branch watersheds.

d) By 3/15/2000, Little Seneca Creek, Patuxent River drainage including the Lower Patuxent, Hawlings River, Haight's Branch, Scott's Branch, and Upper Patuxent watersheds, and Potomac River drainage east of Great Seneca Creek including the Potomac River Direct, Minnehaha Branch, and Rock Run watersheds.

e) By 3/15/2001, Dry Seneca Creek watershed, Potomac River drainage west of Great Seneca Creek including the Potomac River direct, Horsepen, and Broad Run watersheds, and Monocacy River drainage including the Monocacy River Direct, Furnace Branch, Little Monocacy River, Little Bennett Creek, Bennett Creek, and Farney Branch watersheds

3. Montgomery County shall compile and submit any new source identification information including the identification and mapping of storm sewer system outfalls, land use activities, population estimates, runoff coefficients, major structural controls, landfills and controls, publicly owned lands, NPDES dischargers, and industries organized by watershed and Standard Industrial Classification (SIC) codes in the annual reports submitted to MDE pursuant to PART IV "ANNUAL PROGRESS REPORTS" of this permit.

C. <u>Discharge Characterization</u>

1. By 6/17/96, Montgomery County shall submit storm event monitoring data and analysis to MDE for the remaining storm events at each of its five Part 2 representative outfalls.

2. Within 6 months of MDE's approval of Montgomery County's proposed long-term monitoring program, the County shall commence chemical sampling at one outfall and its appropriate in-stream monitoring station.

3. Chemical sampling at these and any additional outfalls or in-stream stations shall comply with procedures developed as a direct result of the County's involvement in NPDES monitoring committee meetings established according to PART III "SPECIAL PROGRAMMATIC CONDITIONS" of this permit.

4. Montgomery County shall complete the following minimum requirements for chemical monitoring:

a) A total of 12 storm events shall be monitored per year at each monitoring location with at least three occurring per quarter. Quarters shall be based on calendar year. If extended dry weather periods occur, baseflow samples shall be taken at least once per month. If no flow is observed at the outfall during periods of dry weather, samples shall be taken at the in-stream monitoring stations only.

b) Three discrete samples shall be taken for stormwater flow at both outfall and in-stream monitoring stations. Samples submitted for analysis shall be representative of the approximate flow at the following three intervals along the hydrograph: the midpoint of the rising limb, the peak, and the midpoint of the falling limb.

c) Flow rates and temperature shall be recorded at points when discrete samples are taken.

d) Collected samples shall be submitted to a laboratory for analysis according to methods listed under 40 CFR Part 136 for the following parameters:

| | |
|---|---|
| $BOD_5$ | Fecal Coliform |
| TKN | Nitrate plus Nitrite |
| Total Phosphorus | Cadmium |
| Copper | Lead |
| Zinc | Oil and Grease |
| pH | TSS |

e) For each storm event, a description of any equipment problems and weather conditions such as duration and intensity shall be recorded.

5. Montgomery County shall incorporate physical and biological monitoring with the chemical monitoring described in PART II., C., 2. above. Physical and biological monitoring shall commence with the chemical monitoring and procedures and protocols shall be determined through the County's involvement in NPDES monitoring committee meetings established according to PART III "SPECIAL PROGRAMMATIC CONDITIONS" of this permit.

6. Beginning in 1996, Montgomery County shall conduct habitat, physical, and biological monitoring on a watershed basis as a County-wide screening tool to identify water quality impairment and establish reference stream criteria. Where the source of impairment is determined not to be a result of physical limitations, chemical specific testing shall be conducted to identify the source of impairment. The source of impairment shall be eliminated in accordance with the County's illicit connection inspection program as identified in PART II., D., 8. and 9. of this permit.

a) Sampling procedures shall be in accordance with Montgomery County's Water Quality Monitoring Program: Stream Monitoring Protocols document which has been incorporated into this permit as Appendix 6, or any subsequent revisions as a result of the NPDES monitoring committee meetings established according to PART III "SPECIAL PROGRAMMATIC CONDITIONS" of this permit.

b) By 3/15/2001, baseline watershed and reference stream biological monitoring shall be completed for all County watersheds.

7. Reporting Frequency and Requirements

a) Chemical laboratory results shall be recorded on MDE's long-term monitoring database (Appendix 3) and submitted with annual reports.

b) Field results and analysis for physical and biological monitoring shall be submitted with annual reports. The analysis shall integrate the results from chemical, physical, and biological monitoring.

c) Annual and seasonal pollutant load estimates, using data collected as a result of the long-term monitoring efforts, shall be submitted with annual reports.

d) Pollutant loads shall be estimated for all identified municipal storm sewer outfalls and submitted to MDE according to the schedule established for GIS development in PART II., B., 2. of this permit.

e) By 3/16/98, Montgomery County shall assess its monitoring program and, if warranted, outline potential alternative sampling sites and procedures.

**D. Management Programs**

1. Montgomery County shall maintain an acceptable stormwater management program in accordance with the Environment Article, Title 4, Subtitle 2, Annotated Code of Maryland.

2. Montgomery County shall conduct preventative maintenance inspections of all stormwater management facilities at least on a triennial basis. Inspections, necessary corrective action, and enforcement actions shall be documented and summarized in annual reports.

3. Montgomery County shall submit information regarding its stormwater management program on the latest version of MDE's stormwater management spreadsheet (Appendix 4) in annual reports.

4. By 3/17/97, Montgomery County shall establish a database for tracking and evaluating the impacts of stormwater waiver issuance in each watershed. Emphasis shall also be placed upon strengthening the criteria for evaluating stormwater management waiver requests and providing enhanced public input.

5. Montgomery County shall conduct watershed studies and submit action plans for protecting surface and ground water resources. These plans shall include restoration/mitigation measures and include an implementation schedule to reduce or eliminate sources of water quality impairment. Montgomery County shall submit summaries of the watershed assessments and action plans according to the following schedule:

   a) By 3/17/97, the Little Falls and Sligo Creek watersheds.

   b) By 3/15/99, the Paint Branch, Little Paint Branch, Upper Rock Creek, and Lower Rock Creek watersheds.

   c) By 3/15/2001, the Watts Branch, Cabin John Creek, and Northwest Branch watersheds.

6. By 3/17/97, Montgomery County shall perform an assessment regarding the effects of road maintenance activities including street sweeping, litter control, deicing procedures, and the application of herbicides for vegetation control on stormwater discharges. This assessment shall include an analysis of alternative practices for reducing pollutants associated with road maintenance activities. By 3/16/98, Montgomery County shall incorporate effective alternative practices in its road maintenance procedures for reducing pollutants.

7. By 6/17/96, Montgomery County shall implement its proposed industrial, residential, and commercial pollution prevention and public outreach programs. These programs are to include educational information regarding the proper use of herbicides, pesticides, and fertilizers. Hazardous waste and general water quality information shall also be provided to the public. Education efforts shall be documented and summarized in annual reports.

8. By 6/17/96, Montgomery County shall implement its illicit connection detection and enforcement program. During the first year, program implementation shall occur in the Little Falls and Paint Branch watersheds. Each year thereafter, program implementation shall be expanded into at least five additional watersheds until all of the County's 29 designated watersheds have been assessed. At a minimum, the program shall include the following:

   a) The number of outfalls to be screened in targeted areas. Targeted areas shall include industrial and commercial land uses and those outfalls where pollutants were detected during Part 1 dry weather flow screening.

   b) Visual inspection of targeted areas. Follow-up inspections using chemical testing shall be performed immediately after discovering an illicit discharge in which the source is not apparent.

   c) Provisions for field screening data to be recorded on MDE's Part 1 field screening database.

   d) Fines for continued noncompliance by illicit dischargers.

   e) Procedures for public identification and reporting of illicit discharges.

   f) Progress reports that include an updated list of targeted outfalls and an inspection schedule.

9. Beginning 6/17/96, Montgomery County shall eliminate any illegal storm drain system discharge discovered through its illicit connection inspection program. Additionally, the County shall work cooperatively with MDE to ensure that industrial dischargers secure NPDES permits and that agricultural sources are minimized.

10. Montgomery County shall maintain an acceptable erosion and sediment control program in accordance with the Environment Article, Title 4, Subtitle 1, Annotated Code of Maryland.

11. By 6/17/96, Montgomery County shall implement "responsible personnel" certification classes to educate construction site operators regarding erosion and sediment control requirements. Education efforts are to be documented and summarized in annual reports.

12. Beginning in 1997, Montgomery County shall evaluate all management programs and identify any necessary changes. This information shall be submitted in annual reports.

**E. Program Funding**

1. Montgomery County shall maintain adequate program funding to comply with all conditions of this permit.

**F. Assessment of Controls**

1. Annually, Montgomery County shall submit estimates of expected pollutant load reductions as a result of its implementation of management programs. Additionally, the effectiveness of resource protection and stream habitat improvements shall be used to assess the effectiveness of the County's management programs and pollutant control strategies.

## PART III. SPECIAL PROGRAMMATIC CONDITIONS

Since the signing of the Chesapeake Bay Agreement in 1983, the State of Maryland has been working toward meeting the goal of reducing by 40% the discharge of nutrients to the Chesapeake Bay by the year 2000. To achieve this nutrient goal, the State has developed strategies to improve the water quality in the tributaries that drain to the Bay. In Maryland, the Bay watershed has been subdivided into ten major tributaries which have each been assigned a 40% nutrient reduction goal. Characterizations of specific tributaries have been made in terms of land use, nutrient loads, and water quality. Additionally, strategy options have been developed based on identified problems in order to guide the restoration effort in each individual tributary.

Montgomery County lies within three of the Chesapeake Bay's ten major tributaries. These include the Upper Potomac, Middle Potomac, and Patuxent River basins. This NPDES permit requires Montgomery County to assist with the implementation of the strategy designed to meet the nutrient reduction goals of the above basins. The specific permit conditions presented below will promote a watershed based approach to controlling the contribution of pollutants from stormwater runoff. Coordination between and among other jurisdictions is a major requirement and the identification of those appropriate jurisdictions will occur jointly with MDE. Additionally, deadlines, priorities, and scheduling to satisfy specific conditions will be determined in conjunction with MDE. In any case, progress toward meeting these conditions shall be reported to MDE.

**A. Programmatic Coordination**

1. Montgomery County shall coordinate water quality restoration and protection efforts in watersheds shared with other jurisdictions. These efforts shall include:

   a) the exchange of information on restoration/protection program effectiveness;

b) the definition of watershed management measures to support restoration/protection efforts;

c) the identification of appropriate watershed boundaries for planning and program development efforts; and

d) the coordination of planning and zoning activities to support the goals of watershed management.

B. Data Management

1. Montgomery County shall develop standards for record keeping and databases to meet the standard permit conditions in Part II of this permit. These standards shall be developed in concert with other appropriate jurisdictions and include:

a) management practice databases and GIS compatibility among jurisdictions for base maps, pollutant source area locations, stormwater management facility location and description, and land use and zoning designations;

b) comparable population estimates and growth projections; and

c) consistent land use and runoff coefficients.

C. Discharge Characterization

1. Montgomery County shall develop standards for discharge characterization. These standards shall be developed in concert with other appropriate jurisdictions and include:

a) coordination of long-term monitoring site selection among other appropriate jurisdictions;

b) standards for field and laboratory methods;

c) standards for monitoring databases; and

d) standards for annual and seasonal pollutant load estimates.

D. Management Programs

1. Montgomery County shall develop management program standards. These standards shall be developed in concert with other appropriate jurisdictions and include:

a) preventative maintenance procedures;

b) watershed management plans and retrofit assessments;

c) development and implementation of public information and educational programs; and

d) watershed inventories, illicit discharge inspection programs, and water quality enforcement.

E. <u>Assessment of Controls and Annual Progress Reporting</u>

1. Montgomery County shall develop standards for loading reduction estimates, annual progress reports, and stormwater management program effectiveness.

2. Along with other jurisdictions, Montgomery County shall evaluate the cumulative impact of its stormwater management waiver policy with regard to receiving water quality.

## PART IV. ANNUAL PROGRESS REPORTS

Annual progress reports required under 40 CFR 122.42(c) will facilitate the long-term assessment of Montgomery County's NPDES stormwater program. According to EPA guidance, these reports shall be based on assessment techniques proposed by jurisdictions in Part 2 NPDES applications. These reports shall include:

*§122.42(c) "(1) The status of implementing the components of the storm water management program that are established as permit conditions;"*

*§122.42(c) "(2) Proposed changes to the storm water management programs that are established as permit conditions...;"*

*§122.42(c) "(3) Revisions, if necessary, to the assessment of controls and the fiscal analysis reported in the permit application...;"*

*§122.42(c) "(4) A summary of data, including monitoring data, that is accumulated throughout the reporting year;"*

*§122.42(c) "(5) Annual expenditures and budget for year following each annual report;"*

*§122.42(c) "(6) A summary describing the number and nature of enforcement actions, inspections, and public education programs;"*

*§122.42(c) "(7) Identification of water quality improvements or degradation;"*

MDE has developed a spreadsheet (Appendix 4) for the reporting and tracking of NPDES data. This spreadsheet lists components of Montgomery County's NPDES stormwater program along with appropriate reporting parameters. Annual progress reports, including MDE's spreadsheet, shall be submitted to MDE by the anniversary date of permit issuance for each year of the permit term.

## PART V. ENFORCEMENT AND PENALTIES

### A. Program Review and Evaluation

In order to assess the effectiveness of the permittee's NPDES program for eliminating non-stormwater discharges and reducing the discharge of pollutants to the maximum extent practicable, MDE will review and evaluate program implementation, annual reports, and periodic data submittal on an annual basis. Procedures for the review of local erosion and sediment control and stormwater management programs exist in Maryland's Sediment Control and Stormwater Management Laws. Additional periodic reviews and evaluations will be conducted to determine compliance with permit conditions. Continuation or reissuance of this permit beyond March 15, 2001 will be subject to MDE's review and evaluation of Montgomery County's compliance and implementation of the conditions of this permit.

### B. Discharge Prohibitions and Receiving Water Limitations

The permittee shall effectively prohibit non-stormwater discharges through its municipal separate storm sewer system. NPDES permitted non-stormwater discharges are exempt from this prohibition. Discharges from the following will not be considered a source of pollutants when properly managed: water line flushing; landscape irrigation; diverted stream flows; rising ground waters; uncontaminated ground water infiltration to separate storm sewers; uncontaminated pumped ground water; discharges from potable water sources; foundation drains; air conditioning condensation; irrigation waters; springs; footing drains; lawn watering; individual residential car washing; flows from riparian habitats and wetlands; dechlorinated swimming pool discharges; street wash water; and fire fighting activities. The discharge of stormwater containing pollutants which have not been reduced to the maximum extent practicable is prohibited.

The permittee shall not cause the contamination or other alteration of the physical, chemical, or biological properties of any waters of the State, including a change in temperature, taste, color, turbidity, or odor of the waters or the discharge or deposit of any organic matter, harmful organism, or liquid, gaseous, solid, radioactive, or other substance into any waters of the State, that will render the waters harmful to:

(1) Public health, safety, or welfare;

(2) Domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial use;

(3) Livestock, wild animals, or birds; or

(4) Fish or other aquatic life.

### C. Duty to Mitigate

The permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit which has a reasonable likelihood of adversely affecting human health or the environment.

## D. Duty to Comply

The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Clean Water Act (CWA) and is grounds for enforcement action; permit termination, revocation, or modification; or denial of a permit renewal application. The permittee shall comply at all times with the provisions of the Environment Article, Title 4, Subtitles 1, 2, and 4; Title 7, Subtitle 2; and Title 9, Subtitle 3 of the Annotated Code of Maryland.

The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems which are installed by the permittee only when the operation is necessary to achieve compliance with the conditions of the permit.

## E. Sanctions

### 1. Penalties Under the CWA - Civil and Criminal

The CWA provides that any person who violates any permit condition is subject to a civil penalty not to exceed $25,000 per day for each violation. Any person who negligently violates any permit condition is subject to criminal penalties of $2,500 to $25,000 per day of violation, or imprisonment of not more than 1 year, or both. Any person who knowingly violates any permit condition is subject to criminal penalties of $5,000 to $50,000 per day of violation, or imprisonment for not more than 3 years, or both.

### 2. Penalties Under the State's Environment Article - Civil and Criminal

Nothing in this permit shall be construed to preclude the institution of any legal action nor relieve the permittee from civil or criminal responsibilities and/or penalties for noncompliance with Title 4, Title 7, and Title 9 of the Environment Article, Annotated Code of Maryland, or any federal, local, or other State law or regulation.

The Environment Article, §9-342, Annotated Code of Maryland, provides that any person who violates a permit condition is subject to a civil penalty up to $1,000 for each violation, but not exceeding $50,000 total. The Environment Article, §9-343, Annotated Code of Maryland, provides that any person who willfully or negligently violates a permit condition is subject to a criminal penalty not exceeding $25,000 or imprisonment not exceeding 1 year, or both.

The Environment Article, §9-343, Annotated Code of Maryland, provides that any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than six months per violation, or both.

The Environment Article, §9-343, Annotated Code of Maryland, provides that any person who knowingly makes any false statement, representation, or certification in any records or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than six months per violation, or both.

## F. Permit Revocation and Modification

### 1. Permit Actions

This permit may be modified, revoked and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, or a notification of planned changes or anticipated noncompliance does not stay any permit condition. A permit may be modified by the Department upon written request by the permittee and after notice and opportunity for a public hearing in accordance with and for the reasons set forth in the Code of Maryland Regulations (COMAR) 26.08.04.10 C.

After notice and opportunity for a hearing and in accordance with COMAR 26.08.04.10., the Department may modify, suspend, or revoke and reissue this permit in whole or in part during its term for causes including, but not limited to the following:

a) Violation of any terms or conditions of this permit;

b) Obtaining this permit by misrepresentation or failure to disclose fully all relevant facts;

c) A change in any condition that requires either a temporary reduction or elimination of the authorized discharge; or

d) A determination that the permitted discharge poses a threat to human health or welfare or to the environment and can only be regulated to acceptable levels by permit modification or termination.

### 2. Duty to Provide Information

The permittee shall furnish to the Department, within a reasonable time, any information which the Department may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit; or to determine compliance with this permit. The permittee shall also furnish to the Department, upon request, copies of records required to be kept by this permit.

## G. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of federal, State, or local law or regulations.

## H. Severability

The provisions of this permit are severable. If any provision of this permit shall be held invalid for any reason, the remaining provisions shall remain in full force and effect. If the application of any provision of this permit to any circumstance is held invalid, its application to other circumstances shall not be affected.

## I. Signature of Authorized Administrator and Jurisdiction

All applications, reports, or information submitted to the Department shall be signed as required by COMAR 26.08.04.01 D. As in the case of municipal or other public facilities, signatories shall be either a principal executive officer, ranking elected official, or other duly authorized employee.

March 13, 1996

Date

J. L. Hearn

J. L. Hearn, Director
Water Management Administration