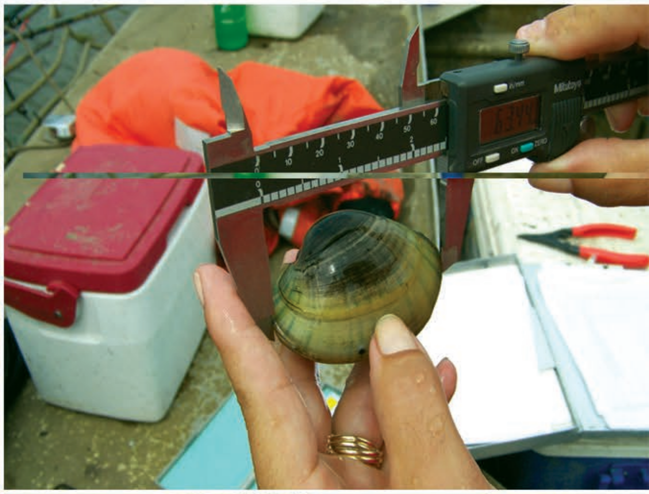
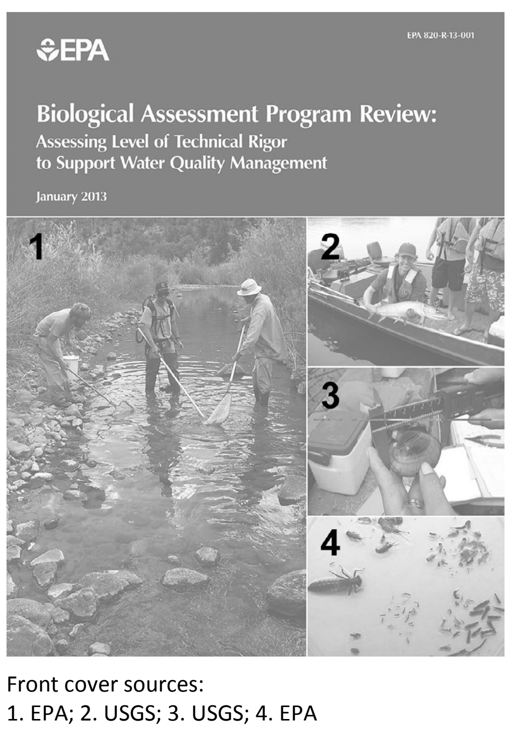
EPA 820-R-13-001

Biological Assessment Program Review:

Assessing Level of Technical Rigor to Support Water Quality Management

February 2013

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Water Quality Management

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BIOLOGICAL ASSESSMENT PROGRAM REVIEW:

ASSESSING LEVEL OF TECHNICAL RIGOR TO SUPPORT

WATER QUALITY MANAGEMENT

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Foreword

State and tribal water quality agencies face challenges to ensure that the best available science serves as the backbone of their monitoring and assessment programs. The degree of confidence with which biological assessment information can be used to answer water quality management questions relies to a considerable degree on a program's level of technical rigor.

This document provides a process, including materials, for states and tribes to evaluate the technical rigor and breadth of capabilities of a biological assessment program. The review is intended to help states and tribes answer the following questions:

- What are the strengths of my technical program?
- What are the limitations of my technical program?
- How do I determine priorities and allocate resources to further develop the technical capabilities of my existing program?
- If I want to use biological assessments to more precisely define my designated aquatic life uses and develop numeric biological criteria, how do I begin technical development?

Using the program review process described in this document, states and tribes can identify the technical capabilities and the limitations of their biological assessment programs and develop a plan to build on the program strengths and address the limitations. The U.S. Environmental Protection Agency (EPA) recommends that the review include both EPA regional participants and agency program managers and staff, and that it be facilitated by a technical expert with expertise in biological assessments and biological criteria derivation. As part of the review process, a state or tribe evaluates how it currently uses biological assessment information to support its overall water quality management program and considers potential future applications using information gained by a strengthened technical program.

The document includes a description of 13 technical elements of a biological assessment program, provides a checklist for evaluating the level of technical development for each element, and includes a method for characterizing the overall level of program rigor. As a technical program is improved, biological assessment information can be used with increasing confidence to support multiple water quality program needs for information. Such needs include more precisely defined aquatic life uses and approaches for deriving biological criteria, monitoring biological condition, supporting causal analysis, and developing stressor-response relationships.

This document is intended to be used as a "how to" manual to guide technical development of a biological assessment program for providing information to meet multiple water quality information needs. Water quality agencies can use the outcomes of the programmatic review to develop the technical strengths of their biological assessment programs and allocate resources to build as robust programs as their resources will allow. The highest level of technical development as described in this document can be thought of as a well-equipped toolbox. Not all tools need to be applied all the time and in all situations. For a water quality program, the type and level of quality of a biological assessment tool (e.g., a collection method, monitoring design, or analytical approach) will depend on the question being asked and the specific environmental circumstances. For this reason this document does not, and is not intended to, establish minimum expectations regarding the amounts or types of biological data that might be considered necessary in the context of decision making in Clean Water Act regulatory programs. However, understanding the different programmatic expectations for the biological assessment data guides the technical review and recommendations for technical development.

CHAPTER 1: BIOLOGICAL ASSESSMENT PROGRAM EVALUATION

1.1 Background

A biological assessment is an evaluation of the biological condition of a water body using surveys of the structure and function of resident biota, including migratory biota that reside in the water body for at least one part of their life cycle (USEPA 2011b). Biological assessment information is important to effectively and accurately answer water quality management questions about condition, protection, and restoration. It is a principal monitoring tool for state and tribal water quality agencies (referred to throughout as water quality agencies) and is used to varying degrees and purposes by all 50 states and increasingly by tribes (USEPA 2002b, 2011c). Over the past 20 years, water quality agencies have developed different abilities to use biological assessment information for water quality management. An agency's ability to use this information at the appropriate level of precision and accuracy to answer a given management question is called its *technical capability*. The technical capability of a program is dependent on its level of *technical rigor*. For the purposes of this document, a technically rigorous biological assessment program:

- Uses scientifically accepted and documented methods.
- Adheres to methods and protocols.
- Documents quality assurance and quality control.
- Provides information to support multiple WQM programs.

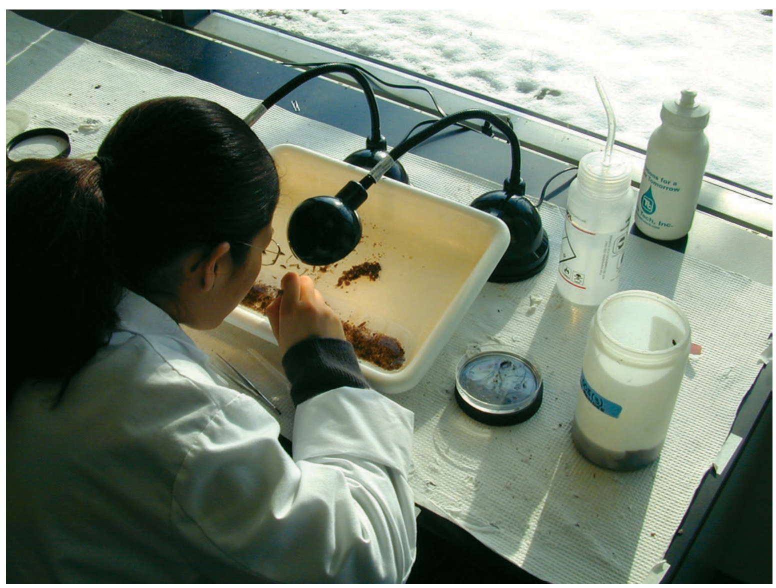
1.2 Why Is the Level of Technical Rigor Important?

The technical rigor of a biological assessment program determines the degree of accuracy and precision in assessing biological condition and deriving stressor-response relationships. With increasing technical rigor, a water quality agency gains increased confidence in data analysis and interpretation, as well as more comprehensive support for a variety of water quality management activities, including the following:

- More precisely defining goals for aquatic life use protection.
- Deriving biological criteria.

- Identifying high quality waters and establishing biological condition baselines.
- Identifying waters that fail to support designated aquatic life uses.
- Supporting development of water quality criteria.
- Conducting causal analysis.
- Monitoring biological response to management actions.

This document is intended to be used as a road map for technical development of a biological assessment program. It provides a step-by-step process for evaluating both the technical rigor of a water quality agency's biological assessment program and the extent to which the water quality agency uses the information to support overall water quality management. The evaluation is based on the degree of technical development of the biological assessment program's survey design, methods, analysis, and interpretation; how biological assessments are integrated into and supported by the monitoring program; how the agency currently uses biological assessments to support its water quality programs; and how it intends to use biological assessments in the future.



The end goal of this evaluation process is an action plan for technical program development and recommendations to enhance the use of biological assessments to support the agency's overall water quality management program (USEPA 2011c). The plan specifies incremental steps for technical and program development based on the strengths and gaps identified in the evaluation.

To date, this process has been applied to biological assessment programs for river and streams and reviews conducted with 22 states and 1 tribe (Yoder and Barbour 2009). However, the technical elements and the review process are applicable to other water body types with water body-specific modifications for biological assessment design, methods, and data analysis.

1.3 The Technical Foundation for a Biological Assessment Program

The determination of a biological assessment program's level of technical rigor is on the basis of evaluating 13 technical elements that provide the foundation of its biological assessment design, data collection and compilation, and analysis and interpretation (Figure 1-1). *Biological assessment design* includes temporal and spatial considerations in developing a monitoring program and selection of sampling sites, characterizing and accounting for natural variability, and determining reference condition. *Data collection and compilation* includes field and laboratory protocols and data handling, typically included in agency standard operating procedures (SOPs). *Analysis and interpretation* comprise all of the data analysis, interpretation, and review procedures used after data are obtained. The 13 technical elements are based on U.S. Environmental Protection Agency's (EPA's) Consolidated Assessment and Listing Methodology (CALM) guidance on collection and use of water quality data and information for environmental decision making (USEPA 2002a), and on EPA's *Evaluation Guidelines for Ecological Indicators* (Jackson et al. 2000; Kurtz et al. 2001). The evaluation guidelines described 15 guidelines in 4 areas (termed "phases" in the Guidelines) comprising conceptual relevance of the indicator, feasibility of implementation, response variability, and interpretation and utility. The CALM guidance describes seven critical technical elements of a biological assessment program. In that guidance EPA also describes four levels of technical program rigor, Levels 1 through 4, with Level 4 being the highest level of rigor. As described in chapter 2 of this document, the original 7 critical technical elements have been refined and expanded to 13 elements on the basis of a water quality agency's assessment program reviews conducted beginning in 2004 (Yoder and Barbour 2009; USEPA 2010b).

Technical Elements of a Biological Assessment Program

Biological assessment design
1. Index period
2. Spatial sampling design
3. Natural variability
4. Reference site selection
5. Reference conditions

Data collection and compilation
6. Taxa and taxonomic resolution
7. Sample collection
8. Sample processing
9. Data management

Analysis and interpretation
10. Ecological attributes
11. Discriminatory capacity
12. Stressor association
13. Professional review

Figure 1-1.The critical technical elements.

The technical elements and the level of development for a rigorous biological assessment program are discussed in more detail in chapter 2. Assessment of the technical elements is the technical backbone of the program review process, and it provides the detailed information needed by an agency program to develop its technical program. An estimate of overall level of program rigor is assigned based on the scoring of the technical elements that correspond with a program's increasing ability to detect incremental levels of biological change along a gradient of stress, associate biological response to stressors and their sources, and integrate biological assessments with other environmental data and information.

1.4 The Biological Program Review Process

The biological program review is a systematic *process* to evaluate the technical rigor of a water quality agency's biological assessment program and to identify logical next steps for overall program improvement. The review is typically conducted over two to three days for both a thorough evaluation of the technical elements and for agency cross-program discussions on the use of biological assessment data and information to support the overall water quality management program. The purpose of the cross-program discussions is to provide an opportunity for managers and staff from different water quality programs to identify the type and level of rigor of biological assessment that best addresses their information needs. Additionally, personnel can share their needs and timing for information to optimize collection and delivery of the data. These discussions might reveal areas for program improvement and coordination that will foster more efficient and comprehensive application of biological assessments. An improved understanding of how an agency uses biological assessment information in its water quality programs helps answer the "so what" question for why an agency would allocate staff and resources for technical development.

The review includes both EPA regional participants and agency program managers and staff, and it is typically facilitated by an independent technical expert with expertise in biological assessments and in biological criteria derivation.

The review team first evaluates the 13 technical elements of a biological assessment program. Each technical element receives a score on the basis of its current state of technical development. These scores are then summed for an overall program score—a higher score reflecting a higher level of technical development, corresponding with increased capability and confidence in use of biological assessment data.[1] A Level 4 assignment is the highest ranking, and Level 1 is the lowest ranking. These levels reflect sequential stages in technical development of a biological assessment program and are intended as a guide for assessing progress and targeting resources.

The review process is designed to evaluate the key gaps in a technical program and to identify incremental steps for addressing the gaps. The scoring of the individual elements provides the essential information for identifying these technical gaps. Incremental improvements in the individual technical elements are followed, often in a short time, by corresponding improvements in the technical capability of the overall program (Figure 1-2). At all levels of technical development described in this document, a state or tribal program is able to use biological assessment information to carry out Clean Water Act (CWA) activities. For example, a defensible decision that aquatic life use is impaired can be based on a qualitative visual observation of overwhelming biological evidence such as nearly total dominance of pollutant

[1] Because the overall score is the result of the summation of individual scores for the 13 separate elements, the overall score does not establish minimum expectations regarding a state's ability to make decisions in context of different CWA regulatory programs. At all levels of technical development, biological assessment information can be used to support water quality decisions.

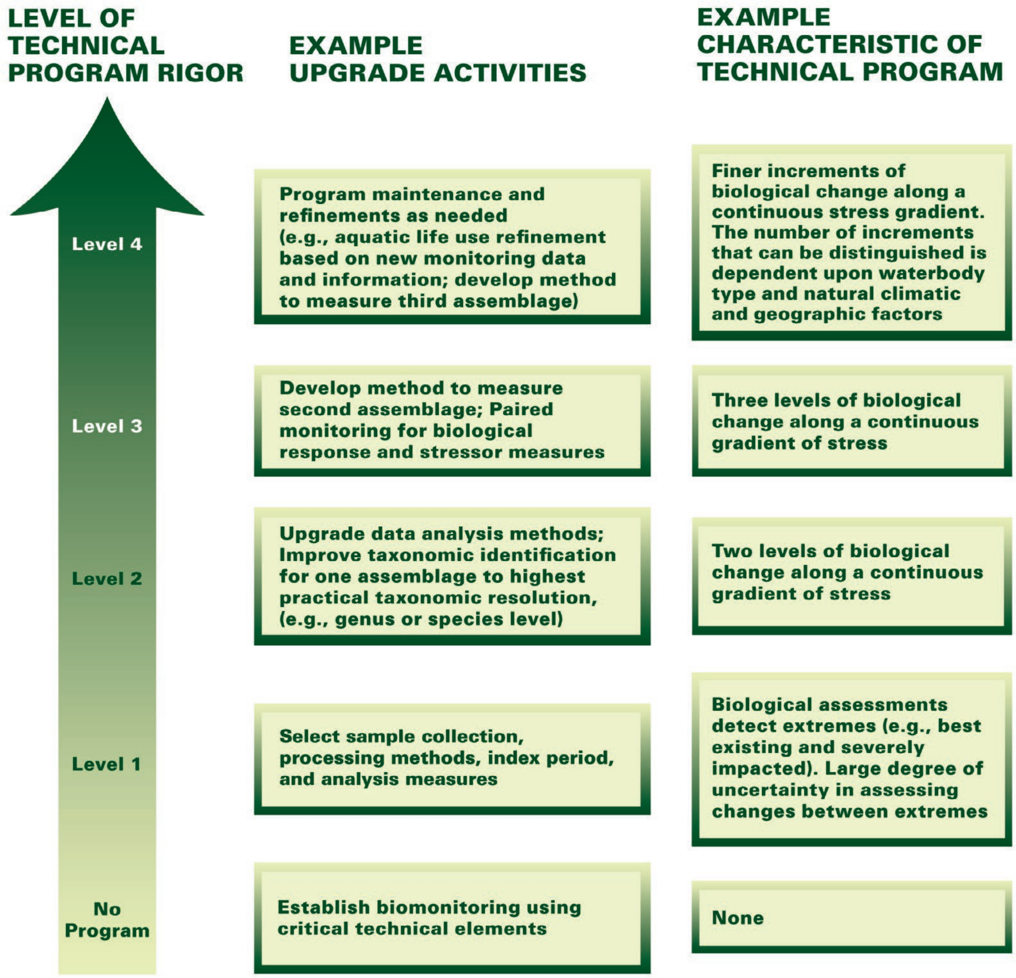


Figure 1-2. Examples of typical upgrade activities state or tribal water quality agencies have taken to incrementally strengthen their technical programs. The example characteristics provided in column three are relevant to a biological assessment program's technical capability to distinguish incremental biological change along a gradient of increasing stress. Improved ability to discriminate biological changes supports more detailed description of designated aquatic life uses and derivation of biological criteria.

tolerant organisms (e.g., scuds, worms, snails), a pervasive algae bloom, or a fish kill. As the technical program is improved, the agency will be able to use biological assessment information with increasing confidence to more precisely define aquatic life uses, develop biological criteria, and, in conjunction with whole effluent, physical, chemical, and land use data, identify stressors and their sources.

Matching the existing level of technical rigor with the intended use of the information can provide insight on the benefit of technical development. An agency can use this understanding to guide decisions and priorities on technical development of its biological assessment program. As part of the review, agency managers and staff from the biological assessment program and other water quality programs discuss how biological assessment information is currently used to support the overall water quality management program and on program enhancements that might lead to more comprehensive and effective use of biological assessment information. On the basis of the reviews conducted beginning in 2004 (Yoder and Barbour 2009; USEPA 2010b), an agency's ability to comprehensively and effectively use biological assessment information is supported by:

- Refined aquatic life use classification to protect existing conditions and maintain improvements.
- Numeric biological criteria adopted into water quality standards (WQS).
- Coordinated biological, whole effluent toxicity (WET), chemical, and physical monitoring to support both condition assessments and causal analysis.

Program managers and staff from the monitoring and assessment programs, WQS, CWA section 305(b) report, 303(d) list, Total Maximum Daily Load (TMDL), National Pollutant Discharge Elimination System (NPDES), and nonpoint source programs jointly discuss information needs and program schedules. A water quality agency might support development of a rigorous technical biological assessment program, but if the types and quality of data, data collection, and analysis are not aligned with water quality management program information needs and implementation schedules, the information might not be most effectively used. The cross-program discussion will help reveal any gaps and inconsistencies that the agency can then address. The long-term goal is to develop a well-integrated biological assessment program that produces information with the appropriate degree of accuracy, precision, and confidence to support multiple water quality program information needs (Table 1-1). The results of these discussions do not affect the scoring of the technical elements but can inform an agency's decision on level of technical development to best support its management objectives and program priorities.

Following the review, the independent technical expert prepares a technical memorandum that describes the program's current level of rigor for the 13 technical elements and identifies the technical gaps revealed in the evaluation. In conjunction with the agency review participants, the technical expert develops recommendations to improve specific technical elements. This information helps the agency target resources more efficiently, address weaknesses, and incrementally strengthen its program to better support water quality management decisions. More information about the biological assessment review process is in chapter 3.

1.5 Benefits of a Rigorous Biological Assessment Program

As stated previously, at all levels of technical development, biological assessment information can be used to support water quality decisions. However, the degree of confidence in the use of information will increase with technical development. For example, improvements in the ability to detect changes in biological assemblages along a gradient of stress can enhance precision in describing high-quality waters and setting incremental restoration targets, as well as discriminating between intermediate levels of condition (e.g., Diamond et al. 2012). Characteristics of high level programs include improved sensitivity in the biological indices to

Table 1-1. Example discussion questions and topics on use of biological assessments to support water quality management program information needs.

Self Assessment Question	Program Implementation
Does the biological assessment program produce adequate data and information to develop biological criteria, provide detailed descriptions of designated aquatic life uses, support identification and protection of high-quality waters, and inform use attainability analysis (UAA)?	Narrative descriptions of aquatic life use classes and attendant numeric biological criteria incorporate elements of natural classification strata consistent with underlying distinction of aquatic ecotypes at appropriate spatial scale for application of the information. The biological assessment program provides data and information to define biological expectations for a specific water body or watershed and support water quality management decisions to protect existing conditions and support improvements.
How is the biological monitoring and assessment program conducted to support multiple water quality management program objectives? Does the program work with other water quality management programs to coordinate biological (including WET), chemical, and physical monitoring and assessments?	Monitoring and assessment is integrated into the overall management of surface water quality to support both determination of general condition and causal analysis. Spatial design is sufficient to detect and characterize chemical and non-chemical pollution gradients and to associate measured changes in biotic assemblages with specific or categories of stressors. Results are expressed to support multiple program uses including WQS attainment, CWA sections 305(b) reporting and 303(d) listing, CWA section 402 NPDES program, and watershed, reach, and site-specific support (i.e., investigations, watershed planning, site-specific water quality criteria development, UAA).
Is there a method developed for stressor identification and implemented as part of the water quality program? How is the information used to support multiple water quality management programs?	Empirical relationships between biological measures and chemical/physical parameters are well-developed and documented. Information is used to support statewide/regional development and refinement of water quality criteria and support stressor identification as an integral part of the assessment process. This, in turn, supports development of TMDLs.

measure incremental biological changes along a gradient of stress (Levels 3 and 4) and a more complete assessment of the community by measuring two or more assemblages (Level 4). A Level 4 program should also be able to support more expedient and robust causal analysis, because the biological assessments are coordinated with WET, chemical, and physical monitoring. Field data are linked with information on sources of stress and watershed characteristics to support source identification. Two examples of program benefits shown by states that have piloted the biological assessment review follow.

Example 1: Aquatic life use refinement. A biological assessment program with a high level of technical rigor provides for a greater degree of confidence in an agency's ability to establish biological thresholds that protect existing conditions, determine potential for improvements, and monitor to track progress and maintain improvements. For example, based on measured changes in biotic assemblages, Vermont has the technical capability to discriminate multiple increments of biological change along a gradient of stress that spans excellent to severely impacted conditions. Based on these data and information, Vermont has adopted three aquatic life use classes in its WQS (e.g., excellent, very good, good). The state has set aquatic life uses classes for its streams and rivers to maintain existing high-quality conditions. The specific use class assigned to a water body is based on its current condition, and, if degraded, its potential for improvement. Ohio has likewise adopted multiple levels of aquatic life use classes (e.g., exceptional warmwater and warmwater habitat). Additionally, Ohio has established biological expectations for agricultural drainage ditches and permanently altered streams (e.g., modified warm water habitat and limited resource waters, respectively) following a use attainability analysis (UAA) process. Ohio's use assignments undergo periodic review and upgrades based on routine, coordinated chemical, physical, and biological monitoring and assessments, including data from WET monitoring.

For both states, biological assessments conducted in conjunction with physical, whole effluent, and chemical monitoring enables them to evaluate the potential for improved conditions in their streams and rivers and consequently set appropriate and attainable goals in their WQS (e.g., designated aquatic life uses). Additionally, routine monitoring provides new data that is used to upgrade waters to a higher aquatic life use class as conditions improve (USEPA 2011c).

Example 2: Causal analysis. A finding of biological impairment does not assist management in correcting the problem unless causes of the impairment can be identified. A common use of stressor identification, or causal analysis, is in the TMDL program in situations for which a water body has been determined to have one or more impaired designated uses but the pollutants causing or contributing to the use impairments are not identified at the time. A monitoring program that collects comprehensive biological (including WET), physical, and chemical information in a coordinated manner will have the ability to examine evidence for causes of observed impairments and to develop stressor-response relationships that can inform stressor identification (e.g., Yoder and Rankin 1995b; Suter et al. 2002). For example, the Maine Department of Environmental Protection (MDEP) evaluated the condition of the Pleasant River watershed with biological indices for benthic macroinvertebrates and algae in combination with chemical and physical data and information. Located in southern Maine, the Pleasant River watershed is primarily forested with some agriculture and increasing amounts of residential development in the downstream portions of the watershed. The Pleasant River has a water quality goal of Class B—good quality conditions.

MDEP sampled algal and macroinvertebrate communities in several locations on the Pleasant River. Biological assessment results showed that the headwater reach attained Class B. Further downstream, the macroinvertebrate samples attained Class B. However, some of the downstream algal samples attained a lower level of quality comparable to Class C conditions (i.e., waters in fair condition). The river segment was also listed as impaired because it did not attain the Class B dissolved oxygen criterion. MDEP used water chemistry data, habitat evaluations, and diagnostic algal and macroinvertebrate metrics to determine that phosphorus enrichment was the probable stressor for these downstream sites. To prepare for developing a TMDL, MDEP evaluated the watershed and identified some farms and residential areas as potential sources of nutrients in the lower part of the watershed. The combination of biological assessments for multiple taxonomic groups and associated chemical, habitat, and land use information allowed MDEP to complete a thorough and more expedient evaluation of the Pleasant River watershed. As a result, MDEP has started developing a TMDL that will effectively target management actions needed to maintain biological conditions in the headwaters and to restore downstream portions of the watershed.

Use of multiple biological assemblages and coordinated biological, WET, chemical, and physical monitoring are characteristics of a Level 4 biological assessment program, and these capabilities can lead to improved confidence in estimating stress-response relationships. A relational database that enables data export and analysis via query supports this function. This level of technical development improves an agency's efficiency in identifying water quality limited waters that must be placed on a state or tribe's CWA section 303(d) list, conducting causal analysis, and assigning probable cause, or causes, of impairment. As a result, an agency should be able to more efficiently develop the appropriate management action to address a TMDL (or suitable alternative means of achieving WQS) when a pollutant has been identified as the cause of a biological impairment. A well-established, well-supported, and comprehensive monitoring program then provides the data needed to track progress and evaluate the effectiveness of the management actions taken, whether monitoring discharges and tracking the effects of permit limits or monitoring the implementation of best management practices (BMPs) for nonpoint source pollution. Paired stressor-response data might also be used to develop or refine chemical water quality criteria (Cormier et al. 2008; USEPA 2010c), and it has been used to identify benchmarks for conductivity (USEPA 2011a).

Overall, a monitoring program that integrates biological assessment, WET, chemical, and physical data is key for the most effective implementation of the biological assessment program and supports use of biological assessments to more precisely define aquatic life uses and derive numeric biological criteria. Additionally, when the monitoring schedule coincides with the cycle of WQS establishment and review, CWA section 305(b) reporting and section 303(d) listing, TMDL development, NPDES permitting, and nonpoint source program implementation, biological and other environmental data are available when needed by water quality management programs. Several states have improved cross program coordination through a rotating basin approach.

A well-established biological monitoring and assessment program will further benefit an agency's water quality program if comparable or consistent sample collection methods and data analysis protocols are developed in conjunction with the biological monitoring programs of other agencies (e.g., at local level and adjacent states, tribes; federal). This approach will support development of regionally consistent taxonomy for biological data and will help address data gaps regarding regionally appropriate, taxon-specific tolerance values and other ecological traits. Such consistent data allow for shared use of reference site data across jurisdictional boundaries. In some places there is a paucity or total lack of reference sites comparable to minimally disturbed conditions. The ability to share data and expand reference site network beyond jurisdictional boundaries might support establishing more robust reference conditions.

1.5.1 Implications for Technical Program Development

The technical capabilities of Level 1 and 2 programs are appropriate for some, but not all, water quality program uses. For example, a Level 1 program can typically differentiate water bodies in the very best and worst conditions, whereas a Level 2 program can more confidentially assess good and poor conditions. Both these programs can make defensible determinations of failure to fully support a water body's designated aquatic life use, but they might fail to detect initial and significant changes in biological condition caused by anthropogenic stress. Some degraded water bodies might not be accurately assessed, and, therefore, no actions are initiated to remediate and restore them. Southerland et al. (2006) estimated that up to 25 percent of impaired sites would escape detection (i.e., would pass as unimpaired, or false negatives) simply from lax reference site-selection criteria. This situation is of particular concern if a threshold is selected at the low boundary of a reference condition.

1.5.2 Benefits of a Biological Assessment Program Review

An agency can use the biological program review to determine the capabilities of its biological assessment program in a consistent, systematic manner that supports further technical development and enables midcourse review and refinement. The review will help determine if information is collected and analyzed with the accuracy and precision appropriate to address a variety of water quality management issues. The agency will be able to propose refinements to its water quality program to enable more comprehensive and efficient use of biological assessment information to support water quality management in a variety of water quality programs (e.g., NPDES permitting, TMDLs). This process and its outcomes help communicate the value of further technical development to agency management and to the public. The process, steps, and workshop materials for the biological program review are further discussed in chapters 2 and 3 of this document.

CHAPTER 2: THE TECHNICAL ELEMENTS OF A BIOLOGICAL ASSESSMENT PROGRAM

A biological assessment program's level of rigor is dependent on the quality and level of resolution of 13 technical elements (Table 2-1).

Table 2-1. Definitions of the technical elements

	Technical Element	Definition
Biological Assessment Design	Index Period	A consistent time frame for sampling the assemblage to characterize and account for temporal variability.
	Spatial Sampling Design	Representativeness of the spatial array of sampling sites to support statistically valid inference of information over larger areas (e.g., watersheds, river and stream segments, geographic region) and for supporting water quality standards (WQS) and multiple programs.
	Natural Variability	Characterizing and accounting for variation in biological assemblages in response to natural factors.
	Reference Site Selection	Abiotic factors to select sites that are least impacted, or ideally, minimally affected by anthropogenic stressors.
	Reference Conditions	Characterization of benchmark conditions among reference sites, to which test sites are compared.
Data Collection and Compilation	Taxa and Taxonomic Resolution	Type and number of assemblages assessed and resolution (e.g., family, genus, or species) to which organisms are identified.
	Sample Collection	Protocols used to collect representative samples in a water body including procedures used to collect and preserve the samples (e.g., equipment, effort).
	Sample Processing	Methods used to identify and count the organisms collected from a water body, including the specific protocols used to identify organisms and subsample, the training of personnel who count and identify the organisms, and the methods used to perform quality assurance/quality control (QA/QC) checks of the data.
	Data Management	Systems used by a monitoring program to store, access, and analyze collected data.
Analysis and Interpretation	Ecological Attributes	Measurable attributes of a biological community representative of biological integrity and that provide the basis for developing biological indices.
	Discriminatory Capacity	Capability of the biological indices to distinguish different increments, or levels, of biological condition along a gradient of increasing stress.
	Stressor Association	Relationship between measures of stressors, sources, and biological assemblage response sufficient to support causal analysis and to develop quantitative stress-response relationships.
	Professional Review	Level to which agency data, methods, and procedures are reviewed by others.

The following section describes each technical element and provides a template for assigning a level of technical rigor to each element. Section 2.2 describes how these scores are summarized to estimate an overall level of technical rigor for a biological assessment program.

2.1 The Technical Elements

2.1.1 Index Period: Characterizing and Accounting for Temporal Variability (Element 1)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Temporal variability is not taken into account.	Sampling period established based on practices of other agencies and/or literature. Sampling outside the index is not adjusted for temporal influence.	Index period established based on a priori assumptions regarding temporal variability of biological community. Effects of the use of index period are documented. Data collected outside the index period data might be adjusted to correct for temporal influences.	Temporal variability is fully characterized and taken into account for all data. Agency information needs and index periods are coordinated so that adherence to an index period is strict.

Biological communities vary over time due to the life cycles of the targeted organisms (e.g., reproduction, recruitment, growth, emergence, and migration) and temporal variations in environmental conditions (e.g., changes in flow), so the characteristics of a biological sample can also vary depending on when that sample is collected. This temporal variability must be taken into account when interpreting biological data and assessing biological condition. Two approaches are commonly used: index periods and continuous models.

An index period is a contiguous time period used to minimize variation among biotic samples associated with systematic phonological changes in population densities and assemblage structure (Munné and Prat 2011; Kosnicki and Sites 2011). Selection of an index period can be based on a priori, existing knowledge regarding the predictable temporal changes in assemblage structure described above, when resident populations are comparatively stable (e.g., periods of growth between recruitment and emergence), and when potential exposure to anthropogenic stressors is highest (e.g., Resh and Rosenberg 1984, 1989; McElravy et al. 1989; Barbour et al. 1996; Bailey et al. 2004; Bollmohr and Schultz 2009). The index period can be further refined or based on analysis of data collected throughout the year to identify those periods in which assemblage composition is most stable. When selecting an index period, a biological assessment program also typically considers availability of sampling crew and accessibility to and safety of sampling sites.

Continuous models can also be used to characterize and account for natural temporal variations in the characteristics of biological assemblage. These statistical models estimate relationships between different biological attributes and the season or day of the year when the samples were collected (e.g., Hawkins 2006). For example, day of the year was the single most important predictor in development of an observed/expected (O/E) index in North Carolina, and the O/E model was adjusted for phonological shifts in species abundance (Hawkins 2006). The day of the year was the single most important predictor in development of the O/E index and the model adjusted for phonological shifts in species abundance. Continuous models can be applied to data collected in index periods or across multiple seasons. Indeed, approaches that combine data collected during index periods with models to account for temporal variations within index periods are often the most effective means of accounting for temporal variations. Also, one can calibrate multiple seasonal indicators and indexes, or develop an average or composite annual characterization based on multiple samples (e.g., Furse et al. 1984; Linke et al. 1999; Cao and Hawkins 2011; Pond et al. 2012).

Scoring of the index period element depends on how thoroughly a program has considered and documented the effects of different index periods on the characteristics of biological data and on decisions derived from this biological data. Example evaluation questions are:

- Is sampling carried out primarily within a defined index period?
  - If not, are the program's indices structured to account for temporal variability?
- What are the justifications for the defined index period, and has variability within the index period been quantified?
- If an alternative approach has been selected, does this approach adequately account for temporal variability?
- Are the monitoring and other water quality management programs coordinated their schedules so that data are provided when the programs need it? Does lack of coordination result in monitoring outside of the index period?

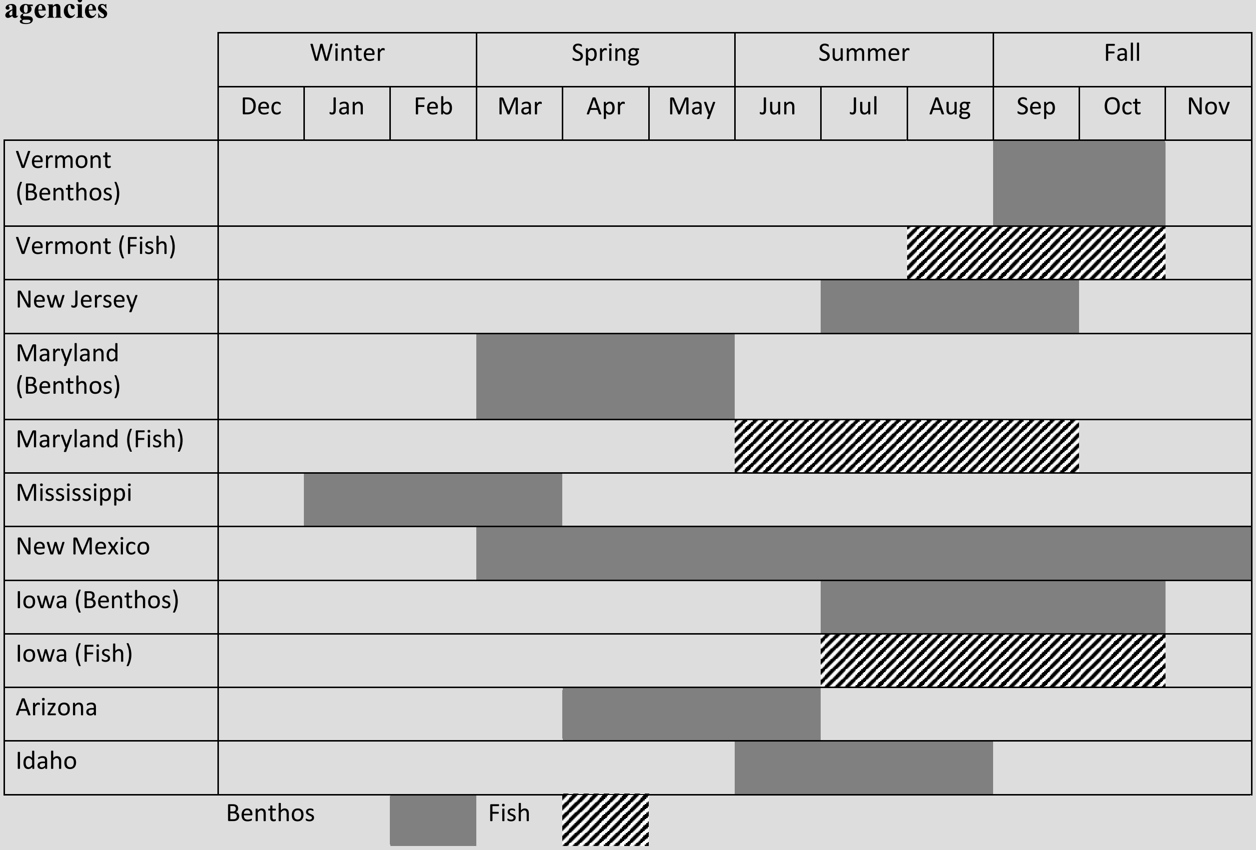
Programs that score highly on this element have documented the effects of the index period or an alternative approach to address temporal variability. Additionally, the monitoring and other water quality management programs have coordinated their schedules so that program information needs (e.g., condition assessments, permit reviews, total maximum daily load [TMDL] development) are coordinated with data delivery.

Frequently Asked Question

Question: What is the optimal time of year to select as an index period?

Answer: Selection of an index period is part of the overall design process that takes into account scientific knowledge, objectives, costs, logistics, and information desired from the monitoring program (Hughes and Peck 2008). For example, seasonal phenology influences the species composition in streams; late-instar (and hence easy to identify) stoneflies and mayflies occur in early spring, but in early summer they might be present only as very small early instars (e.g., McCord and Lambrecht 2006). Fish sampling is generally avoided in the spawning seasons of anadromous fish (Hughes and Peck 2008). Safety and logistics are also issues, as is scheduling the sequence of field, laboratory, data processing, and reporting tasks; sampling might be dangerous during the spring freshet (snowmelt), and high elevation streams might only be accessible in the summer (Hughes and Peck 2008). As depicted in Table 2-2, the index period can vary by state and assemblage group.

Table 2-2. Examples of biological assessment index periods for different state water quality agencies



2.1.2 Spatial Sampling Design (Element 2)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Study design consisting of isolated, single, fixed-point sites.	Low density fixed station design. Multiple sites are used for assessment of a water body or watershed condition. Spatial coverage suitable for general condition assessments. Non-random designs at coarse scale used (e.g., 4–8 digit hydrologic unit code [HUC]). Inference of site data to larger unit of assessment based on "rules of thumb" and might be supplemented by upstream/downstream assessments.	Low density random or stratified random sampling design which allows for a statistically valid inference of biological condition to a spatial unit larger than a site. The primary goal is to assess aggregate condition and trends on a statewide or regional basis.	High density (e.g., intensive) monitoring at comprehensive spatial sampling design suitable for watershed assessments (e.g., 10–12 digit HUC) and in support of multiple water quality management program needs for information (e.g., condition assessments, use refinement, use attainability analyses [UAAs], permits). As needed, the spatial sampling combines monitoring designs to optimize cost and efficiency in data collection and analysis (e.g., combination of upstream-downstream, intensive, probabilistic, and/or pollution gradient designs). Typically includes a rotating sequence of watershed units organized to provide data for management program support.

Water quality programs have multiple needs for information (e.g., status and trends, stressor identification, targeted studies, discharge monitoring). This technical element addresses how well a biological assessment program is able to (1) deploy monitoring designs that address the suite of water quality program information needs; (2) cover the pollution gradients that are relevant to the impairments that are detected; and (3) provide data relevant to the scale required for specific management program needs (e.g., stream segment, watershed, region, statewide) and that support statistically valid inferences of site data to the unit of assessment.

Study design pertains to the spatial array of sampling sites to support assessments at watershed and stream- or river-segment specific scales. It also includes the ability to provide biological assessment data and information to address multiple water quality program questions (e.g., status and trends, environmental outcomes of management actions, as well as relevant targeted studies such as discharge monitoring and TMDL implementation) at the same scale at which management is being applied. A biological assessment program will need to determine what sampling design, or combination of sampling designs, will provide the full suite of information needed to address its priority management questions (e.g., for site-specific use attainability determinations, biological criteria derivation, targeted assessments, causal analysis, statewide and regional status).

Whether single or multiple sampling designs are employed, they will need to support multiple management program support tasks. Multiple, overlapping monitoring designs can be appropriately scaled to address these specific needs when the designs are incorporated into an overall spatial network for monitoring (e.g., upstream-downstream; intensive, probabilistic, gradient design). For example, sampling upstream and downstream of a discharge is conducted to specifically quantify the effects of that discharge. A gradient design is appropriate for refinement or development of biological or other types of water quality criteria. Spatially intensive sampling can be designed for specific studies and purposes including site-specific criteria development or refinement. A probabilistic monitoring design can be tailored for condition assessments at different spatial scales (e.g., watershed, basin, ecological region, statewide). In some cases, with upfront planning, the monitoring designs can be complementary with sampling sites providing data relevant to more than one purpose.

Study designs also need to factor in adjustments for effects of natural gradients. This adjustment is typically accomplished iteratively when accounting for natural spatial variability (see technical element three) and dependent upon assessment objective (e.g., define stressor gradient, assess condition, determine cause of impairment in a stream segment). For example, in streams and rivers, the structure of aquatic assemblages changes naturally and predictably as one moves downstream from steeper, narrow, shaded, small steams to low-gradient, open-canopied, large streams (Vannote et al. 1980). Sampling sites might be located in linear juxtaposition to one another in a river or stream network. In these situations observations at nearby sites might be spatially autocorrelated and, hence, not statistically independent of one another (e.g., NAS 2002). These considerations should be addressed in the spatial sampling design and in subsequent analysis of data to accurately and precisely define the expected biological community for a water body (e.g., refined aquatic life use) and to minimize risk of making nonattainment decisions on the basis of natural changes in assemblage as one samples further downstream.

Scoring of this technical element is based on the degree to which the selected sampling sites can inform multiple water quality information needs and support decisions at different spatial scales. Example evaluation questions are:

- Is the spatial study design sufficient to represent the majority of water types in the area of interest?
- Are all pollution impacts and gradients adequately characterized?
- For condition assessments, how well can inferences be made to unsampled sites within the unit of assessment (e.g., site, stream segment, watershed, basin, statewide, ecological region)?
- For specific water bodies of concern, can valid inferences be made on differences in condition upstream and downstream of a discharge, and on changes before and after implementation of best management practices (BMPs)?

Programs that achieve high scores on this technical element have implemented an integrated sampling design, or combination of sampling designs, that provide the data and information necessary to support water quality management decisions at multiple spatial scales (e.g., specific sites, entire watersheds, basins, ecological regions, statewide).

Frequently Asked Questions

Question: What type of study design can efficiently support statewide condition assessments and 305(b) reports?

Answer: A probabilistic sampling design can be used to randomly select sampling sites from the population of water bodies so that inferences from this random subsample can be made to the entire population (Herlihy et al. 2000; Olsen and Peck 2008). A probabilistic design is the most efficient sampling design for statewide condition assessments such as the Clean Water Act (CWA) section 305(b) reports since all potential sampling locations have a known probability of being selected and inference to larger geographical area is statistically robust (e.g., Thompson 1992; Olsen et al. 1999; Olsen et al. 2009). When resources are not available to sample all basins statewide in any particular year, a rotating basin approach can be implemented.

Question: What type of study design can support assessing use designations, conducting use attainability analyses (UAAs), and providing information about multiple stressors at a watershed scale?

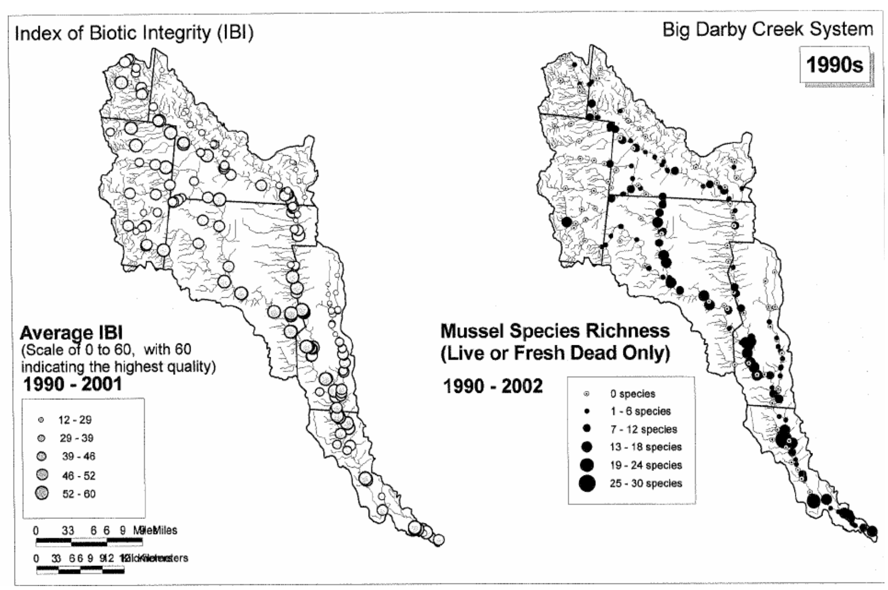


Figure 2-1. Geometric Watershed Design used to support multiple management needs in the Big Darby Creek watershed, Ohio (Ohio EPA 2004).

Answer: There are several sampling designs that could be used when appropriately designed to answer these questions, including a survey, gradient, or random designs tailored to the appropriate spatial scale. For example, a geometric and intensive watershed design was used at the 11-digit hydrologic unit code (HUC) scale in Big Darby Creek, Ohio, and, when considering serial autocorrelation between adjacent sites, is nearly equivalent to a census of the stream reaches of the watershed (Figure 2-1). The data were used to determine if the current aquatic life use of stream and river segments was appropriate and attainable and then to determine the status of each site. The data were also used to delineate impairments for reporting (e.g., CWA section 305[b]/303[d]), and causes and sources were determined to support specific water quality management actions (i.e., TMDLs, National Pollutant Discharge Elimination System [NPDES] permits, stormwater permitting, 401 certifications) and support watershed planning (i.e., section 319 planning and implementation). Ohio conducts four to five of these assessments annually with a rotating basin approach, and, in the aggregate, each contributes to a statewide inventory of streams and rivers and is part of a database that supports many program maintenance and developmental needs. These data are aggregated upwards to produce regional and statewide assessments for meeting CWA 305b reporting and internal program goal tracking (e.g., the Ohio 2020 goals).

Question: What are the benefits of combining probabilistic design surveys with intensive surveys designed to answer multiple water quality management questions?

Answer: Developing the technical capacity to conduct different types of survey designs enhances the breadth and depth of the monitoring program's ability to answer multiple water quality management questions and to more efficiently leverage resources. For example, in 2008, New York State Department of Environmental Conservation's (NYSDEC's) Stream Biomonitoring Unit merged a random probabilistic design survey with its legacy statewide basin studies. This *hybrid* survey design allows it to fit the needs of two primary objectives of its program: surveying targeted of-interest sites, and creating an unbiased random data set (Figure 2-2). Targeted sites include those that allow for the characterization of regional reference conditions, long-term temporal trend monitoring, assessment of unassessed waters, and the monitoring of sites that are of department, regional, and/or public interest. The random data set gives the ability to project aquatic life use attainment in an un-biased, statistically sound manner across the entire state, and provides uniform comparability between basin data sets and other national data sets. Targeted sites make up approximately 60 percent of the total number of sites sampled each year while random sites compose 40 percent.

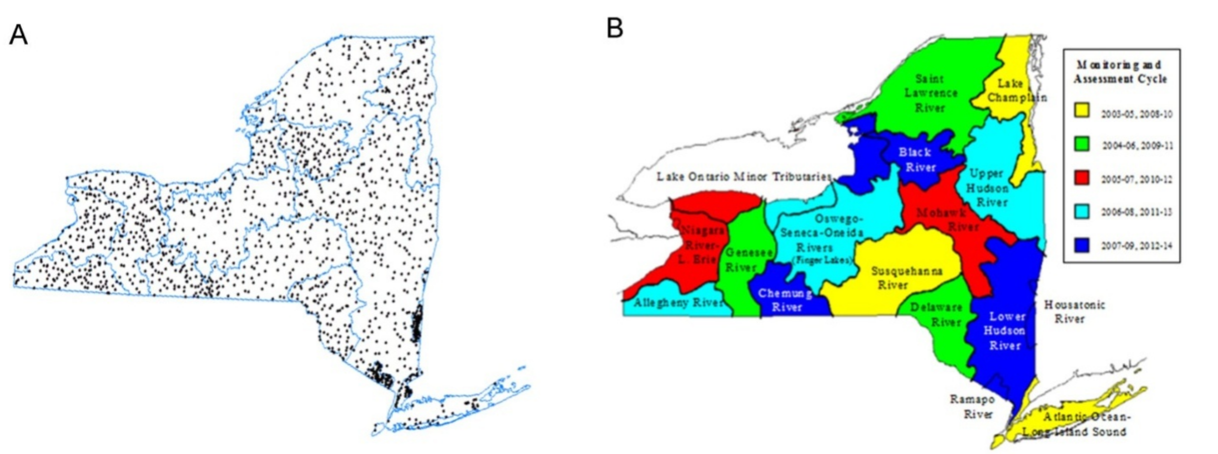


Figure 2-2. New York has integrated a probabilistic spatial survey design (A) into its routine rotating integrated basin studies program (B) (Source: NYSDEC 2009).

2.1.3 Natural Variability: Characterizing and Accounting for Spatial Variability (Element 3)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
No or minimal partitioning of natural variability in aquatic ecosystems. Does not incorporate differences in watershed characteristics such as size, gradient, temperature, elevation, etc.	Classification scheme is based on assumed, first-order classes. These include strata such as fishery-based cold or warmwater classes. There is no formal consideration of regional strata such as bioregions or aggregated ecoregions. Intra-regional strata such as watershed size, gradient, elevation, temperature are not addressed. Usually applied uniformly on a statewide basis.	A fully partitioned and stratified classification scheme or modeling approach is employed. Classes and/or continuous models are defined to take critical details of spatial variability into account. Inter-regional landscape features and phenomena are appropriately sequenced with intra-regional strata. Subcategories of lotic ecotypes are defined (e.g., includes the full strata of lotic water body types). Characterization of spatial variability is confined within jurisdictional boundaries.	Scheme to fully account for natural variation is periodically refined and updated as new data and methods become available. Classes, continuous models, or both, are examined to identify the most appropriate scheme for monitoring and assessment, regulatory support, and cost-effectiveness. Developed at scales that transcend jurisdictional boundaries when necessary to strengthen inter-regional classification outcomes; recognizes the full zoogeographical aspects of biological assemblages.

Biological assemblage structure varies spatially among different sites, often associated with variations in abiotic environmental conditions (Theinemann 1954; Hynes 1970; Poff 1997). Both local (e.g., water temperature, flow, and alkalinity) and regional environmental conditions (e.g., basin topography, climate) strongly influence assemblage structure, and when interpreting biological data and assessing condition, natural variations in assemblage structure must be characterized and taken into account to ensure that changes in assemblage structure can be confidently attributed to anthropogenic rather than natural factors.

Well-developed schemes to account for natural variation use a combination of large-scale physical characteristics (e.g., watershed drainage size, elevation, geographic location) and local site characteristics (e.g., temperature, alkalinity, substrate) (Moss et al. 1987; Reynoldson et al. 1997; Bailey et al. 1998; Marchant et al. 1999; Joy and Death 2002; Hawkins et al. 2000a; Oberdorff et al. 2002). The principal approaches used are classification (or typology), continuous models, and combinations of discrete and continuous models.

Classification schemes define classes of water bodies such that sites in each class are assumed to be similar with one another in terms of naturally varying abiotic factors. Then, biological assemblages observed at sites in each class are examined to determine if they are more similar to one another than among classes. These classes can be defined *a priori* based on an ecological understanding of natural factors that structure biological assemblages (Omernik 1987; Rabeni and Doisy 2011) to help design sampling strategies that represent all water body types in a study area. Classification schemes can also include classes of water bodies that pertain to inherent environmental requirements (e.g., warm and cold water, strata), differences in discrete lotic strata (headwaters to large rivers), and continuous changes in assemblage structure across natural environmental gradients (e.g., Moss et al. 1987). Classes can also be specified *a posteriori* by statistically examining how assemblage structure varies across different environmental gradients and defining discrete classes based on the results of these analyses (Gerritsen et al. 2000). In either case, the biological condition at a particular site is assessed by comparing to reference conditions in the class to which the site belongs.

Natural variations in assemblage structure can also be taken into account using models that represent changes in structure over continuous environmental gradients (Growns 2009; Hawkins and Vinson 2011; van Sickle and Hughes 2000). These models are based on statistical analyses that can be used to infer changes in assemblage structure due to different environmental variables (Clarke et al. 1996; Bailey et al. 1998; Marchant et al. 1999; Hawkins et al. 2000b; Simpson and Norris 2000; Joy and Death 2002). When a model is used to assess a site, a site-specific prediction of biological characteristics is calculated, and the observed characteristics assessed relative to this prediction. This information can also be used to supplement or refine discrete classification approaches.

A comprehensive classification and/or modeling scheme is dependent on the spatial density of the monitoring program. Sufficient spatial coverage is needed to test or verify a proposed classification and/or modeling scheme (see Technical Element 2).

Scoring of Technical Element 3 is based on the degree to which the scheme accounts for observed natural variability in biological assemblage structure. Example evaluation questions are:

- Does classification or modeling the effects of natural gradients sufficiently reduce natural variability relative to anthropogenic variability?
- Does the classification scheme and/or modeling process sufficiently include all the common regional and watershed strata in the study area?
- Is the approach sufficient to support the precision and accuracy needed in estimates of biological index values?
- Does the classification and/or model take into account information and considerations from beyond a state or tribe’s jurisdictional boundaries?

Programs that score highly in this technical element have demonstrated that their scheme to describe natural variability (whether classification and/or continuous models) accounts for the major sources of natural variability in the study area, and that the majority of the remaining variability in biological characteristics can be attributed to human activities.

Frequently Asked Questions

Question: What is meant by an ecoregional classification for biological assessment?

Answer: Partitioning the water bodies of an agency by natural variability in the biota results in a classification that can improve assessment of ecological condition. As an example, natural classification in Mississippi resulted in five bioregions (not counting the delta region in gray) as a basis for biological assessment (Figure 2-3). Bioregions are geographically distinct regions of water bodies that roughly correspond to ecoregions or aggregations of ecoregions.

Question: How would a multivariate cluster analysis serve as a form of classification?

Answer: Clustering the biological data from reference sites reveals the inherent natural variability among sites. Clusters can be selected that represent classes for assessment membership.

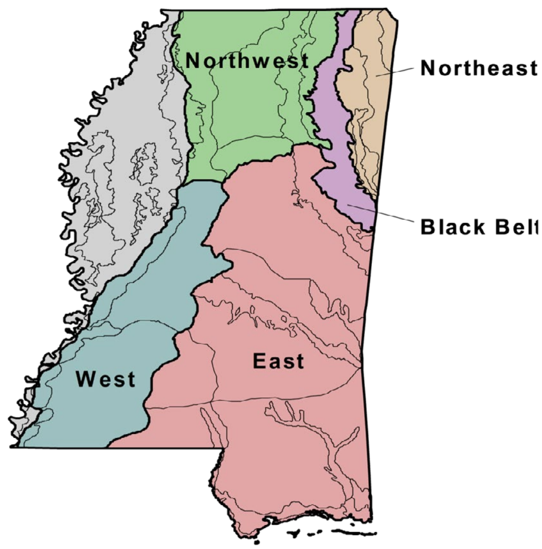


Figure 2-3. Example of bioregions as established for the Mississippi.

2.1.4 Reference Site Selection (Element 4)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Informal best professional judgment (BPJ) used in selection of control sites. No screens are used. Limited, if any, documentation and supporting rationale.	Based on "best biology" (i.e., BPJ on what the best biology is in the best water body). Minimal non-biological data used. Minimal documentation.	Selection based on narrative descriptions of non-biological characteristics. Combines BPJ with narrative description of land use and site characteristics. Might use chemical and physical data thresholds as primary filters.	Based on quantitative descriptions of non-biological characteristics with primary reliance on abiotic data on landscape conditions and land use. Chemical and physical data might be used as secondary filters or in a hybrid approach for severely altered landscapes. Independent data set used for validation.

Reference site selection is the basis for developing benchmarks against which a biological monitoring program can assess the biological condition of test sites (e.g., Hughes et al. 1986; Barbour et al. 1996; Bailey et al. 2004; Stoddard et al. 2006; Hawkins et al. 2010). Reference site selection is primarily based on abiotic factors that define sites that are "least stressed," or ideally, "minimally stressed" by anthropogenic stressors and include knowledge of whether invasive species are present (e.g., Hughes et al. 1986; Karr and Chu 1999; Bailey et al. 2004). Abiotic characteristics and attributes should be the principal screens for selecting candidate reference sites because such screens avoid circularity that is inherent in including ambient biological characteristics to define reference sites for assessing biological condition.

Factors to be considered in selecting reference sites include human population density and distribution, proximity to the influence of discharges, proximity to physical modifications of stream and river channels, road density, and the proportion of mining, logging, agriculture, urbanization, grazing, or other land uses. Candidate reference sites are evaluated with respect to these factors to determine the degree of human modification that has occurred. Sites that are minimally disturbed by potential stressor(s) are considered to be in reference condition (Bailey et al. 2004; Stoddard et al. 2006). Ideally, sites are eliminated if they have undergone direct human modification, especially to riparian zones and instream habitat (Bryce et al. 1999). However, in some pervasively altered regions or altered systems, "least disturbed" sites that represent the best available conditions have been used (e.g., Angradi et al. 2009).

Examples of evaluation questions are:

- Do factors for reference site selection emphasize abiotic measures of anthropogenic activity?
- Are procedures for selection of sites well documented? Do those procedures include consideration of watershed development, near stream development, and riparian condition?
- Are chemical, physical, and whole effluent toxicity (WET) sampling data used to validate either the absence of anthropogenic disturbance or the level of allowed disturbance?

Programs that score highly in this technical element use several layers of abiotic filters to identify reference sites for their study area, primarily based on landscape data from the surrounding catchment and other information that characterizes the level of disturbance. Independent data sets are used to validate reference site selection.

Frequently Asked Questions

Question: How do factors for reference site selection influence calibration of a biological index or indicator and setting a threshold for biological criteria or for CWA section 303(d) listing decisions?

Answer: Biological criteria are typically derived from a reference site database (USEPA 1990, 1998, 2001). The reference site approach is typically also a basis for biological listing methodologies and for U.S. Environmental Protection Agency's (EPA's) national surveys of stream condition (Herlihy et al. 2008). The factors for reference site selection help define the quality of the reference condition (e.g., undisturbed, minimally or moderately disturbed, least disturbed) (Stoddard et al. 2006). Herlihy et al. (2008) examined the effects of different quality of reference sites from the large database of the U.S. Wadeable Streams Assessment (WSA). Poorer quality reference sites (equivalent to relaxing the factors for reference site selection to accept more sites) resulted in assessments in which more test sites were similar to reference than assessments done with reference sites selected based on more stringent site selection factors. In other words, when the reference sites are influenced by human disturbance, an agency might lose its ability to accurately define the desired biological condition and to differentiate biologically degraded sites from reference. The quality of the reference sites as defined by the factors for reference site selection can inform selection of a biological threshold. The percentile selection should be based on the degree to which human activities influence the study area. For example, in the WSA, the threshold for a specific ecological region was adjusted from 10 to 25 percent of the reference site distribution to account for the presence of pervasive human disturbance at reference sites (Herlihy et al. 2008).

Question: What if the pool of reference sites has to include sites with substantial disturbance even though the sites are least-disturbed in the context of the region? For example, in the Midwest, row crops and grain farming are the primary land use, and virtually no unaffected water bodies exist.

Answer: Regions with extensively altered landscapes might require a model to extrapolate current conditions to a reasonable reference. For example, a PCA-based regression model was used to project "true" reference in regions where all reference sites are highly altered (Herlihy et al. 2008). Kilgour and Stanfield (2006) developed regressions between biotic condition and percent impervious cover, and extrapolated biotic condition for very low impervious cover scenarios. In a slightly different approach when naturally occurring conditions can be estimated, Chessman and Royal (2004) used species responses to temperature, flow regime, and riverbed composition to predict the species composition of different rivers with given combinations of naturally occurring temperature, flow, and bed composition. In some cases, an agency might manage to the least disturbed condition and set incremental restoration targets that support improvements as technology and BMPs are applied. If appropriate, the expectations for an adjacent ecological region could be used to establish reference. For example, Ohio concluded that least affected reference sites did not exist in the Lake Huron/Lake Erie Plain (HELP) ecological region and used the biological expectations for a neighboring ecological region to determine a biological threshold. The key step is to recognize when minimally altered conditions do not exist, and then derive a reasonable alternative for deriving a protective biological criteria.

2.1.5 Reference Conditions (Element 5)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
No reference condition has been developed. Biological data are assessed using BPJ or based on the presence of targeted or iconic taxa.	Reference condition based on biology of an estimated 'best' site or water body. Single reference sites are used to assess biological data collected throughout a watershed. A site-specific control or paired watershed approach might be used.	Reference condition is based on a regional aggregate of reference site information. Data representing most of the major natural environmental gradients but limited in number and/or spatial density. Overall number and coverage of reference sites insufficient to support statistical evaluation of the biological condition at test sites.	Reference condition is based on data from many reference sites that span all major natural environmental gradients in the study area. Reference condition can be estimated for individual sites by modeling biota-environmental relationships. The number of reference sites is sufficient to support statistical evaluation of biological condition at test sites. Reference sites are resampled periodically. In highly altered regions or water body types, alternative methods are used to develop reference condition.

A primary goal for a biological assessment program is to estimate the expected biological condition (reference condition) for individual sites as accurately and precisely as possible. The reference condition serves as the benchmark for judging condition of the site and as basis for derivation of biological criteria. This technical element considers the number of reference sites that are available and the degree to which those reference sites account for natural environmental gradients (e.g., elevation, water body size) (Figure 2-4). This element also considers whether the number of reference sites is sufficient to support appropriate use designation and the derivation of numeric biological criteria. It is important to consider how well the reference site network is re-monitored and reevaluated. Reference condition should also be tracked by the periodic resampling of reference sites and as an integral function of the overall monitoring program.

Using a representative network of reference sites ensures that the assessment of a test site is based on a comparison with its most appropriate benchmark. Accordingly, development of meaningful reference conditionsalso requires an adequate spatial coverage to obtain a sufficient sample of reference sites.When sufficient reference site data are not available, assessments might not be possible or might be conducted with more uncertainty. In regions where all water bodies are severely altered, alternative methods might be used, including historical data, models, or hindcasting (e.g., Dodds and Oakes 2004; Kilgour and Stanfield 2006; Angradi et al. 2009).

Scoring of this technical element is based on the degree to which a sufficient number, or network, of reference sites are available to establish reference condition. Example evaluation questions are:

- Is the pool of reference sites sufficient to characterize the natural gradients in the study area (e.g., basin, ecological region, statewide)?
- Is the number of reference sites sufficient to support the use designation and derivation of biological criteria?
- Are reference sites systematically resampled to track changes in reference condition over time?
- In regions or water bodies with no adequate reference sites, are alternative methods used effectively (e.g., historical data, modeling)?

High level programs should demonstrate that the network of reference sites fully represents all the major natural environmental gradients in the study area and that the number of reference sites is sufficient to support both appropriate use designation and derivation of attendant biological criteria. Figure 2-4 provides an example approach for assessing the representativeness of reference sites.

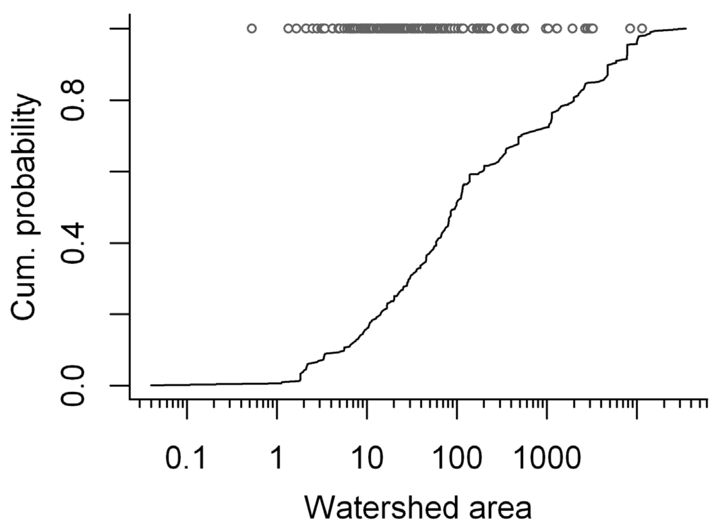


Figure 2-4. Example approach for assessing representativeness of reference sites. The solid line shows the cumulative distribution function of watershed areas for different streams in the assessed population, and the open circles show the watershed areas of the available reference sites. In this example, presence of reference sites for a watershed area is given by the density of the open circles. The majority of the watershed areas are well-represented by reference sites, because there is a high density of open circles above steep portions of the solid line; except for the largest streams (> 1,000 km^2). (USEPA 2006)

Frequently Asked Questions

Question: How does the number of reference sites (N) affect characterization of biological characteristics at a regional scale?

Answer: The number of reference sites affects both the ability to account for spatial variability (see Technical Element 3) and the precision with which thresholds can be specified. As discussed in Technical Element 3, many natural abiotic environmental factors can influence assemblage structure, and the number of reference sites directly affects the number of these factors that can be taken into account. For example, macroinvertebrate assemblage structure might vary primarily with changes in stream size (or catchment area) and, secondarily, with changes in alkalinity. Linear regression models generally require at least 10 sites per explanatory variable to accurately estimate a relationship, so at least 20 reference sites are required to model changes in assemblage structure with respect to both stream size and alkalinity. Additional reference sites that span other natural gradients would provide increased capabilities to more precisely specify natural expectations for different types of streams in the study area.

Once spatial variability is taken into account, distribution of expected index values derived from reference sites must be quantified so that index values at test sites can be evaluated. More specifically, to assess condition, one must test whether index values at a test site are within the range of index values observed in reference sites. Increased numbers of reference sites allows one to more precisely estimate the reference distribution, and therefore, more confidently assess test sites.

Question: How does the number of reference sites (N) affect the derivation of numerical biological criteria?

Answer: Determining the appropriate number of reference sites for deriving biological criteria is usually most applicable on a regional basis because of differences in reference site heterogeneity both within and between regions. In a more heterogeneous region, where natural conditions are more variable among streams, either (1) a larger reference sites pool will be necessary to accurately derive a biological criteria threshold, or (2) further partitioning of the natural variability through classification analysis might be needed. As illustrated in Figure 2-5, the variability in reference quality is reduced as the number of reference sites increases to estimate the biological criteria threshold.

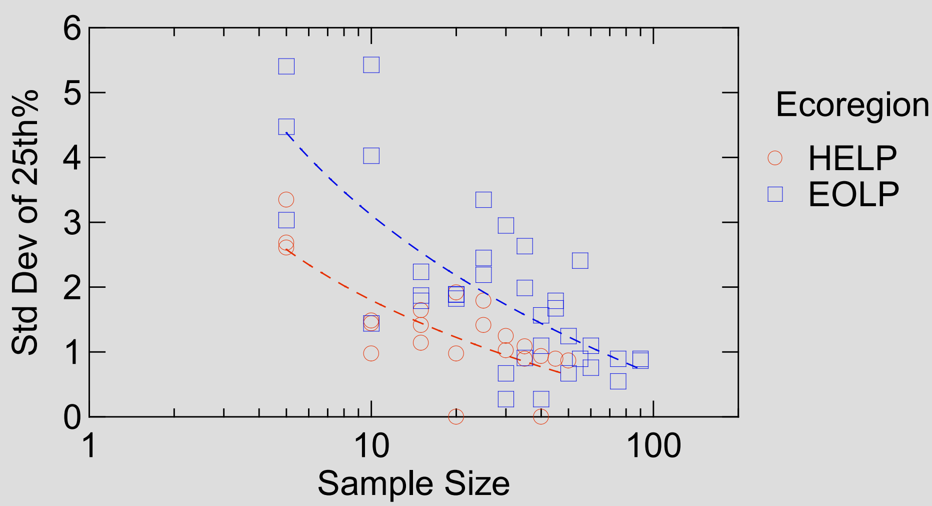


Figure 2-5. Standard deviations of 25th percentile fish assemblage Index of Biotic Integrity (IBI) scores estimated by randomly drawing reference sites at a given sample size (x-axis) five times for wading sites in the Lake Huron/Lake Erie Plain (HELP) and Erie Ontario Lake Plain (EOLP) ecoregions of Ohio (modified from Yoder and Rankin 1995a).

2.1.6 Taxa and Taxonomic Resolution (Element 6)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
One taxonomic assemblage (e.g., benthic macroinvertebrates, fish, algae, aquatic macrophytes). Very coarse taxonomic resolution (e.g., order/family). Expertise: amateur naturalist or stream watcher. Validation: none. QA/QC: none.	One taxonomic assemblage. Low taxonomic resolution (e.g., family). Expertise: novice or apprentice biologist. Validation: family level certification for macroinvertebrates. No certification available for fish or algae. QA/QC: mostly for taxonomic confirmation of voucher collections. Some sorting QA/QC implemented.	One taxonomic assemblage. Fine taxonomic resolution: genus/species for benthic macroinvertebrates and algae, species for fish. Expertise: trained taxonomist. Validation: genus-level certification or equivalent for benthic macroinvertebrates. Expert fish taxonomist or equivalent. Formal courses or training in algal taxonomy. QA/QC: addresses measuring bias, precision, and accuracy in all phases of sample processing through identification (e.g., outside validation of identification); voucher collection maintained.	Same as Level 3 except that two or more taxonomic assemblages are assessed. Rationale for selection of taxonomic groups should be well documented.

This taxonomic resolution technical element addresses the resolution to which organisms are taxonomically identified (order, family, genus, or species) and, for the highest level programs, how many different assemblages are included. Four assemblages have been primarily used in freshwater biological assessment and in making aquatic life use attainment decisions: benthic macroinvertebrates, fish, algae, and aquatic macrophytes. Methods for measuring amphibian assemblages (e.g., early life stages of salamanders) are also being developed (Moyle and Randall 1998; Whittier et al. 2007a, 2007b) for certain water body types such as primary headwater streams (Ohio EPA 2012). Each assemblage has different habitat ranges and preferences and might be susceptible to anthropogenic stressors in different manners and degrees.

As more assemblages are assessed, one can more confidently infer the condition of the entire biological community (e.g., Carlisle et al. 2008). Hence, collecting and assessing different assemblages provides a more complete assessment of the condition of aquatic life in a water body. For example, assemblages that represent more than one trophic level (primary producers, consumers, predators) might increase the ability to both assess the overall condition of the aquatic community and measure responses to multiple stressors that might affect the community. Additionally, some detectable changes in assemblages, or members of an assemblage, might provide a measure of initial stress and provide information helpful to protection of high-quality waters (e.g., Petty et al. 2010; Brooks et al. 2011; Danielson et al. 2012).

Collected organisms must be identified taxonomically before one can infer biological condition from a sample of these organisms, and the resolution of these identifications (e.g., order, family, genus, species) can influence inferences regarding the degree of biological alteration (e.g., Lenat and Resh 2001; Waite et al. 2004; Feio et al. 2006; Hawkins 2006; Pond et al. 2008; Cao and Hawkins 2011). In some cases, a finer level of taxonomic resolution allows one to better assess the sensitivity of the collected organisms to different types of stress. For example, the temperature requirements of mayflies in a certain family might vary substantially, so identifying taxa to genus or species when possible within this family might allow one to better understand the impacts of altered temperature on a water body (Vannote and Sweeney 1980). Conversely, in some regions, the number of different genera in each family might be comparatively low, so identification to family yields nearly as much information as identification to species or genus (Hawkins and Norris 2000b). In other regions, taxonomic resolution can be limited by existing taxonomic information on native fauna (e.g., Buss and Vitorino 2010). Taxonomic identification requires substantial training and practice, and quality assurance/quality control (QA/QC) of the identifications is critical for maintaining consistent standards of identification (e.g., Stribling et al. 2008).

Scoring of this technical element is based primarily on the resolution of the taxonomic identifications and on the level of QC and the number of assemblages that are routinely collected. Example evaluation questions are:

- What level of resolution is used for taxonomy and related biological attributes?
- How many assemblages are monitored?
- What training and certifications are required for persons identifying organisms?
- What are the enumeration and identification QA/QC procedures?

To score highly in this element, at least two assemblages should be used to more completely assess the condition of the entire aquatic community, and organisms should be identified to the finest practicable level of resolution. For example, for benthic macroinvertebrates this includes genus and/or species for key groups, and for fish it would include species resolution in accordance with the American Fisheries Society nomenclature (Nelson et al. 2004). Furthermore, staff who identify collected organisms should be formally trained and certified.

Frequently Asked Questions

Question: What is the best taxonomic level of identification?

Answer: The best level of taxonomic identification will vary depending on purpose of assessment and other considerations, such as the number of genera within each family in a region (Hawkins and Norris 2000b). Typically, species level is more responsive to impacts from stressors, but coarser level taxonomy can produce more precise indices (Hawkins 2006). The current ability to accurately and precisely achieve species level identification varies with the assemblage. Fish, diatoms, and macrophytes can usually be identified to species, whereas macroinvertebrates can usually be identified to genus. Lower levels of identification can improve one’s ability to estimate stress-response relationships but only if that lower level of identification is not associated with a substantial increase in the uncertainty of the identifications (Stribling et al. 2008; Buss and Vitorino 2010).

Question: What is the best assemblage to assess biological condition?

Answer: Assemblages comprise different numbers and kinds of species that, in turn, differ in their sensitivities to stressors and also their occurrence and sensitivity by the water body type. The type of water body being assessed and its location (i.e., position in the landscape or river continuum) can influence the selection of assemblages to sample.

For example, small primary headwater streams (<1–10 km^2 catchment) typically have low fish species diversity, and development of fish indices can be challenging (McCormick et al. 2001; Hitt and Angermeier 2011). As such, assessing amphibian assemblage in these stream types is an alternative (e.g., Fausch et al. 1984; Moyle and Randall 1998; Whittier et al. 2007a, 2007b; Ohio EPA 2012). For wetlands, emergent macrophytes are the dominant macrobiota and are typically used for assessing wetlands (e.g., Fennessy et al. 2007), but they have also been used in rivers (Moore et al. 2012). Assemblages might also vary along the length of a waterway. For example, preferred assemblages for the Upper Mississippi River include fish, macroinvertebrates, and submerged aquatic macrophytes in the impounded portions but fish and macroinvertebrates in the open river reaches (Yoder et al. 2011).

Question: Level 4 requires 2 or more assemblages. What could the mix of assemblages include?
Answer: The mix of assemblages should be complementary rather than redundant in terms of their ecological, ecophysiological, and ecotoxicological properties (i.e., not represent the same trophic level or have the same habitat requirements). Assemblages vary in importance across water body types and respond differently to given stressors. They also respond to different intensities of the same stressor which, in turn, affects assessments of condition (e.g., Carlisle et al. 2008; Smucker and Vis 2009). For example, one approach might be to strike a balance among trophic levels: one or more animal assemblage (e.g., benthic macroinvertebrates, fish, zooplankton, benthic infauna [in estuaries]) and one plant assemblage (e.g., emergent macrophytes, floating/submerged macrophytes, periphyton, phytoplankton).

Question: Why are two or more assemblages recommended for a Level 4 program?
Answer: Measuring the response of two or more biological assemblages along a gradient of stress provides increased confidence in the program's capability to detect effects of stressors on aquatic life. There are multiple pathways in which stressors might affect the biota, and a more comprehensive measure of the biotic community provides greater confidence that these effects will be detected.
Examples of the responses of different assemblages to stressors include:

- Certain species of benthic macroinvertebrates have demonstrated consistent and measurable responses to metal toxicity. Clements et al. (2000) used cumulative criterion units to quantify metals concentrations in 95 sites in the Southern Rocky Mountain ecoregion, and they observed changes in the benthic macroinvertebrate assemblage to different levels of metals. The authors showed that highly contaminated sites had significantly lower densities of scrapers and predators and also lower in abundance and species richness of mayflies. Highly contaminated sites also had decreased abundance of mayflies, caddisflies, and stoneflies (i.e., ephemeroptera, plecoptera, trichoptera [EPT] taxa).
- A shift in species composition can signal changes in water quality. When associated with changes in levels of individual or categories of stressors, this information can be used to support identification of probable causes of biological impairment (e.g., Carlisle et al. 2008). For instance, a shift in benthic groups from those that filter the water for food to those that graze the sediments have been correlated with increase in suspended sediment load in a stream or river in absence of other stressors (Kaller and Hartman 2004). Carlisle et al. (2008) found that fish and macroinvertebrates in Appalachian streams were most sensitive to agriculture and urban land uses, while diatoms were most sensitive to chemical changes associated with mining.
- An initial increase in water column algae and shift in species composition can be an indicator of early nutrient enrichment (McCormick and Cairns 1994). Benthic diatoms have long been used as indicators of chemical water quality (e.g., Patrick 1949), and recent developments include quantitative models that infer water quality conditions from the observed diatom assemblage (e.g., Pan et al. 1996; Kelly 1998; Potapova and Charles 2003; Ponader et al. 2008; Danielson et al. 2011).
- The presence of lesions and tumors on fish can be caused by pulp and paper mill discharges (Flinders et al. 2009), pharmaceuticals (Kang et al. 2002; Lovy et al. 2007), and other types of chemicals or industrial/municipal discharges (Yoder and Rankin 1995b; Yoder and DeShon 2003). Dyer and Wang (2002) examined upstream and downstream data from 221 wastewater treatment plants in Ohio and observed impairments in fish communities downstream of large treatment plants.

- Multiple assemblages were evaluated in 268 Appalachian streams, and both fish and macroinvertebrate indices were responsive to urban and agriculturally influenced streams. Diatom assemblages were responsive to mining influence (Carlisle et al. 2008).

Question: How do we get taxonomic certification?

Answer: For some assemblages (algae, fish), professional certification of an individual's ability to accurately and precisely identify taxa is not available. However, because the accurate and precise identification of aquatic organisms is the foundation for biological assessment and monitoring programs for lakes, streams, rivers, and wetlands, certification programs are being developed. For macroinvertebrates, The Society for Freshwater Science recognized this issue a decade ago and has implemented a certification program for those professionals who identify macroinvertebrate assemblages for use in assessing aquatic habitats in North America. This program was designed to certify that trained and skilled persons are providing credible and reliable aquatic macroinvertebrate identifications at the genus and/or family level. The certification program tests a candidate's knowledge and skills in aquatic macroinvertebrate taxonomy and provides the successful applicant with a certificate of proficiency.[2]

Selected states might also offer certifications that address taxonomic and other biological assessment skills and qualification. For example, Ohio offers certification as a Qualified Data Collector under the Ohio Credible Data Law. Three levels are offered: Levels 1, 2, and 3. Level 3 is required for acceptance of data by Ohio Environmental Protection Agency (Ohio EPA) for CWA section 303(d) listing and use designation assignments under the Ohio Water Quality Standards (WQS). The certification is obtained by completing a required training class and then completing performance-based testing for fish (including habitat assessment) or macroinvertebrate assemblage assessment. Certification is also available for the Primary Headwater Habitat assessment methodology and for chemical/physical sampling. Additionally, California has developed a process to document the quality of the taxonomic identifications directly. Re-identification of a percentage (typically 10 percent) of taxonomic data by a QC laboratory is routinely required of most projects in California. Summaries of discrepancies are stored with the original data, providing users of the final data set with direct information about the quality of the original data, much as QA batch data provides information about chemistry analyses. In effect, California audits the data instead of the data providers. California also requires that taxonomists who provide data for the state be active members of the Southwest Association of Freshwater Invertebrate Taxonomists and follow its standard taxonomic effort protocols and reporting standards.[3]

Question: What is DNA barcoding, and is there potential for future application in biological assessments?

Answer: DNA barcoding is a technique by which organisms (fish, macroinvertebrates, macrophytes, algae) can be catalogued into species based on the nucleotide sequence of one or more gene (e.g., the mitochondrial c oxidase I gene for fish and macroinvertebrates). A recent approach to characterize the composition, and possibly the health of communities, is integrating DNA barcoding with metagenomics. Metagenomics refers to the technique developed to sequence all genetic material present in an environmental sample (soil or water). Moreover, next generation sequencing technology is allowing for the DNA of all species in a sample to be isolated and sequenced at once (i.e., resulting in a metagenome). Once a metagenome is obtained, sequencing of a specific gene region (barcoding) allows one to distinguish the species composition of organisms at a specific location. However, this approach cannot currently provide information regarding the relative abundance of the species present in the collections, which is an important factor in using species level data for water quality monitoring. One long-term goal of the DNA barcode approach is to link biodiversity with existing knowledge of species susceptibilities and tolerances to environmental stressors so that one can describe and evaluate the condition of a community given its biological signature.

[2] http://www.nabstcp.com/

[3] http://swamp.mpsl.mlml.calstate.edu/resources-and-downloads/standard-operating-procedures

2.1.7 Sample Collection (Element 7)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Approach is cursory and relies on operator skill and BPJ. Training limited to that which is conducted annually for non-biologists who compose the majority of the sampling crew. Methods are not systematically documented as standard operating procedures (SOPs).	Textbook methods are used without considering the applicability of the methods to the study area. SOPs to specify methods but methods are neither well documented nor evaluated for producing comparable data across agencies. A cursory QA/QC document might be in place. Training consists of short courses (1–2 days) and is provided for new staff and periodically for all staff.	Methods are evaluated for applicability to study area and refined (if needed). Detailed and well documented SOPs are updated periodically and supported by in-house testing and development. A formal QA/QC program is in place with field replication requirements. Rigorous training required for all professional staff.	Same as Level 3, but methods cover multiple assemblages. A field audit of sampling crews is performed annually to ensure that protocols and proper sample handling/documentation are followed.

The sample collection technical element consists of standard operating procedures (SOPs) used to collect and preserve biological samples and take field measurements. Standardized and well-tested field methods minimize the variability in biological samples associated with differences in sampling procedures. A robust QA/QC system provides assurance that SOPs are followed. Numerous studies have demonstrated that the field methods used can have strong effects on the characteristics of the collected organisms. For example, samples collected in slow water, depositional areas provide a different set of taxa compared with samples collected in riffles (Parsons and Norris 1996). As such, for benthic macroinvertebrates, sampling protocols should specify how different habitats in a stream reach are selected for sampling (Gerth and Herlihy 2006; Rehn et al. 2007). Similarly, greater sampling effort (e.g., more time spent collecting) results in larger numbers of individuals and taxa. Use of different sampling equipment (e.g., kicknets vs. Surber samplers) alter the characteristics of the collected assemblage (e.g., Stark 1993; Cao et al. 2007; Cao and Hawkins 2011).

Scores for this technical element are based on the extent of standardization and evaluation of field sampling methods and the completeness of the QA/QC system. Example evaluation questions are:

- Are standardized methods used to select sampling locations (e.g., single or multiple habitats, transects) within a selected site and to collect and preserve samples?
- How is QA/QC incorporated in sample collection?

Biological assessment programs that score highly for this technical element have developed well-defined and rigorous SOPs that specify details of the collection (e.g., where samples are collected, what sampling equipment should be used, when samples should be collected, how samples should be preserved). The QA/QC system should provide for regular audits of field crewand replication of samples at a certain proportion of sites, assign responsibility, define personnel qualifications, establish protocols, define preventative and corrective action, provide information tracking, and ensure that study objectives are met (USEPA 1995; Stribling et al. 2008). Voucher specimens are retained to verify the accuracy of taxonomic identifications.

Frequently Asked Questions

Question: How does sample collection influence the rigor of a biological assessment?

Answer: Sample collection is the genesis of biological assessment data; therefore, how it is designed and executed influences the ability of a biological assessment to adequately and accurately describe biological quality. However, biological assessment sample collection should be sufficiently cost-effective so as to produce a sample with 2–3 hours' effort in the field.

Question: How do I know which method is best for my biological indicator (Figure 2-6)?

Answer: Methods should have a well-developed SOP, and all field personnel should be trained by qualified professionals. The SOP should minimize the decisions that need to be made in the field, and the training should provide guidance for how to handle unusual situations. If well-developed SOPs and training are done by qualified professionals with appropriate checks and/or audits in place, the actual sampling could be done by more junior personnel under the direction of senior level staff. This type of apprenticeship or mentoring is important for maintaining consistency in sample collection and minimizing variability due to who is doing the sampling at any one location and/or time.

Figure 2-6. Stream sampling methods.

2.1.8 Sample Processing (Element 8)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Organisms are sorted, identified, and counted in the field using dichotomous keys.	Organisms are sorted, identified, and counted primarily in the field by trained staff. Adequate QA/QC is not possible. For fish, cursory examination of presence and absence only. Agency SOPs not developed or published.	All samples (except for fish) are processed in the laboratory. A formal QA/QC program is in place. Rigorous training is provided. Voucher organisms are retained for ID verification. SOPs are published and available to others.	Same as Level 3, but applied to multiple assemblages. Subsampling level is tested. Presence of fish deformities, erosions, lesions, tumors (DELT) and other anomalies are quantified and documented.

Sample processing refers to the protocols (i.e., SOPs) that are followed to subsample, sort, identify, and count the organisms collected from a water body. These protocols include the specific methods for identifying organisms (e.g., by employing established keys), for training of the personnel who count and identify the organisms, and for QA/QC. Consistent protocols for sample processing can minimize the potential that differences in sample processing cause differences in site assessments.

Protocols for subsampling, including how the subsample is selected and how many organisms are counted should be specified. For most assemblages, it is infeasible to identify all the organisms in the sample, and, therefore, a subsample of the collected organisms is identified and counted. In general, the more organisms that are identified, the more accurately and precisely one can characterize the structure of the biological assemblage (e.g., Barbour and Gerritsen 1996; Ostermiller and Hawkins 2004; Cao and Hawkins 2005; Cao et al. 2007). However, sample processing costs increase with subsampling effort, so the relative benefits of increased subsampling effort versus processing costs should be considered and documented.

The most appropriate protocols can depend on the assemblage that is collected. For example, macroinvertebrates are more effectively sorted and identified in the laboratory (Nichols and Norris 2006), whereas fish are typically identified and counted in the field prior to returning them to the water body. (Note that when field identifications are used, voucher specimens should be retained for QA in the laboratory.) Similarly, the presence of deformities, erosions, lesions, and tumors (DELT) usually can only be assessed with fish samples.

Scores for this technical element are based on the degree to which sample processing is standardized, and the degree to which QA/QC procedures are both documented and implemented. Example evaluation questions are:

- Are standardized methods for sample processing in place?
- Do methods include processing macroinvertebrate and algae samples in the laboratory, retaining voucher specimens for fish, and using a formal QA/QC program?

- Is the increased accuracy and precision of more intense subsampling effort for macroinvertebrates and algae relative to the costs of subsampling documented?
- For fish, does the program record DELT and other anomalies?

Programs that score highly on this technical element process macroinvertebrate and algae samples in the laboratory, count DELT anomalies on fish, retain voucher specimens, and use a formal QA/QC program. The process used to select subsampling effort for macroinvertebrates and algal assemblages is documented, and it is sufficient for accurate and precise characterizations of assemblage structure.

Frequently Asked Question

Question: How does the level of macroinvertebrate subsampling affect the results of biological assessment?

Answer: In general, precision of site-specific estimates of taxon richness might improve with both sampling and subsampling effort. However, there may be diminishing returns for increasing subsample effort, and various studies have suggested that subsampling more than 500 macroinvertebrate organisms yields little or no additional precision or accuracy (e.g., Barbour and Gerritsen 1996; Ostermiller and Hawkins 2004; Cao and Hawkins 2005; Cao et al. 2007). The costs of increased sampling and subsampling effort at single sites needs to be considered in the overall program design with the information expected to be gained from more extensive sampling (increased number of sites and sample density). Depending on the questions to be answered, increased subsampling effort might increase precision and power for before-after and upstream-downstream investigations, while increased extent of sites might increase power for statewide status and trends investigations.

2.1.9 Data Management (Element 9)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Sampling event data organized in a series of spreadsheets (e.g., by year, by data-type). QA/QC is cursory and mostly for transcription errors. Might be paper files only.	Databases for physical-chemical, and biological data, and geographic information exist (Access, dBase, Geographic Information System [GIS], etc.) but are not linked or integrated. Data-handling methods manuals are available. QA/QC for data entry, value ranges, and site locations. A documented data dictionary defines data fields in terms of field methods and data collection.	Relational databases that integrate all biological, physical, and chemical data (Oracle, SQL Server, Access, etc.). Validation checks that guard against inadvertently storing incorrect or incomplete sampling data. Fully documented and implemented QA/QC process. Structure provides for data export and analysis via query includes dedicated database management. Fully documented data dictionary. Access to all databases is available for routine analysis in support of condition assessment.	Same as Level 3 adding automated data review and validation tools. Numerous built-in data management and analysis tools to support routine and exploratory analyses. Ability to track history of changes made to the data. Ability to control who has privilege to change, update, or delete data. Data import and export tools. Integrated connection to GIS showing monitored sites in relation to other relevant spatial data layers. Fully documented metadata according to accepted database standards. Reports on commonly used endpoints are easily retrieved (e.g., menu driven).

The data management technical element evaluates the processes and systems that are used by a monitoring program to store and access collected data. A reliable, well-designed, and quality-assured database and management system is fundamental to a program's ability to effectively use monitoring information to assess environmental problems and allows historical data to be used to evaluate trends and provide historical context. Proper data management ensures that the appropriate data can be retrieved and analyzed when necessary and with ease of access, and that historical data are archived in a data repository to protect against data loss (e.g., Michener and Jones 2012).

Proper data management also requires documented metadata, that is, data about the data. Metadata documents are the who, what, why, where, when, and how of the data in the database, so it would include documentation of methods, units, design, objectives. The metadata ranges from methodological description of the study (or studies) to the data dictionary describing fields in the database. Metadata can be coded into Ecological Metadata Language, a metadata specification developed for ecology, based on work sponsored by the National Science Foundation (The Knowledge Network for Biocomplexity; http://knb.ecoinformatics.org/index.jsp).

Scoring of this technical element is based on the degree to which data management systems permit the program to retrieve data in formats that are useful for conducting analyses and supporting decision making. A low score in this element would be associated with simple spreadsheet storage of monitoring data. Higher scores would be associated with data stored in a relational database allowing integration with spatial data and providing stakeholders with Web access. Also, the methods used for archiving data and for making the data available to outside users are considered. Example evaluation questions are:

- Are data storage and analysis programs in place to access data, determine data quality, and manipulate the data to evaluate the relationship between measures of stressors or categories of stressors with biological assemblage response?
- Does data management include comprehensive and integrated storage of biological assessment, physical, chemical, WET, and watershed observations, such that these can be integrated with respect to space and time?

For a program to score high on this technical element, all monitoring data are stored in a relational database allowing integration with spatial data and providing users and stakeholders with Web access to access raw and summary data. Transparent and well-documented QA/QC procedures are in place for data storage and retrieval, including protocols for tracking changes in taxonomic nomenclature over time. All relevant data collected by the agency are in one integrated database system.

Frequently Asked Questions

Question: How do I know what type of data management system I need?
Answer: Data organization and management allows users to perform assessments and reorganize and summarize data according to analysis needs, including exploratory analyses, index development, and more advanced research. Use of spreadsheets is the minimum level of an electronic database management system, but spreadsheets are deficient in error checking and data integration, and they are limited in the amount of information that can be stored. A relational database addresses these shortcomings. A thorough QA/QC check on the database ensures a "clean" data set for use throughout an agency's program. A small relational database management system (RDBMS) such as Microsoft Access could serve as a logical step from spreadsheets to a more sophisticated relational database. These smaller systems can be used to develop a biological assessment database that includes most of the relational data integrity and validation features of a larger RDBMS. Most large RDBMS are installed on a server that provides options for making the database available through a network or Internet connection. Larger RDBMS are usually installed and administered by an agency's information technology (IT) department. IT departments can help program managers identify qualified professionals to assist with creating a custom database to meet the data management and analysis needs of biological assessment programs.

When developing a relational database, it is important to recognize that data access depends on creating and running queries, which must be properly programmed to extract appropriate data, and to make extracted data tables available to outside users as flat files.

Question: If I'm able to use electronic spreadsheets or even a small RDBMS such as Microsoft Access, why do I need a data dictionary (metadata)?
Answer: A well-documented data dictionary defines not only how the data in a particular field relate to field operations and data collection, but it specifies how those values are stored and validated. Creating a well-documented data dictionary requires the data manager to address questions ranging from fairly simple to more complex. For example, are the data numeric or text? Are they allowed to be null? The answers to these questions might show that multiple types of data are being stored in one field and should be separated. Answering these questions helps to bridge the gap between using spreadsheets and moving toward a more robust data management system.

2.1.10 Ecological Attributes (Element 10)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Biological program relies solely on the evaluation of the presence or absence of targeted or key species. No rationale is provided for selection of indicators. Assessment endpoints and ecological attributes are not defined.	Biological program based on "off the shelf" indicators for one biological assemblage. Rationale for selection of indicators is partially documented. Generic assessment endpoints and ecological attributes are defined but not specifically evaluated for state or regional conditions.	Biological program based on well-developed ecological attributes for one biological assemblage. Rationale for attribute selection is thorough and well-documented. Explicit linkage is provided between management goal, assessment endpoints, and ecological attributes.	Same as Level 3, but biological program based on well-developed ecological attributes for two or more biological assemblages (e.g., faunal, flora) for more complete assessment of the members of an aquatic community.

The objective of the 1972 CWA is to "… to restore and maintain the chemical, physical and biological integrity of the Nation's waters." However, the CWA does not provide an explicit description of biological integrity nor specify ecological assessment endpoints and scientific methods to measure integrity. One description of biological integrity is "a balanced, integrated, and adaptive community of organisms having a composition and diversity comparable to that of natural habitats of the region" (Frey 1975; Karr and Dudley 1981). Primarily based on this definition or on later refinements (Karr and Chu 2000), states and tribes have used biological assessments to measure the condition of biological communities relative to biological integrity.

This technical element evaluates how well a biological assessment program has selected and operationally defined assessment endpoints that adequately represent biological integrity. Assessment endpoints are measurable characteristics, or attributes, representative of a management goal (USEPA 1998). The attributes provide the basis for development of quantitative measures (e.g., biological indices) to assess attainment of the management goal. Selection of attributes to measure biological integrity includes consideration of their ecological relevance, susceptibility to known or potential stressors, and relevance to the management goal (USEPA 1998). Ecologically relevant attributes might be identified at any level of organization (e.g., individual, population, community, ecosystem, landscape). Typically states and tribes have identified species diversity and abundance as ecologically relevant attributes for measuring biological integrity and have developed biological indices using measures of taxonomic diversity and completeness, composition, trophic state, and trophic composition.

Full consideration of all three selection criteria (e.g., ecological relevance, susceptibility to known or potential stressors, relevance to management goal) provides the best foundation for development of biological indices to measure biological integrity. Poorly defined attributes can lead to miscommunication and uncertainty in applying assessment results to making a judgment on attainment of the management goal. For example, susceptibility of an ecological attribute to stressors and/or levels of human disturbance in the environment is important in selecting attributes but should be considered in the context of how well an attribute can represent the management goal. Otherwise, an attribute could be selected that leads to a biotic index that provides a robust and precise measure of human disturbance but not an accurate measure of biological integrity.

Scientists from EPA, U.S. Geological Survey, state and tribal agencies, and academic institutions jointly developed a conceptual scientific model that describes the response of 10 ecological attributes to increasing anthropogenic stress (Davies and Jackson 2006, Table 2-3). This model, the Biological Condition Gradient (BCG), is based on a suite of ecological attributes used by different state and tribal biological assessment programs across the country. The BCG was developed to provide a common framework for interpretation of biological assessments regardless of methods or regional differences. The ecological attributes of the BCG might serve as a template, or starting point, for states and tribes to consider in their selection of attributes.

Scoring for this technical element is based on how a biological assessment program has selected and operationally defined ecological attributes to assess biological integrity and then used them as the basis for development of biological indices. Because the condition of a biological community can be more confidently assessed with more than one biotic assemblage, the number and type of assemblages are considered in the evaluation (e.g., Carlisle et al. 2008). Example evaluation questions are:

- Are ecological attributes defined that provide for development of biological indices to measure attainment of biological integrity? If so, what are the ecological attributes and what is the basis for their selection?
- What aquatic assemblages are assessed?
- How is the linkage between biological integrity, ecological attributes, and biological indices defined, tested, and documented?

Programs that receive the highest scores for this technical element have well-developed ecological attributes for two or more assemblages. The linkage between biological integrity, assessment endpoints, ecological attributes and the resulting biological indices is explicit and documented.

Table 2-3. Biological and other ecological attributes used to characterize the BCG

Attribute	Description
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	Taxa known to have been supported according to historical, museum, or archaeological records, or taxa with restricted distribution (occurring only in a locale as opposed to a region), often due to unique life history requirements (e.g., sturgeon, American eel, pupfish, unionid mussel species).
II. Highly sensitive (typically uncommon) taxa	Taxa that are highly sensitive to pollution or anthropogenic disturbance. Tend to occur in low numbers, and many taxa are specialists for habitats and food type. These are the first to disappear with disturbance or pollution (e.g., most stoneflies, brook trout [in the east], brook lamprey).
III. Intermediate sensitive and common taxa	Common taxa that are ubiquitous and abundant in relatively undisturbed conditions but are sensitive to anthropogenic disturbance/pollution. They have a broader range of tolerance than highly sensitive taxa (attribute II) and can be found at reduced density and richness in moderately disturbed sites (e.g., many mayflies, many darter fish species).
IV. Taxa of intermediate tolerance	Ubiquitous and common taxa that can be found under almost any conditions, from undisturbed to highly stressed sites. They are broadly tolerant but often decline under extreme conditions (e.g., filter-feeding caddisflies, many midges, many minnow species).
V. Highly tolerant taxa	Taxa that typically are uncommon and of low abundance in undisturbed conditions but that increase in abundance in disturbed sites. Opportunistic species able to exploit resources in disturbed sites (e.g., tubificid worms, black bullhead).
VI. Nonnative or intentionally introduced species	Any species not native to the ecosystem (e.g., Asiatic clam, zebra mussel, carp, European brown trout). Additionally, there are many fish that have expanded their range within North America because they have been introduced to areas where they were not native.
VII. Organism condition	Anomalies of the organisms; indicators of individual health (e.g., deformities, erosions, lesions, tumors [DELT]).
VIII. Ecosystem function	Processes performed by ecosystems, including primary and secondary production; respiration; nutrient cycling; decomposition; their proportion/dominance; and what components of the system carry the dominant functions. For example, shift of lakes and estuaries to phytoplankton production and microbial decomposition under disturbance and eutrophication.
IX. Spatial and temporal extent of detrimental effects	The spatial and temporal extent of cumulative adverse effects of stressors, (e.g., widespread tile drainage and stream channelization throughout an ecoregion resulting in extirpation of several species of native macroinvertebrates and fish).
X. Ecosystem connectance	Access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation (e.g., levees restrict connections between flowing water and floodplain nutrient sinks [disrupt function]; dams impede fish migration and spawning).

Source: Modified from Davies and Jackson 2006.

Frequently Asked Questions

Question: Are all 10 BCG attributes necessary to characterize biological integrity?

Answer: The selection of attributes might depend on the spatial scale and specific water body being assessed. Each attribute provides some information about the biological condition of a water body. Combined into a conceptual model comparable to the BCG, the attributes can offer a more complete picture about current water body conditions and also provide a basis for comparison with naturally expected water body conditions. All states and tribes that have applied a BCG for streams, rivers, and wetlands have used the first seven attributes that describe the composition and structure of biotic community on the basis of the tolerance of species to stressors and, where available, included information on the presence or absence of native and nonnative species, and, for fish and amphibians, used measures of overall condition (e.g., size, weight, abnormalities, tumors). Though not measured directly in state or tribal stream biological assessment programs, the last three BCG attributes of ecosystem function and connectedness and spatial and temporal extent of stressors can provide valuable information when evaluating the potential for a stream, river, or wetland to be protected or restored. For example, a manager can choose to target resources and restoration activities to a stream where there is limited spatial extent of stressors or there are adjacent intact wetlands and stream buffers or intact hydrology, rather than a stream with comparable biological condition but where adjacent wetlands have been recently eliminated, hydrology altered, and stressor input is predicted to increase.

However, for comprehensive water body-wide assessments of large systems like estuaries and coastal ecosystems, the full suite of attributes might be important for application at both a single habitat scale similar to streams and for a landscape level assessment that describes the distribution and connectedness of habitats within an ecosystem necessary for the survival and resiliency of the resident biota (e.g., fish, benthic invertebrates, migratory water birds, aquatic mammals).

Question: I have a calibrated index. Why do I need to consider the ecological attributes of the BCG?

Answer: The BCG serves as a conceptual model, or framework, for organizing and communicating information on biological community response to increasing levels of stress in aquatic ecosystems. The BCG was developed in partnership with scientists from state and tribal biological assessment programs from across the country (Davies and Jackson 2006). The BCG attributes and levels of condition represent shared, measurable patterns of biological response to increasing stress condition regardless of location and method. Many of the state and tribal scientists involved in BCG development had already derived biological indices based on methods and approaches developed in the 1980s through 1990s (e.g., index of biotic integrity (IBI) for fish [Karr et al.1986]). Therefore, there is both conceptually and quantitatively a close association between BCG attributes and the biological indices currently used by many states and tribes. The suite of BCG attributes can serve as a template for reviewing and improving an existing biological index or for developing a new index.

Question: What is a trait-based approach?

Answer: A trait-based approach predicts patterns of species attributes (i.e., reproductive, physiological, behavioral) and environmental conditions (Poff et al. 2006; Pollard and Yuan 2010). This approach has not been consistently applied or formally articulated until the last decade. It is based on sound theoretical concepts, such as the Habitat Templet Concept, which predicts that habitat and environmental conditions select organisms with particular life-history strategies and biological traits (Southwood 1977, 1988). Many studies have demonstrated that patterns in the traits of species can be related to environmental conditions (e.g., Townsend et al. 1997; Richards et al. 1997; Statzner et al. 2005; Van Kleef et al. 2006).

2.1.11 Discriminatory Capacity (Element 11)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Coarse method (low signal) and detects only high and low values. Supports distinguishing only extreme change in biological condition at the upper and lower ends of a generalized stress gradient.	A biological index for one assemblage is established but is not calibrated for water body classes, regional or statewide applications. BPJ based on single dimension attributes. The index can distinguish two general levels of change in biological condition along a generalized stress gradient.	A biological index for one assemblage has been developed and calibrated for statewide or regional application and for all classes and strata of a given water body type. The index can distinguish 3 to 4 increments of biological change along a continuous stress gradient. Supports narrative evaluations (e.g., good, fair, poor) based on multimetric or multivariate analyses that are relevant to the selected ecological attributes (Technical Element 10).	Same as Level 3 but biological indices for two or more assemblages have been developed and calibrated. Additionally, the indices can distinguish finer increments of biological change along a continuous stress gradient. The number of increments that potentially can be distinguished is dependent on water body type and natural climatic and geographic factors.

This technical element addresses how a biological assessment program has developed one or more biological indices based on ecological attributes (Technical Element 10) and the degree of sensitivity of the indices in distinguishing incremental change along a continuous gradient of stress. Detailed descriptions of biological change along a gradient of stress can provide detailed descriptions of a state's designated aquatic life uses for specific water bodies and regions and lead to biological criteria development. Additionally, depending on the sensitivity, or discriminatory capacity, of the index, the information can be used to help identify high-quality waters and establish incremental restoration goals for degraded waters.

The ability of a biological index to measure change along a continuous gradient of stress includes consideration of the appropriate scale for application of the index (e.g., a specific water body, class of water body, region, statewide) and defining, and wherever possible, quantifying overall variability and sources of uncertainty.

The BCG discussed in the preceding section (Technical Element 10) is a conceptual model that describes measurable increments of biological change along a gradient of stress (Davies and Jackson 2006). Six general increments of change have been described for each of the BCG's ecological attributes. The gradient ranges from natural, undisturbed conditions to severely degraded conditions caused by anthropogenic stresses. These incremental changes can serve as a template for developing biological indices that represent aspects of biological integrity and show a predictable, measurable response to increasing levels of stress.

Scoring of this technical element is based on the demonstrated ability of the biological index to detect increments of change along a continuous gradient of stress. Examples of evaluation questions are:

- Is the index developed and calibrated at the appropriate scale for its intended application?
- Is the index developed and verified by independent data sets?
- What is the sensitivity of the index to detect shifts in biological assemblages along a full gradient of anthropogenic stress?
- How well defined, quantified, and documented is overall variability and its sources?
- What biotic assemblages are assessed?

Programs that score highly on this technical element have well-developed indices for one or more assemblages and have demonstrated the ability of their indices to distinguish incremental levels of biological condition change along a continuous stressor gradient for specific water body types and regions. Sources of uncertainty are well defined and quantified. For a program to score at the highest level, well-developed biological indices for two or more assemblages are used for a more complete assessment of biological integrity.

Frequently Asked Questions

Question: Can an agency's existing biological index be refined rather than replaced to improve discriminatory capacity?
Answer: As a biological index is further developed, it can be recalibrated and compared with performance of the previous iteration to compare past and present results. Recalibration of an index or model should be considered, for example, when sample collection or processing protocols change; classification is refined; level of taxonomic identification is made more precise; or, the data set is substantially expanded to include longer time-series, stressor conditions, or reference characteristics. These technical improvements can influence discriminatory capacity of an index or model.

Developing a quantitative translation between the original and refined index might require a special study where samples are collected simultaneously using the two protocols (for methodological changes). For example, in New England, alternative sampling and index methods were run side-by-side at the same sites (Snook et al. 2007). For minor methodological changes (e.g., taxonomic level, sampling or subsampling effort), analysis could be performed on samples that are virtually reformatted to provide two samples reflecting each protocol. For example, if Chironomidae (midges) were previously identified at the family level, but are currently identified at the genus level, the identifications in new samples could be reset at family level for calculation of the old index. Then comparisons of old and new indices could be performed on the reformatted and complete samples, yielding old and new index scores that could be compared through regression or other analyses. This would allow prediction of one index from the other and comparison of the assessment thresholds.

Question: Are the same increments of measurement expected for all aquatic water body ecotypes or in all regions of the United States?
Answer: The number of increments that can be distinguished is dependent not only on the water body ecotype and natural climatic and geographic factors that define the assemblage characteristics, but the effect of anthropogenic stressors. For example, the sensitivity of an index developed for a forested, high-gradient stream might support distinguishing five to six increments of change along a continuous stressor gradient while an intermittent, seasonal, or desert stream might support only three increments. Some of this is due to inherent natural characteristics of the assemblages and some might be due to current limitations of science and practice.

2.1.12 Stressor Association (Element 12)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
No ability to develop relationships between biological responses and anthropogenic stress.	Site-specific paired biological and stressor samples for studies of an individual water body or a segment of a water body (e.g., a stream reach). Stress-response relationships are developed based on assemblage attributes at coarse level taxonomy (e.g., family for benthic macroinvertebrates). Information might be used on a case-by-case basis to inform a first order causal analysis.	Low spatial resolution for paired biological and stressor samples in time and space across the state at basin or sub-basin scale (e.g., HUC 4–8). Stress-response relationships developed for one assemblage using regression analysis. Taxonomy at level sufficient to detect patterns of response to stress (e.g., species or genus for benthic macroinvertebrates or periphyton, species for fish). Relational database supports basic queries. Information is frequently used to inform causal analysis. Reevaluation of stress-response relationships on an as-needed basis.	High spatial resolution for paired biological (including DELT anomalies and other indicators of organism health) and stressor samples in time and space across the state at watershed or subwatershed scales (e.g., HUC 10–12). Other data (e.g., watershed characteristics, land use data and information, flow regime, habitat, climatic data) are linked to field data for source identification. Stress -response relationships are fully developed for two or more assemblages, stressors, and their sources using a suite of analytical approaches (e.g., multiple regression, multivariate techniques). Relational database supports complex queries. Information is routinely used to inform causal analysis and criteria development. Ongoing evaluation of stress- response relationships and monitoring for new stressors is supported.

Stressor association refers to the use of biological assessment data at appropriate levels of taxonomy to develop relationships between measures of biological response and anthropogenic stressors, including both stressor and their sources (Yuan and Norton 2003; Huff et al. 2006; Yuan 2010; Miller et al., 2012). This includes examination of biological assessment data for patterns of response to categorical stressors (Yoder and Rankin 1995b; Riva-Murray et al. 2002; Yoder and DeShon 2003). A capability for developing these relationships extends the use of biological assessments from assessing condition to informing identification of possible causes and sources of a biological impairment at multiple scales.[4]

The technical capability to associate biological response with stressors and their sources affecting aquatic systems requires a comprehensive database that should include biological, chemical, physical, and WET data and information; detailed watershed and land use

[4] For more information about stressor identification, see EPA's Causal Analysis/Diagnosis Decision Information System website at: http://www.epa.gov/caddis.

information; locations of discharges; discharge monitoring; Geographic Information System (GIS) capability to assemble watershed and discharge information and relate them to the correct sampling sites, etc. Paired biological and other relevant environmental data support developing quantitative stress-response relationships. A relational database that enables data export and analysis via query is required to support this function. Since chemical sampling is often more frequent (several times per year) than biological sampling, the database should be able to accommodate queries to relate the higher-frequency chemical sampling to lower-frequency biological sampling. It should also be able to reveal the spatial coincidence of biological and chemical/physical sampling locations to reveal the extent to which these are actually paired.

Stressor association, is directly dependent on a high level of technical development of other elements, particularly the elements for spatial sampling design, taxa and level of taxonomic resolution, database management, and discriminatory capacity. These elements are important building blocks for the data collection and analysis needed to more confidently identify stressors and their sources and to estimate stress-response relationships. For example, the ability to estimate these relationships relies on paired stressor and response sampling at appropriate spatial and temporal scales and a level of taxonomic resolution and index sensitivity sufficient to detect incremental biological changes along a stress gradient. Also, a relational database that supports complex queries enables efficient and full utilization of data. A high level of technical development for each of these elements and others provides the foundation for stressor association.

Scoring for this technical element is based on the degree to which biological assessments are used to estimate stress-response relationships and discern patterns of response to individual or categorical stressors. Example evaluation questions are:

- Are biological sample collection and stressor sample collection coordinated? What assemblages are sampled and to what level of taxonomy?
- Does the database support analysis of biological responses to individual stressors or categories of stressors? If so, at which spatial scale(s)?
- Is a systematic approach for identifying stressors at biologically degraded sites used? Is this information used on a routine basis to support identification of probable cause of the biological impacts and source of the stressors?
- Does the database support the continued analysis of biological responses, including WET, to individual stressors or categories of stressors especially as additional data are collected and as stressors change over time?

Programs receiving the highest score on this technical element collect data and conduct analyses that enable the estimation of relationships between biological responses for two or more assemblages and the dominant stressors in their regions. Data sets are examined to discern patterns of response to categorical stressors and for source identification. To elucidate stress-response relationships, the biotic and abiotic data and measurements must be both temporally and spatially linked in data sets. Within-site variability is characterized and appropriately incorporated into the analysis. New monitoring data and information on changes in land use and new stressors are systematically gathered and evaluated as a part of the routine monitoring and assessment program so that new stressors and their biological impacts are detected and stressor-response variables developed accordingly. Information is used to inform causal analysis and support criteria development. Timely information is also provided to other water quality programs to meet their information needs on stressor-response relationships and causal analysis.

Frequently Asked Questions

Question: What biological assessment information can be used as a basis for diagnosing problems?

Answer: Appropriately detailed biological assessment information is needed to discriminate between different categories of stressors and requires analyses of large data sets to reveal patterns of biological response across spatial and temporal gradients. To further examine for patterns of biological response to stress, equally detailed information on stressors, habitat, potential sources, and the natural background condition are also needed.

Question: How does one analyze stress-response?

Answer: There is a large and growing base of literature exploring different approaches to analyzing stress-response relationships from field data. Methods range from simple regressions to complex multivariate models and new methodologies (see Legendre and Legendre 1998 for an overview). The objective is to find community-level diagnostics, also called biological response signatures, which are characteristics of a biological community and are associated with specific stressors or categories of stressors and can be used diagnostically. In some cases, these indicators have been used by agencies to identify possible stressors from biological data (Yoder and DeShon 2003; Yoder and Rankin 1995b; Riva-Murray et al. 2002). A further refinement to this approach compares stressor-specific tolerance values associated with taxa collected at sampling sites with those from an expected assemblage predicted by a RIVPACS-type model (Huff et al. 2006; Hubler 2008). Additionally, new analytical approaches are being explored for identifying patterns of biological response to individual stressors, types or categories of stressors, and/or their sources (e.g., Shipley 2000; USEPA 2000; Oksanen and Minchen 2002; Cade and Noon 2003; Cormier et al. 2008; Baker and King 2009; King and Baker 2010; USEPA 2010a; Cormier et al. 2013).

Question: What are biomarkers, and can they be used for diagnosis?

Answer: Biomarkers are histopathological or biochemical signatures found in organisms that indicate some combination of stress, exposure to specific chemicals, or a disease. They are typically assayed from single individuals, where several individuals from a single site are sampled. They have been used most often in attempts to diagnose causes of observed impairments or mortality in fish. For example, Ripley et al. (2008) examined protein expression profiles of smallmouth bass in the Shenandoah River to identify candidate causes of biological impairment of the river and of several fish kills. They found that fish in the Shenandoah are immunologically stressed; however, there are multiple candidate causes of the stress (eutrophication, pesticides, agricultural animal runoff) (Ripley et al. 2008). Biomarkers of exposure to polycyclic aromatic hydrocarbons (PAHs) were examined in fish in contaminated rivers in Ohio, and they were key in identification of PAHs as one of several causes of biological impairment in the rivers (Lin et al. 2001; Yoder and DeShon 2003). This example illustrates how biological assessments in combination with other biological, chemical, or physical information support more robust causal analysis.

2.1.13 Professional Review (Element 13)

(Lowest) 1.0	2.0	3.0	4.0 (Highest)
Review is limited to editorial aspects. No technical review.	Internal technical review only.	Outside review of documentation and reports are conducted on an ad hoc basis.	Formal process for technical review to include multiple reference and documented system for reconciliation of comments and issues. Process results in methods and reporting improvements. Can include production of peer-reviewed journal publications by the agency.

The professional review technical element is the level to which agency data, methods, and procedures are reviewed, especially with regard to external stakeholder and scientific peer reviews. Subjecting documented methods and assessment reports to rigorous scientific peer review is ultimately the best way to ensure that an agency's data and scientific underpinnings are credible. Inherently, scientific peer reviews should be conducted in an objective and independent manner (outside the agency and with no vested interest in the outcome) by technical and other experts able to provide valid critique and suggestions, and where recommendations for improvement and refinement are taken in good faith. Validation of SOPs for all aspects of the assessment and monitoring program by outside experts is an initial step in establishing confidence in the resulting data. Programs that do not address and implement critical recommendations fail to benefit from an independent endorsement of their procedures and assessments.

The scoring for this technical element is based on the level of scientific peer review. Example evaluation questions are:

- Are documented methods and assessment reports subject to a rigorous scientific peer review process?
- What type of peer review is conducted, and how does the agency address review comments and document its response?

To score high in this technical element, a program will have a formal process for routine scientific peer review of data and documents. Programs with a high level of rigor ensure that reviews are done by outside, independent reviewers. The agency will also have an established, transparent process for documenting and tracking how it responds to comments from reviewers. Technical approaches might be included in peer review journal articles.

Frequently Asked Question

Question: Agency documents and reports are subjected to a thorough internal review by management—why is that not sufficient?

Answer: A peer review by technical experts from outside the agency is crucial to validating all aspects of a biological assessment program. Peer review provides feedback for strengthening a program and validation for the technical foundation to support water quality management decisions. In particular, publishing biological assessment protocols through a peer-reviewed process demonstrates a high level of technical rigor and acceptance in the scientific community.

2.2 Determining the Overall Technical Program Level of Rigor

A technical element's scoring matrix or "checklist" has been developed to rate or score the key technical elements according to a four-tiered narrative description along a sliding scale that ranges from 1 to 4 (Appendix E). The checklist is used to evaluate each element and rate it independently as part of the overall program evaluation process. The scoring of the individual technical elements is based on the role of each element in supporting a biological assessment program's ability to:

- Assess biological condition of a water body in terms of biological integrity.
- Define biological change along a gradient of stress.
- Relate biological response to stressors and develop stress-response relationships.

EPA recognizes that the components of the various technical elements are inherently interrelated and the status or refinement of one element can influence others. However, focusing on individual elements first and then aggregating them into a cumulative rating provides an estimate for the overall level of rigor of a biological assessment program. The individual technical element scores can be used to prioritize specific areas for corrective actions and improvement, and these are detailed in Appendix E. The checklist should be completed for major water body types (e.g., flowing waters, lakes,

☛ The 13 technical elements are evaluated equally for the purpose of identifying strengths and areas for improvement. Clearly, several entail greater level of effort for development. Many are building blocks for others. For example, Technical Element 5, Reference Condition, evaluates the number of reference sites that are available based on reference site section factors (Technical Element 4); the degree to which the reference sites represent natural environmental gradients (Technical Element 3) and whether the number of sites is sufficient to support statistical evaluation of condition and derivation of numeric biological criteria. Likewise, Technical Element 12, Stressor Association, is influenced by whether there is sufficient spatial resolution (Technical Element 2) and natural classification (Technical Element 3) to characterize both natural and stress gradients as well as number of assemblages used to measure aquatic life use and detect stress-response relationships (Technical Element 6). Fundamental to this element is an adequate data management system (Technical Element 9) so that data is readily accessible and can be manipulated for complex analysis. The relationships between the technical elements and level of effort and sequence for each are part of the discussion in development of recommendations and action plan.

wetlands) with the assemblages used for each water body type noted. Different levels of biological assessment rigor might be evident among the different water body types and assemblages sampled, which is important for the water quality agency to determine and reconcile for management purposes.

It is important that the determination of the level of rigor be done with care to avoid an erroneous classification of the program. The evaluation of each technical element and the overall level of rigor of a biological assessment program should be done with the direct input of the state or tribal manager, supervisor(s), and technical staff. Documentation about the biological assessment program will be needed to complete various aspects of the checklist. The checklist should be completed for each water body ecotype as appropriate for the natural classification framework (e.g., lake, flowing waters, wetland, and per ecological region or other classification factors such as elevation) that the water quality agency routinely monitors. It is possible that different levels of rigor are being implemented for the different water body ecotypes within the jurisdiction of the state or tribe. The overall program score provides an indication of a biological assessment program's capability to derive biological criteria, describe biological change along a gradient of stress and develop response-stress relationships (Table 2-4).[5]

Table 2-4. Scoring associated with technical element levels of rigor

Level of Rigor	CE Score	% CE Score[6]
4	49–52	≥ 93.2
3	43–48	≥ 81.7–93.1
2	34–42	≥ 66.4–81.6
1	13–33	24.0–66.3

The central tendency of a biological assessment program's technical capability for each technical element is evaluated to arrive at a score. A score for one element might end up as a 3.5 if its central tendency is comparable to the technical capabilities of Level 3 but it has some technical characteristics of a Level 4 program and none of Level 2. It is important to emphasize that the evaluation process is intended to guide program development building on existing technical capabilities and addressing the gaps revealed in the review, rather than being viewed as a report card.

Summing the individual scores of the 13 technical elements provides a raw score for the biological assessment program with a range of 13–52. This score is then converted to a percent score by dividing the raw CE score by 52. The thresholds for determining the four levels of rigor

[5] Because the overall score is the result of the summation of individual scores for the 13 separate elements, the overall score does not establish minimum expectations regarding a state's ability to make decisions in context of different CWA regulatory programs. At all levels of technical development, biological assessment information can be used to support water quality decisions.

[6] The percent CE score is calculated based on 0.5 increments between CE raw scores.

are based on an allowable deviation from the maximum cumulative score of 52 across all 13 elements (Table 2-5). These thresholds correspond with improved program capabilities to detect shifts in biological assemblages along a gradient of stress, more comprehensively assess the biotic community, detect the suite of stressors impacting the biota, and quantify stressor-response relationships. For Level 4, there is a 3-point deviation or departure, a 9-point departure for Level 3, and an 18-point departure for Level 2. Deviations greater than 18 result in a Level 1 assignment.

Table 2-5. Allowable deviation of technical elements scores for each of the four levels of rigor

Level of Rigor	Departure from maximum cumulative score
4	-3
3	-9
2	-18
1	greater than -18

The levels of rigor are based on departures across the 13 technical elements as opposed to a strictly linear interpretation across the four narrative descriptions of each element (e.g., 3 x 13 = 39 as the maximum score for Level 3, 2 x 13 = 26 as the maximum score for Level 2). As such, the delineations of the four levels are based on the aggregate degree of departure across all 13 elements and in recognition that the overall level of rigor is an aggregate reflection of all 13 elements combined. It also recognizes the scoring across the four element narratives as an ordinal gradient as opposed to rigid and discrete categories. Based on the pilot evaluations, state and tribal biological assessment programs might exhibit characteristics of adjacent categories—hence the sliding scoring scale in 0.5 point increments.

The pilot testing done with states in 2002–2004 and follow-up evaluations conducted with selected states through 2010 show a congruence between the level of rigor and the formal adoption of numeric biological criteria and refined aquatic life uses in WQS (Table 2-6). Of the three states that have adopted numeric biological criteria and/or refined aquatic life uses in their WQS, two are Level 4 programs and one is 0.5 point from Level 4. Of the remaining five Level 3 states, three were considering developing numeric biological criteria and refined aquatic life uses, and each was expecting to continue technical development towards Level 4 as a result of ongoing technical and program developmental efforts. For states either achieving or developing a Level 4 program, coordinated biological, WET, chemical, and physical assessments and implementation of stressor identification as part of the water quality management program were either in place or being planned for.

Table 2-6. State Pilot Biological Assessment Reviews: Correspondence of the level of rigor to adoption or development of refined aquatic life uses and/or biological criteria in state WQS

CE Level (n)	Refined Aquatic Life Uses &Biological Criteria in WQS[7]	Refined Aquatic Life Uses & Biological Criteria in Development	Not Developing Refined Aquatic life Uses &/or Biological Criteria in WQS
4 (2)	2		
3 (5)	1	3	2
2 (14)	0	0	14
1 (0)	0	0	0

The guiding principles of the technical elements approach are intended to help state and tribal monitoring and assessment programs achieve levels of standardization, rigor, reliability, and reproducibility that are reasonably attainable under current technology and available funding (Yoder and Barbour 2009). While the assignment of a biological assessment program to one of the four levels of rigor has meaning and utility as a summary tool for assessing overall progress, how a state or tribe responds to the evaluation results is the critical action. For Level 4 programs, the focus is on program maintenance and how the program is incorporating new advances in the science and technology of biological assessment. In contrast, for Level 1, 2 and 3 programs, the focus is on the technical developments that are either already underway or that need to take place to meet the agency's needs for biological assessment data and information.

[7] includes biologically-based refined uses only.

CHAPTER 3: THE PROGRAM EVALUATION PROCESS

3.1 Introduction to the Evaluation Process

The biological program review is a systematic process to evaluate the technical capabilities of a state's biological assessment program and to identify next steps for overall program improvement. In this process, an expert reviewer conducts in-person interviews with the water quality agency and guides discussions with water quality agency managers and staff. Regional U.S. Environmental Protection Agency (EPA) managers and/or staff typically participate in the review and provide support to the process. The number of water quality agency personnel engaged in the review usually varies depending on the topic of discussion. The biological assessment and Water Quality Standards (WQS) program managers and technical staff are present throughout the review and constitute the core technical review team. Managers and staff from other programs within the agency, as well as other state agencies that conduct biological monitoring and assessments, might participate for the full workshop or engage for specific topics, overall summary discussions, and the concluding session (see Figure 3-1).

The expert reviewer acts as a facilitator to provide an objective perspective on a state's biological assessment program and to lead the review process, including the scoring of the individual technical elements and writing the results (e.g., the technical memorandum). Important considerations for selection of an expert reviewer include:

- Expertise in biological assessments and aquatic ecology.
- In-depth experience in conducting biological assessments and data analysis.
- Practical and applied knowledge of state and tribal biological assessment programs.
- Ability to facilitate the review and complete the technical memorandum objectively.

The review is composed of two parts (Figure 3-1). The first part of the review provides an overview of the biological assessment program and involves discussion of many aspects of the biological assessment program and how that information is used by different water quality programs. The second part of the review, the technical elements review, is the evaluation by the core review team of the technical rigor of the biological assessment program. The first part of the review focuses on program background to provide context for a state or tribal water quality management program to evaluate the type and quality of biological assessments appropriate to answering specific information needs. Using the review results as a road map, a state or tribe can develop a technical program to support its intended use of biological assessments. This is why the first part of the review process includes discussion of how a program functions and whether the biological assessment program is providing the type and level of information needed by the state or tribe. This discussion sets the stage for the technical evaluation—the determination of biological assessment program strengths and limitations in context of an agency's water quality management program information needs.

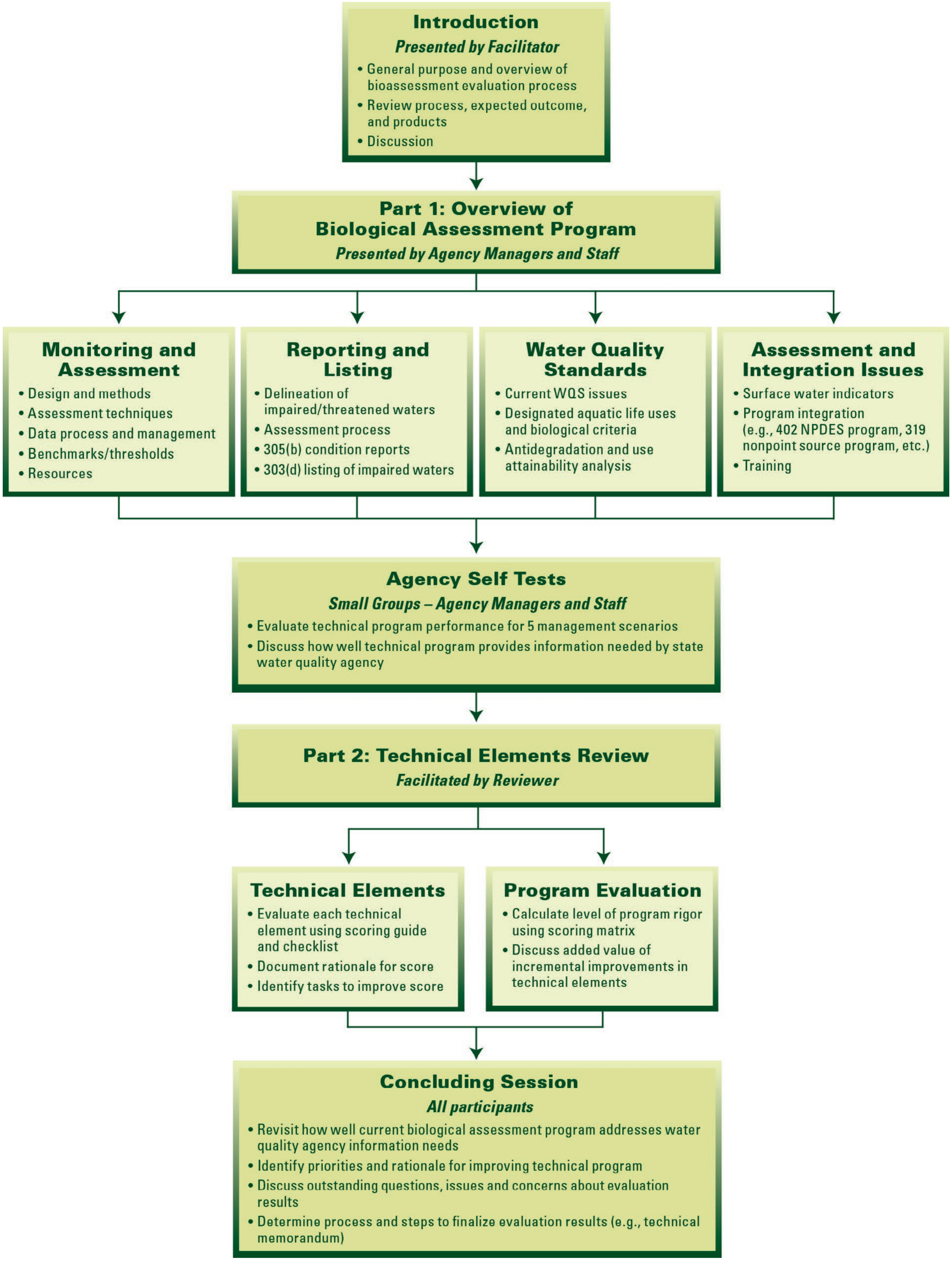


Figure 3-1. Flow chart of the 3-day biological assessment program evaluation process.

During the first part of the review—the overview—the reviewer leads the team in a discussion of the water quality agency's monitoring and assessment program, WQS and programs such as the Total Maximum Daily Load (TMDL), National Pollutant Discharge Elimination System (NPDES) permits, and nonpoint source programs. The discussion also serves as baseline fact finding for scoring each of the 13 technical elements of a biological assessment program and for identifying how the agency is currently using biological assessments and considering future applications (a complete listing of all annotated discussion topics is available in Appendix B: Interview Topics for Agency Review). This discussion provides managers and technical personnel with a better understanding of the program's history, why decisions were made, and how managers and staff interact across the monitoring and assessment program, WQS, listing, TMDL, NPDES, and nonpoint source programs. The discussion provides insight to the agency participants on the current technical strengths and deficits of the biological assessment program and the improvements needed to better support water quality management.

In the second part of the program review, the core review team evaluates 13 technical elements of a biological assessment program associated with biological assessment design, methods, and analysis. Through evaluation of the technical elements, the review team works together to assign a level of rigor (1–4) for the overall program based on the factors outlined in Chapter 2. On the basis of the discussion in the first part of the review, the review team develops a list of recommendations that the water quality agency can use to improve its program.

The final outcome of the program review is a technical memorandum written by the reviewer in collaboration with the full review team. In the memorandum, the reviewer describes important attributes of the overall program, summarizes the water quality agency's biological assessment program, justifies the assignment of the program's level or rigor, and recommends future actions. A step-by-step guide for conducting a biological assessment program evaluation is below.

3.2 Preparation for the Review

For a biological program review to be successful, preparation is necessary for the reviewer as well as the water quality agency personnel. Key tasks for the water quality agency include 1) identifying a comprehensive list of program managers and staff to attend the review; 2) communicating the importance and purpose of each person's participation; and 3) providing materials that the expert reviewer uses to become knowledgeable about the state program.

3.2.1 Identifying Participants

It is essential that water quality agency personnel from different program areas are engaged in the discussions so that data quality and information requirements are accurately represented and properly implemented, especially with regard to EPA published methodologies. Participation from different water quality programs, for example, is also important in the review to build a shared understanding and broad perspective on the existing use of biological assessment information and to begin to identify the technical program gaps and areas for improved use. One person from the water quality agency is designated as the lead for the effort. This state contact is responsible for bringing together the appropriate state personnel and ensuring that necessary documentation is compiled for the review.

Participants should include both agency managers and staff involved in the following programs:

- WQS
- Monitoring and assessment
- Reporting and listing
  - Section 305(b)/303(d) integrated report and listings
- TMDL development and implementation
- Planning
- Nonpoint source assessment and management
- Dredge and fill (section 404/401)
- NPDES program
- Other relevant programs

The reviewer will designate a member of the water quality agency review team to serve as a note taker. The note taker should be available for the entire evaluation and is responsible for ensuring that all discussion is captured. These notes will aid the reviewer with developing the technical memorandum.

3.2.2 Materials Provided as Basis for Program Review

This guidance document itself should be distributed to the water quality agency personnel prior to beginning the program review to provide participants with an understanding of the technical elements and the checklist process. The document also introduces the water quality agency to the next steps in the biological criteria implementation process, including the option for the water quality agency to develop a timeline for achieving a biological assessment program of Level 4 rigor by setting specific milestones for program development.

The appendices include the materials to be used during the evaluation and as supplemental information. By reviewing this chapter and appendices prior to the on-site visit, personnel can familiarize themselves with their content. Some of these documents serve simply as templates and are modified by the reviewer prior to the review.

- **Agenda (Appendix A)**—outlines the basic structure of a biological assessment program evaluation. It is conceptual in design, open to input from both the water quality agency and reviewer, and serves as a starting point for coordinators to plan the evaluation. A review-specific agenda is developed prior to the review itself.

- **Water Quality Agency Interview Topics** (**Appendix B)**—provides an overview of the major topics addressed during the biological assessment evaluation. The water quality agency is also encouraged to identify topic areas of interest and is free to steer the discussion accordingly. The reviewer and note taker each utilize this format for recording answers and discussion content.
- **Water Quality Agency Self-Assessments (Appendix C)**—designed to facilitate internal consideration about how the water quality agency's present biological assessment program can respond to specific water quality program information needs.
- **Technical Memorandum Template** (**Appendix D)**—serves as an example of the scope and content of the technical memorandum, the principal product of the biological assessment program evaluation.
- **Technical Elements Checklist (Appendix E)**—worksheet for evaluating the degree of development for each technical element of an agency's biological assessment program and associated comments on the elements for the biological assessment program.

3.2.3 Preparation of Documents

Prior to the review, the water quality agency compiles documentation that describes the state's decision-making process, the legal and regulatory framework, and technical components of the overall water quality management program (electronic links or documents are preferred). Access to the following materials should be provided to the independent expert reviewer prior to the site visit:

- Monitoring strategy
- WQS documents
- Biological standard operating procedures (SOPs)
- Listing methodology/guidance
- Section 305(b) report/303(d) list
- Example biological assessment reports/watershed assessments
- Any other materials the agency might determine relevant to the review, such as SOPs for other types of data (e.g., stressors, Geographic Information Systems [GIS])

The reviewer uses these materials to prepare for the interview and in developing the technical memorandum. The water quality agency also prepares an overview of its biological program that includes a brief history and a description of both current and planned program developments. The detail and mode of this presentation is left to the discretion of the water quality agency.

3.3 Part 1: Overview of Current Water Quality Program

3.3.1 Introduction and Overviews

(1) Participants

At the beginning of the evaluation, the water quality agency lead introduces managers and technical staff and briefly describes the purpose and scope of the biological assessment program review process. Individual personnel also offer detail about their specific roles with respect to the water quality agency's biological assessment program. The introductions provide an opportunity for the reviewer to become more familiar with the participants.

(2) Role of Biological Assessment

The reviewer begins the evaluation by giving a presentation to briefly introduce the key concepts of biological assessment-based aquatic life uses and biological criteria in relation to a water quality agency's biological monitoring and assessment program. The presentation, *Aquatic Life Uses: A Conceptual and Practical Basis for Determining Water Quality Management Goals and Outcomes Using Biological Assessments,* covers the relationships of biological, chemical, and physical indicators and criteria in the assessment of a water body's ecological health and the importance of using a system with which the biological response to stress in a water body can be evaluated. Topics included are:

- The linkage of biological assessments to other monitoring and assessment programs, with a focus on the WQS program.
- Information on how a biological assessment-based approach to water quality management support meeting the goals set forth by the water quality agency and Clean Water Act (CWA).
- Case examples of biological assessment programs that either currently achieve, or are building towards, high quality technical programs.

(3) Agency Objectives for Biological Assessment

The next step of the process is the water quality agency presenting an overview of its biological assessment program. This overview helps inform the assessment of the technical elements that follows by defining current technical components, use of the biological assessment information, and how the information produced aligns with managers' expectations and information needs. The water quality agency monitoring coordinator is asked to articulate how the water quality agency views the purpose, goals, and objectives of its monitoring program. This is helpful to have on record as it defines, in the water quality agency's own words, what the water quality agency wants to accomplish and how it intends to use information gathered from monitoring efforts. The water quality agency should include a brief history and any current developments or updates, but the remainder of the presentation's specifics is left up to the water quality agency. Personnel can develop an overview that is water quality agency- and program-specific by highlighting the key aspects that are self-identified as being of high importance.

3.3.2 Monitoring and Assessment

Monitoring and assessment includes the systematic collection of data from the environment and their subsequent analysis to allow assessments regarding attainment status, severity, and extent of impairments, stressor identification, and pollutant source identification. Monitoring and assessment is used to support the reporting requirements mandated by the CWA and other water quality agency efforts to characterize the status of water bodies and plan and implement restoration efforts. Discussion of current agency data quality objectives and measurement quality objectives (DQOs and MQOs, respectively) is a critical part of this discussion and documentation. In addition to specific agency objectives, it is useful to gather information on whether the agency aligns its monitoring program with, or directly feeds into, local and federal monitoring and assessments. When the agency personnel later conduct a self-assessment, the DQOs, MQOs, and other information will factor into this assessment and might be reviewed and revised as a consequence.

The following information is discussed during the evaluation:

- Spatial sampling design—The water quality program personnel describe the sampling design(s) employed by the water quality agency (e.g., how the water quality agency determines sampling locations, such as using a rotating basin approach, a probability-based approach, or via fixed stations). In addition, the water quality agency identifies the various water body types for which a monitoring and assessment program exists, as the design might vary among resource types.
- Index periods—The water quality agency clarifies whether a seasonal index period exists by indicator and/or assemblage and whether considerations are given for index periods during attenuated flows.
- Chemical/physical/whole effluent toxicity (WET) assessment—To clarify the design and logistics of the water quality agency's sampling regime (e.g., chemical, physical, WET), the agency personnel provide the reviewer with specifics regarding survey design, parameters and indicators, sampling frequency, sampled media (i.e., water, sediment, fish tissue), and the type of samples collected (e.g., grabs, composites). In addition, the group identifies goals of the sampling, such as characterizing ambient conditions, long-term trend assessments, and the determination of reference conditions. Finally, agency personnel provide the reviewer with information regarding laboratory support, specifically quality assurance/quality control (QA/QC) procedures and analytical costs.
- Reference condition—Agency personnel provide information on whether reference sites have been established, and if so, how many and for what period. The water quality agency provides additional detail about reference conditions, such as how reference is determined (e.g., reference site selection), and explanation of the spatial organization of reference sites and the degree to which these sites are stratified by landscape or other classification schemes and method for determining nonattainment of reference condition (i.e., membership or non-membership in a set of reference sites).

- Data processing and management—A relational database is essential to a highly rigorous biological assessment program. The water quality agency provides information on several technical elements related to data: (1) how biological, chemical, and physical data are stored and whether analysis can be conducted across multiple sampling types and data sets; (2) data management QA/QC procedures (including any documentation); and (3) the accessibility of these data to both agency personnel and outside parties.
- Basin assessments—The water quality agency responds to questions about the scale of basin assessments (e.g., using hydrologic unit code [HUC] units as a basis for expressing spatial scale), how basins are selected, the number of sites in a typical assessment unit (e.g., site density), and the number of basin assessments the water quality agency conducts each year. In addition, any stratifying factors are discussed, such as watershed area or stream order, flow, and the total number of sampling sites. Analysis of the data acquisition process culminates with a discussion of the study planning process to determine the level of integration, if any, of the various monitoring disciplines and interactions with water quality management programs. Finally, to garner an understanding of the assessment process, the sequence of data analysis and reporting will be determined and any logistical concerns identified.
- Monitoring strategy—The water quality agency provides the latest version of its monitoring strategy for review and responds to questions about the frequency of updates. Through discussion the reviewer will establish whether DQOs are clearly defined and evaluate the usefulness of the strategy to guide implementation of the monitoring program and to ensure use of the information to support water quality program information needs.
- Resources—The water quality agency provides specifics regarding the allocation of full time employees (FTEs), particularly how they are allocated to monitoring and assessment for each of the major scientific disciplines and the proportion of monitoring and assessment FTEs compared to those devoted to other water quality management programs. The water quality agency should provide an organizational table for the CWA components of the various programs at the staff level, and it should include any contracted resources. Finally, the water quality agency should identify current funding sources, any existing resource limitations, and what additional resources, if any, are needed.

3.3.3 Reporting and Listing (CWA sections 305[b] and 303[d]) and TMDLs

This part of the evaluation deals with the process of producing integrated CWA section 305(b) and 303(d) reports, which identify waters with impaired or threatened uses, and TMDLs. These reports are often used to delineate program priorities and allocate resources, and the information in these reports will help the reviewer make determinations about how its biological assessment program is used.

- Identification of waters with impaired or threatened uses—The water quality agency provides information on the procedures, protocols, and assessment methods for identifying waters with impaired or threatened uses. The water quality agency provides details on what data (biological, physical, and/or chemical) and methodology are used to determine aquatic life use impairments, and whether such impairments are based on assessment of aquatic life assemblages. Discussion can include the degree to which impairments are characterized for level of severity, extent, and cause. Finally, the water quality agency provides details on the extent to which the state's waters have been assessed and what percentage of the total waters this figure comprises.
- Data acquisition and management process—The water quality agency explains the process for making assessments of condition and status, including how the data and information is documented and quality controlled and protected against unauthorized changes. The water quality agency also describes requirements regarding any data acquired by outside organizations (e.g., volunteer groups, water collaboratives), such as admission requirements and accuracy determinations. Finally, the reviewer evaluates the water quality agency's legislation (if any) pertaining to data management.
- CWA section 303(d) list topics—The water quality agency should describe the extent to which biological assessment information has been used to identify waters with impaired or threatened uses, under which 305(b)/303(d) integrated reporting categories such waters are assigned, and how the information is used in the planning process for establishing TMDL development schedules as part of the 303(d) list submittal. The water quality agency should also describe and discuss any issues concerning the integration of biological information into one assessment methodology for both CWA section 305(b) and 303(d) reporting.
- CWA section 303(d) list and TMDL development and implementation topics—The water quality agency should describe the extent to which data from biological assessments and stressor identification evaluations are used in the development of TMDLs and the evaluation of their implementation. Finally, the reviewer will want to discuss any specific CWA section 303(d) or TMDL resource considerations.

3.3.4 Water Quality Standards

The WQS section of the review focuses on the development and integration of designated aquatic life uses and biological criteria in the state's WQS program. WQS are the basis for judging the effectiveness of water quality management programs. The water quality agency should provide all participants with a copy of the state's WQS during the evaluation, and the reviewer asks participants to refer to specific parts of the document as they become relevant during the discussion.

- General issues—The water quality agency describes the basis of the agency's WQS, such as how chemical water quality criteria are derived and whether site-specific criteria have ever been developed. The water quality agency describes its antidegradation policy and implementation procedures. The discussion should also include how the monitoring and assessment program is integrated with the WQS program.
- Designated uses—The water quality agency should provide a description of its aquatic life use designations and explain the process for assigning uses to water bodies. The reviewer will want the agency to describe any other special considerations, such as tributary rules and application of default uses. In addition, any triggers for re-designations should be described. The water quality agency should describe what it recognizes as waters meeting the CWA section 101(a)(2) goals.
- Use attainability analysis (UAA)—The water quality agency should explain its protocol for conducting a UAA and describe what data or information might initiate the process. Discussion of current technical issues or obstacles encountered when conducting UAAs can be included to help determine need for additional biological assessment information or other types of environmental data.
- Biological criteria—The water quality agency provides the reviewer with information to determine whether biological criteria have been developed and whether such criteria are narrative, numeric, or both. Secondly, participants describe habitat assessments and associated criteria, if applicable. The agency provides information to help the reviewer understand the linkage between biological criteria and aquatic life designated uses and how this information has been used to support water quality management programs.

3.3.5 Integration of Monitoring, Reporting, Standards, and Management

Integrating information gathered from monitoring and assessment efforts with other water quality management programs is integral to the overall program's effectiveness. The topics below are designed to assess the state's development, use, and integration of biological assessment information into water quality management programs.

- Indicators for surface waters—The water quality agency should describe its existing measures of the effectiveness of its water quality management programs. In addition, the agency should gauge the dependency of these indicators on monitoring data and identify the most important measures of water quality management program success.
- Program integration—The water quality agency explains how water quality management programs have relied on information gathered from ambient monitoring and assessment, focusing discussion on specific programs, including WQS, nonpoint source assessment and management, TMDLs, NPDES permitting, CWA section 404/401 dredge and fill permits, and any other important permitting and planning schemes. The agency should explain how data gathered via monitoring and assessments are viewed in context of their importance to application to other water quality management programs.

- Training—The water quality agency provides information on training of agency program personnel, including the depth of training and its frequency. In addition, the water quality agency clarifies whether such training is extended to outside entities affected by management programs.

3.3.6 Self-Assessments

During the on-site review, the water quality agency completes two self-assessments. In the self-assessments, the reviewer guides the water quality agency through discussion questions (see Appendix C) to discuss how its existing program would respond to given situations and to consider what additional technical capability would optimize its program capability and efficiency. Cross program discussion will foster a more complete understanding within the agency of whether the current biological assessment program is providing the needed data and information in the appropriate time frame to support multiple water quality programs and potentially identify areas where technical changes would enhance use of the data and better support agency water quality program goals and objectives.

The water quality agency is asked to modify the discussion questions prior to the on-site evaluation to make them as relevant and applicable as possible, including substituting any terminology (e.g., specific types of aquatic resources). Agency personnel proceed through each of the discussion questions and summarize how the programs currently incorporate biological assessment information to support their programs and develop recommendations for improvements. Agency personnel are encouraged to include comments describing each answer and specifics on how the current state program would respond to the discussion question. Upon completion, the reviewer collects the information and recommends and uses them to help develop recommendations for technical development of the biological assessment program to be included in the technical memorandum.

3.4 Part 2: Technical Elements Evaluation

Following a brief presentation regarding the technical elements evaluation process, the reviewer leads a discussion about the 13 technical elements (described in chapter 2). During this discussion participants provide input on scoring (see chapter 2 and Appendix E). Once a score has been assigned for each of the 13 elements, the numbers are tabulated and converted to a percentage that yields the agency's level of rigor. The water quality agency also provides information about any in-progress improvements to the biological assessment program that will result in the elevation of the score for specific technical elements.

3.4.1 Technical Elements of State Biological Assessment Programs: A Process to Evaluate Program Rigor and Comparability

The review typically begins with an overview presentation of the evaluation process. The presentation can include ways states and tribes can determine their current level of rigor and how to use this information to achieve specific milestones to improve the overall level of program rigor. The overview can also include examples of previous assessments, specifically those from the EPA regional pilots that were conducted annually during 2002–2008 (Yoder and Barbour 2009; this document). The presentation might also include general recommendations that were made to the pilot states and tribes, which prescribe implementing high-level biological assessment programs as a continual, iterative process involving the creation of regional working groups consisting of water quality agency staff and regional EPA personnel.

3.4.2 Technical Elements Checklist

As described in Chapter 2, the 13 technical elements checklist (see Appendix E) is used to assign a level of rigor to a water quality agency's biological assessment program. Agency personnel and the reviewer will discuss the basis for the scores using the checklist for each of the 13 elements. The reviewer will assign a preliminary score for each of the 13 elements and take notes regarding the score's justification and any ongoing water quality agency efforts and/or program developments that would affect the score. A tour of field and/or laboratory facilities might also be conducted during this portion of the review. Once each of the 13 elements has been scored, the results are tabulated and a score is assigned. These results are discussed by the review team and steps to address program gaps are identified. The score determines the level of rigor of an agency's biological assessment program. The water quality agency and reviewer will discuss the results of the technical elements exercise during the on-site visit and through follow-up conversations after the technical memorandum has been received and reviewed by the water quality agency.

3.5 Preparation of Technical Memorandum

The final output of the biological assessment program evaluation is the technical memorandum. Using the detailed information and documents provided by the water quality agency, the reviewer prepares a technical memorandum that summarizes the agency's biological assessment program, assigns the program a level of rigor, and justifies this assignment by providing the scoring's rationale. The technical memorandum includes recommendations on how the water quality agency can improve its biological assessment program and the development and use of numeric biological criteria, and on what steps it can take to achieve a higher level of rigor. These recommendations typically include enhancements relative to design, methodology, and execution of credible data.

Following completion of the technical memorandum, the reviewer submits it to the water quality agency and EPA regional staff for review and comment. Once the comments are received, they are incorporated into a final version. A template for the technical memorandum is available in Appendix D.

3.6 Action Plan Development

The ultimate goal of the biological program review is to produce the data and information needed by water quality agencies to strategically plan and allocate resources to develop and support a high-quality biological assessment program. In addition to evaluating the technical elements of a biological assessment program, identification of water quality program information needs (e.g., CWA section 303[d] listing, TMDLS, NPDES, nonpoint sources) and the flow of data from the monitoring program to the different water quality programs is an essential part of the evaluation. The program review produces technical recommendations for development of a high-quality biological assessment program and for effective use of the data and information that the technical program will generate.

In 2006 EPA Region 5 convened a region and state workshop on development of biological assessment and criteria programs. A central theme at the workshop was the importance of parallel efforts to:

- Establish early dialogue between management and technical staff to determine how high quality biological assessment information will be incorporated into the water management program. This dialogue is critical to ensure that the monitoring program plans for the design and production of data and information that will support water program information needs.
- Plan for the appropriate use of biological assessment information as the monitoring and assessment program's level of technical rigor increases. At all levels of technical development, biological assessment information can be used to support water quality decisions. The degree of confidence with which this can be done varies depending on the questions being addressed. The information produced by a program with a low level of rigor might be used to support screening for high-quality or severely degraded conditions (e.g., looking for "hot spots" that need immediate attention) and to identify water quality limited waters. Additionally, the biological assessment methods characteristic of a low level program might be used to support special studies as long as the degree of confidence (e.g., within site variability) is characterized and documented. As the level of program rigor is increased, more comprehensive and detailed condition assessments can be produced to further support CWA section 305(b) reporting and 303(d) listing decisions and report environmental outcomes from water quality management actions. As the state further develops and refines its biological assessment measures in conjunction with chemical, physical, WET, and landscape assessments, the monitoring and assessment program is increasingly able to provide information that contributes to stressor identification and development of attainable restoration targets.

Based on the discussions with the 23 program reviews done to date, the technical program needs to be developed within context of management needs and agency policy so that the information ultimately produced is used to support water quality management. For example, a biological assessment program with a high level of rigor might have the technical capability to develop biological measures sensitive to early changes in biological assemblages. The agency might consider incorporating these measures into its numeric biological criteria and refining its aquatic life uses to support protection of excellent and good conditions and implement preventive actions. In the pilot states where the dialogue between the monitoring program and the parts of the water program that use the data did not occur regularly, biological assessment information to support water quality management had not been fully realized.

3.7 Summary

The integration of rigorous biological assessments with other environmental data and assessments (e.g., chemical, WET, physical, landscape) is important for developing a comprehensive, data-driven but cost effective approach to support water quality management (USEPA 2011c). Despite advancements and successes in water quality management since the CWA was enacted, pollutants (e.g., pathogens, metals, nitrogen, and phosphorus pollution) continue to be major causes of water quality degradation. Additionally, the impact of other significant stressors, including habitat loss and fragmentation, hydrologic alteration, invasive species, and climate change, can be better understood using analytical tools and information that can operate at the ecosystem scale, such as biological assessments.

The biological assessment program review can be a first step toward identifying the specific actions a water quality agency can take to attain a rigorous biological assessment program. Additionally, an agency's overall ability to make management decisions is enhanced by using biological assessment to more precisely define designated aquatic life uses, develop numeric biological criteria, and associate biological response to chemical, physical, and landscape data (USEPA 2011c). The results of the review are intended to inform incremental technical development, future use refinements, and biological criteria derivation in context of sound scientific information and well-integrated monitoring and assessment information. For example, Minnesota's biological assessment program underwent a review in 2005 and then developed a plan with milestones to implement the review recommendations. The review process helped Minnesota Pollution Control Agency produce a detailed plan for technical program development to support refining the state's designated aquatic life uses and development of numeric biological criteria for streams and rivers.[8] Likewise, the California biological assessment program underwent a technical elements review in 2009. At the time of the review, California was already implementing a plan to develop its biological assessment program, but participation in the review process helped California align its program to the national elements framework. This helped California reinforce the importance of several key program elements (e.g., reference conditions, data management) and helped secure sustained management support. In 2009 the state initiated a public process to develop biological objectives (numeric biological criteria) for perennial streams and rivers.[9] This effort has included the development of guidance for selecting and evaluating candidate causes of biological impairment in different regions of the state, using the EPA's causal assessment process as a starting point. The biological objectives will be used to establish numeric scoring tools for measuring stream ecological integrity and define numeric thresholds needed to protect the state's designated aquatic life uses.

Aquatic life can vary from water body to water body. One major challenge in defining and assessing designated aquatic life uses is separating the natural variability that is a function of water body type and the ecological region from the variability that results from exposure to

[8] http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-rulemaking/tiered-aquatic-life-use-talu-framework.html

[9] http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml

stressors. Rigorous biological assessment programs can provide the detailed information required to more precisely define the expected biotic community for a water body and derive numeric biological criteria. By accounting for natural variability in aquatic systems, rigorous biological assessments can help reduce a source of uncertainty and error in water quality management. Additionally, in nature there is a continuous gradient of biological response to increasing exposure to stressors. A rigorous biological assessment program can support other agency water quality programs with the technical capability to discriminate levels of biological response along a stressor gradient to help identify and protect high-quality waters and set attainable restoration goals for degraded waters.

By conducting rigorous biological assessments in conjunction with chemical, WET, physical, and landscape data and assessments, more detailed relationships between the aquatic resource, stressor agents, and management actions can be developed. This means that an agency's biological assessment program can provide data and information for more than general status assessments as required by CWA section 305(b) and that can be used to inform impact assessments, studies, and investigations to support an agency's section 303(d) list, TMDL, NPDES permitting, and nonpoint source programs. Each of these programs relies on monitoring and assessment and the WQS programs to provide an accurate delineation of impairments and their associated causes, as well as determine attainment of specific requirements (e.g., criteria) on which calculations of water quality based limits are based.

The biological assessment program review process provides information and technical recommendations to the agency to further develop its technical rigor and to enhance program application. It is the agency's decision on when and how to implement the review results and recommendations for program improvements. Involvement of EPA staff in the review process is recommended to align agency efforts and resources to support the desired program development and foster agency partnerships. For example, regional EPA staff was involved throughout the Minnesota review and were instrumental is aligning EPA support and assistance. In California, strong and sustained support from regional EPA staff helped consolidate the state's biological assessment infrastructure development and enabled the state to rapidly develop the technical basis for the state's biological criteria. If an agency is interested in conducting a biological assessment program review, it is recommended that agency personnel contact EPA's regional or headquarters biological criteria program for further information and to plan a review.

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Acronyms and Abbreviations

BCG	biological condition gradient
BMP	best management practice
BPJ	best professional judgment
CALM	Consolidated Assessment and Listing Methodology
CWA	Clean Water Act
DELT	deformities, erosions, lesions, and tumors
DQO	data quality objective
EOLP	Erie Ontario Lake Plain
EPA	U.S. Environmental Protection Agency
EPT	ephemeroptera, plecoptera, trichoptera taxa
FTE	full-time employee
GIS	geographic information system
HELP	Lake Huron/Lake Erie Plain
HUC	hydrologic unit code
IBI	index of biological/biotic integrity
IT	information technology
MDEP	Maine Department of Environmental Protection
MQO	measurement quality objective
NPDES	National Pollutant Discharge Elimination System
NYSDEC	New York State Department of Environmental Conservation
Ohio EPA	Ohio Environmental Protection Agency
QA	quality assurance
QC	quality control
PAH	polycyclic aromatic hydrocarbon

RDBMS	relational database management system
SOP	standard operating procedure
TMDL	total maximum daily load
UAA	use attainability analysis
WET	whole effluent toxicity
WQS	water quality standards
WSA	Wadeable streams assessment

GLOSSARY

aquatic assemblage	An association of interacting populations of organisms in a water body; for example, fish assemblage or a benthic macroinvertebrate assemblage.
aquatic community	An association of interacting assemblages in a water body, the biotic component of an ecosystem.
aquatic life use	A beneficial use designation in which the water body provides, for example, suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms.
attribute	The measurable part or process of a biological system.
benthic macroinvertebrates or benthos	Animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard no. 30 sieve (28 meshes per inch, 0.595-mm openings); also referred to as benthos, infauna, or macrobenthos.
best management practice	An engineered structure or management activity, or combination of those, that eliminates or reduces an adverse environmental effect of a pollutant.
biological assessment or bioassessment	An evaluation of the biological condition of a water body using surveys of the structure and function of a community of resident biota.
biological criteria or biocriteria	Narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions; as such, biological criteria serve as an index of aquatic community health.
biological indicator or bioindicator	An organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions.
biological integrity	The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in a region.

biological monitoring or biomonitoring	Use of a biological entity as a detector and its response as a measure to determine environmental conditions; ambient biological surveys and toxicity tests are common biological monitoring methods.
biological survey or biosurvey	Collecting, processing, and analyzing a representative portion of the resident aquatic community to determine its structural and/or functional characteristics.
Clean Water Act	The act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 *et seq*.
Clean Water Act 303(d)	This section of the act requires states, territories, and authorized tribes to develop lists of impaired waters for which applicable WQS are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that the jurisdictions establish priority rankings for waters on the lists and develop TMDLs for the waters. States, territories, and authorized tribes are to submit their lists of waters on April 1 in every even-numbered year.
Clean Water Act 305(b)	Biennial reporting requires description of the quality of the nation's surface waters, evaluation of progress made in maintaining and restoring water quality, and description of the extent of remaining problems.
criteria	Elements of state water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.
DELT	Presence of deformities, erosions, lesions, and tumors as a measure of organism health, typically assessed for fish.
designated uses	Those uses specified in WQS for each water body or segment whether or not they are being attained.
disturbance	Human activity that alters the natural state and can occur at or across many spatial and temporal scales.
ecoregion	A relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

function	Processes required for normal performance of a biological system (might be applied to any level of biological organization).
guild	A group of organisms that exhibit similar habitat requirements and that respond in a similar way to changes in their environment.
historical data	Data sets from previous studies, which can range from handwritten field notes to published journal articles.
index of biological/biotic integrity	An integrative expression of site condition across multiple metrics; an IBI is often composed of at least seven metrics.
invasive species	A species whose presence in the environment causes economic or environmental harm or harm to human health. Native species or nonnative species can show invasive traits, although that is rare for native species and relatively common for nonnative species. (Note that this term is not included in the biological condition gradient [BCG].)
least disturbed condition	The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a water body within a class or region. Such waters have the least amount of human disturbance in comparison to others in the water body class, region, or basin. Least disturbed conditions can be readily found but can depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition can change significantly over time as human disturbances change.
metric	A calculated term or enumeration that represents some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.
minimally disturbed condition	The physical, chemical, and biological conditions of a water body with very limited, or minimal, human disturbance.
multimetric index	An index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score before being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition. See **index of biological/biotic integrity.**

narrative biological criteria	Written statements describing the structure and function of aquatic communities in a water body that support a designated aquatic life use.
native	An original or indigenous inhabitant of a region; naturally present.
nonnative or intentionally introduced species	With respect to an ecosystem, any species that is not found in that ecosystem; species introduced or spread from one region of the United States to another outside their normal range are nonnative or non-indigenous, as are species introduced from other continents.
numeric biological criteria	Specific quantitative measures of the structure and function of aquatic communities in a water body necessary to protect a designated aquatic life use.
periphyton	A broad organismal assemblage composed of attached algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates.
rapid bioassessment protocols	Cost-effective techniques used to survey and evaluate the aquatic community to detect aquatic life impairments and their relative severity.
reference condition (biological integrity)	The condition that approximates natural, unaffected conditions (biological, chemical, physical, and such) for a water body. Reference condition (biological integrity) is best determined by collecting measurements at a number of sites in a similar water body class or region undisturbed by human activity, if they exist. Because undisturbed conditions can be difficult or impossible to find, minimally or least disturbed conditions, combined with historical information, models, or other methods can be used to approximate reference condition as long as the departure from natural or ideal is understood. Reference condition is used as a benchmark to determine how much other water bodies depart from this condition because of human disturbance. See **minimally disturbed condition** and **least disturbed condition**

reference site

A site selected for comparison with sites being assessed. The type of site selected and the types of comparative measures used will vary with the purpose of the comparisons. For the purposes of assessing the ecological condition of sites, a reference site is a specific locality on a water body that is undisturbed or minimally disturbed and is representative of the expected ecological integrity of other localities on the same water body or nearby water bodies.

sensitive taxa

Taxa intolerant to a given anthropogenic stress; first species affected by the specific stressor to which they are *sensitive* and the last to recover following restoration.

sensitive or regionally endemic taxa

Taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often because of unique life history requirements. Can be long-lived, late-maturing, low-fecundity, limited-mobility, or require mutualist relation with other species. Can be among listed endangered/threatened or special concern species. Predictability of occurrence often low; therefore, requires documented observation. Recorded occurrence can be highly dependent on sample methods, site selection, and level of effort.

sensitive - rare taxa

Taxa that naturally occur in low numbers relative to total population density but can make up large relative proportion of richness. Can be ubiquitous in occurrence or can be restricted to certain microhabitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or coldwater obligates; commonly k-strategists (populations maintained at a fairly constant level; slower development; longer lifespan). Can have specialized food resource needs or feeding strategies. Generally intolerant to significant alteration of the physical or chemical environment; are often the first taxa observed to be lost from a community.

sensitive - ubiquitous taxa

Taxa ordinarily common and abundant in natural communities when conventional sample methods are used. Often having a broader range of thermal tolerance than sensitive or rare taxa. These are taxa that constitute a substantial portion of natural communities and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.

stressors	Physical, chemical, and biological factors that adversely affect aquatic organisms.
structure	Taxonomic and quantitative attributes of an assemblage or community, including species richness and relative abundance structurally and functionally redundant attributes of the system and characteristics, qualities, or processes that are represented or performed by more than one entity in a biological system.
taxa	A grouping of organisms given a formal taxonomic name such as species, genus, family, and the like.
taxa of intermediate tolerance	Taxa that compose a substantial portion of natural communities; can be r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics). Can be eurythermal (having a broad thermal tolerance range). Can have generalist or facultative feeding strategies enabling use of relatively more diversified food types. Readily collected with conventional sample methods. Can increase in number in waters with moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration.
threatened waters	Waters that are currently attaining water quality standards, but which are expected to exceed water quality standards by the next 303(d) listing cycle.
tolerant taxa	Taxa that compose a small proportion of natural communities. They are often tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution- or habitat-induced stresses. They can increase in number (sometimes greatly) in the absence of competition. Commonly r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), able to capitalize when stress conditions occur; last survivors.
total maximum daily load	The calculated maximum amount of a pollutant a water body can receive and still meet WQS and an allocation of that amount to the pollutant's source.
water quality management (nonregulatory)	Decisions on management activities relevant to a water resource, such as problem identification, need for and placement of best management practices, pollution abatement actions, and effectiveness of program activity.

water quality standard A law or regulation that consists of the designated use or uses of a water body, the narrative or numerical water quality criteria (including any biological criteria) that are necessary to protect the use or uses of that water body, and an antidegradation policy.

whole effluent toxicity The aggregate toxic effect of an aqueous sample (e.g., whole effluent wastewater discharge) as measured by an organism's response after exposure to the sample (e.g., lethality, impaired growth or reproduction); WET tests replicate the total effect and actual environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants.

Appendix A: Agenda for On-Site Interaction Meeting

State/Tribal Agency Biological Assessment Program Evaluation

AGENDA

Day 1	Date
	Building #____ Room ____
9:30–10:00 am	**Welcome and Introductions** • Refinements to the agenda • General purpose and overview
10:00–11:30	**[Agency] Biological Assessment Program Review & Development** • Key concepts and examples • Development of state programs • U.S. Environmental Protection Agency (EPA) methods and key documentation
11:30–1:00 pm	**LUNCH**
1:00–2:00	**Overview of [name of water quality agency to be reviewed] Biological Assessment Program by [Agency] staff** • Brief history of [water quality agency] biological program • Current developments and updates
2:00–5:00	**[Agency] Monitoring & Assessment Program—following list of annotated discussion topics** Monitoring & Assessment Program ▪ Water body types ▪ Spatial design ▪ Basin assessments

- Indicators—chemical, physical, biological
- Data management
- Resources for monitoring and assessment

Reporting & Listing

- Delineation of impairments
- Assessment process
- 305(b)/303(d)
- Other program support

DAY 2 Date

Building #____ Room ____

9:00–10:30 am **[Agency] Managers' Overview of Biological Assessment-based Programs**

- Process overview
- Concepts and examples–implications for water quality standards (WQS)

10:30–11:30 **Assessment and Integration**

- Using indicators to measure effectiveness
- Using monitoring and assessment to support water quality management programs

11:30–1:00 pm **LUNCH**

1:00–3:00 **Water Quality Standards**

- General description of [Agency] WQS
- Structure of designated uses and attendant criteria
- Aquatic life uses and biological criteria

- Use attainability analyses (UAAs), site-specific modifications, etc.
- Implications

3:00–5:00 **Agency Self-Assessments**

- Complete agency self-assessments and discuss results (might be beneficial to have the agency complete the self-assessments prior to the biological assessment program evaluation)

DAY 3 Date

Building #____ Room ____

8:30–11:30 am **Technical Elements Review of [Agency] Biological assessment Program**

- Overview of technical elements review process
- Scoring each element in the technical elements checklist

11:30–1:00 pm **LUNCH**

1:00–2:00 **Technical Elements Review (continued)**

2:00–4:30 **Q&A**

- Follow-up on any of the previous days' topics

APPENDIX B: INTERVIEW TOPICS FOR AGENCY REVIEW

State/Tribal Monitoring and Assessment and Water Quality Standards Program Interviews: Annotated List of Discussion Topics

Introduction

A critical component of the biological program review is the detailed interviews of key agency program managers and staff. The purpose of these discussions is to understand the existence and extent of data-driven water quality management. These interviews are an opportunity to better define and understand the uses of monitoring and assessment information in the water quality agency and to determine the opportunities, incentives, impediments, and barriers to the fuller use of this information in support of water quality management programs. In addition, the interviews examine the intersections of biological assessment with water quality standards (WQS), designated aquatic life uses, and criteria.

The biological program review is focused on current and planned uses of monitoring and assessment information in support of all relevant water quality management programs. This includes the following broad program areas that water quality management agencies have in common:

- WQS focusing on designated uses and criteria
- Reporting and listing (watershed assessments, Clean Water Act [CWA] section 305(b)/303(d) reporting) and total maximum daily load (TMDL) development schedules
- Water quality planning, TMDL development and implementation, nonpoint source assessment and management, dredge and fill (CWA section 404/401)
- National Pollutant Discharge Elimination System (NPDES) program (CWA section 402)

Managers and staff who can speak to the operation and management of these programs should attend the interview when these topics are discussed.

The following topics are intended to guide the interview process. These topics are also intended to help the agency determine who from the agency programs should attend each day's discussions.

Monitoring and Assessment Program

Monitoring is the systematic collection of chemical, physical, and biological (including WET) data in the ambient environment. Assessment is the analysis and transformation of that data into meaningful information that includes attainment/nonattainment determinations, characterization of impairments (extent and severity), associations between impaired status and causes (i.e., agents) and sources (i.e., activity or origin), and data and information to develop improved tools, indicators, criteria, and policies. Monitoring and assessment supports the reporting that is required by the CWA (sections 305[b], 303[d] list, 319, etc.) and that is used by the agency for allied purposes (watershed assessments, site-specific assessments, planning, TMDL development, etc.). The following are core topics for discussion. The agency might wish to add other topics.

1. Spatial design
    - Is a rotating basin approach used? Describe the sequence and cycle and, linkages to management activities.
    - Is the spatial design probability-based (scale and scope, statewide, regional, etc.)?
    - Fixed station (e.g., tenure and history)
    - What resource types are covered (wadeable streams, large rivers, great rivers, lakes, wetlands, headwater streams, etc.)?
    - Is the spatial design for the monitoring program aligned with, or directly feeding into, other monitoring and assessment programs at the local, regional, or federal level?
2. Basin assessments
    - At what scale are assessments done (major basin, subbasin, watershed, subwatershed)? Hydrologic unit code (HUC) units?
    - What is the site-selection process (targeted, random, other)?
    - What stratifying factors are considered (watershed area, stream order, other)?
    - How many sites are assessed each year?
    - What site density (i.e., the number of sites allocated to a specific study area) is used?
    - What is the data analysis and reporting sequence?
    - What are the bottlenecks in data analysis and reporting?
    - Are there other significant logistical issues?
    - What study planning process is used? Are all affected disciplines integrated?
3. Index periods
    - Describe the seasonal sampling index periods by indicator (summer-fall, monthly, other).
    - Explain the flow attenuated considerations (loading estimates, event related, summer-fall low flow, etc.).
4. Biological (including WET)/chemical/physical assessment
    - What media are assessed (water, sediment, tissues, etc.)?

- What is the purpose of sampling (ambient characterization, model calibration, long-term trends, reference/background, etc.)?
- Which parameter groups are considered? How are the groups selected?
- What type of laboratory support is available?
- Describe the sampling design and logistics (survey design, frequency, grabs vs. composites).
- Are there exceedance issues (magnitude, duration, frequency)?

5. Reference condition
   - Have reference sites been established? For what purposes (e.g., biological criteria, nutrients, background conditions)?
   - How many reference sites are used?
   - What is the spatial organization and stratification (ecoregions, hydrologic units, physiographic regions, other)?
   - How is reference condition established (data driven, cultural, least affected)?
6. Data processing and management
   - How are data stored (WQX, other system)?
   - How are data accessed by staff for analysis?
   - What resources are dedicated to data management (full time employees [FTEs])?
   - What are the quality assurance/quality control (QA/QC) procedures for ensuring data quality?
   - What is the timetable for entry and validation?
   - Describe the ease of data availability within and outside the agency.
   - What is the demand for data from outside the agency?
7. Monitoring strategy
   - Discuss the latest monitoring strategy available (please provide a copy).
   - Is the strategy a useful document?
   - Should the strategy serve as documentation of data acceptability?
   - Are data quality objectives (DQOs) defined?
   - How frequently is the strategy updated?

8. Resources

   - How many FTEs are devoted to monitoring and assessment by discipline (chemical/physical, biological assessment, TMDL/modeling, etc.)?
   - What proportion of FTEs is devoted to water quality management programs? (provide a table of organization for the CWA parts of the water quality agency program)
   - What funding sources are available? What are their limitations? Is the agency leveraging resources with other programs?
   - Are current resources adequate? If not, what is needed?

Reporting and Listing (305[b]/303[d]) and TMDLs

Reporting and listing are the processes of producing the integrated CWA section 305(b)/303(d) report, which includes the list of waters with impaired or threatened uses and TMDL development schedules. The information contained in these reports and lists is not only important to determining the effectiveness of a water quality agency's water quality management programs, but is increasingly being used to set program priorities and allocate funding. Monitoring and assessment information is an indispensable element of this process and how it is generated and applied determines, in part, the accuracy of the statistics that are reported and used. Thus, it is important to determine and understand how each water quality agency uses monitoring and assessment information to support these determinations.

1. Delineation of impaired or threatened waters

   - What are the procedures and protocols for determining impaired waters (including extent and severity)?
   - What are the primary arbiters of impairment and threat?
   - What data qualifiers are used (analogs to the formerly used monitored and evaluated categories)?
   - What is the extent of extrapolation from single and aggregate sampling sites? How was this developed, and has it been tested?
   - What data are the basis of decisions about aquatic life use impairment (biological, chemical/physical, mix of both, best professional judgment [BPJ], etc.)?
   - Is determination of causes and sources of impairment and threat linked to an impairment or threat?
   - How are determinations of severity, extent, and incremental change made?

- How is the universe of resources defined (miles of rivers and streams, lake acres, etc.)?
- How does the water quality agency account for the proportion of resources that are actually assessed?

2. Assessment process
   - Explain “chain-of-custody.” Do the same staff who collect and analyze sampling data also produce the assessments? Are there any “hand-offs”?
   - How are data from volunteer organizations used? Are there “admission” requirements? Any testing of accuracy? Pressure to accept data?
   - How are data from other organizations handled? What are the acceptance requirements?
   - Are there requirements for credible data or similar legislation?
3. 305(b) reporting topics
   - How are trends assessed (e.g., tracking of aggregate condition through time, by resource type, designated uses, etc.)?
   - How is CWA section 305(b) reporting information used by agency to guide water quality management? Is it the 305(b) report viewed by management as a report card? Does it have other uses? Does it distinguish impairment by point and nonpoint sources? Any subsets within each?
   - What is the extent to which outside groups use 305(b) reporting information?
   - What would be the impact of any changes due to assessment method?
4. 303(d) listing and TMDLs
   - Describe the relationship between former CWA section 305(b) report and existing 303(d) list (e.g., conversion process, issues, concerns, gaps, and shortfalls).
   - Is TMDL development coordinated or aligned with ambient monitoring and assessment?
   - Are biological data used in the TMDL process? Are there any issues and concerns? Conflicts?
   - How are biological impairments considered? Which listing category?
   - Are there sufficient biological assessment tools available to help develop defensible TMDLs that will contribute to restoration of impaired aquatic life uses? If not, what is needed and how long will it take?

Water Quality Standards

WQS provide the basis for water quality management and for judging the effectiveness of water quality management programs.

- General WQS issues
  - Describe the structure of the water quality agency's current WQS (designated uses, criteria, and antidegradation policy and implementation procedures).
  - How are chemical water quality criteria derived? Any modifiers or adjustment factors?
  - How are existing uses determined?
  - When and where are site-specific criteria used? How many instances?
  - How would better monitoring and assessment affect the WQS process?
- Designated uses
  - Describe aquatic life designated uses in the state WQS (a copy of the relevant parts of the WQS is requested).
  - Are individual waters designated? Are there default uses? Undesignated waters? Tributary rules? Other issues?
  - What triggers individual water body designations? Are they always downgrades? Does anything trigger an upgrade? Is there a regular process for inventorying these needs?
  - Are there designated uses that are less than the CWA section 101(a)(2) goal uses? Are they defined?
  - Is there a process to use biological assessments to more precisely define designated aquatic life uses and develop numeric biological criteria to protect those uses?
  - What is the level of water quality agency interest in use of biological assessment to more precisely define uses (advantages, disadvantages, barriers to development and implementation)?
- Use attainability analysis (UAA)
  - Does the agency have experience with UAAs (number attempted/completed, problems, issues)?
  - Outline/describe the existing UAA process. Is it routine? Special project oriented? What triggers a UAA? What are preferred data and information requirements?

- How do stakeholders perceive the UAA process (pros and cons, requests for and by whom, etc.)?
- Has the emphasis on CWA section 303(d) listing increased the "interest" in UAAs?
- What criteria are used to determine attainability of uses?
- What are the likely stressors in your state? What are the sources of the stressors?

- Biological criteria
  - Have biological criteria been adopted or proposed (narrative, numeric)?
  - How are biological criteria linked to designated uses?
  - Are biological assessments used to more precisely define designated aquatic life uses and develop numeric biological criteria?
  - What are the advantages and disadvantages of biological criteria in WQS?
  - How would numeric biological criteria affect the use review process?
  - Describe habitat assessments and criteria.
  - What are stakeholder perceptions and viewpoints on biological criteria?

Assessment Integration Issues

The integration of monitoring and assessment information within water quality management programs is an important and emerging issue. The National Environmental Performance Partnership System promotes joint priority setting and planning through the increased use of environmental goals and indicators. Shared goals and milestones could be used to more comprehensively report to the public and environmental decision makers about the status of water resources in the water quality agency and to document progress in meeting these goals. The goals and milestones could also be used to more effectively target programmatic efforts at all levels. It is important to be able document achievements so that environmental successes are recognized, funding is maintained at appropriate levels, and effective management programs continue to be implemented. The following are aimed at assessing the water quality agency's efforts to develop and use indicators and integrate them into water quality management.

1. Indicators for surface waters
   - What efforts have been taken to develop a process for using environmental indicators to fulfill the role as a measure of the effectiveness of water quality management programs (provide any documentation)?
   - Are any implemented or practiced?
   - How dependent are these systems on monitoring data?

- What is the awareness of past U.S. Environmental Protection Agency (EPA) indicator development efforts (i.e., national indicators for surface waters, hierarchy of indicators, etc.)?
- Is there any recognition of indicator roles (i.e., stress, exposure, response roles of indicators)?
- What is (are) the most important measure(s) or indicator(s) of water quality management program success in your water quality agency?

2. Program integration
   - Are there any examples in which water quality management programs rely on ambient monitoring and assessment information?
   - Is monitoring and assessment information used to support:
     - The NPDES permitting process (e.g., reasonable potential determinations and permit compliance)? CWA section 402 NPDES program including stormwater phase I or II?
     - CWA section 319/nonpoint source planning and implementation?
     - CWA 404/401 process? Other programs?
   - How is monitoring and assessment information and resulting assessments and reports, regarded by the above programs (essential, useful, nice to have, inconsequential)?
3. Training
   - Are training opportunities afforded to staff and/or management?
   - How do these relate to indicators development, monitoring and assessment, biological assessment, or ecological principles in general?
   - Does your agency receive requests for field demonstrations (fish, bugs, sampling, etc.) for internal and external purposes?
   - Is training available for external entities?

Appendix C: Self-Assessments by State/Tribal Agency Managers

The self-assessment exercise is conducted during the on-site evaluation. The technical expert walks participants through a discussion of how biological assessment information can be more effectively used to support water quality program needs for information. It is important that representatives from different water quality programs participate in order to: (1) gain a cross-program understanding of how biological assessments can be used to support multiple water quality programs; (2) identify the type of biological assessment information needed by their programs and timing for information delivery; and, (3) identify efficiencies for more cost effective biological assessments. Programs interested in conducting a review do not need to complete these self-assessment questions in advance. The results of these discussions do not factor into scoring of the technical elements.

The topics and questions included in the worksheets are provided as examples that can be used to initiate cross program discussion.

SELF-ASSESSMENT 1

Use of biological assessments to protect aquatic life use

1. Answering these questions requires a thorough understanding of the aquatic life uses in your water quality agency's water quality standards law.
    - To know this, you have to be familiar with the aquatic life uses in your water quality standards and understand what parts, if any, of the aquatic life uses are assessed with biological assessment data.
2. For aquatic life uses that are assessed using biological assessment data, an estimate of what biological condition gradient (BCG) level, or levels, your water quality agency's uses provide protection is recommended;
    - To know this, the biological monitoring technical staff can determine (for example, by a consensus of professional judgment) to what BCG level(s) your water quality agency's biological criteria thresholds (e.g., numeric criteria, Rapid Bioassessment Protocol (RBP), or Index of Biological Integrity (IBI) ranges) provide protection. Alternatively, if your program does not have numeric biological criteria, the staff can evaluate what BCG level your state uses for listing biologically impaired waters. In other words, how does biologically-based aquatic life use attainment measured by numeric biological criteria and/or CWA section 303(d)-listing thresholds map to a BCG level?
    - Familiarity with your water quality agency's application of biological criteria thresholds in regulatory decision-making is important to help identify how biological assessment information can be used to guide the discussion on added value of further technical improvement (i.e., be familiar with findings that have triggered an agency response based on aquatic life use attainment as determined by biological assessment and criteria).
    - Example scenarios characteristic of situations your agency encounters are recommended to help focus the discussion and the identification of current strengths and limitations of the biological assessment program.

WORKSHEET FOR TOPIC 1: PROTECTION OF HIGH QUALITY WATERS

Example: A watershed with minimal impacts to aquatic systems from anthropogenic stress. Streams, wetlands, lakes, and rivers support high quality biological communities based on biological indices (e.g., benthic macroinvertebrates, algal, and/or fish assemblages). The presence of reproducing native species is documented. Downstream waters such as bays and estuaries support a range of biological conditions, including high quality biological communities in areas that are minimally impacted.

1. Does the existing biological assessment program provide information to detect declines in biological condition in high quality waters?

_____YES _____NO

2. If yes, does the program provide information to detect declines within the assigned aquatic life use class?

_____YES _____NO

If no to either of the above two questions, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 1: PROTECTION OF HIGH QUALITY WATERS (page 2)

3. Does the existing biological assessment program provide information to support an agency action to assign the highest quality waters to different aquatic life use categories?

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

4. Does the existing biological assessment program currently provide information to support agency decisions and actions (e.g., antidegradation policies, best management practices) to protect the highest quality waters?

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 2: PROTECTION OF CURRENT CONDITIONS

Example: A watershed with a mix of minimal to moderate impacts to aquatic systems from anthropogenic stress. Streams, wetlands, lakes, and rivers support a range of biological conditions based on biological indices (e.g., benthic macroinvertebrates, algal, and/or fish assemblages). The presence of reproducing native species has been observed in waters where there is minimal anthropogenic stress. Downstream waters such as bays and estuaries also support a comparable range of biological conditions and levels of anthropogenic stress.

1. Does the existing biological assessment program provide information to detect declines in biological condition?

_____YES _____NO

2. If yes to above, are the current indices sufficiently sensitive to detect incremental declines within the assigned aquatic life use class?

_____YES _____NO

If no to either of the above questions, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 2: PROTECTION OF CURRENT CONDITIONS (page 2)

3. Does the biological assessment program provide information that the agency could use to evaluate potential impacts on the aquatic community? (For example, a new and/or modification to an existing industrial, transportation, or residential development is proposed that might have an impact on aquatic life in the watershed.)

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 2: PROTECTION OF CURRENT CONDITIONS (page 3)

4. If an evaluation for potential impacts indicates that the proposed activity would result in a further decline in biological condition, would the biological assessment information used in the evaluation support an agency action to minimize or prevent the predicted decline?

_____YES _____NO

If yes, what changes to the type, amount, or quality of biological assessment information would be useful to provide better support?

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 3: PROTECTION OF IMPROVED CONDITIONS

Example: A watershed with mix of minimal to severe impacts from anthropogenic stress. Streams, wetland, lakes, and rivers support a range of biological conditions from poor to excellent based on biological indices (e.g., benthic macroinvertebrates, algal, and/or fish assemblages). The presence of reproducing native species is documented only in higher quality waters. Some of the severely impacted waters have been assigned a limited or modified aquatic life use based on the findings of a use attainability analysis. Incremental improvements in biological conditions in several water bodies have been observed. For a few of the severely impacted waters, incremental improvements have been observed but conditions still do not meet a higher use class. Downstream waters such as bays and estuaries also support a comparable range of biological conditions and levels of anthropogenic stress.

1. Does the existing biological assessment program provide information to detect incremental improvements in biological condition?

_____YES _____NO

2. If yes to above, are the current indices sufficiently sensitive to detect incremental changes within the assigned aquatic life use class?

_____YES _____NO

If no to either of the two questions above, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 3: PROTECTION OF IMPROVED CONDITIONS (page 2)

3. Does the biological assessment program produce information to support an agency decision to report and take action to protect improved aquatic life condition in a water body where incremental improvements have been observed?

_____YES _____NO

If yes, please identify the specific management programs currently supported by biological assessment data. Are there improvements to the type, quality, or delivery of the data that can enhance use of the data?

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 4: SUPPORT USE CLASSIFICATION

Example: A watershed with a mix of minimal to severe impacts from anthropogenic stress. Streams, wetlands, lakes, and rivers support range of biological conditions from poor to excellent based on biological indices (e.g., benthic macroinvertebrates, algal, and/or fish assemblages). The presence of reproducing native species in the higher quality waters is well documented.

1. Does the biological assessment program produce information to support refining an aquatic life use goal for water bodies?

_____YES _____NO

If no, what changes to the type, amount or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

SUMMARY WORKSHEET: SELF ASSESSMENT SESSION 1

Discussion Topics	YES	NO
1. Protect high quality waters		
2. Protect current conditions		
3. Protect improved conditions		
4. Support for use classification		

Summary observations and key recommendations:

SELF-ASSESSMENT 2

Use of biological assessments to support water quality management programs

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1. To answer these questions requires a thorough understanding of the information flow and management decision-making process within and between programs in your agency. In some cases this communication and decision-making may primarily occur at the technical staff level, but in other cases it may occur between program managers (e.g., between the permitting and the monitoring manager, or the water quality standards coordinator and the monitoring manager) or even at the level of the water Program Director or agency Commissioner.

   - The questions are most usefully answered during a cross-program group discussion that includes representatives from all programs and levels of management.

2. For state agencies with aquatic life uses that are assessed using biological monitoring data, it is helpful to estimate to what BCG level, or levels, your water quality agency's aquatic life uses and numeric biological criteria provide protection;

   - To know this, the biological monitoring technical staff can determine (for example, by a consensus of professional judgment) to what BCG level(s) your water quality agency's biological criteria thresholds (e.g., numeric criteria, RBP, modeled index (e.g. RIVPACS), or IBI ranges) provide protection. Alternatively, if your program does not have numeric biological criteria, the staff can evaluate what BCG level your state uses for listing biologically impaired waters. In other words, how does biologically-based aquatic life use attainment measured by numeric biological criteria and/or CWA section 303(d)-listing thresholds map to a BCG level?

3. The group answering this self-assessment should have some familiarity with your water quality agency's application of biological criteria thresholds in regulatory decision-making (i.e., be familiar with findings that have triggered an agency response based on aquatic life use attainment/non-attainment as determined by biological assessment and criteria).

4. Example scenarios characteristic of situations your agency encounters are recommended to help focus the discussion and the identification of current strengths and limitations of the biological assessment program.

WORKSHEET FOR TOPIC 1: SUPPORT FOR WATER QUALITY STANDARDS

1. Does the biological assessment program provide data to support derivation of numeric biological criteria?

_____YES _____NO

If yes, please list the water body types for which numeric biological criteria have been developed:

Primary Headwater Streams	_____YES	_____NO
Streams	_____YES	_____NO
Rivers	_____YES	_____NO
Large Rivers	_____YES	_____NO
Lakes	_____YES	_____NO
Wetlands	_____YES	_____NO
Estuaries	_____YES	_____NO
Other (add below)	_____YES	_____NO
[water body type]	_____YES	_____NO
[water body type]	_____YES	_____NO
[water body type]	_____YES	_____NO

If yes to any of the above, are there improvements or refinements to the type, amount, quality, or delivery of the data that would be useful? Please specify any recommendations for further technical development.

If no to any of the above, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 1: SUPPORT FOR WATER QUALITY STANDARDS (page 2)

2. Does biological assessment information, whether from monitoring or from peer reviewed literature, contribute to review of existing water quality criteria and/or to detection of the need for new criteria or site-specific modifications?

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 1: SUPPORT FOR WATER QUALITY STANDARDS (page 3)

3. Has your agency ever used biological assessments to assess effects or determine the need for criteria for observed stressors for which there are no existing criteria?

Potential examples are listed below.

Habitat alteration	_____YES	_____NO
Water withdrawal/flow alterations	_____YES	_____NO
Suspended sediment	_____YES	_____NO
Nutrient effects	_____YES	_____NO
Other [list below if needed]	_____YES	_____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 1: SUPPORT FOR WATER QUALITY STANDARDS (page 4)

4. During a triennial review, does the biological assessment program provide a list of waters that are attaining biological conditions higher than their currently assigned aquatic life use?

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 1: SUPPORT FOR WATER QUALITY STANDARDS (page 5)

5. Does the biological assessment program produce information to support designating a water body to an antidegradation tier?

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 2: SUPPORT FOR CWA SECTION 303(D) AND TMDL PROGRAMS

1. Does the biological assessment program provide data and information used to support assessments for CWA section 303(d) purposes?

_____YES _____NO

If yes, what changes to the type, amount, or quality of biological assessment information and/or the timing of data availability improve support to your program? (Please provide specific recommendations.)

If no, what additional type, amount, or quality of biological assessment information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 2: SUPPORT FOR CWA SECTION 303(D) AND TMDL PROGRAMS (page 2)

2. If biological assessment data has been used as the sole basis for putting one or more waters on the 303(d) list (Category 5 of the Integrated Reporting Guidance [IRG]) for failure to fully support the designated aquatic life use, was the non-support determination based on:

2a. Failure to meet a state numeric biological criteria? Or

2b. Conditions inconsistent with one or more narrative WQC?

_____YES _____NO

If yes for 2b, was the determination regarding failure to meet narrative water quality criteria based on:

- Numeric biological thresholds issued as guidance values, rather than having been incorporated into the state's WQS regulations _____
- Qualitative guidance on how to interpret biological assessment data _____
- Primarily, the best professional guidance of state agency staff _____

If yes for any of these aspects, what changes to the type, amount, or quality of biological assessment information and/or the timing of data availability would improve use of biological assessments as sole basis for 303(d) listing of water bodies?

If no, what changes to the type, amount, or quality of biological assessment information might lead to use of biological assessments as the sole basis for 303(d) listing of water bodies?

WORKSHEET FOR TOPIC 2: SUPPORT FOR CWA SECTION 303(D) AND TMDL PROGRAMS (page 3)

3. Has biological assessment data been used (in the absence of evidence of failure to meet one or more chemical or physical water quality criteria) as the basis for making an affirmative determination that one or more water bodies fully supports its designated aquatic life use, and thereby belongs in Category 1 or 2 of the IRG? (Here "an affirmative determination of full support" is intended to be distinguished from simply determining that available information does not justify concluding that aquatic life use is NOT supported, which would call for putting the water body in Category 3 of the IRG, as to aquatic life use.)

If yes, would changes to the type, amount, or quality of biological assessment information improve support to your program? (Please provide specific recommendations.)

_____YES _____NO

If no, what changes to the type, amount, or quality of biological assessment information (in the absence of evidence of failure to meet one or more chemical or physical water quality criteria) might lead to use of biological assessments as the basis for declaring a water to be fully supportive of its designated aquatic life use?

WORKSHEET FOR TOPIC 2: SUPPORT FOR CWA SECTION 303(D) AND TMDL PROGRAMS (page 4)

4. Does the biological assessment program provide data and information used in support of stressor identification analyses for waters identified as having impaired aquatic life use based on biological assessments? If yes, were any individual (e.g., a particular pollutant or altered flow) stressors identified? (Please list them.)

_____YES _____NO

If yes, were there any individual stressors for which biological assessment data was the sole basis of identifying the stressors? (Please list these stressors.)

If there were no individual stressors identified using only biological assessment data:

- How was biological assessment data used to supplement other kinds of data and information in the course of identifying individual stressors? (If possible, answer on a stressor-by-stressor basis)
- What, if any, categories of stressors (e.g., heavy metals, PAHs, nutrients) were identified using biological assessment data alone?

Would changes to the type, amount, or quality of biological assessment information and/or the timing of data availability provide better support for stressor identification?

_____YES _____NO

If so, please provide specific recommendations on improvements to the biological assessment program that would improve particular aspects of your stressor identification efforts.

WORKSHEET FORTOPIC 2: SUPPORT FOR CWA SECTION 303(D) AND TMDL PROGRAMS (page 5)

5. Does the biological assessment program provide data and information to support development of TMDLs?

_____YES _____NO

If yes, in which of the following aspects of TMDL development have biological assessment data played a direct role?

__ Calculating of the overall water body-pollutant loading capacity:

__ Selecting a margin of safety:

__ Identifying sources of the pollutant of concern:

__ Allocating loads among existing and future sources:

__ Other aspects:

For any of these aspects, what changes to the type, amount, or quality of biological assessment information and/or the timing of data availability would enable such information to play a larger role? (If possible, answer on a TMDL function-by-function basis).

If no, what changes to the type, amount, or quality of biological assessment information and/or the timing of data availability would enable such information to play a direct role in TMDL development? (If possible, answer on a TMDL function-by-function basis.)

WORKSHEET FOR TOPIC 3: SUPPORT FOR CWA SECTION 402 NPDES PROGRAM

1. Is biological assessment information used to support the CWA section 402 NPDES program?

_____YES_____NO

If yes, how is the NPDES program supported by biological assessment information?

Impact assessment	_____YES_____NO
Water quality-based effluent limits (WQBELs)	_____YES_____NO
Mixing zone determination	_____YES_____NO
WET limits and monitoring	_____YES_____NO
Causal diagnosis	_____YES_____NO
Other (please specify)	_____YES_____NO

Would changes to the type, amount, or quality of biological assessment information and/or the timing of data availability improve support to your program? (Please provide specific recommendations.)

If no to any of the above questions, what additional type, amount, or quality of technical information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 3: SUPPORT FOR CWA SECTION 402 NPDES PROGRAM (page 2)

2. During NPDES permit reissuance, is information about biological condition downstream of the point source reviewed for evidence of any need to evaluate and potentially change permit limits to address observed problems? If yes, does the biological assessment program provide data and information to support the NPDES program for this purpose?

_____YES_____NO

If yes, would changes to the type, amount or quality of biological assessment information and/or the timing of data availability improve support to your program? (Please provide specific recommendations.)

If no, what additional type, amount, or quality of technical information would be useful? Would changes to data collection, data analysis, and/or internal communication (e.g., notification of permit reissuance schedule) contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 4: SUPPORT FOR CWA SECTION 319 PROGRAM

1. Does the biological assessment program provide data and information to support implementation of the CWA section 319 program?

_____YES _____NO

If yes, would changes to the type, amount, or quality of biological assessment information and/or the timing of data availability improve support to the program? (Please provide specific recommendations.)

If not, what additional type, amount, or quality of technical information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 5: SUPPORT FOR SECTION 401 CERTIFICATION

1. Does the biological assessment program provide data and information to support your agency's section 401 certification program?

_____YES _____NO

If yes, would changes to the type, amount, or quality of biological assessment information and/or the timing of data availability improve support to the program? (Please provide specific recommendations.)

If not, what additional type, amount, or quality of technical information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

WORKSHEET FOR TOPIC 6: SUPPORT FOR [insert program]

1. Does the biological assessment program provide data and information to support implementation of _______________________?

_____YES _____NO

If yes, would changes to the type, amount, or quality of biological assessment information and/or the timing of data availability improve support to the program? (Please provide specific recommendations.)

If not, what additional type, amount, or quality of technical information would be useful? Would changes to data collection and analysis and/or internal communication contribute to the use of biological assessments? Are there additional recommendations?

SUMMARY WORKSHEET: SELF ASSESSMENT 2

Discussion Topics	YES	NO
1. Water Quality Standards		
2. CWA section 303(d) and TMDL Programs		
3. CWA section 402 NPDES Programs		
4. CWA section 319 NPS Programs		
5. CWA section 401 certification		
6.		
7.		
8.		

Summary observations and key recommendations:

APPENDIX D: TECHNICAL MEMORANDUM TEMPLATE

TECHNICAL MEMORANDUM

Technical Elements Evaluation of the [State/Tribal] Biological Assessment Program

[State/Tribal Agency]

[Location]

[Dates of Third Party Assessment]

Purpose:

To evaluate the technical program and to make recommendations for enhancements relative to design, methodology, and execution for credible data as a basis of making informed decisions regarding the ecological condition of [state/tribal agency's] surface waters.

Attendance:

Agency Participant Contact, Organization, (email) Phone Number (XXX) (XXX-XXXX)

[List all state/tribal agency and U.S. Environmental Protection Agency (EPA) attendees]

Basis for Evaluation

Since 1990, EPA has supported the development of water quality agency biological assessment programs via the production of methods documents, case studies, regional workshops, and evaluations of individual water quality agency programs. EPA recommends that states and tribes use biological assessments to more precisely define their designated aquatic life uses and adopt numeric biological criteria necessary to protect those uses (USEPA 1990, 1991).

Overview and Summary of [State/Tribal Agency] Program and Significant Issues

The [date of evaluation] evaluation of the [state/tribal agency] biological assessment program addressed a range of topics, as summarized below. A biological program review was also completed using a standardized checklist and scoring methodology. The results are discussed as part of this memorandum.

Please provide a detailed summary of the agency's program for the flowing topics:

A. Monitoring and Assessment Program

____

B. Water Quality Standards (WQS): Designated Uses

____

C. Delineation of Impaired Waters

____

Biological assessment program evaluation

The following is a description of the current status of the program and the results of the technical elements evaluation.

Biological assessment program description

Please provide a detailed summary of the state's biological assessment program.

Critical elements evaluation

A biological program review was conducted by proceeding through the technical elements checklist (Appendix E) in accordance with the methodology described in *The Biological Program Review: Assessing Level of Technical Rigor to Support Water Quality Management* (EPA 820-R-13-001. The document includes a description of 13 technical elements of a biological assessment program, the checklist for evaluating the level of technical development for each element, and a method for characterizing the overall level of program rigor. The [water quality agency] critical elements evaluation yielded a raw score of __ out of a maximum possible score of 52. This is a Level __ program (range __ – __). The critical technical elements of biological assessment programs are described and divided into four general levels of technical development with Level 4 the highest level of rigor. A Level 4 program is able to provide the most comprehensive support for a water quality management program. As a technical program is improved, biological assessment information can be used with increasing confidence to support multiple water quality program needs for information. These needs include more precisely defined aquatic life uses and approaches for deriving biological criteria, supporting causal analysis, and developing stressor-response relationships.

Highlights of each element are indicated in Table D-1 (hypothetical example shown). The improvements that are needed to elevate the score for each element are described by element in the same order that they appear in the attached checklist as follows:

Table D-1. Example review results: The following recommendations were made to a state water quality agency as a result of their critical elements evaluation

Element	Comment
Element 1: Index Period Score assigned = 2.0	The score of2.0 reflects a varied adherence to a seasonal index period. Logistical bottlenecks seem to be the principal reason for deviations that can extend into the following spring of each year. Elevating the score for this element will require a strict adherence to the August 15–November 15 index period.
Element 2: Spatial Sampling Design Score assigned = 2.0	The score of 2.0 conservatively reflects the synoptic design and spatial density of sampling sites that is employed. Elevating the score to the maximum of 4.0 will require a greater spatial density within watershed assessment units particularly getting beyond the “pour point” as the only sampling site on a river or stream.
Element 3: Natural Variability Score assigned = 2.0	The CE score of 2.0 should be elevated to 4.0 with the developments that are already underway including the addition of new regional reference sites and the fuller inclusion of the other bioregions.
Element 4: Reference Site Selection Score assigned = 3.0	As criteria are further refined (site-scoring process) for reference sites, the CE score of 3.0 should improve to 4.0 because it is being employed in the selection of new regional reference sites.
Element 5: Reference Conditions Score assigned = 3.0	The CE score of 3.0 should improve to 4.0 with the additional regional reference sites that are being established as part of the ongoing improvements described for elements 3 and 4.
Element 6: Taxa and Taxonomic Resolution Score assigned = 3.0	The CE score of 3.0 reflects the full development of the macroinvertebrate assemblage and the in progress development of a second and third assemblage. Reaching the CE score of 4.0 is contingent on the full development and use of a second assemblage.
Element 7: Sample Collection Score assigned = 3.0	The CE score of 3.0 reflects the full development of the macroinvertebrate assemblage (i.e., for the mountain region only) and the in-progress development of a second and third assemblage. Reaching the CE score of 4.0 is contingent on the full development and use of a second assemblage and for all applicable bioregions.

Element	Comment
Element 8: Sample Processing Score assigned = 3.0	The CE score of 3.0 reflects the full development of the macroinvertebrate assemblage for the mountain bioregion and the in progress development of the other bioregions and a second and third assemblage. Reaching the CE score of 4.0 is contingent on the full development and use of a second assemblage.
Element 9: Data Management Score assigned = 3.0	The CE score of 3.0 can be improved to 4.0 once the data management system includes all data (i.e., habitat and fish) and is readily accessible.
Element 10: Ecological Attributes Score assigned = 2.0	The CE score of 2.0 should increase with the development of the macroinvertebrate multimetric index (MMI) for all bioregions. A descriptive analysis of the biological condition gradient (BCG) for each representative bioregion and application of these concepts to the full development of the biological indicators and assemblages will improve the score to 4.0.
Element 11: Discriminatory Capacity Score assigned = 2.0	The CE score of 2.0 will be increased to at least 3.0 with the full development of the macroinvertebrate MMI and the derivation of appropriately detailed numeric biological criteria. Achieving a score of 4.0 will require that this be accomplished for a second biological assemblage.
Element 12: Stressor Association Score assigned = 2.0	The comparatively low CE score of 2.0 is a common characteristic of biological assessment programs that are in development and/or which have singularly been focused on status assessments with no or limited coordination with other environmental assessments. Improving the score for this element will occur as a result of addressing preceding elements 2, 3, 6, 10, and 11 and gaining a familiarity with how diagnostic capacity is developed. This will require some dedication to exploratory analyses in which the response of the biological assemblages is evaluated along the stressor axis of the BCG.
Element 13: Professional Review Score assigned = 2.0	The CE score of 2.0 can be elevated to 4.0 by instituting a more formal peer review process and by publishing some of the ongoing developments in peer reviewed journals.

Critical Elements Summary

Please provide a detailed summary of the agency's critical elements performance and include a discussion of ongoing program improvements that will increase the rigor of the agency's biological assessment program.

Recommendations

Summary of recommendations to the agency on how to improve the rigor of its biological assessment program and recommendations for program enhancements to support more comprehensive and efficient use of biological assessments in an agency's water quality program.

Citations

USEPA (U.S. Environmental Protection Agency). 1990. *Biological Criteria: National Program for Surface Waters*. EPA 440-5-90-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC. <http://www.epa.gov/bioindicators/pdf/EPA-440-5-90-004Biologicalcriterianationalprogramguidanceforsurfacewaters.pdf>. Accessed October 2012.

USEPA (U.S. Environmental Protection Agency). 1991. *Policy on the Use of Biological Assessments and Criteria in the Water Quality Program.* U.S. Environmental Protection Agency, Washington, DC. <http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/upload/2002_10_24_npdes_pubs_owm0296.pdf>. Accessed February 2013.

Appendix E. Technical Elements Checklist

The following is a checklist for evaluating the degree of development for each technical element of a biological assessment program and associated comments on the elements for the [water quality agency] biological assessment program. The point scale for each element ranges from lowest to highest resolution.

Element 1	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Index Period	Temporal variability is not taken into account.	Sampling period established based on practices of other agencies and/or literature. Sampling outside the index is not adjusted for temporal influence.	Index period established based on *a priori* assumptions regarding temporal variability of biological community. Effects of the use of index period are documented. Data collected outside the index period data might be adjusted to correct for temporal influences.	Temporal variability is fully characterized and taken into account for all data. Agency information needs and index periods are coordinated so that adherence to an index period is strict.	**Points** —

Element 2	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Spatial Sampling Design	Study design consisting of isolated, single, fixed-point sites.	Low density fixed station design. Multiple sites are used for assessment of a water body or watershed condition. Spatial coverage suitable for general condition assessments. Non-random designs at coarse scale used (e.g., 4–8 digit hydrologic unit code [HUC]). Inference of site data to larger unit of assessment based on "rules of thumb" and might be supplemented by upstream/downstream assessments.	Low density random or stratified random sampling design which allows for a statistically valid inference of biological condition to a spatial unit larger than a site. The primary goal is to assess aggregate condition and trends on a statewide or regional basis.	High density (e.g., intensive) monitoring at comprehensive spatial sampling design suitable for watershed assessments (e.g., 10–12 digit HUC) and in support of multiple water quality management program needs for information (e.g., condition assessments, use refinement, use attainability analyses [UAAs], permits). As needed, the spatial sampling combines monitoring designs to optimize cost and efficiency in data collection and analysis (e.g., combination of upstream-downstream, intensive, probabilistic, and/or pollution gradient designs). Typically includes a rotating sequence of watershed units organized to provide data for management program support.	**Points** —

Element 3	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Natural Variability	No or minimal partitioning of natural variability in aquatic ecosystems. Does not incorporate differences in watershed characteristics such as size, gradient, temperature, elevation, etc.	Classification scheme is based on assumed, first-order classes. These include strata such as fishery-based cold or warmwater classes. There is no formal consideration of regional strata such as bioregions or aggregated ecoregions. Intra-regional strata such as watershed size, gradient, elevation, temperature are not addressed. Usually applied uniformly on a statewide basis.	A fully partitioned and stratified classification scheme or modeling approach is employed. Classes and/or continuous models are defined to take critical details of spatial variability into account. Inter-regional landscape features and phenomena are appropriately sequenced with intra-regional strata. Subcategories of lotic ecotypes are defined (e.g., includes the full strata of lotic water body types). Characterization of spatial variability is confined within jurisdictional boundaries.	Scheme to fully account for natural variation is periodically refined and updated as new data and methods become available. Classes, continuous models, or both, are examined to identify the most appropriate scheme for monitoring and assessment, regulatory support, and cost-effectiveness. Developed at scales that transcend jurisdictional boundaries when necessary to strengthen inter-regional classification outcomes; recognizes the full zoogeographical aspects of biological assemblages.	 **Points** —

Element 4	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Reference Sites Selection	Informal best professional judgment (BPJ) used in selection of control sites. No screens are used. Limited, if any, documentation and supporting rationale.	Based on "best biology" (i.e., BPJ on what the best biology is in the best water body). Minimal non-biological data used. Minimal documentation.	Selection based on narrative descriptions of non-biological characteristics. Combines BPJ with narrative description of land use and site characteristics. Might use chemical and physical data thresholds as primary filters.	Based on quantitative descriptions of non-biological characteristics with primary reliance on abiotic data on landscape conditions and land use. Chemical and physical data might be used as secondary filters or in a hybrid approach for severely altered landscapes. Independent data set used for validation.	**Points** —

Element 5	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Reference Conditions	No reference condition has been developed. Biological data are assessed using BPJ or based on the presence of targeted or iconic taxa.	Reference condition based on biology of an estimated 'best' site or water body. Single reference sites are used to assess biological data collected throughout a watershed. A site-specific control or paired watershed approach might be used.	Reference condition is based on a regional aggregate of reference site information. Data representing most of the major natural environmental gradients but limited in number and/or spatial density. Overall number and coverage of reference sites insufficient to support statistical evaluation of the biological condition at test sites.	Reference condition is based on data from many reference sites that span all major natural environmental gradients in the study area. Reference condition can be estimated for individual sites by modeling biota-environmental relationships. The number of reference sites is sufficient to support statistical evaluation of biological condition at test sites. Reference sites are resampled periodically. In highly altered regions or water body types, alternative methods are used to develop reference condition.	**Points** —

Element 6	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Taxa and Taxonomic Resolution	One taxonomic assemblage (e.g., benthic macroinvertebrates, fish, algae, aquatic macrophytes). Very coarse taxonomic resolution (e.g., order/family). Expertise: amateur naturalist or stream watcher. Validation: none. QA/QC: none.	One taxonomic assemblage. Low taxonomic resolution (e.g., family). Expertise: novice or apprentice biologist. Validation: family level certification for macroinvertebrates. No certification available for fish or algae. QA/QC: mostly for taxonomic confirmation of voucher collections. Some sorting QA/QC implemented.	One taxonomic assemblage. Fine taxonomic resolution: genus/species for benthic macroinvertebrates and algae, species for fish. Expertise: trained taxonomist. Validation: genus-level certification or equivalent for benthic macroinvertebrates. Expert fish taxonomist or equivalent. Formal courses or training in algal taxonomy. QA/QC: addresses measuring bias, precision, and accuracy in all phases of sample processing through identification (e.g., outside validation of identification); voucher collection maintained.	Same as Level 3 except that two or more taxonomic assemblages are assessed. Rationale for selection of taxonomic groups should be well documented.	Points —

Element 7	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Sample Collection	Approach is cursory and relies on operator skill and BPJ. Training limited to that which is conducted annually for non-biologists who compose the majority of the sampling crew. Methods are not systematically documented as standard operating procedures (SOPs).	Textbook methods are used without considering the applicability of the methods to the study area. SOPs to specify methods but methods are neither well documented nor evaluated for producing comparable data across agencies. A cursory QA/QC document might be in place. Training consists of short courses (1–2 days) and is provided for new staff and periodically for all staff.	Methods are evaluated for applicability to study area and refined (if needed). Detailed and well documented SOPs are updated periodically and supported by in-house testing and development. A formal QA/QC program is in place with field replication requirements. Rigorous training required for all professional staff.	Same as Level 3, but methods cover multiple assemblages. A field audit of sampling crews is performed annually to ensure that protocols and proper sample handling/documentation are followed.	**Points** —

Element 8	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Sample Processing	Organisms are sorted, identified, and counted in the field using dichotomous keys.	Organisms are sorted, identified, and counted primarily in the field by trained staff. Adequate QA/QC is not possible. For fish, cursory examination of presence and absence only. Agency SOPs not developed or published.	All samples (except for fish) are processed in the laboratory. A formal QA/QC program is in place. Rigorous training is provided. Voucher organisms are retained for ID verification. SOPs are published and available to others.	Same as Level 3, but applied to multiple assemblages. Subsampling level is tested. Presence of fish deformities, erosions, lesions, tumors (DELT) and other anomalies are quantified and documented.	**Points** —

Element 9	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Data Management	Sampling event data organized in a series of spreadsheets (e.g., by year, by data-type). QA/QC is cursory and mostly for transcription errors. Might be paper files only.	Databases for physical-chemical, and biological data, and geographic information exist (Access, dBase, Geographic Information System [GIS], etc.) but are not linked or integrated. Data-handling methods manuals are available. QA/QC for data entry, value ranges, and site locations. A documented data dictionary defines data fields in terms of field methods and data collection.	Relational databases that integrate all biological, physical, and chemical data (Oracle, SQL Server, Access, etc.). Validation checks that guard against inadvertently storing incorrect or incomplete sampling data. Fully documented and implemented QA/QC process. Structure provides for data export and analysis via query includes dedicated database management. Fully documented data dictionary. Access to all databases is available for routine analysis in support of condition assessment.	Same as Level 3 adding automated data review and validation tools. Numerous built-in data management and analysis tools to support routine and exploratory analyses. Ability to track history of changes made to the data. Ability to control who has privilege to change, update, or delete data. Data import and export tools. Integrated connection to GIS showing monitored sites in relation to other relevant spatial data layers. Fully documented metadata according to accepted database standards. Reports on commonly used endpoints are easily retrieved (e.g., menu driven).	 **Points** —

Element 10	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Ecological Attributes	Biological program relies solely on the evaluation of the presence or absence of targeted or key species. No rationale is provided for selection of indicators. Assessment endpoints and ecological attributes are not defined.	Biological program based on "off the shelf" indicators for one biological assemblage. Rationale for selection of indicators is partially documented. Generic assessment endpoints and ecological attributes are defined but not specifically evaluated for state or regional conditions.	Biological program based on well-developed ecological attributes for one biological assemblage. Rationale for attribute selection is thorough and well-documented. Explicit linkage is provided between management goal, assessment endpoints, and ecological attributes.	Same as Level 3, but biological program based on well-developed ecological attributes for two or more biological assemblages (e.g., faunal, flora) for more complete assessment of the members of an aquatic community.	**Points** —

Element 11	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Discriminatory Capacity	Coarse method (low signal) and detects only high and low values. Supports distinguishing only extreme change in biological condition at the upper and lower ends of a generalized stress gradient.	A biological index for one assemblage is established but is not calibrated for water body classes, regional or statewide applications. BPJ based on single dimension attributes. The index can distinguish two general levels of change in biological condition along a generalized stress gradient.	A biological index for one assemblage has been developed and calibrated for statewide or regional application and for all classes and strata of a given water body type. The index can distinguish 3 to 4 increments of biological change along a continuous stress gradient. Supports narrative evaluations (e.g., good, fair, poor) based on multimetric or multivariate analyses that are relevant to the selected ecological attributes (Technical Element 10).	Same as Level 3 but biological indices for two or more assemblages have been developed and calibrated. Additionally, the indices can distinguish finer increments of biological change along a continuous stress gradient. The number of increments that potentially can be distinguished is dependent on water body type and natural climatic and geographic factors.	 **Points** —

Element 12	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Stressor Association	No ability to develop relationships between biological responses and anthropogenic stress.	Site-specific paired biological and stressor samples for studies of an individual water body or a segment of a water body (e.g., a stream reach). Stress-response relationships are developed based on assemblage attributes at coarse level taxonomy (e.g., family for benthic macroinvertebrates). Information might be used on a case-by-case basis to inform a first order causal analysis.	Low spatial resolution for paired biological and stressor samples in time and space across the state at basin or sub-basin scale (e.g., HUC 4–8). Stress-response relationships developed for one assemblage using regression analysis. Taxonomy at level sufficient to detect patterns of response to stress (e.g., species or genus for benthic macroinvertebrates or periphyton, species for fish). Relational database supports basic queries. Information is frequently used to inform causal analysis. Reevaluation of stress-response relationships on an as-needed basis.	High spatial resolution for paired biological (including DELT anomalies and other indicators of organism health) and stressor samples in time and space across the state at watershed or subwatershed scales (e.g., HUC 10–12). Other data (e.g., watershed characteristics, land use data and information, flow regime, habitat, climatic data) are linked to field data for source identification. Stress -response relationships are fully developed for two or more assemblages, stressors, and their sources using a suite of analytical approaches (e.g., multiple regression, multivariate techniques). Relational database supports complex queries. Information is routinely used to inform causal analysis and criteria development. Ongoing evaluation of stress- response relationships and monitoring for new stressors is supported.	
					Points
					—

Element 13	(Lowest) 1.0	2.0	3.0	4.0 (Highest)	Comments
Professional Review	Review is limited to editorial aspects. No technical review.	Internal technical review only.	Outside review of documentation and reports are conducted on an ad hoc basis.	Formal process for technical review to include multiple reference and documented system for reconciliation of comments and issues. Process results in methods and reporting improvements. Can include production of peer-reviewed journal publications by the agency.	**Points** —

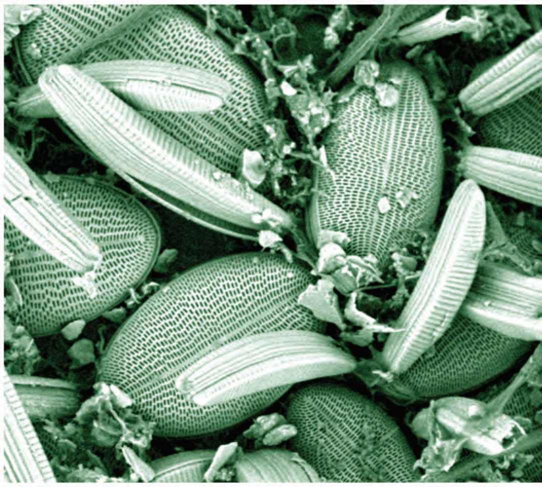
EPA 820-R-13-001

A Primer on Using Biological Assessments to Support Water Quality Management

October 2011






The Hoopa Valley Tribe and neighboring tribes use traditional redwood canoes for subsistence fishing and ceremonial purposes.

U.S. Environmental Protection Agency
Office of Science and Technology
Office of Water, Washington, DC
EPA 810-R-11-01

A Primer on Using Biological Assessments to Support Water Quality Management

Contact Information

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Narragansett Bay Estuary Program
New Jersey Department of Environmental Protection
Ohio Environmental Protection Agency
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Pennsylvania Department of Environmental Protection
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Utah Department of Environmental Quality
Vermont Department of Environmental Conservation
Virginia Department of Conservation and Recreation

Acknowledgements (continued)

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Tool #1: Biological Assessment Program Evaluation (2001 – 2009)

Alabama, Arizona,
California, Connecticut, Colorado, Florida, Illinois, Indiana, Iowa, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Fort Peck Tribes (Assiniboine and Sioux), New Hampshire, New Mexico, Ohio, Rhode Island, Texas, Vermont, Wisconsin

Tool #2: The Biological Condition Gradient (2000–2005)

State and Tribal Workgroup Members
Arizona Department of Environmental Quality – Patti Spindler
California Department of Fish and Game – Jim Harrington
Colorado Department of Public Health and Environment – Robert McConnell, Paul Welsh
Florida Department of Environmental Protection – Russ Frydenborg, Ellen McCarron, Nancy Ross
Idaho Department of Environmental Quality – Mike Edmondson
Kansas Department of Health and Environment – Bob Angelo, Steve Haslouer, Brett Holman
Kentucky Department for Environmental Protection – Greg Pond, Tom VanArsdall
Maine Department of Environmental Protection – David Courtemanch, Susan Davies
Maryland Department of the Environment – Joseph Beaman, Richard Eskin, George Harmon
Minnesota Pollution Control Agency – Greg Gross
Mississippi Department of Environmental Quality – Leslie Barkley, Natalie Guedon
Montana Department of Environmental Quality – Randy Apfelbeck, Rosie Sada
Nevada Division of Environmental Protection – Karen Vargas
North Carolina Department of Environment and Natural Resources – David Lenat, Trish MacPherson
Ohio Environmental Protection Agency – Jeff DeShon, Dan Dudley
Ohio River Valley Water Sanitation Commission – Erich Emery
Oregon Department of Environmental Quality – Doug Drake, Rick Hafele
Pyramid Lake Paiute Tribe – Dan Mosley
Texas Commission on Environmental Quality – Charles Bayer
Vermont Department of Environmental Conservation – Doug Burnham, Steve Fisk
Virginia Department of Environmental Quality – Alexander Barron, Larry Willis
Washington State Department of Ecology – Robert Plotnikoff
Wisconsin Department of Natural Resources – Joe Ball, Ed Emmons, Robert Masnado, Greg Searle, Michael Talbot, Lizhu Wang

U.S. Environmental Protection Agency
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Regional (R) Offices: Peter Nolan (R1), Jim Kurtenbach (R2), Maggie Passmore (R3), Ed Decker, Jim Harrison, Eve Zimmerman (R4), Ed Hammer, David Pfeifer (R5), Philip Crocker, Charlie Howell (R6), Gary Welker (R7), Tina Laidlaw, Jill Minter (R8), Gary Wolinsky (R9), Gretchen Hayslip (R10)

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Jan Ciborowski, University of Windsor
Jeroen Gerritsen, Tetra Tech, Inc.
Richard Hauer, University of Montana
Charles Hawkins, Utah State University
Bob Hughes, Oregon State University
Lucinda Johnson, University of Minnesota
James Karr, University of Washington
Dennis McIntyre, Great Lakes Environmental Center
Gerald Niemi, University of Minnesota
Ed Rankin, Center for Applied Bioassessment and Biocriteria
Jan Stevenson, Michigan State University
Denice Wardrop, Pennsylvania State University
Chris Yoder, Midwest Biodiversity Institute

Tool #3: The Stressor Identification and Causal Analysis/Diagnosis Decision Information System (2000 – 2010)

States
Connecticut, Iowa, Maine, Minnesota, Mississippi, Ohio, Washington, West Virginia

Office of Research and Development: Core Technical Development Team
Laurie Alexander, Susan Cormier, David Farrar, Michael Griffith, Maureen Johnson, Michael McManus, Susan Norton, John Paul, Amina Pollard, Kate Schofield, Patricia Shaw-Allen, Glenn Suter, Lester Yuan, C. Richard Ziegler

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http://www.epa.gov/caddis/caddis_authors.html

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Contents

Figures

Tables

Foreword

This guide serves as a primer on the role of biological assessments in a variety of water quality management program applications, including reporting on the condition of the aquatic biota, establishing biological criteria, and assessing the effectiveness of Total Maximum Daily Load determinations and pollutant source controls. This guide provides a brief discussion of technical tools and approaches for developing strong biological assessment programs and presents examples of successful application of those tools.

The objective of the Clean Water Act (CWA), and water quality management programs generally, is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Although we have achieved major water quality improvements over the past four decades and have reduced the discharge of many toxic chemicals into our nation's waters, many environmental challenges remain, such as loss and fragmentation of habitat, altered hydrology, invasive species, climate change, discharge of new chemicals, stormwater, and nitrogen or phosphorus (nutrient) pollution. In the face of such challenges, how can we best deploy our water quality programs to meet the vision of the CWA for protection of aquatic life?

Biological integrity has been defined to mean the capability of supporting and maintaining a balanced, integrated, and adaptive community of organisms having a composition and diversity comparable to that of natural habitats of the region (Frey 1975; modified by Karr and Dudley 1981). **Biological assessments** can be used to directly measure the condition of the biota residing in a waterbody and provide information on biological integrity. Resident biota include species that spend all or a part of their life cycle in the aquatic environment.

Measuring the condition of the resident biota in surface waters using biological assessments and incorporating that information into management decisions can be an important tool to help federal, state, and tribal water quality management programs meet many of the challenges. Biological assessments are an evaluation of the condition of a waterbody using surveys of the structure and function of a community of resident biota (e.g., fish, benthic macroinvertebrates, periphyton, amphibians) (for more information, see *Biological Assessment Key Concepts and Terms*)[1]. Assessments of habitat condition, both instream and riparian, are typically conducted simultaneously. Such information can reflect the overall ecological integrity of a waterbody and provides a direct measure of both present and past effects of stressors on the biological integrity of an aquatic ecosystem. The benefit of a biological assessment program is based in its capability to:

- Characterize the biological condition of a waterbody relative to water quality standards (WQS).
- Integrate the cumulative effects of different stressors from multiple sources, thus providing a holistic measure of their aggregate effect.
- Detect aquatic life impairment from unmeasured stressors and unknown sources of impairment.
- Provide field data on biotic response variables to support development of empirical stressor response models.
- Inform water quality and natural resource managers, stakeholders, and the public on the environmental outcomes of actions taken.

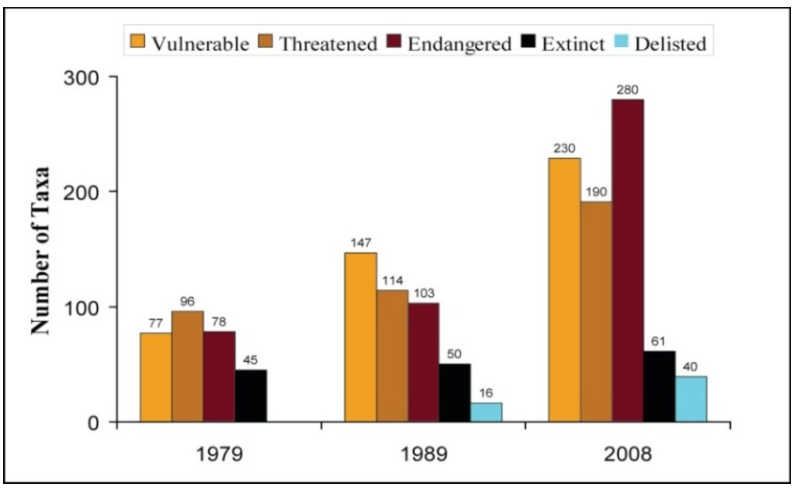
[1] http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/upload/primer_factsheet.pdf

It is EPA's long-standing policy that biological assessments should be fully integrated in state and tribal water quality programs and used together with whole effluent and ambient toxicity testing, and with chemical-specific analyses, to assess attainment of designated aquatic life uses in WQS (USEPA 1991b). Each of these methods can be used to provide a valid assessment of aquatic life use impairment. Biological assessments complement chemical-specific, physical, and whole effluent toxicity measures of stress and exposure by directly assessing the response of the community in the field (USEPA 1991a). Measurable changes in the biotic community—for example, the return of native species, decrease in anomalies and lesions in fish and amphibians, and decrease in pollution-tolerant species paired with an increase in pollution-sensitive species—can be readily communicated to the public and the regulated community. This can result in greater stakeholder understanding of effects from stressors and support for management actions. Additionally, as response-stressor relationships are documented, biological assessments in concert with stressor data can be used to help predict and track environmental outcomes of management actions.

Chapter 1. Incorporating Biological Assessments into Water Quality Management

1.1 Why Is Measuring Biological Condition Important?

With the passage of the Clean Water Act (CWA) in 1972 and subsequent national investment in water infrastructure and regulation, much work has been done to restore rivers, lakes, streams, wetlands, and estuaries. However, despite our best efforts and many documented successes, we continue to lose aquatic resources (Figure 1-1) (H. John Heinz III Center for Science, Economics, and the Environment 2008; Jelks et al. 2008; USEPA 2006). Pollutants (e.g., pathogens, metals, nitrogen, phosphorus pollution) continue to be major causes of water quality degradation. Additionally, the impact of other significant stressors, including habitat loss and fragmentation, hydrologic alteration, invasive species, and climate change, can be better understood using analytical tools and information that can operate at the ecosystem scale, such as biological assessments.



Source: Jelks et al. 2008

Figure 1-1. Numbers of imperiled North American freshwater and diadromous fish taxa.

Note: The increase in total number of taxa identified as vulnerable, threatened, or endangered might be due in part to improvements in our understanding, naming, and assessing aquatic resources, resulting in more complete and accurate assessments.

Biological assessments can be used to directly measure the overall biological integrity of an aquatic community and the synergistic effects of stressors on the aquatic biota residing in a waterbody where there are well-developed biological assessment programs (Figure 1-2) (USEPA 2003). Resident biota function as continual monitors of environmental quality, increasing the sensitivity of our assessments by providing a continuous measure of exposure to stressors and access to responses from species that cannot be reared in the laboratory. This increases the likelihood of detecting the effects of episodic events (e.g., spills, dumping, treatment plant malfunctions), toxic nonpoint source (NPS) pollution (e.g., agricultural pesticides), cumulative pollution (i.e., multiple impacts over time or continuous low-level stress), nontoxic mechanisms of impact (e.g., trophic structure changes due to nutrient enrichment), or other impacts that periodic chemical sampling might not detect. Biotic response to impacts on the physical habitat such as sedimentation from stormwater runoff and physical habitat alterations from dredging, filling, and channelization can also be detected using biological assessments.

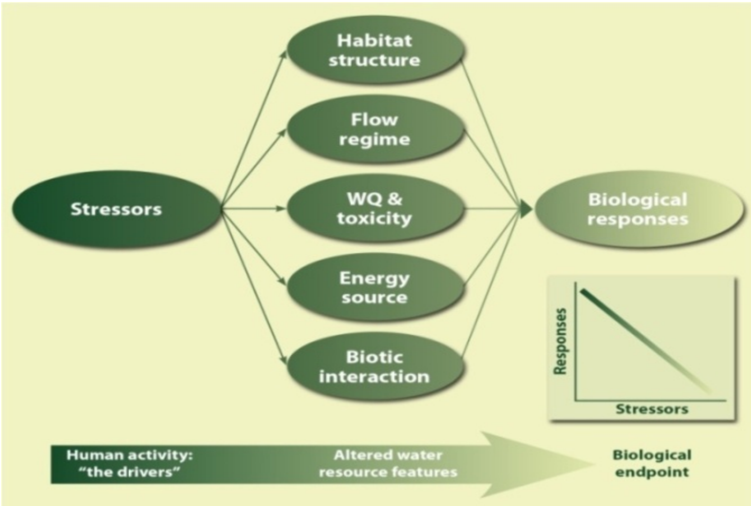
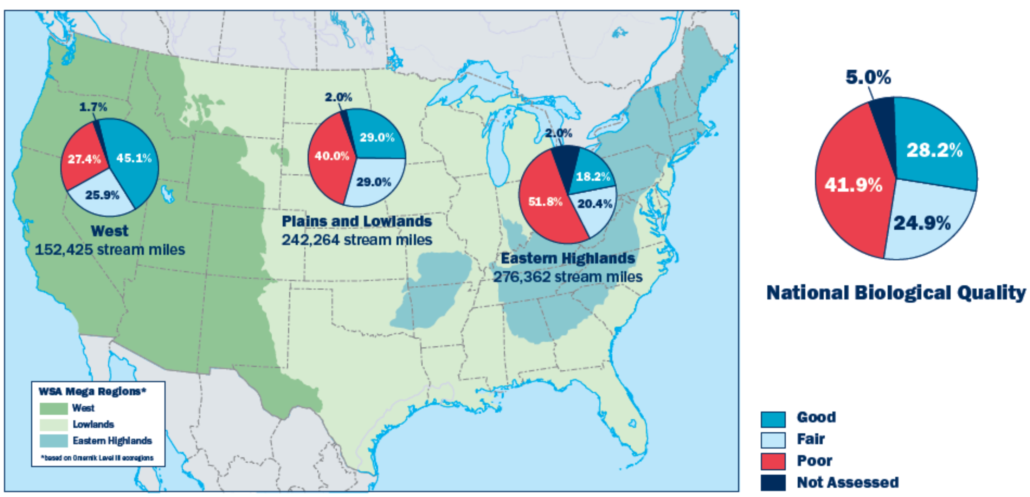


Figure 1-2. Biological assessments provide information on the cumulative effects on aquatic communities from multiple stressors. Figure courtesy of David Allen, University of Michigan.

States and tribes have used biological assessments to set environmental goals, detect degradation, prioritize management actions, and track improvements (USEPA 2002). Multiple examples of applications are presented in Chapter 3. Additionally, the U.S. Environmental Protection Agency (EPA) [2] and U.S. Geological Survey (USGS) [3] are conducting national and regional assessments of the condition of aquatic communities and the presence and distribution of stressors that affect the aquatic biota. The EPA National Aquatic Resource Surveys (NARS) program employs a probability-based sampling design while the USGS National Water-Quality Assessment (NAWQA) Program utilizes a targeted design. The data provide a baseline for assessing biological conditions and key stressors over time and tracking environmental improvements at the national or regional level (Figure 1-3).



Source: USEPA 2006.

Figure 1-3. Biological condition of our nation's streams. In its first survey of stream condition, EPA found that 28 percent of the nation's stream miles are in good condition compared to the best existing reference sites in their regions, 25 percent are in fair condition, and 42 percent are in poor condition.

[2] http://water.epa.gov/type/watersheds/monitoring/nationalsurveys.cfm.

[3] http://water.usgs.gov/nawqa.

1.2 Using Biological Assessment Information in State and Tribal Water Quality Management Programs

Biological assessment information has been used by states and tribes to:

- ***Define goals for a waterbody***—Information on the composition of a naturally occurring aquatic community can provide a description of the expected biological condition for other similar waterbodies and a benchmark against which to measure the biological integrity of surface waters. Many states and tribes have used such information to more precisely define their designated aquatic life uses, develop *biological criteria*, and measure the effectiveness of controls and management actions to achieve those uses.
- ***Report status and trends***—Depending on level of effort and detail, biological assessments can provide information on the status of the condition of the expected aquatic biota in a waterbody and, over time with continued monitoring, provide information on long-term trends.
- ***Identify high-quality waters and watersheds***—Biological assessments can be used to identify high-quality waters and watersheds and support implementation of state and tribal antidegradation policies.
- ***Document biological response to stressors***—Biological assessments can provide information to help develop biological response signatures (e.g., a measurable, repeatable response of specific species to a stressor or category of stressors). Examples include sensitivity of mayfly species (pollution-sensitive aquatic insects) to metal toxicity or temperature-specific preferences of fish species. Such information can provide an additional line of evidence to support stressor identification and causal analysis (USEPA 2000a), as well as to inform numeric criteria development (USEPA 2010a).
- ***Complement pollutant-specific ambient water quality criteria***—Biological assessment information can complement water quality standards (WQS) by providing field information on the cumulative effects on aquatic life from multiple pollutants, as well as detecting impacts from pollutants that do not have EPA recommended numeric criteria.
- ***Complement direct measures of whole effluent toxicity (WET) tests***—Biological assessments can provide information to help document improvements in aquatic life following actions taken to address the aggregate toxic effects of wastewater discharge effluents detected through laboratory WET tests. Additionally, biological assessments complement WET tests by directly measuring the cumulative or post-impact effects that both point source and NPS contaminants have on aquatic biota in the field.
- ***Address water quality impacts of climate change***—EPA, states, and tribes are exploring how biological assessments can be used in concert with physical, chemical, and land use data to help identify baseline biological conditions against which the effects of global climate change on aquatic life can be studied and compared. Such information could enable a water quality management program to calibrate biological assessment endpoints and criteria to adjust for long-term climate change conditions. Additionally, long-term data sets will enable trends analysis and support predictive modeling and forecast analysis.

1.3 Water Quality Program Applications and Case Studies

The CWA employs a variety of regulatory and nonregulatory approaches to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. Those approaches are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The role of biological assessment information to support such approaches is described below, and case studies of successful implementation are provided in Chapter 3.

Water Quality Standards

State and tribal WQS programs can use biological assessment information in developing descriptions of CWA-designated aquatic life uses in terms of the expected biological community. For example, in states and tribes that identify high-quality waters for antidegradation purposes on a waterbody-by-waterbody basis, biological assessments can provide information to help define and protect existing aquatic life uses and identify Tier 2 waters (e.g., where the quality of the waters exceed levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water) and Outstanding National Resource Waters (ONRWs). Maryland is using biological assessments to help identify high-quality streams for antidegradation purposes on a waterbody-by-waterbody basis (case study 3.3). Pennsylvania is exploring the use of biological assessment information to help assess attainment of aquatic life uses and to describe biological characteristics of waters along a gradient of condition (case study 3.4). This information may potentially be used to support protection of waters of the highest quality that require special protection. Arizona used biological assessments to develop numeric biological criteria using the reference condition approach (Stoddard et al. 2006) that takes into account the quality of the reference sites (case example 3.2).

Some states have calibrated biological response to gradients of anthropogenic stress impacting surface waters (see Chapter 2, Tool #2, *The Biological Condition Gradient*). This approach, when applied to WQS by defining the designated aquatic life uses along a gradient of condition, has provided these states with the capability to improve waters incrementally, protect high-quality waters, and help identify factors that affect attainability. For example, Maine assigns a waterbody to a specific condition class on the basis of its current condition and potential for improvement. Numeric biological criteria have been developed for each class and adopted into their WQS (case study 3.1). Over the past 30 years, the use designations for many streams and rivers in Maine have been upgraded according to documented biological improvements and attainment of the biological criteria that define higher quality use classes. This approach is sometimes referred to as tiered aquatic life uses and has also been implemented by the State of Ohio (case study 3.5).

Additionally, biological assessments can provide information on the species composition at a site under consideration for site-specific criteria. Using the species recalculation procedure, a state or tribe can adjust chemical water quality to reflect the chemical sensitivity of species that occur at a site (USEPA 1994). Biological assessment information may support modification of the default species sensitivity distribution to better reflect the expected community composition at the site. For example, if the site is a naturally occurring warm body of water, coldwater fish species could be replaced by resident warmwater fish species in the species sensitivity distribution from which a site-specific criterion is calculated.

Monitoring and Assessment

Biological monitoring and assessments provide data to aquatic resources managers at the local, state, tribal, regional, and national levels to help assess status and trends of aquatic resources as well as to measure the effectiveness of management actions to protect or restore waters. For example, the biological monitoring program in Montgomery County, Maryland, produces biological assessment information on the condition of the County's streams and the effectiveness of innovative best management practices (BMPs) for stormwater control.[4] At the state level, the Maryland Department of the Environment (MDE) conducts biological monitoring to evaluate permit effectiveness, conduct impact assessments, and identify high-quality waters (case studies 3.3 and 3.12). Also, Maryland Department of Natural Resources (MDNR)[5] provides MDE and the public with a statewide biological assessment of status and trends for streams and rivers that may serve as a yardstick for measuring the overall effectiveness of local and state management actions.

Biological assessment information has been used by counties and state/tribal agencies to facilitate collaboration and effective use of limited resources. For example, two state agencies in Oregon jointly conducted biological assessments to address their information needs (case study 3.17). For the Oregon Department of Fish and Wildlife (ODFW), monitoring of aquatic benthic macroinvertebrate communities in streams and rivers, in conjunction with chemical and physical monitoring, provided important information on water quality and habitat conditions identified as critical to coho salmon viability. Oregon's Department of Environmental Quality (ODEQ) used the same biological assessment information to assess attainment of the designated uses to protect and maintain salmonid populations.

At the national level, biological data from the *National Aquatic Resource Surveys*[6] are being used in EPA's strategic plan to track improvements in water quality for streams, rivers, wetlands, and coastal waters. The results of the first national surveys for streams and coastal waters are included in EPA's *Report on the Environment.*[7] These surveys, which incorporate a statistical probabilistic design, are key tools for communicating to the public what the Agency knows about the condition of the nation's waters at national and regional scales. The biological components of the national surveys will continue to provide nationally consistent indicators of water quality that can be used to gauge the overall effect of the national investment in protecting and restoring the nation's watersheds.

EPA also uses biological assessments to assess status and trends at a regional or large ecosystem scale (e.g., in the Upper Mississippi River Basin or the Great Lakes) and measure biological response to restoration efforts related to disasters (e.g., Hurricane Katrina and the Gulf of Mexico oil spill). National and regional biological assessments provide information that helps facilitate interagency collaboration for large-scale restoration and protection efforts. For example, a recent USGS multiregional assessment found that alteration of streamflow is a major predictor of biological integrity of both fish and macroinvertebrate communities (Carlisle et al. 2010). Alterations in stream flow are associated with riparian disturbance and can influence the release of nitrogen, phosphorus, and sediments into streams (Poff and Zimmerman 2010). The combined results of national, regional, and state/tribal ecological assessments will provide the data needed to predict and better manage future impacts of stressors from

[4] For an additional example, see http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/biocriteria/npdesmaryland.cfm.

[5] http://www.dnr.state.md.us.

[6] http://water.epa.gov/type/watersheds/monitoring/nationalsurveys.cfm.

[7] http://www.epa.gov/roe.

human activities such as urban development, water allocation, and agriculture. The results of different program actions to address different stressors and their sources can be related to a common measure of environmental improvement—the condition of the aquatic biota.

Identification of Impaired and Threatened Waters in States' Integrated Water Quality Reports

Under section 303(d) of the CWA and supporting regulations (40 CFR 130.7), states, territories, and authorized tribes (hereafter referred to as states) are required to develop lists of impaired and threatened waters that require Total Maximum Daily Loads (TMDLs). Impaired waters are those that do not meet any applicable WQS, including designated uses, narrative criteria and numeric criteria such as biological criteria adopted as a standard. EPA recommends that states consider as threatened those waters that are currently attaining WQS, but which are expected to not meet WQS by the next listing cycle (every 2 years). Consistent with EPA recommendation, many states consolidate their section 303(d) and section 305(b) reporting requirement into one "integrated" report.

If biological assessments indicate that a waterbody is impaired or threatened, the waterbody is included on the state's section 303(d) list and scheduled for TMDL development. Some 30 states have used biological assessment information as the basis for concluding that designated aquatic life use(s) were not supported and included these waters on their section 303(d) lists. In some cases, these listings were based on comparison of the biological assessments to state-adopted numeric biological water quality criteria. However, in most cases, biological assessments were treated as translations of one or more of a state's narrative water quality criteria or as direct evidence that designated aquatic life uses were not supported.

How to reconcile conflicting results among different datasets (e.g., chemical, physical, biological) is discussed in EPA's Integrated Reporting Guidance (IRG) for the 2006 sections 303(d) and 305(b) reporting cycle. Also discussed in the IRG, if a designated use, such as aquatic life, is not supported and the water is impaired or threatened, the fact that the specific pollutant may not be known does not provide a basis for excluding the water from the section 303(d) list.[8] These waters are often identified on a state's list as cause or pollutant unknown. These waters must be included on the list until the pollutant is identified and a TMDL completed or the state can demonstrate that no pollutant(s) cause or contribute to the impairment. For example, in 1998, Iowa listed a 20-mile segment of the North Fork Maquoketa River as aquatic life use impaired—cause unknown, based on biological assessments. Using EPA's CADDIS stressor identification (SI) methodology, Iowa determined that the aquatic life use was impaired due to sediments, nutrients, and ammonia (see Tool #3, Stressor Identification and Causal Analysis/Diagnosis Decision Information System). A TMDL was developed for each of these pollutants and these were approved by EPA in 2007 (case study 3.7).

Development of Total Maximum Daily Loads

Under the CWA, states are required to develop TMDLs for impaired and threatened waters on their 303(d) lists. States and tribes may use biological assessments to support developing one or more water quality targets for the pollutant of concern on the basis of well-documented stressor-response relationships, from reference conditions or through use of mechanistic modeling. This is done in conjunction with other water quality monitoring data, such as data on concentrations of specific

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[8] EPA Integrated Reporting Guidance for the 2006 Section 303(d) and 305(b) Reporting Cycle website: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/2006IRG_index.cfm

stressors and toxicity effects. For example, Connecticut has developed a relationship between pollutant loads, stormwater flows, and impervious land cover (IC) for streams in small watersheds with no other known point source discharge (case study 3.8). Connecticut used these relationships to develop a TMDL for a small stream identified as impaired based on biological assessments. Because the cause of impairment was unknown, an SI was completed. The SI determined that the most probable cause of impairment was the complex array of pollutants transported by stormwater into the stream. The TMDL is expressed as a reduction target for specific segments of the stream and is to be implemented through reduction of IC where practical and improved stormwater management throughout the watershed. Connecticut will evaluate progress toward the TMDL's implementation using biological assessments in conjunction with surface water chemistry assessments.

Additionally, EPA is encouraging states and tribes to develop TMDLs on a watershed basis (e.g., to bundle TMDLs together) to enhance program efficiencies and foster more holistic analysis. Ideally, TMDLs would be incorporated into comprehensive watershed strategies, while biological assessments would provide information on how the aquatic community responds to the full array of restoration activities. EPA is launching the Recovery Potential Screening Tools and Resources website (USEPA 2012),[9] designed to help state, tribal, and other restoration programs evaluate the relative restorability of impaired waters and help prioritize TMDL development. The website provides an approach to identify the use impaired waters and watersheds most likely to respond well to restoration, as well as information on methods, tools, technical information, and instructional examples that managers can customize for restoration programs in any geographic locality. Application of a gradient of biological response to levels of stress, like the Biological Condition Gradient (BCG) (see Chapter 2, Tool # 2, *The Biological Condition Gradient*), can provide a framework to help assess incremental progress in restoring a waterbody's aquatic life use and report environmental outcomes.

National Pollutant Discharge Elimination System Permits

Under section 402 of the CWA, point source discharges of pollutants to waters of the United States are covered by National Pollutant Discharge Elimination System (NPDES) permits. Under EPA regulations at 40 CFR 122.44(d), an NPDES permit must contain water quality-based effluents if it is found that a discharge will cause, have the reasonable potential to cause, or contribute to an excursion above a WQS. States must assess permitted effluent discharges in a manner that is consistent with EPA NPDES regulations (40 CFR 122.44).[10] States and tribes can use biological assessment information in addition to chemical-specific and WET data to support development of permit conditions that will protect water quality, including attainment of state WQS. Data from biological assessments can be used independently from, or in combination with, WET or chemical data to assess WQS attainment (USEPA 1991b). If any one or a combination of these three assessment methods demonstrates that the applicable WQS are not attained, appropriate and corrective action would be taken to address the findings as necessary, including compliance with applicable NPDES permit development provisions at 40 CFR PART 122.44(d)(1).

While narrative biological criteria might exist for many states and some authorized tribes in their WQS, in order for biological assessment information to effectively support the NPDES permit process there should be an EPA-approved numeric interpretation of the narrative biological criteria. States and tribes that have adopted biological criteria in their WQS may benefit from the use of biological assessment

[9] EPA Recovery Potential Screening website: http://www.epa.gov/recoverypotential.

[10] For more information on NDPES regulations, go to http://cfpub.epa.gov/npdes/regs.cfm?program_id=45.

data as an additional biological check of permit controls, including limits, to see if they result in abating pollutant impacts, restoring water quality, or preventing further degradation. In addition, biological assessments as a "special studies/additional monitoring" permit condition can be used to assess overall permit effectiveness to control source pollutant(s) and used as an NPDES permit trigger to reopen and potentially modify the permit[11] if the biological assessment studies indicate that the permitted discharge continues to impact the receiving waterbody.

Also, while biological assessments can establish that aquatic life use impairment exists in the area of the discharge, the cause of the impairment might be wholly or partially due to point sources or NPS pollution. In such cases, an NPDES permit could establish controls based on the portion of impairment that is related to the effluent. Thus, additional chemical analysis and WET tests and/or source identification are typically conducted. For example, Vermont has used biological assessment information to support changes to effluent limits for metals on the basis of impact analysis, WET tests, and documented stressor-response relationships between metals and the aquatic biota (case study 3.9). That information helped support requiring additional treatment technologies that resulted in improved water quality. Upstream and downstream biological assessments were part of the follow-up monitoring plan and, with chemical and WET data, documented the resulting improvements in ambient biological and chemical conditions. Thus, in conjunction with required NPDES effluent monitoring such as WET and chemical-specific information, Vermont used biological assessments and its EPA-approved biological criteria to support narrative NPDES permit requirements to protect aquatic life. Currently Vermont has refined aquatic life uses (e.g., tiered aquatic life uses) and narrative biological criteria in its WQS supported by published peer-reviewed technical procedures for translating the narrative biological criteria into a numeric threshold.

NPS Pollution

Biological assessments can be a sensitive indicator of cumulative effects from multiple and unpredictable stressors from NPS pollution. Tracking water quality conditions using biological assessments is one way to assess whether the biological community is affected by NPS pollution and that efforts to improve degraded waters using voluntary BMPs are effective. In managing NPS pollution, a natural resource agency could initiate cooperative land use programs in an area or install BMPs to improve the water resource and establish biological goals as a benchmark for restoration. Before-and-after biological assessments compared to the biological benchmark make it possible to evaluate the success of management actions. For example, Michigan has used biological assessments to help determine biological impairments, target restoration efforts, and monitor results in Carrier Creek (case study 3.11).

Compliance Evaluation and Enforcement Support

Regulatory authorities can use biological assessment information to support enforcement actions by helping to document biological impacts and measure recovery of the aquatic community due to mitigation and cleanup actions. For example, a fish kill in a tributary to the Potomac River in Maryland and the District of Columbia was caused by illegal dumping of pesticide wastes in Maryland. Biological and chemical sampling data were used to locate the source of the pesticide wastes, identify the responsible party, and show subsequent improvements in water quality as a result of enforcement activities (case study 3.12). Biological assessment information, in conjunction with biological assays and chemical and physical assessments, can assist enforcement agencies in assessing damage and levying

[11] As prescribed under NPDES regulatory requirements for permit reopeners/modifications (CFR 122.44). For more information on NDPES regulations, go to http://cfpub.epa.gov/npdes/regs.cfm?program_id=45.

fair and reasonable damage assessments on those proven responsible for toxic spills, and determining the rate and level of stream recovery.

Watershed Protection

Increasingly, EPA, states, territories, and tribes are implementing CWA programs on an integrated watershed basis—including air, land, and ecosystem relationships and related regulatory tools such as those used in the Chesapeake Bay[12] and the National Estuary programs (NEPs)[13] (USEPA 2007). Biological assessments are used in watershed-level programs to help define ecological goals and assess progress in achieving those goals. Recently, EPA has embarked on the Healthy Watershed Initiative, which focuses on protecting high-quality waters and watersheds (USEPA In draft). It is a strategic approach that identifies healthy waters and watersheds at the state level and then targets resources at both the state and local levels for their protection. Biological assessments provide critical information and measurable benchmarks to identify high-quality waters in healthy watersheds and then, over time, evaluate how effectively such systems are being protected. The State of Virginia is using biological assessments in its own Healthy Watersheds initiative to define protection and restoration goals that resonate with the public (case study 3.14). EPA's Office of Research and Development (ORD) is working with several states, territories, and NEPs to develop biological assessment tools and approaches that can be applied at multiple scales to protect estuarine and coastal ecosystems and their watersheds (case study 3.16). Additionally, the BCG (see Chapter 2, Tool # 2) can be applied as a field-based assessment framework to describe the health of waterbodies and their watersheds and communicate the biological condition to the public (USEPA In draft). And, in conjunction with refined aquatic life uses and biological criteria adopted into WQS, a BCG-like framework can be used to support management actions to protect existing high-quality waters in a healthy watershed, as demonstrated by the State of Maine (case study 3.1).

[12] Chesapeake Bay Program website: http://www.chesapeakebay.net.

[13] National Estuary Program website: http://water.epa.gov/type/oceb/nep/estuaries_index.cfm.

Chapter 2. Tools for Improving the Use of Biological Assessments in Water Quality Management

EPA has published several documents that provide guidance on incorporating biological assessment information into water quality programs, many of which have been in use for several years. They include technical guidance on developing biological criteria and general program guidance on application of biological assessment information in different water quality programs. A summary of these documents is provided in Appendix A. Additionally, other technical support documents, or technical tools, have been recently developed to further assist states and tribes in developing robust biological assessment programs and applying biological assessment information. Three of these recent tools are listed below and briefly summarized in the following pages.

- ***Tool #1: The Biological Assessment Program Review.*** The level of program rigor determines how well the monitoring and assessment program produces the information needed to support management decision making. A review process and checklist have been developed and piloted by regions, states, and tribes to help assess the technical capability of a state or tribal biological assessment program and strategically determine where to invest resources to develop a technically robust biological assessment program.
- ***Tool #2: The Biological Condition Gradient (BCG).*** The BCG is a conceptual model that describes how biological attributes of aquatic ecosystems might change along a gradient of increasing anthropogenic stress. The model can serve as a template for organizing field data (biological, chemical, physical, landscape) at an ecoregional, basin, watershed, or stream segment level. A BCG calibrated with field data can help states and tribes more precisely define biological expectations for their designated aquatic life uses, interpret current condition relative to CWA objective and goals, track biological community response to management actions, and communicate environmental outcomes to the public. The BCG was designed to help map different biological indicators on a common scale of biological condition to facilitate communication among programs and across jurisdictional boundaries. The BCG is currently being field tested in several regions and states.
- ***Tool #3: Stressor Identification (SI) and Causal Analysis/Diagnosis Decision Information System (CADDIS).*** In 2010 EPA updated its technical support document on causal analysis and literature database to help states and tribes identify the most probable cause of impairment to a waterbody. Specific databases on biological response to stress have been compiled and will undergo continuous updating so that the best available and peer-reviewed literature will be accessible as part of CADDIS. This document and database will assist states that have listed waters as impaired on the basis of biological assessments when the cause of impairment is not known.

2.1 Tool #1: Biological Assessment Program Review

Purpose: To provide a stepwise process to assist states in evaluating the technical capability of their biological assessment programs and to strategically determine where to invest resources to enhance the technical capability of their programs.

This tool can be used to answer questions, including the following:

- Does the quality of data being generated support the management decisions I need to make?
- What are the strengths and needs of my existing program?
- How do I build on my current program and further strengthen it?

Source: EPA's website on key concepts for using biological indicators: http://www.epa.gov/bioiweb1/html/keyconcepts.html

The information provided below describes technical elements of a biological assessment program, summarizes the process and benefits of conducting a program review, and discusses regional/state pilot programs.

The Program Review Process

The critical technical elements review is a systematic ***process*** to evaluate biological assessment program rigor and to identify logical next steps for overall program improvement. The document provides a ***template*** for evaluating critical technical components of a biological assessment program that are scored to arrive at a level of program rigor, from level 1 (the least rigorous) to level 4 (the most rigorous) (Table 2-1). The review provides a framework for identifying programmatic strengths and weaknesses and helps program managers and technical staff members determine key tasks to upgrade the technical abilities of their program (Figure 2-1). The evaluation process also identifies opportunities to improve integration of WQS and monitoring and assessment programs. This review process was initially piloted in EPA Region 5 and more recently applied and further refined in Region 1. Initial programs reviews have focused on biological assessments of streams and rivers, but with some refinements in methodology this evaluation process can be applied to other types of waterbodies. The states have used the results of the review to target resources and prioritize actions to strengthen the technical basis of their biological assessment programs.

The first part of the review involves discussion on the design of the existing monitoring and assessment program, the degree to which there is systematic collection of data from the environment, and how well the data analysis produces information suitable for making the various decisions asked of it—such as determining attainment of aquatic life uses, identifying high-quality waters for antidegradation purposes on a waterbody-by-waterbody basis, evaluating the severity and extent of impairments, and supporting causal analysis and pollutant source identification (i.e., toxicity identification evaluation [TIE] and toxicity reduction evaluation [TRE]). It is essential that experts in the different program areas be engaged in the discussions to help ensure that data quality and information requirements are accurately represented and properly implemented, especially with regard to EPA-published methodologies. The information helps document how monitoring and assessment information is used to support the reporting requirements mandated by the CWA and other state or tribal efforts to characterize the status of waterbodies and plan for implementing restoration efforts. This part of the program review might also examine how the state or tribe uses biological assessment information to more precisely define aquatic life uses and develop biological criteria.

Table 2-1. Key features of the technical attributes for levels of rigor in state/tribal biological assessment programs (streams and rivers).
(Terms in the table are included in the glossary, this template can be modified and applied to other waterbody types.)

	Attributes of levels of biological assessment program rigor			
Key features	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Temporal and spatial coverage	Variable data collection times; upstream/downstream and fixed stations	Index period for convenience; non-random design at a coarse scale (e.g., 4- to 8-digit hydrologic unit code [HUC])	Calibrated seasonal index periods; statewide spatial design using rotating basins at a coarse scale (e.g., 4- to 8-digit HUC)	Scientifically-derived temporal sampling for management decisions; multiple spatial designs for multiple issues; 11- to 14-digit HUC
Natural classification of aquatic ecosystems	No partitioning of natural variability; no incorporation of differences in stream characteristics such as size, gradient	Classification usually a geo-graphical or other similar organization (e.g., fishery-based cold or warmwater; lacks intra-regional strata [size, gradient])	Classification based on a combination of landscape features and physical habitat structure; considers all intra-regional strata and specific ecosystems	Fully partitioned and stratified classification scheme that transcends jurisdictions and recognizes zoogeographical aspects of assemblages
Reference conditions	No reference conditions; presence and absence of key taxa are based on best professional judgment	A site-specific control or paired watershed approach can be used for assessment; regional reference sites are lacking	Reference conditions used in watershed assessments; regional reference sites are too few in number or spatial density	Regional reference conditions are established in the applicable waterbody ecotypes and aquatic resource classes
Sampling and sample processing	Approach is cursory and relies on operator skill and best professional judgment, producing highly variable and less comparable results	Textbook methods are used rather than in-house development of standard operating procedures to specify methods	Methods are calibrated for state purposes and are detailed and well documented; supported by in-house testing and development	Same as Level 3, but methods cover multiple assemblages; high taxonomic resolution
Data management	Sampling event data are organized in a series of spreadsheets	Separate databases are used for physical, chemical, and biological data with separate GIS shapefiles of sites	A true relational database is specifically designed to include data validation checks (e.g., Oracle, SQL Server, Access)	Relational database of biological assessment data with automated data review validation tools and geospatial analysis
Biological endpoints and thresholds	Assessment based on presence or absence of targeted or key species; attainment thresholds are not specified and no BCG	A biological index or endpoint is by specific waterbodies; single dimension measures used	A biological index, or model, developed and calibrated for use throughout the state for the various waterbody types	Biological indexes, or models, for multiple assemblages are developed and calibrated for a state and uses the BCG
Causal analysis	Support for causal analysis is lacking	Coarse indications of response via assemblage attributes at gross level (i.e., general indicator groups)	Developed indicator guilds and other aggregations to support causal associations; diagnostic capability is supported by studies	Response patterns are most fully developed and supported by extensive research and case studies across spatial and temporal scales

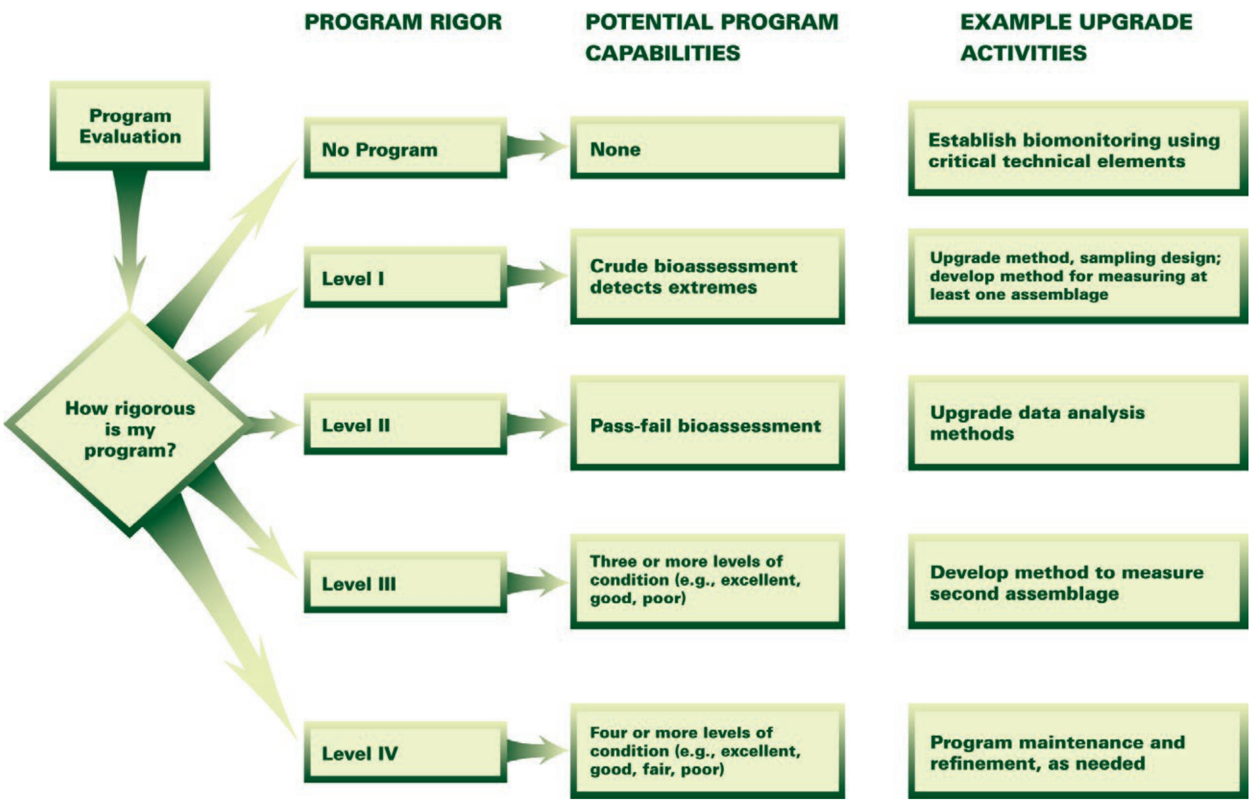


Figure 2-1. Key features of the program review process and examples of commensurate upgrades.

Evaluation of Critical Technical Elements of a State's or Tribe's Biological Assessment Program

The program review evaluates 13 critical technical elements of a biological assessment program associated with design, methods, and data interpretation (e.g., survey design, method of classification, procedures to establish reference conditions, protocols for sampling collection and processing, data management and analysis, formal peer review). On the basis of the discussions in the first phase of the review, where program information needs are identified, a list of recommendations is developed according to the strengths and gaps identified in the technical program evaluation. The recommendations are presented in a logical, stepwise progression so that a state or tribe can build on its technical program strengths and target resources effectively to address the program gaps. Participation of program managers and technical staff representing different water quality programs is important in the review to build a shared understanding and broad perspective on existing use of biological assessment information and begin to identify the technical program gaps and areas for improved use.

Case Example: Technical Evaluations in Minnesota and Connecticut

The Minnesota Pollution Control Agency (MPCA) decided in 2005 to use biological assessment information to develop refined aquatic life uses and numeric biological criteria in its WQS to meet its objectives of setting management goals for waterbodies on the basis of their best potential condition. MPCA also found biological assessment information as useful to educate and engage stakeholders and the public. MPCA used the Critical Technical Elements Program Evaluation process to determine *where* its program was in 2005 and what tasks were yet to be accomplished to reach its stated goals. Using the findings, MPCA developed a detailed plan for developing a technical program sufficiently rigorous to support adoption in the state's WQS in 2011–2014 of the most appropriate aquatic life uses and numeric biological criteria. MPCA continues to follow the plan, addressing the priority recommendations identified in the program evaluation, and is proceeding with biological criteria development. As part of this effort, MPCA is exploring application of the BCG, the second tool discussed in this document, to develop biological goals for their waters that are tailored to specific waterbody types and uses.

The Connecticut Department of Environmental Protection (CT DEP) has been monitoring aquatic biological conditions using benthic macroinvertebrates since the late 1980s and has steadily upgraded its technical program over the years. The state operates a statewide monitoring and assessment program that includes multiple spatial designs to produce both statewide assessments using probabilistic design and listings of impaired waters using targeted sampling design. CT DEP underwent a Critical Elements Program Evaluation in 2006 to help identify and prioritize additional technical program improvements needed to develop numeric biological criteria for different levels of quality along a gradient of condition (e.g., excellent and good quality waters). The program was evaluated at a level 2 with specific tasks identified to build its technical capability (e.g., improved spatial resolution in watershed assessment design from 8-digit HUC to 10- to 12-digit HUC; a regionally-calibrated multimetric index for benthic macroinvertebrates and one for fish that distinguishes between coldwater and warmwater assemblages; instituting an independent peer review process). Since the review, CT DEP has improved the technical capability of the biological assessment program to a level 3 and now has two numeric indices and enhanced spatial monitoring design.

These examples show how states and tribes can use the results of the Critical Elements Program Evaluation to develop a *blueprint* for making orderly improvements and attaining the technical proficiency to respond to management questions and improve decision making—including support for condition assessments, attainment of WQS, diagnosis of biological impairment, and effectiveness monitoring. The program review process identifies specific and successive improvements that are needed to improve the rigor of the biological assessment program and a checklist so that progress can be identified and tracked.

2.2 Tool #2: The Biological Condition Gradient

Purpose: To provide a common scale of biological condition to support comparisons between programs and across jurisdictional boundaries.

This tool can be used to help answer questions, including the following:

- What biological community should be at a site, e.g., natural conditions?
- Are we protecting our high-quality waters?
- Are we making progress to restore our degraded systems?
- Are our actions making real and lasting environmental improvements?

Source: *The biological condition gradient: A descriptive model for interpreting change in aquatic ecosystems* (Davies and Jackson 2006)

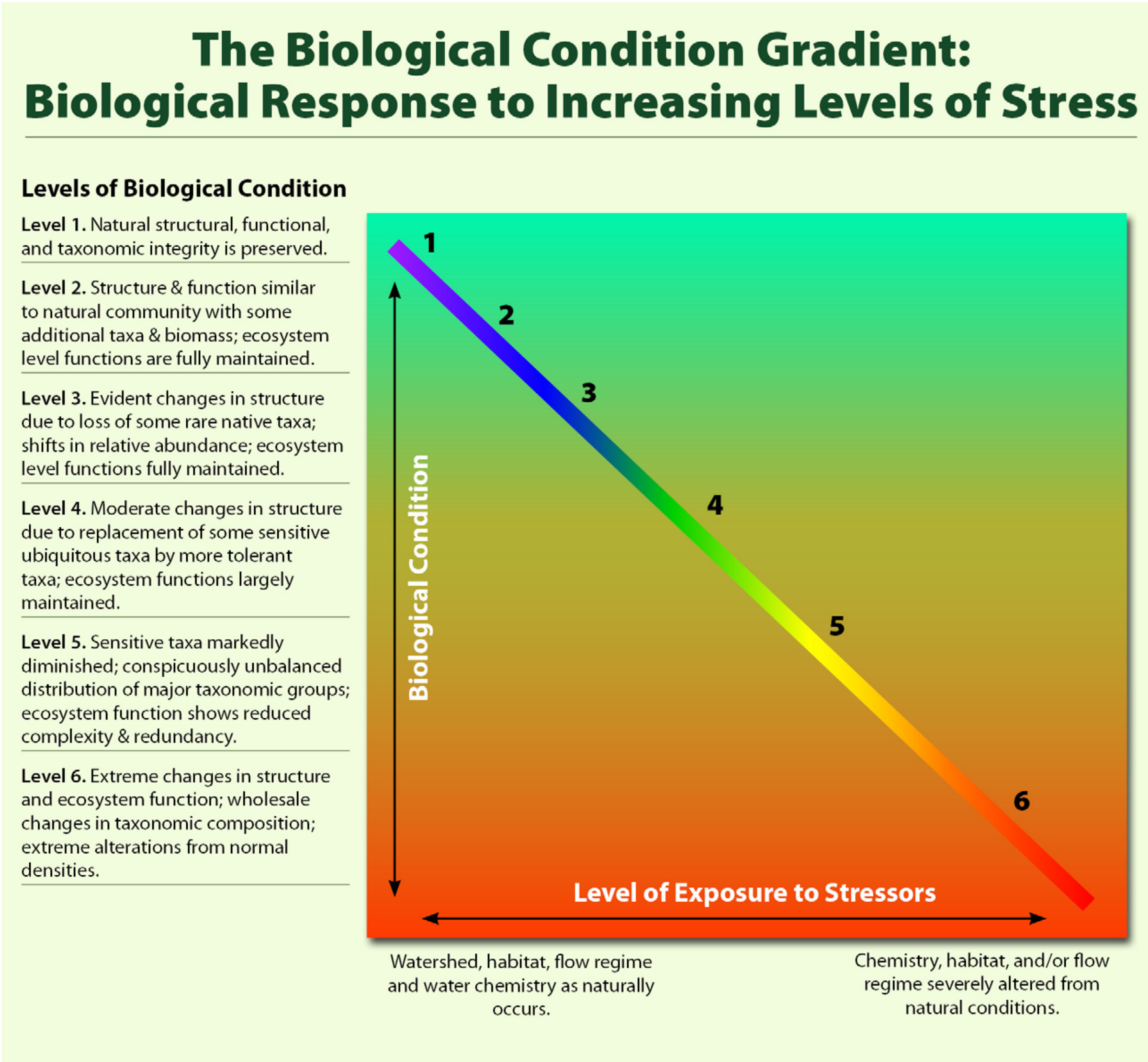
This section provides an overview of the BCG and how it can be calibrated for specific use by a state or tribe. The BCG is being applied and tested in several regions and states.

What Is the BCG?

Over the past 40 years, states have independently developed technical approaches to assess biological condition and set designated aquatic life uses for their waters. The BCG was designed to provide a means to map different indicators on a common scale of biological condition to facilitate comparisons between programs and across jurisdictional boundaries in context of the CWA. The BCG is a conceptual, narrative model that describes how biological attributes of aquatic ecosystems change along a gradient of increasing anthropogenic stress. It provides a framework for understanding current conditions relative to natural, undisturbed conditions (Figure 2-2). Some states, such as Maine and Ohio, have used a framework similar to the BCG to more precisely define their designated aquatic life uses (case studies 3.1 and 3.5).

Agreeing that, even in different geographic and climatological areas, a similar sequence of biological alterations occurs in streams and rivers in response to increasing stress, biologists from across the United States developed the model (Davies and Jackson 2006). The model shows an ecologically based relationship between the stressors affecting a waterbody (e.g., physical, chemical, biological impacts) and the response of the aquatic community (i.e., biological condition). The model is consistent with ecological theory and can be adapted or calibrated to reflect specific geographic regions and waterbody type (e.g., streams, rivers, wetlands, estuaries, lakes). Approaches to calibrate the BCG to region-, state-, or tribe-specific conditions are being piloted in several ecological regions by multiple states and tribes.

In practice, the BCG is used to first identify the critical attributes of an aquatic community (see Table 2-2) and then describe how each attribute changes in response to stress. Practitioners can use the BCG to interpret biological condition along a standardized gradient, regardless of assessment method, and apply that information to different state or tribal programs. For example, Pennsylvania is exploring the use of a BCG calibrated to its streams to complement its existing biological indices for macroinvertebrates and to describe the biological characteristics of waters along a gradient of condition. The state is evaluating using this information to help assess aquatic life use impairments and to describe waters of the highest quality (case study 3.4).



Source: Modified from Davies and Jackson 2006.

Figure 2-2. The BCG.

Note: The BCG was developed to serve as a scientific framework to synthesize expert knowledge with empirical observations and develop testable hypotheses on the response of aquatic biota to increasing levels of stress. It is intended to help support more consistent interpretations of the response of aquatic biota to stressors and to clearly communicate this information to the public, and it is being evaluated and piloted in several regions and states.

The BCG model provides a framework to help water quality managers do the following:

- Decide what environmental conditions are desired (goal-setting)—The BCG can provide a framework for organizing data and information and for setting achievable goals for waterbodies relative to "natural" conditions (e.g., condition comparable or close to undisturbed or minimally disturbed condition).
- Interpret the environmental conditions that exist (monitoring and assessment)—Practitioners can get a more accurate picture of current waterbody conditions.

- Plan for how to achieve the desired conditions and measure effectiveness of restoration—The BCG framework offers water program managers a way to help evaluate the effects of stressors on a waterbody, select management measures by which to alleviate those stresses, and measure the effectiveness of management actions.
- Communicate with stakeholders—When biological and stress information is presented in this framework, it is easier for the public to understand the status of the aquatic resources relative to what high-quality places exist and what might have been lost.

How Is the BCG Constructed?

The BCG is divided into six levels of biological conditions along the stressor-response curve, ranging from observable biological conditions found at no or low levels of stress (level 1) to those found at high levels of stress (level 6) (Figure 2-2). The technical document provides a detailed description of how 10 attributes of aquatic ecosystems change in response to increasing levels of stressors along the gradient, from level 1 to 6 (see Table 2-2). The attributes include several aspects of community structure, organism condition, ecosystem function, spatial and temporal attributes of stream size, and connectivity.

Each attribute provides some information about the biological condition of a waterbody. Combined into a model like the BCG, the attributes can offer a more complete picture about current waterbody conditions and also provide a basis for comparison with naturally expected waterbody conditions. All states and tribes that have applied a BCG used the first seven attributes that describe the composition and structure of biotic community on the basis of the tolerance of species to stressors and, where available, included information on the presence or absence of native and nonnative species and, for fish and amphibians, observations on overall condition (e.g., size, weight, abnormalities, tumors).

The last three BCG attributes of ecosystem function and connectance and spatial and temporal extent of detrimental effects can provide valuable information when evaluating the potential for a waterbody to be protected or restored. For example, a manager can choose to target resources and restoration activities to a stream where there is limited spatial extent of stressors or there are adjacent intact wetlands and stream buffers or intact hydrology versus a stream with comparable biological condition but where adjacent wetlands have been recently eliminated, hydrology is being altered, and stressor input is predicted to increase. Pennsylvania is evaluating indicators comparable to the BCG spatial and connectance attributes IX and X to characterize the biological conditions of streams in healthy watersheds where resources may be well spent to successfully protect such waters (see case study 3.4). Additionally, several of EPA's NEPs, in conjunction with EPA ORD, are exploring application of those attributes at a whole-estuary scale (e.g., distribution and connectance of critical aquatic habitats and associated biota) (see case study 3.16).

Additionally, individual attributes might uniquely respond to a specific stressor or group of associated stressors (biological response signatures) (Yoder and Rankin 1995; Yoder and Deshon 2003). That information could contribute to the causal analysis of biological impairment discussed in Tool #3*, Stressor Identification (SI) and Causal Analysis/Diagnosis Decision Information System (CADDIS)*.

Table 2-2. Biological and other ecological attributes used to characterize the BCG.

Attribute	Description
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	Taxa known to have been supported according to historical, museum, or archeological records, or taxa with restricted distribution (occurring only in a locale as opposed to a region), often due to unique life history requirements (e.g., sturgeon, American eel, pupfish, unionid mussel species).
II. Highly sensitive (typically uncommon) taxa	Taxa that are highly sensitive to pollution or anthropogenic disturbance. Tend to occur in low numbers, and many taxa are specialists for habitats and food type. These are the first to disappear with disturbance or pollution (e.g., most stoneflies, brook trout [in the east], brook lamprey).
III. Intermediate sensitive and common taxa	Common taxa that are ubiquitous and abundant in relatively undisturbed conditions but are sensitive to anthropogenic disturbance/pollution. They have a broader range of tolerance than attribute II taxa and can be found at reduced density and richness in moderately disturbed sites (e.g., many mayflies, many darter fish species).
IV. Taxa of intermediate tolerance	Ubiquitous and common taxa that can be found under almost any conditions, from undisturbed to highly stressed sites. They are broadly tolerant but often decline under extreme conditions (e.g., filter-feeding caddisflies, many midges, many minnow species).
V. Highly tolerant taxa	Taxa that typically are uncommon and of low abundance in undisturbed conditions but that increase in abundance in disturbed sites. Opportunistic species able to exploit resources in disturbed sites. These are the last survivors (e.g., tubificid worms, black bullhead).
VI. Nonnative or intentionally introduced species	Any species not native to the ecosystem (e.g., Asiatic clam, zebra mussel, carp, European brown trout). Additionally, there are many fish native to one part of North America that have been introduced elsewhere.
VII. Organism condition	Anomalies of the organisms; indicators of individual health (e.g., deformities, lesions, tumors).
VIII. Ecosystem function	Processes performed by ecosystems, including primary and secondary production; respiration; nutrient cycling; decomposition; their proportion/dominance; and what components of the system carry the dominant functions. For example, shift of lakes and estuaries to phytoplankton production and microbial decomposition under disturbance and eutrophication.
IX. Spatial and temporal extent of detrimental effects	The spatial and temporal extent of cumulative adverse effects of stressors; for example, groundwater pumping in Kansas resulting in change in fish composition from fluvial dependent to sunfish.
X. Ecosystem connectance	Access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation. For example, levees restrict connections between flowing water and floodplain nutrient sinks (disrupt function); dams impede fish migration, spawning.

Source: Modified from Davies and Jackson 2006.

Calibrating the Conceptual Model to Local Conditions

The BCG can serve as a starting point for defining the response of aquatic biota to increasing levels of stress in a specific region. Although the BCG was developed primarily using forested stream ecosystems, the model can be applied to any region or waterbody by calibrating it to local conditions using specific expertise and local data. To date, most states and tribes are calibrating the BCG using the first seven attributes that characterize the biotic community primarily on the basis of tolerance to stressors, presence/absence of native and nonnative species, and organism condition. Although the model has been developed for six levels of condition, six levels might not be necessary or feasible depending on limitations in data or level of technical rigor (see Chapter 2, Tool #1, *Biological Assessment Program Evaluation*) or naturally occurring conditions. For example, ephemeral streams in the arid Southwest naturally support a community of aquatic organisms that tolerate extreme conditions that range from intense, monsoon-like precipitation to extensive periods of drought. Those organisms might also be able to tolerate the presence of stressors. Thus, the range of response to anthropogenic stress in such streams (e.g., moderately tolerant to very tolerant species) might be abbreviated compared to that of a forested stream community in a temperate climate (e.g., very sensitive to very tolerant species). Three or four tiers might be suitable for those waters.

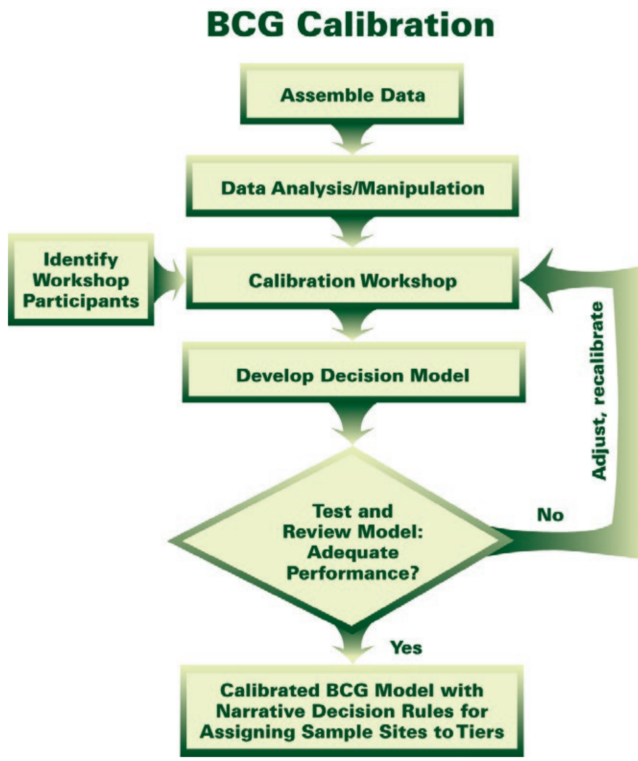


Figure 2-3. Steps in a BCG calibration.

It is a multistep process to calibrate a BCG to local conditions (Figure 2-3). That process is followed to describe the native aquatic assemblages under natural conditions; identify the predominant regional stressors; and describe the BCG, including the theoretical foundation and observed assemblage response to stressors. Calibration begins with the assembly and analysis of biological monitoring data. Next, a calibration workshop is held in which experts familiar with local conditions use the data to define the ecological attributes and set narrative statements. For example, narrative decision rules for assigning sites to a BCG level on the basis of the biological information collected at sites. New Jersey is one of several states that are field testing this approach. Documentation of expert opinion in assigning sites to tiers is a critical part of the process. A decision model can then be developed that encompasses those rules and is tested with independent data sets. A decision model based on the tested decision rules is a transparent, formal, and testable method for documenting and validating expert knowledge (see Table 2-3 for examples). A quantitative data analysis program can then be developed using those rules. EPA recommends peer review of model.

Table 2-3. Example of narrative decision rules for distinguishing BCG Level 2 from Level 3 for streams, modified from New Jersey BCG expert workshop

Attributes	**Rules for BCG Level 2** Structure and function of community similar to natural community with some additional taxa and biomass	**Rules for BCG Level 3** Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance
Total taxa	More than 12 taxa	More than 12 taxa
Highly Sensitive Taxa (Attribute II only)	More than two taxa	May be absent
Richness of Sensitive Taxa (combination of Attributes II and III,see table 2-2)	Attribute II + Attribute III are more than 50% of total taxa richness	Attribute II + Attribute III are more than 35% of total taxa richness
Abundance of Tolerant Taxa (Attribute V)	Abundance of Attribute V is less than 20% of community	Abundance of Attribute V is less than 50% of community

In the example above, both BCG levels 2 and 3 support comparable levels of overall taxa (e.g., total taxa). However, there is a shift from BCG level 2 to BCG level 3 in proportion and abundance of sensitive and tolerant taxa (e.g., a decrease in proportion of sensitive taxa and an increase in abundance of pollution-tolerant taxa). The BCG describes incremental shifts in community composition and other biological parameters along a gradient of increasing anthropogenic stress. The BCG can be used to detect measurable changes in the aquatic biota before there is a complete loss of a certain type or category of taxa such as loss of pollution sensitive or native species. This tool will enable earlier detection and support action to prevent loss of species or other biological changes. This tool can be used to raise the discriminatory power of biological assessment programs in a nationally consistent, transparent manner. Narrative decision rules are the first step in formalizing expert opinion and expressing empirical findings that can then be tested and validated.

Case Example: New Jersey BCG Calibration

New Jersey developed and calibrated a BCG for its upland streams. The New Jersey Department of Environmental Protection (NJ DEP) convened an expert panel workshop that included aquatic biologists and water quality experts familiar with the aquatic fauna that inhabit these streams. The panel developed descriptions of the ecological attributes for these streams in New Jersey and created the narrative rules for assigning sites to levels along the stressor gradient.

The expert panel reviewed the list of taxa from the New Jersey Ambient Biological Monitoring Network to assign taxa to attributes I–VI. Next, the panel examined macroinvertebrate data from 58 upland stream sites and reached consensus on the level assignments for all sites reviewed. The panel was able to distinguish five separate levels (levels 2–6, see below) for New Jersey upland streams. The first level described in Davies and Jackson (2006) consists of entirely pristine sites and was not included because the panel could not identify any level 1 (pristine) sites in New Jersey.

On the basis of the characterization of sites identified as belonging to different BCG levels, the panel developed a set of narrative decision rules and descriptions for distinguishing among the levels.

BCG level 2 (Minimal changes in structure and function)—Because of extensive historical land clearing, cultivation, and early industrial use followed by abandonment and reforestation from the early 20th century, the least stressed watersheds are thought to reflect at best BCG level 2. Most of the 19th century legacy is in changed stream morphology and hydrology that persist in valley bottoms (Walter and Merritts 2008). Watersheds are predominantly forested, with recreational use but little residential or agricultural use. The group consensus was that several richness criteria (i.e., total taxa, highly sensitive taxa, and all sensitive taxa) must all be met for a site to be considered to be in level 2.

BCG level 3 (Evident changes in structure and function)—A typical level 3 stream has a largely forested watershed but some areas of suburban development or limited agriculture. Criteria for level 3 are similar to those for level 2, but richness of the sensitive organisms is somewhat reduced and sensitive organisms do not numerically dominate the assemblage. All the criteria for level 3 were considered critical.

BCG level 4 (Moderate changes in structure and function)—Typical level 4 streams in New Jersey often have relatively extensive suburban and commercial development, some agricultural land use, but substantial areas of natural land cover, often mixed with residential areas. In BCG level 4, the sensitive taxa are present and still constitute a significant fraction of the community, but they are far reduced below their dominance in level 2 and their subdominance in level 3. The assemblage has degraded but maintains ecosystem functions as represented by the sensitive taxa.

BCG level 5 (Major changes in structure and function)—BCG level 5 is discriminated from level 4 by a significant reduction of sensitive taxa (attributes II and III) to the point where they are merely incidental if present and are not a functional part of the community. Although BCG level 5 can have high abundance and high taxa richness, the assemblage is dominated by intermediate and tolerant taxa, and sensitive taxa have all but disappeared.

BCG level 6 (Severe changes in structure and function)—BCG level 6 reflects nearly complete disruption and degradation of the biological community to either very low abundance (less than 50 organisms in New Jersey's standard sampling procedure) or very low taxon richness. While extremely low abundance often indicates toxic conditions, extremely low richness coupled with high abundance often indicates organic enrichment and high-density urban runoff.

New Jersey is considering using the calibrated BCG and the narrative decision rules to help identify high-quality waters on a waterbody-by-waterbody basis for antidegradation purposes.

2.3 Tool #3: Stressor Identification (SI) and Causal Analysis/Diagnosis Decision Information System (CADDIS)

Purpose: To identify the cause of aquatic life impairment when a waterbody is listed because of biological impairment and the cause is unknown.

This tool can be used to answer questions such as the following:

- How can I use biological and stressor information to identify cause of biological impairment?

Sources: *Stressor Identification Guidance Document* (USEPA 2000a); EPA's CADDIS website: http://www.epa.gov/caddis

This section describes how biological assessment information can be used to help identify stressors for impaired waters where cause of impairment is unknown.

How Can Biological Information Be Used for Stressor Identification?

Once a biological impairment has been determined, water quality managers examine existing water quality and landscape data and information to determine the cause and source of impairment, also known as stressor identification (SI). Typically, states and tribes identify the probable causes of the impairment and then, step-by-step, implement additional controls or management practices (or both) to fix the problem. Monitoring the response of the biota to management actions then helps to provide the necessary information on whether the primary stressors were correctly identified and the management actions effective. The biological response information provided in the initial assessment often includes useful information for identifying stressors; for example, the relationship between biological indicators and stressors such as the disappearance of certain benthic species sensitive to a specific toxin (e.g., sensitivity of aquatic life stage of mayflies to metal toxicity) or a shift in dominate community traits related to the increase of a stressor (e.g., a change in primary producer base because of zebra mussel invasion). Additionally, states and tribes have successfully implemented management actions that address co-occurring stressors supported by documented improvements in water quality. Maryland and the District of Columbia were able to use biological assessment data to document the biological effects of a pesticide spill that resulted in a fish kill in Rock Creek, a tributary to the Potomac River. The information was used as the basis for enforcement actions, and subsequent data were able to support a quantitative assessment of the biological impact and evidence of stream recovery (case study 3.12).

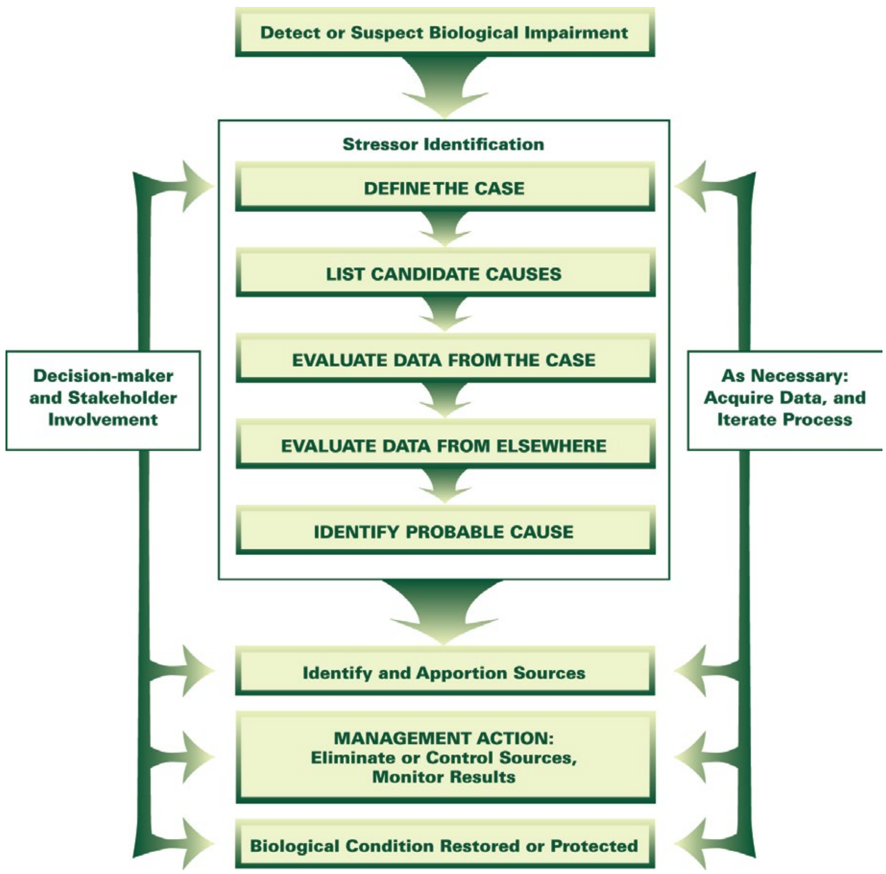
Stressor ID/CADDIS

In 2000 EPA's Office of Water and ORD developed a process for identifying any type of stressor or combination of stressors that causes biological impairment. The *Stressor Identification Guidance Document* (USEPA 2000a) is intended to lead water resource managers through a formal and rigorous process that identifies stressors causing biological impairment in aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions.

The SI process is prompted by biological assessment data indicating that a biological impairment has occurred. The general SI process entails critically reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and providing conclusions about which stressor(s) are causing the impairment. The SI process is iterative, usually beginning with a retrospective analysis of available data. The accuracy of the identification depends on the quality of data and other information used in the SI process. In some cases, additional data collection might be necessary to accurately identify the stressor(s). The conclusions can be translated into management actions, and the effectiveness of those management actions can be monitored (Figure 2-4).

The core of the SI process consists of the following three main steps:

- Listing candidate causes of impairment.
- Analyzing new and previously existing data to generate evidence for each candidate cause.
- Producing a causal characterization using the evidence generated to draw conclusions about the stressors that are most likely to have caused the impairment.



Source: USEPA 2010b

Figure 2-4. Stressor identification process.

Again, the SI process is iterative. Practitioners will begin by analyzing available data to see if sufficient information is already available. The kinds of information needed include information on the type of impairment, the extent of the impairment, any evidence of the usual causes of impairment (e.g., hydrologic alteration, invasive species, habitat loss, toxicants, total nitrogen and phosphorus), and other information from the site. The evidence is considered first and then other, less direct kinds of evidence are gathered and evaluated, if needed. For example, one might consider other situations that are similar and can provide useful insights.

CADDIS is an online application of the SI process that uses a step-by-step guide, worksheets, technical information, and examples to help scientists and engineers find, access, organize, share, and use environmental information to evaluate causes of biological effects observed in aquatic systems such as streams, lakes, and estuaries.[14] CADDIS also contains updates, clarifications, and additional material developed since the SI guidance document was published in 2000.

[14] http://cfpub.epa.gov/caddis/index.cfm.

Case Example: Nutrient Management in the Little Miami River, Ohio

In the early 1980s, Ohio EPA designated the Little Miami River as an Exceptional Warmwater Habitat (EWH) following the first complete biological survey of the mainstem and key tributaries in the Ohio WQS under the new system of tiered aquatic life uses adopted in 1978. While not all sites sampled in 1983 attained the EWH biological criteria for both the fish and macroinvertebrate assemblages, sufficient sites did attain the EWH use, thus demonstrating the potential for attainment of that use as long as critical habitat were present.

In 1988, more stringent effluent limits for typical wastewater treatment plant (WWTP) parameters (e.g., biochemical oxygen demand [BOD], ammonia-N, common heavy metals) were established for municipal WWTPs. In 1993, as part of the Ohio EPA rotating basin approach, both water quality and biological improvements were observed, accompanied by increase in waters achieving the EWH use. These improvements resulted from water quality-based permitting at municipal WWTPs and compliance with more stringent effluent limits. However, suburban development in the surrounding communities resulted in increased WWTP flows and loads through the 1990s and the level of stress on aquatic systems increased. In 1998 biological assessment results again documented a decline in EWH attainment. The decline was associated with increased phosphorus loadings, which had not been targeted as part of the earlier water quality-based permitting. Additionally, increased diel dissolved oxygen variations and elevated phosphorus concentrations were observed. Following a determination that the observed degradation was related to loadings discharged primarily during summer low flows (i.e., from municipal WWTPs), the largest WWTPs implemented a phased reduction of phosphorus loadings through NPDES permits.

A follow-up biological assessment in 2007 documented attainment of the EWH biological criteria along most of the mainstem of the Little Miami River after point source phosphorus controls were implemented. The findings documented the effectiveness of the nutrient removal provided by the WWTPs and confirmed the original hypothesis that the biological impairments were indeed linked to phosphorus loadings discharged by the point sources. This example highlights the value of conducting before-and-after biological assessments to support NPDES permitting.

Source: Ohio EPA (Environmental Protection Agency). 2009. *Biological and Water Quality Study of the Lower Little Miami River and Selected Tributaries 2007 Including the Todd Fork Watershed*. Watershed assessment units 05090202 06, 07, 08, 09 and 14. Clermont, Clinton, Hamilton, and Warren counties. Ohio EPA technical report EAS/2009-10-06. 201 pp.

Case Example: Causal Assessments of Impairment in Iowa

The Iowa Department of Natural Resources (IDNR) identified causes of biological impairment of the Little Floyd River using EPA's SI methodology (Haake et al. 2010). Through its biological monitoring program and using Iowa's benthic macroinvertebrate index, IDNR identified the Little Floyd River as impaired, with biotic index scores well below the reference population for the area. IDNR applied the SI process to biological, chemical, and physical data collected from the river.

Candidate causes for the biological impairment were flow alteration, substrate alteration, turbidity, altered basal food source, low dissolved oxygen concentrations, high temperature, and high ammonia concentrations. Biological metrics specific to the impairment were used to identify a less impaired location in the stream to help discover the cause of more severe effects in other parts of the stream. These paired biological, physical, and chemical data from the stream were used to develop evidence of co-occurrence of exposure and effects and evidence of preceding causation; that is, the presence of sources and mechanistic pathways leading to conditions where exposure could occur. Evidence that the exposure level was sufficient to cause either the fish or the invertebrate effects was developed from two Iowa data sets with paired biological, physical, and chemical data. The interquartile range of values for the various stressors from ecoregion reference sites were compared to the values observed for the Little Floyd River. Also, the mean value at statewide random sites was compared to the values in the Little Floyd River. All the supporting or discounting evidence was weighted, and the body of evidence for each candidate cause was weighed.

The formal process revealed that sediment deposition, hypoxia, heat stress, and ammonia toxicity were probable causes of impaired biological condition in the Little Floyd River. Other causes were discounted if they were unlikely or deferred if the data were insufficient to make a determination. The assessment was used to develop a recovery plan for the stream and was a contributing impetus for developing temperature criteria as part of IDNR's WQS. Without Iowa's basic commitment to integrated monitoring and use of biological, physical, and chemical data, the analysis and the SI would not have been possible.

Source: Haake, D.M., T. Wilton, K. Krier, A.J. Stewart., and S.M. Cormier. 2010. Causal assessment of biological impairment in the Little Floyd River, Iowa, USA. *Human Ecological Risk Assessment* 16(1):116–148.

Chapter 3. Case Studies

Biological assessments, in conjunction with other data (chemical, toxicity, physical, landscape), provide water quality management programs the data and information necessary to document the effectiveness of management actions to protect and restore water quality and to clearly communicate that information to the public. Biological assessment data, WET test results, and physical and chemical monitoring are used to build the relationship between the stressors being managed and the biological impact of the stressors. By relating biological condition to the level and type of stress, results of individual program actions can be related to a common measure of actual environmental improvements—the condition of the aquatic biota (Figure 3-1). The ultimate goal is a water quality management program that integrates biological, physical, and chemical data to create a more complete picture of resource conditions that supports effective implementation of the NPDES and TMDL programs.

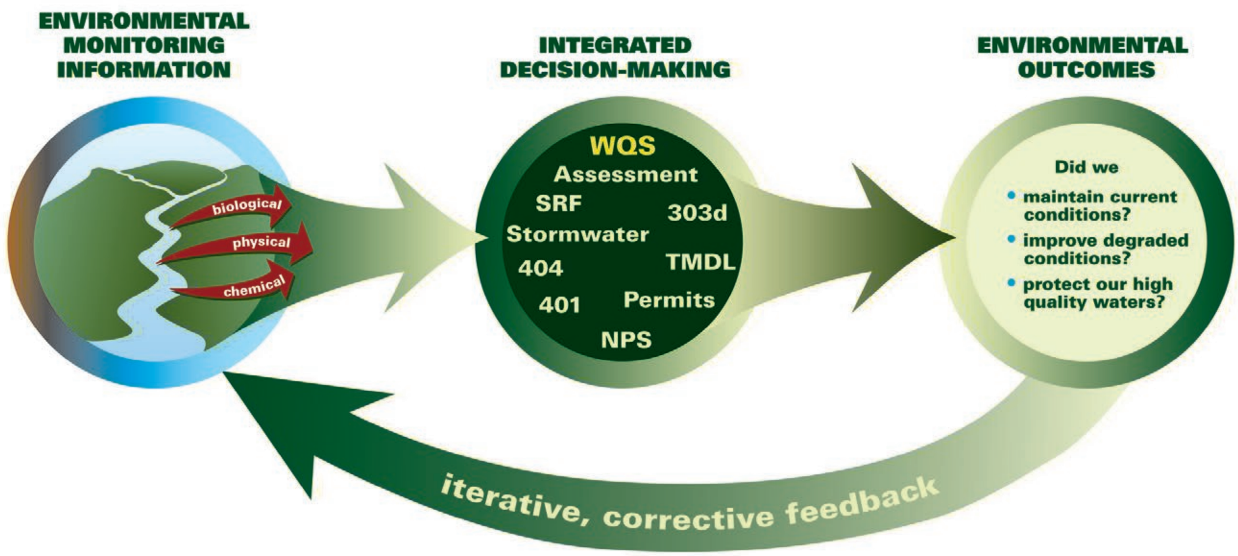


Figure 3-1. Biological data and assessments support integrated decision making.

By quantifying the stressor-response relationships, it is possible to explain to stakeholders the effects on aquatic life. For example, biological assessment data can be used to document the effects on aquatic life from an undetected toxic effluent from a point source, increasing impervious surfaces in a watershed, the loss of wetlands, or the effects of channelization. Once management actions are implemented, biological assessment data can measure the biological benefits of addressing those effects. That information helps the public understand what is being protected or what could be restored and whether state or tribal water quality standards (WQS) (i.e., aquatic life protection) are being met. Typically, with improved understanding of what is at stake, the public is more informed, motivated, and engaged in working with the state/tribal or local agencies in setting goals for protection or restoration and designing solutions that work.

Over the past four decades, state and tribal water quality programs have used technical tools and information on biological condition to support management decisions. Development of practical methods and technical approaches for biological assessment programs includes field testing by state and tribal programs. These technical advancements build upon existing approaches and can be used by states and tribes to strengthen their biological assessment and biological criteria programs. This chapter presents 17 examples of how states and tribes have incorporated such information and tools into their programs or are exploring additional biological condition applications.

The case studies are listed below.

Case Studies

3.1	Protecting Water Quality Improvements and High Quality Conditions in Maine
3.2	Arizona's Development of Biological Criteria
3.3	Protection of Antidegradation Tier II Waters in Maryland
3.4	Using Complementary Methods to Describe and Assess Biological Condition of Streams in Pennsylvania
3.5	Use of Biological Assessments to Support Use Attainability Analysis in Ohio
3.6	Screening Tool to Assess Both the Health of Oregon Streams and Stressor Impacts
3.7	North Fork Maquoketa River TMDL in Iowa
3.8	Addressing Stormwater Flow in Connecticut's Eagleville Brook TMDL for Biological Impairment
3.9	Vermont's Use of Biological Assessments to List Impaired Waters and to Support NPDES Permit Modification and Wastewater Treatment Facility Upgrades
3.10	Restoration of Red Rock Creek by the Grand Portage Band of Lake Superior Chippewa
3.11	Using Biological Assessment Data to Show Impact of NPS Controls in Michigan
3.12	Using Biological Assessment as Evidence of Damage and Recovery Following a Pesticide Spill in Maryland and the District of Columbia
3.13	Support for Dredge and Fill Permitting in Ohio
3.14	Virginia INSTAR Model for Watershed Protection
3.15	Examination of Climate Change Trends in Utah
3.16	Applications of Biological Assessment at Multiple Scales in Coral Reef, Estuarine, and Coastal Programs
3.17	Partnerships in the Protection of Oregon's Coho Salmon

3.1 Protecting Water Quality Improvements and High Quality Conditions in Maine

Abstract

Maine has used biological, habitat, and other ecological information to designate aquatic life uses that reflect the highest achievable conditions of its waterbodies and has used antidegradation policy to maintain and protect high existing conditions. Maine uses a Biological Condition Gradient to designate levels of protection for its waterbodies (e.g., designated aquatic life uses) and to assign numeric biological criteria to protect those uses. Maine describes the system as a tiered use classification. For Maine, tiered aquatic life uses highlight the relationship between biology, water quality, and watershed condition in determining the need for waterbody protection to maintain existing high quality conditions or the potential for water quality improvement to attain water quality standards. Maine's integrated, data-driven approach has resulted in documented improvement in water quality throughout the state, including upgrades of designated uses of more than 1,300 stream miles, from Class C to Class B, and from Class B to Class A or AA waters (Outstanding National Resource Waters).

In 1983 the Maine Department of Environmental Protection (ME DEP) initiated a statewide biological monitoring and assessment program and revised water quality standards (WQS) by 1986 to recognize high levels of water quality condition. Maine established four classes for freshwater rivers and streams (see Table 3-1). All four classes meet or exceed the Clean Water Act (CWA) section 101(a)(2) goal for aquatic life protection. Every waterbody is assigned to one of four tiers by considering its existing biological condition, its highest achievable condition on the basis of biological potential, aquatic habitat, watershed condition, levels of dissolved oxygen, and numbers of bacteria (Table 3-1). Agency biologists developed a linear discriminant model to measure the biological attainment of each class, establish numeric biological criteria, and assign corresponding antidegradation tiers for purposes of statewide planning (see Table 3-1, column 6). Part of Maine's antidegradation policy requires that where any actual measured water quality criterion exceeds that of a higher class, that quality must be maintained and protected [Maine Revised Statutes Title 38, §464.4(F)]. In effect, by having multiple levels of aquatic life use standards in law, Maine has established a means of improving water quality in incremental steps, and of using antidegradation reviews and reclassification upgrades to maintain and protect water quality and aquatic life conditions that exceed existing or designated aquatic life uses.

The following case study offers an example of how Maine has used tiered use classifications and antidegradation policy cooperatively in its water quality management program. In conjunction with habitat and other chemical and physical parameters, Maine assigns waters to designated use classes (AA, A, B, or C; Table 3-1) on the basis of the *potential* for water quality improvement. In the 1980s, monitoring on the Piscataquis River near the towns of Guilford and Sangerville found aquatic life conditions insufficient to meet even the minimum Class C conditions at which the river was classified. The segment of the river in the Guilford-Sangerville area had a history of poor water quality, including recurrent fish kills from poorly treated industrial and municipal wastes. However, the state determined that this segment of the river could attain at least Class C. The state determined that sewage treatment plant and industrial discharges were the only significant source of stressors to the river, with very good quality upstream conditions and good salmonid production elsewhere. Additionally, the river's habitat structure and hydrologic regime were very good.

Table 3-1. Criteria for Maine river and stream classifications and relationship to antidegradation policy.

Class	Dissolved oxygen criteria	Bacteria criteria	Habitat narrative criteria	Aquatic life narrative criteria*** and management limitations/restrictions	Corresponding federal antidegradation policy tiers
AA	As naturally occurs	As naturally occurs	Free-flowing and natural	As naturally occurs**; no direct discharge of pollutants; no dams or other flow obstructions.	3 (Outstanding National Resource Water [ONRW])
A	7 ppm; 75% saturation	As naturally occurs	Natural**	Discharges permitted only if the discharged effluent is of equal to or better quality than the existing quality of the receiving water; before issuing a discharge permit the Department shall require the applicant to objectively demonstrate to the department's satisfaction that the discharge is necessary and that there are no reasonable alternatives available. Discharges into waters of this class licensed before 1/1/1986 are allowed to continue only until practical alternatives exist.	2 1/2
B	7 ppm; 75% saturation	64/100 mg (g.m.) or 236/100 ml (inst.)*	Unimpaired**	Discharges shall not cause adverse impact to aquatic life** in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous** to the receiving water without detrimental changes to the resident biological community.**	2 to 2 1/2
C	5 ppm; 60% saturation; and 6.5 ppm (monthly avg.) when temperature is </= 24 °C	125/100 mg (g.m.) or 236/100 (inst.)*	Habitat for fish and other aquatic life	Discharges may cause some changes to aquatic life**, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous** to the receiving waters and maintain the structure** and function** of the resident biological community. **	1 to 2

Source: Maine DEP (modified). http://www.maine.gov/dep/blwq/docmonitoring/classification/reclass/appa.htm.

Notes:

* g.m. = geometric mean; inst. = instantaneous level.

** Terms are defined by statute (Maine Revised Statutes Title 38, §466).

*** Numeric biological criteria in Maine regulation Chapter 579, Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams.

Four years after issuance of new National Pollutant Discharge Elimination System (NPDES) permits requiring better industrial pretreatment and improved wastewater treatment at the Guilford-Sangerville treatment facility, follow-up monitoring found water quality improvements that exceeded Class C and attained Class B aquatic life conditions. The achievement of higher water quality conditions was preserved through a classification upgrade process (supported by the industry and the two towns). The river was upgraded to Class B and now attains those higher aquatic life use goals. The redesignation process requires the state legislature to enact a statutory change of a waterbody's classification and can take considerable time to complete. However, during the reclassification process the improved water quality conditions existing in the Piscataquis River were protected through implementation of the state's Tier II antidegradation policy. The value secured by maintaining the higher quality condition was demonstrated in 2009 when the Piscataquis River was designated as critical habitat for the restoration of the endangered Atlantic salmon.

The management actions based on documented improvements in the biological condition in this example demonstrate the complementary application of the state's tiered aquatic life use classification and the Tier 2 and 2½ antidegradation policy. Using that approach, water quality upgrades from Class C to B and from B to A or AA have been repeated in many parts of the state, and subsequently maintained and protected. Overall, Maine has redesignated more than 1,300 miles of streams to a higher class on the basis of biological information (e.g., biological improvements due to point source controls, nonpoint source practices, dam operational modifications or removal) and societal values (e.g., water quality and habitat protection for wild trout populations; critical species protection, especially Atlantic salmon habitat and tribal petitions).

3.2 Arizona's Development of Biological Criteria

Abstract

Arizona has adopted in its water quality standards both narrative and numeric biological criteria to help protect aquatic life uses in wadeable, perennial streams designated for either coldwater aquatic and wildlife or warmwater aquatic and wildlife. The biological criteria allow the state to define expected conditions relative to reference streams. The state implements a two-step verification process to confirm attainment of the biological criteria for waters that score just below the attainment threshold. Arizona Department of Environmental Quality uses the biological assessment results in its 305(b) reports on the condition of its aquatic resources.

Development of Numeric Biological Criteria

Arizona began a biological assessment program in 1992, following EPA's Rapid Biological Assessment Protocols for wadeable streams and rivers (Plafkin et al. 1989). Standard operating procedures for macroinvertebrate monitoring in perennial, wadeable streams and for laboratory processing and taxonomic identification were established and have been periodically reviewed and updated (ADEQ 2010). A statewide reference monitoring network was established to develop an index of biological integrity (IBI) as the macroinvertebrate assessment method.

A classification analysis was first performed on the statewide macroinvertebrate data set to identify regions of statistically different macroinvertebrate communities across the state (Spindler 2001). Elevation-based regions were the result of the classification analysis, consisting of two broad macroinvertebrate regions and community types:

- A warmwater community below 5,000 feet elevation
- A coldwater community above 5,000 feet elevation

All wadeable, non-effluent-dependent perennial streams in the regions, with some documented exceptions, are predicted to have the same general macroinvertebrate community type. IBIs were then developed for both a warmwater and coldwater community using the statewide reference site data (ADEQ 2007).

In the initial stages of development, Arizona's numeric biological criteria were based on the idea that the structure and function of aquatic benthic macroinvertebrate communities provide information on the overall quality of their surface waters and on attainment of the state's designated aquatic life uses. Measuring the composition and structure of the biological communities in minimally disturbed surface waters provides reasonable approximation of biological integrity and, thus, the basis for establishing the reference condition (Stoddard et al. 2006). The reference condition provides the benchmark for evaluating the biological condition of surface waters that could have been subjected to relatively greater amounts of disturbance.

However, on the basis of the state's scrutiny of the reference site database and further investigation of surrounding land use, the state concluded that its reference sites represent *best available*, or *least disturbed*, conditions for each watershed. There was uncertainty as to whether some of the reference sites at the lower range of the reference distribution were truly minimally disturbed conditions. For example, while reference sites were in a wilderness area for streams considered to be in pristine condition, much of the watershed upstream was extensively grazed, and the index scores for the reference sites were lower than the mean. In addition, there was variability because of sites later found to be intermittent in flow, and samples were affected by extreme flooding in the reference data set. Because of that uncertainty in reference quality in the low end of the reference database, Arizona selected the 25th percentile of the reference site distribution to be protective of the aquatic life use.

Minimally Disturbed Condition: The physical, chemical, and biological conditions of a waterbody with very limited human disturbance compared with natural, undisturbed conditions. There might be some changes to the composition of the resident aquatic biota, but native species are present.

Least Disturbed Condition: The best existing physical, chemical, and biological condition of a waterbody affected by human disturbance. These waters have the least amount of human disturbance in comparison to others within the waterbody class, region, or basin. Least disturbed condition is a relative term, and the actual condition may depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition might change significantly over time as human disturbances change.

Arizona established a two-stage process for determining nonattainment of the numeric biological criteria. On the basis of statistical analysis of reference, stressed, and test data sets, an attainment threshold of 25 percent was selected. The nonattainment biological criteria threshold was set at the 10th percentile of reference, the level at which a majority of stressed samples occurs in the Arizona Department of Environmental Quality (ADEQ) database. An inconclusive zone falls between the 10th and 25th percentiles of reference. The zone of uncertainty encompasses variability in IBI scores near the 25th percentile. To verify the biological integrity of the *inconclusive* samples, verification sampling is required before making an attainment decision. Verification monitoring must be conducted during the next immediate spring or fall index period. (A fall-based IBI scoring system is being developed.) If the waterbody in question scores at or less than the 25th percentile of reference, it will then be judged as not attaining. Such a verification approach provides an opportunity to confirm the status of waters that score just below the attainment threshold of the biological criteria.

Adoption of Numeric Biological Criteria

On January 31, 2009, Arizona adopted biological criteria, as part of the revised Arizona surface water quality standards (WQS), applicable to wadeable, perennial streams with either a coldwater or warmwater designated aquatic life use. The biological criteria consist of two parts: a narrative statement (Arizona R18-11-108) and numeric criteria (ARS R18-11-108.01). The narrative is presented as follows:

> A wadeable, perennial stream shall support and maintain a community of organisms having a taxa richness, species composition, tolerance, and functional organization comparable to that of a stream with reference conditions in Arizona.

The numeric criteria are laid out in text and numeric form (Table 3-2) in the state's biological criteria rule in the WQS as follows:

> The biological standard in R18-11-108(E) is met when a biological assessment result, as measured by the Arizona IBI [index of biological integrity], for cold or warm water is: 1) Greater than or equal to the 25th percentile of reference condition, or 2) Greater than the 10th percentile of reference

condition and less than the 25th percentile of reference condition and a verification biological assessment result is greater than or equal to the 25th percentile of reference condition.

Table 3-2. Arizona numeric biological criteria IBI scores

Biological assessment result	IBI scores	
	coldwater	**warmwater**
Greater than or equal to the 25th percentile of reference condition	$\geq$ 52	$\geq$ 50
Greater than the 10th and less than the 25th percentile of reference condition	46–51	40–49

Source: Arizona R18-11-108.01

ADEQ uses the biological assessment results in its 305(b) reports on the condition of its aquatic resources. More information about the biological criteria, sampling methods, establishing reference condition, and the method for determining nonattainment of the biological criteria is provided in *Biocriteria Implementation Procedures* (ADEQ 2008) and in *Technical Support Documentation for the Narrative Biocriteria Standard* (ADEQ 2007).

3.3 Protection of Antidegradation Tier II Waters in Maryland

Abstract

Maryland is identifying high-quality waters for antidegradation purposes on a waterbody-by-waterbody basis. Maryland has designated Tier II waters on the basis of two indices of biotic integrity—fish and benthic invertebrates—and provides additional protection so that those waters are not degraded. New or increased point source dischargers and local sewer planning activities that have the potential to affect Tier II waters are required to examine alternatives to eliminate or reduce discharges or impacts. The state has developed requirements that must be met for projects that do not implement a no-discharge alternative. To help local planners to determine whether a planned activity has the potential to affect a Tier II water, the state has developed geographic information system shapefiles that identify such waters. Those files are provided to local jurisdictions to improve their knowledge of where Tier II waters occur. Biological assessments, in conjunction with chemical and physical assessments, are then conducted to determine the status of those waters and detect trends in condition.

In its state water quality standards (WQS), Maryland adopted an antidegradation policy for protecting all waters for existing and designated uses. High-quality (Tier II) waters receive additional attention and regulatory protections. Identification of Tier II waters, in this case streams, is based on a waterbody-by-waterbody approach using biological survey data, from which two indices of biotic integrity (IBIs) are developed—one for benthic invertebrates and one for fish. Those with both scores above 4 are designated Tier II waters. The state has identified more than 230 high-quality water segments. To protect downstream high-quality waters, a watershed approach to protection is applied. Tier II waters must be protected so that water quality does not degrade to minimum standards, and that requirement has implications for potential discharges and local planning activities.

Application of Tier II Protection

The Maryland Department of the Environment (MDE) requires that applicants for amendments to county plans (i.e., water and sewer plans) or permits for new or expanding point source discharges evaluate alternatives to eliminate or reduce discharges or impacts [COMAR 26.08.02.04-1(B)]. Applicants for permits must consider whether the receiving waterbody is Tier II (or whether a Tier II determination is pending); MDE reviews proposed amendments to county plans discharging to Tier II waters. In both cases, discharges to Tier II waters require a Tier II review [2.26.08.02.04-1(F)].

MDE has developed a cooperative approach to protecting Tier II waters. Monitoring and WQS programs work with the National Pollutant Discharge Elimination System (NPDES) permitting program to help screen for potential effects from new or expanded discharges and to develop permit conditions to minimize those effects and maintain existing high-quality waters. Outreach materials are available to educate county planners about Tier II waters, and geographic information system (GIS) shapefiles that planners can use to help locate Tier II waters within their jurisdictions have been developed.[15] That information provides Maryland county planners a way to determine early on whether their projects could affect Tier II waters.

[15] More information about GIS is at http://www.gis.com/content/what-gis.

A list of recommendations for land-disturbing projects that are not able to implement a no-discharge alternative provides the following initial guidance:

1. Implementation of environmental site design (also known as low-impact development)—Design elements and practices must be approved for Tier II waters with opportunity provided for exploration of appropriate alternatives and justification for structural elements in the proposed designs.
2. Expanded riparian buffers—Buffers must be at a minimum of 100 feet; wider buffers may be required depending on slope and soil type.
3. Biological, chemical, and flow monitoring in the Tier II watershed—Applicants may be required to conduct biological assessments in conjunction with chemical, physical, and flow assessments to help determine the remaining assimilative capacity and cumulative impacts of current and future development. Depending on project specifics, additional monitoring may be required, such as the completion of a hydrogeologic study for a major mining project or additional pH monitoring because of impacts associated with instream grout applications seen in many common transportation projects.
4. Additional practices—Depending on the potential for project-specific effects on water quality, applicants may be required to implement other practices, such as enhanced sediment and erosion control practices or implementation of more environmentally protective alternatives.

If those general requirements cannot be implemented, applicants must submit a detailed hydrologic study and alternatives analysis to demonstrate that the assimilative capacity of a waterbody will be maintained. The assimilative capacity of a waterbody is typically site-specific and determined through studies of the waterbody. In terms of WQS, assimilative capacity is a measure of the capacity of a receiving water to assimilate additional pollutant(s) but still meet the applicable water quality criteria and designated uses.

3.4 Using Complementary Methods to Describe and Assess Biological Condition of Streams in Pennsylvania

Abstract

The Pennsylvania Department of Environmental Protection (PA DEP) has developed a new benthic macroinvertebrate index of biotic integrity (IBI) to assess the health of wadeable, freestone (e.g., high gradient, soft water) streams. Additionally, PA DEP calibrated a benthic macroinvertebrate Biological Condition Gradient (BCG) and is exploring using the BCG to more precisely describe biological characteristics in Pennsylvania streams. Potentially, the BCG can be used in conjunction with the IBI to identify aquatic life impairments and to describe the biological characteristics of waters assigned special protection. PA DEP is also exploring using a discriminant analysis model with additional taxonomic, habitat, and landscape parameters to describe exceptional value waters.

Describing Waters along a Gradient of Condition

Pennsylvania Department of Environmental Protection (PA DEP) has developed a new benthic macroinvertebrate index of biotic integrity (IBI) for the wadeable, freestone (high-gradient, soft-water) streams in Pennsylvania using the reference condition approach (PA DEP 2009). PA DEP has alternative assessment methods in place for other stream types (i.e., low-gradient pool-gliders, karst [limestone]-dominated). The IBI provides an integrated measure of the overall condition of a benthic macroinvertebrate community by combining multiple metrics into a single index value. PA DEP uses the IBI to assess attainment of aquatic life uses.

> A **metric** is a measurable aspect of a biological community that responds in a consistent, predictable manner to increasing anthropogenic stress. Examples of metrics include **taxa richness**, which is a measure of the number of different kinds of organisms (taxa) in a sample collection, and **% dominance**, which is a measure of which species compose the majority of organisms present in a sample collection.
>
> To gain a more comprehensive view of an aquatic community, multiple types of metrics are combined into a **biological, or biotic, index**. The typical biological index may include information from 7 to 12 different metrics. The metric values are typically scored on a unitless scale of 0 to 100 and averaged to obtain a single value.

Additionally, PA DEP is exploring use of a Biological Condition Gradient (BCG) to describe the biological characteristics of freestone streams along a gradient of condition. PA DEP conducted a series of three expert workshops in 2006, 2007, and 2008 to calibrate a BCG along a gradient from minimally to heavily stressed conditions (PA DEP 2009). The BCG is a narrative model based on measurable attributes, or characteristics, of aquatic biological communities expected in natural conditions (e.g., presence of native taxa, some pollution tolerant taxa present but typically not dominant, absence of invasive species). Additionally, the BCG model includes attributes that describe interactions among biotic communities (e.g., food web dynamics), the spatial and temporal extent of stress, and the presence of naturally occurring habitats and landscape condition (for more information, see Tool # 2, *The Biological Condition Gradient*). To date, states and tribes that have applied the BCG have used the BCG attributes that describe the taxonomic composition of the resident aquatic biota and, where available, information on fish condition, for example lesions and abnormalities (BCG attributes I–VII) (see Table 2-2). Some states are exploring the application of additional attributes on food web dynamics, extent of stress, and landscape condition (BCG attributes VIII–X). These efforts are providing valuable information that will aid the U.S. Environmental Protection Agency (EPA) in further refining the BCG.

To develop the BCG for its streams, biologists from PA DEP, in conjunction with external taxonomic experts and scientists, e.g., the Delaware River Basin Commission, Western Pennsylvania Conservancy, and EPA, used the BCG attributes that characterize specific changes in community taxonomic composition (PA DEP 2009). For example, in the highest tiers of the BCG, locally endemic, native, and sensitive taxa are well represented (attributes I and II) and the relative abundances of pollution-tolerant organisms (attribute V) are typically lower. With increasing stress, more pollution-tolerant species may be found with concurrent loss of pollution-sensitive species (attribute VI). At the beginning of the expert workshops, the biologists first assigned or adjusted BCG attributes to each macroinvertebrate taxon (e.g., pollutant-sensitive or tolerant) and then reviewed taxa lists from samples representing minimally disturbed to severely disturbed site conditions (Figure 3-2). The evaluated samples included sites judged as either reference quality (e.g., at or close to minimally disturbed conditions) or heavily stressed based on specific selection criteria (PA DEP 2009). To further test the robustness of the BCG process, additional sites that were not part of the reference or heavily stressed sample groups were evaluated. Those sites represented a range of site conditions, including moderately to heavily stressed site conditions (non-reference and moderately stressed; see Figure 3-2). Using the BCG tier descriptions of predicted changes in the attributes as a guide, they assigned each site to one of the six BCG tiers.

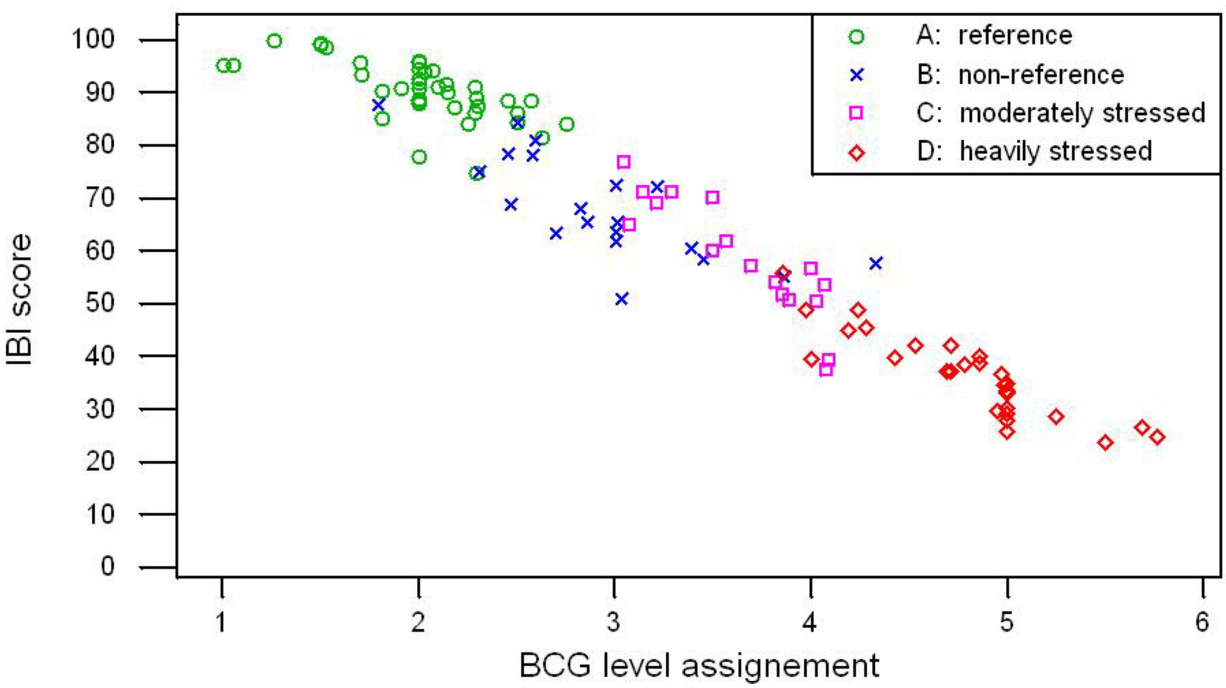


Figure 3-2. Comparison of calibrated BCG tier assignments (mean value) and IBI scores for freestone streams representing range of conditions from minimal to severely stressed.

For all the evaluated samples, PA DEP biologists analyzed the relationship between a sample's BCG tier assignment with its corresponding IBI score (PA DEP 2009). A strong correlation existed between the calibrated BCG tier assignments and the IBI scores (Figure 3-2). Based on these results, PA DEP is evaluating using the BCG to describe the biological characteristics of streams along a gradient of condition; for example, the reference sites clustered at IBI scores near 80 and above. Based on taxonomic information and without knowledge of the IBI scores, the experts assigned these sites to BCG tiers 1.5 to 2.5. BCG tier 2 represents close to natural conditions (e.g., minimal changes in structure and function relative to natural, or pristine, conditions; supports reproducing populations of native species of fish and benthic macroinvertebrates). This information can meaningfully convey to the public the biological characteristics of waters in the context of the Clean Water Act and the goal to protect aquatic life. Using both the IBI and BCG, PA DEP might be able to develop a cost-effective, publicly transparent approach to routinely monitor and assess the condition of its freestone streams and to help identify potential high-quality (HQ) or exceptional value (EV) streams.

Describing Exceptional Value Waters

Pennsylvania's regulations define waters of EV that are of unique ecological or geological significance. EV streams are given the highest level of protection and constitute a valuable subset of Pennsylvania's aquatic resources. To support protection of these waters, PA DEP is considering the use of a discriminant analysis model to evaluate the relationship between condition of the watershed, a stream, and its aquatic biota (e.g., the connection of riparian areas with a stream and the floodplain or the spatial extent of stressors and their sources in the watershed). PA DEP is evaluating the use of a discriminant model that incorporates measures of land use and physical habitat along with IBI scores and indicator taxa richness to make distinctions between EV and HQ waters. The abiotic measures PA DEP is using address habitat fragmentation and spatial and temporal extent of stress and are comparable to the national BCG model attributes IX (extent of stress) and X (ecosystem connectance). The results of this effort could potentially support decisions on where to target resources for sustainable, cost-effective protection of EV waters and healthy watersheds. Through this work, PA DEP is providing EPA valuable feedback on the technical development and potential program application for BCG attributes IX and X.

Potential Application to Support Protection of Waters of Highest Quality

PA DEP is exploring new approaches to help identify streams that are of the highest quality and might require special protection. For example, a stream might be found to meet the expected biological condition of an HQ or EV water based on its IBI score and BCG tier assignment. This information could be used to support further study to determine whether its designation should be as an HQ water or if it meets the additional criteria for designation as an EV water. When biological information is presented in context of a BCG framework, it is easier for the public to understand the status of the aquatic resources, including waters that are in excellent condition and require additional protection.

3.5 Use of Biological Assessments to Support Use Attainability Analysis in Ohio

Abstract

Ohio uses biological assessment information in conjunction with physical habitat assessments to strengthen use attainability analyses (UAAs) in the state. The technical and programmatic underpinnings for Ohio's use attainability determinations is the state's aquatic life use classification approach, which is based on the relationship between biology, habitat, and the potential for water quality improvement. Ohio's biological monitoring and assessment program provides timely, statewide information on the status of waterbodies and the data to support a UAA if needed, including when biological conditions improve and an upgrade of a designated use is warranted. Typically, in situations where the habitat needed to meet aquatic life uses is present, Ohio has taken management actions to address water quality issues and restore impairments.

In 1990 Ohio used biological assessment information to specify levels of biological condition for specific streams and rivers based on ecoregional reference sites. As a result, the state refined definitions of some aquatic life uses, adopted new ones, and assigned biological criteria to key uses to support a tiered approach to water quality management within the Ohio water quality standards (Table 3-3).

Table 3-3. Summary of Ohio's beneficial use designations for the protection of aquatic life in streams.

Beneficial use designation	Key attributes
Coldwater habitat (CWH)	Native cold water or cool water species; put and take trout stocking.
Exceptional warmwater habitat (EWH)	Unique, unusual, and highly diverse assemblage of fish and invertebrates.
Seasonal salmonid habitat (SSH)	Supports lake run steelhead trout fisheries.
Warmwater habitat (WWH)	Typical assemblages of fish and invertebrates, similar to least impacted reference conditions.
Limited warmwater habitat (LWH)	Temporary designations based on 1978 WQS. Predate Ohio tiered aquatic life use classification and were not subjected to UAA; being phased out as UAA are conducted for each LWH waterbody or segment. Most of the LWH waterbodies or segments have been redesignated as WWH or higher with the exception of some mine-drainage-affected segments that were designated LRW.
Modified warmwater habitat (MWH)	More tolerant assemblages of fish and macroinvertebrates are present relative to a WWH assemblage, but otherwise generally similar species to WWH present; irretrievable modifications of habitat preclude complete recovery to least impacted reference condition.
Limited resource water (LRW)	Fish and macroinvertebrates severely limited by physical habitat or other irretrievable condition; minimum protection afforded by the CWA.

Source: Ohio EPA, April 2004. http://www.epa.ohio.gov/portals/35/wqs/designation_summary.pdf.

When designating aquatic life uses, the quality of habitat is a major factor in a use attainability analysis (UAA) process to determine the potential for restoration and expected biological condition for streams and rivers in Ohio. If sufficient good habitat attributes are not present, such as higher quality substrates and sufficient instream cover, a determination about restorability is made. If habitat is sufficient or could be restored, it is assumed that any observed biological impairments are due to the effects of other stressors (e.g., metals, nutrients) that could be remediated through readily available water quality management options (e.g., permit conditions and/or best management practices [BMPs]) and the biological assemblage restored. The aquatic life use classifications are based on ecological conditions, and in 1990 biological criteria were developed to protect each use. Ohio's biological criteria include two indices based on stream fish assemblages (Index of Biological Integrity [IBI] and Modified Index of Well-Being [MIwb]) and one index based on stream macroinvertebrate assemblages (Invertebrate Community Index [ICI]). The biological criteria were developed based on regional reference conditions and are stratified by each of the state's five level 3 ecoregions and three site types (headwater, wadeable, and boatable sites).

Using these aquatic life use classifications, Ohio has been able to determine attainable levels of condition for streams and rivers. For example, in the mid-1980s biological surveys of Hurford Run, a small stream located in an urban/industrial area of Canton, Ohio, showed that the stream was severely impaired by toxic chemical pollutants and that some sites had no fish at all. Hurford Run is channelized for nearly its entire length. Because of the severity of the biological impairment, a UAA was conducted to determine if the warmwater habitat (WWH) aquatic life use was attainable and, if not, to determine the most appropriate designated use for the stream. Based on biological and habitat assessments, the most appropriate aquatic life uses for the different segments of Hurford Run could be determined. For example, very poor habitat quality from historical channelization in the *upper reach of Hurford Run* and the associated hydrological modifications (e.g., ephemeral flows) resulted in a limited warmwater habitat (LWH) designation for this upper reach.

The *middle reach of Hurford Run* has been subject to extensive, maintained channel modifications that also resulted in degraded habitat features, though water is always present. Channel maintenance practices resulting in poor-quality substrates, poorly developed pools and riffles, and a lack of instream cover preclude biological recovery to assemblages consistent with the WWH use, which indicated that the middle reach should be designated a modified warmwater habitat (MWH), reflecting the attainable biological potential for a channel-modified stream determined by scientific studies. The *lower reach of Hurford Run* was previously relocated and channelized, but over time the reach has naturally recovered sufficient good-quality habitat attributes, such as coarse substrates and better developed riffle and pool features associated with the WWH use for this ecoregion. Biological assessments confirmed the presence of aquatic assemblages typical of WWH. Based on this information, this segment was designated as WWH. The designated aquatic life uses reflect the current best possible condition in each segment of Hurford Run and provide a basis for management actions to ensure that the associated criteria are met and the use is protected. Numeric biological criteria have been established for key designated aquatic life uses, and a segment is listed on the 303(d) list if it is in nonattainment of the biological criteria. Additionally, the different segments are routinely monitored by the state and the condition reevaluated on a regular basis. If there is any information indicating that a higher use is being attained or could be attained, that water is considered for redesignation to the higher use.

Ohio has also used biological assessment data to refine its water quality criteria in some cases. For instance, when Ohio's aquatic life use classifications were established in 1978, Ohio established dissolved oxygen criteria to protect each designated use. Initially, a dissolved oxygen criterion of 6 mg/L as a minimum was established for exceptional warmwater habitat (EWH) waters to protect highly sensitive species supported by this use. However, analyses of ambient biological and chemical data suggested that the 6 mg/L minimum criterion was over-protective for EWH waters. Data showed a relationship between stressors and biological measures, with dissolved oxygen concentrations less than 5.0 mg/L being associated with IBI scores not in attainment of EWH biological criteria. And, in general, data showed that with dissolved oxygen greater than 5.0 mg/L, IBI scores are much more likely to attain EWH. These results were used to justify refining the EWH criteria to the current 6 mg/L average, 5 mg/L minimum (Ohio EPA 1996). The criterion revision also supported the redesignation of some rivers and streams from WWH to EWH.

3.6 Screening Tool to Assess Both the Health of Oregon Streams and Stressor Impacts

Abstract

The Oregon Department of Environmental Quality conducted a study in the John Day River Basin to both evaluate the biological health of streams using biological sampling for macroinvertebrates and to identify the causes of stream impairment using biological monitoring information. The state used the PREDATOR model to evaluate waterbody conditions in perennial streams. Stressor identification models were used to measure the effects of stress from two sources of nonpoint source pollution (excessive temperature and fine sediment). A comparison of modeling results to sampling data showed that both modeling and direct measurements are useful in identifying streams not meeting benchmarks and identifying cause of impairment. Oregon will continue to use the model results to evaluate the ability to identify causes of biological impairment on the basis of macroinvertebrate data and will use that information to improve water quality.

The John Day River Basin in northeastern Oregon is one of the state's most important scenic waterways. It drains nearly 8,100 square miles of land and is one of the nation's longest free-flowing river systems (BLM 2010). Oregon Department of Environmental Quality (ODEQ) evaluated the biological health of streams in the John Day River Basin using biological sampling for macroinvertebrates. The study also identified the causes of stream impairment with the aid of biological monitoring information. The focus of the studies conducted by ODEQ was to model the biological condition and explore the relative importance of the two most common nonpoint source (NPS) stressors—elevated temperature and excess fine sediments—using macroinvertebrate data.

Biological Condition Model (PREDATOR)

ODEQ sampled benthic macroinvertebrates in 76 perennial, wadeable streams in the John Day River Basin. The biological condition of the streams was modeled using ODEQ's PREDictive Assessment Tool for ORegon (PREDATOR) (Hubler 2008). The model predicts the kinds of macroinvertebrates expected to occur at reference sites with similar environmental conditions (precipitation, air temperature, elevation, and ecoregion). For example, high-elevation sites that experience higher precipitation levels and cooler air temperatures in eastern Oregon would be expected to support macroinvertebrates similar to those found at reference sites that are both geographically and environmentally similar.

The PREDATOR model uses 176 reference sites across five Level III ecoregions in Oregon (Omernik 1987). The model output is the ratio of the macroinvertebrates observed at a test site (O) to the expected macroinvertebrates (E), or O/E. Values less than 1.0 represent a loss of reference macroinvertebrates at the test site relative to natural conditions. ODEQ classifies sites into one of three biological condition classes: *least disturbed*, *moderately disturbed*, and *most disturbed*. Oregon's least disturbed class supports native populations of aquatic macroinvertebrates and natural habitat.

The results of the study indicated that almost half of the sites were in least disturbed conditions, or equivalent to reference (O/E values close to 1.0). Just over one-quarter (28 percent) were in most disturbed conditions with O/E values down to 0.47, indicating loss of over half of the expected, or native, species.

NPS Pollutant Stressor Models

To use macroinvertebrates to measure the effects of stress from NPS pollution (temperature and fine sediments), ODEQ used two *stressor identification (*SI) models (Huff et al. 2006). Temperature stress (TS) and fine sediment stress (FSS) are two new biological indices used to infer seasonal maximum temperature and percent fine sediments based entirely on the macroinvertebrates collected at a site.

Those indices consistently and predictively respond to increased levels of temperature or fine sediments and are used to model macroinvertebrate-specific changes to the stressors (e.g., stressor-response signatures).

Comparisons of Stressor Model Output to Field Measurements

Water quality and physical habitat information was also collected as part of the John Day River Basin study. Direct comparisons of the SI models (assemblage response signatures) to their equivalent physical measurements (water column temperature and fine sediment load) show similar abilities in determining the extent of streams failing to meet benchmarks. However, the SI models showed a stronger relationship to biological condition than did the physical measurements of temperature and fine sediments. Most of the test sites in good condition according to the PREDATOR model coincided with the SI model outcomes also in good condition. The test sites in good biological condition supported specific macroinvertebrates with temperature and fine sediment preferences similar to reference assemblages. Conversely, the majority of sites in poor biological condition (most disturbed) had TS and FSS values above the reference benchmark for the SI model. To further identify the relative importance of temperature and fine sediments to biological condition, ODEQ routinely performs more quantitative analyses. Regression models of the relationship between PREDATOR and SI models can be used to identify the strength and significance of relationships. Additionally, relative risk analysis is used to quantitatively rank the importance of stressors to biological condition.

Conclusions

ODEQ developed two SI models that can be used to identify the relative importance of two common NPS stressors— elevated temperatures and fine sediments—to biological condition. ODEQ's primary objective with the analysis was to explore the ability of macroinvertebrate data to identify causes of biological impairment.

The results from the study show that about one-half of the perennial, wadeable streams in the John Day River Basin are in good condition, one-quarter are in fair condition, and one-quarter are in poor condition. SI models were used to identify primary causes of biological impairment from NPS pollution. Although biological measures and physical measures were comparable in their ability to detect the extent of sites with NPS stressors above levels typically observed at reference sites, the biological measures showed a stronger relationship to biological condition.

The models for biological condition and SI show promise as sensitive and cost-effective screening tools for detecting NPS impairment to streams and targeting best management practices (BMPs) to address the primary stressors, elevated temperature and excessive fine sediment loads. The SI models also provide benchmarks to measure the response of the biological community to BMP implementation. Combining the information from the models can help scientists better understand the risks associated with NPS pollution in Oregon streams and more efficiently target resources to improve water quality.

Complementary Application of Biological Condition and Stressor Identification Models: An Example

Biological Condition: North Fork Deer Creek had a list of 14 expected macroinvertebrate taxa that were frequently observed at reference sites with similar geographical and environmental characteristics. However, only nine of the expected taxa were observed at the sampling site, resulting in a rating of most disturbed condition (O/E = 9/14 = 0.64).

Stressor Identification: The SI models were used to infer temperature and fine sediment conditions using the tolerances and abundances of all macroinvertebrates collected at North Fork Deer Creek. The dominant macroinvertebrates in the creek showed high tolerances to fine sediments, while the same taxa showed preferences for cooler water over warmer water. For example, five taxa were indicators (taxa that exhibit strong preferences) of higher fines at a site, compared to one indicator taxa for low fines. Additionally, five taxa were indicators of cool water conditions in North Fork Deer Creek, compared to one indicator taxa of warmwater conditions.

The tolerances of the most abundant macroinvertebrates observed in North Fork Deer Creek indicate that excess fine sediments are the most likely cause of the poor (most disturbed) biological condition.

3.7 North Fork Maquoketa River TMDL in Iowa

Abstract

In 1998 the Iowa Department of Natural Resources (IDNR) determined that a 19.5-mile segment of the North Fork Maquoketa River (NFMR) was not meeting its aquatic life use due to a biological impairment of "unknown cause." This determination was based on biological assessments of benthic macroinvertebrate and fish populations. All collected data were used by IDNR in the development of a stressor identification (SI) process that showed that the primary pollutants in the NFMR were sediment, nutrients (specifically phosphorus), and ammonia. In 2007 IDNR completed a Total Maximum Daily Load report for the NMFR that used results of the SI process and calls for steep reductions in sediment reaching the river and in nutrients and agricultural manure releases. IDNR also identified a variety of best management practices to improve water quality and is encouraging local residents and businesses to take action to restore their watershed.

Water Quality Impairment of the North Fork Maquoketa River

The North Fork Maquoketa River (NFMR) is designated by Iowa for aquatic life protection as a class B (WW-2)[16] water. In 1998 the NFMR was determined not to be meeting its aquatic life uses based on biological assessments of the benthic macroinvertebrate population that showed low total abundance and species diversity and several reported fish kill events of unknown source. Iowa subsequently placed the 19.5-mile segment that extends from the headwaters near Luxemburg to Dyersville on its 1998 Clean Water Act (CWA) section 303(d) list of impaired waters. The segment was listed for a biological impairment of "unknown causes" (IDNR no date).

Monitoring and Stressor Identification

Iowa Department of Natural Resources (IDNR) conducted additional biological monitoring of the NFMR between 1999 and 2005. Data collection included the number of benthic macroinvertebrates (by lowest practical taxon), number of fish (by species), and instream and riparian habitat assessments. IDNR used these data to calculate a Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and a Fish Index of Biotic Integrity (FIBI) that quantify several aquatic community characteristics such as relative abundance of sensitive and tolerant species, and the proportion of organisms belonging to various feeding, spawning, or habitat classifications. BMIBI and FIBI scores for the NFMR watershed are provided in Table 3-6. For the sites sampled, the BMIBI and FIBI ranged from poor to fair (Table 3-4). None of the BMIBI or FIBI scores attained the reference biological criteria (Table 3-5). Qualitative scoring guidelines for the BMIBI and FIBI are summarized in Table 3-4, while reference values are included in Table 3-5.

[16] Under the CWA, class B waters are designated for the protection of aquatic life uses. The WW-2 classification is for small streams.

Table 3-4. Qualitative scoring guidelines for the BMIBI and FIBI.

Biological Condition Rating (BCR)	BMIBI	FIBI
Poor	0–30	0–25
Fair	31–55	26–50
Good	56–75	51–70
Excellent	76–100	71–100

Source: http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedResearchData/WaterImprovementPlans/PublicMeetingsPlans.aspx. (Note that the NFMR TMDL .pdf document is available under the heading "Final Water Quality Improvement Plans.")

Table 3-5. Reference criteria for assessing biological integrity.

Ecoregion[a]	BMIBI	FIBI
52B Ref. (Paleozoic Plateau)	61	59
47C Ref. (Iowan Surface)	59	71 (riffle), 43 (non-riffle)

Source: http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedResearchData/WaterImprovementPlans/PublicMeetingsPlans.aspx. (Note that the NFMR TMDL .pdf document is available under the heading "Final Water Quality Improvement Plans.")

[a] The watershed contributing to flow in the NFMR upstream from Dyersville, Iowa, is a transitional area that is divided between two ecological regions of Iowa. Roughly two-thirds of the lower portion of the watershed is located in the Iowan Surface of the Western Corn Belt Plains, while the upper third is located in the Paleozoic Plateau (Driftless Area) ecoregion.

Table 3-6. BMIBI and FIBI results for the NMFR Watershed.

(BCR rating in parenthesis)

Site	Year	BMIBI	FIBI
REMAP 147	2005	42 (Fair)	34(Fair)
TMDL 28	2001	47 (Fair)	29 (Fair)
TMDL 28	2005	26 (Poor)	37 (Fair)
New Wine Park	1999	N/A[a]	32
TMDL 29	2001	47 (Fair)	26 (Fair)
TMDL 30	2001	51 (Fair)	33 (Fair)
TMDL 30	2005	48 (Fair)	7 (Poor)
H2	1999	53 (Fair)	37 (Fair)

Modified from http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedResearchData/WaterImprovementPlans/PublicMeetingsPlans.aspx. [Note that a new link to the Web page where the NFMR TMDL .pdf document is available under heading "Final Water Quality Improvement Plans."]

[a] Insufficient numbers of organisms for BMIBI calculation. To calculate the BMIBI, at least 1 of 3 quantitative benthic macroinvertebrate sample replicates must contain 85 or more individual specimens. The three replicates had 70, 25, and 54 specimens, respectively.

In addition to biological monitoring, IDNR also collected monthly water quality samples in 2001 and 2005 (March through November) for several chemical and physical parameters, such as flow, dissolved oxygen, temperature, pH, nitrate + nitrite, and total phosphorus. The data showed water quality impacts relative to levels measured at least disturbed ecoregion reference stream sites—especially elevated concentrations of ammonia, nitrate-nitrogen, total phosphorus, and total suspended solids. Occasional violations of dissolved oxygen criteria were found, and large diurnal fluctuations in dissolved oxygen concentrations in the stream were indicative of elevated primary production levels. All collected biological, chemical, and physical data were used in the stressor identification (SI) process (IDNR 2006).

IDNR staff followed the Protocol for SI to determine the cause of the biological impairment in NFMR (see Tool # 3, *Stressor Identification (SI) and Causal Analysis/Diagnosis Decision Information System (CADDIS)*). The SI procedure relates impairments described by biological assessments to one or more specific causal agents (pollutants). It also separates water quality (pollutant) impacts from habitat alteration impacts. Although the SI did not reveal any single stressor that is clearly the dominant cause of biological impairment, IDNR determined that the primary pollutant-related causal factors in the NFMR were sediment, nutrients (specifically phosphorus), and ammonia.

Total Maximum Daily Load Development

In 2007, IDNR completed *Total Maximum Daily Loads for Sediment, Nutrients, and Ammonia: North Fork Maquoketa River, Dubuque County, Iowa*. Results of the SI process were used, and IDNR considered impacts from the point and nonpoint sources of pollution in development of the Total Maximum Daily Load (TMDL). Although IDNR concluded that one wastewater treatment plant in the NFMR watershed should be included in the TMDL and in developing a wasteload allocation for the existing phosphorus load, that facility did not contribute significantly to the overall sediment load. IDNR also identified several potential nonpoint sources for nutrients, sediment, and ammonia—failed on-site septic tank treatment systems, agricultural activities (e.g., cattle in streams, fertilizer use, soil erosion, land-applied manure), wildlife, and runoff from developed areas (IDNR 2007).

To meet water quality improvement goals for the NFMR, the TMDL includes a 77 percent reduction in sediment reaching the river (20,200 pounds of sediment per year) and a 73 percent reduction in nutrients and manure releases. The TMDL has two parts. The first includes setting specific and quantifiable targets for sediment, oxygen demand, total phosphorus, and ammonia loads to the stream. Additional biological and water quality monitoring will determine whether the prescribed load reductions result in attainment of water quality standards. These monitoring data will also be used to determine whether the implemented TMDL and watershed management plans have been effective in addressing water quality impairments in the NFMR. EPA approved the IDNR TMDL in 2008.

IDNR has identified a variety of BMPs to improve water quality, as well as to encourage residents and businesses in the watershed to take action. IDNR has also identified possible practices to reduce sediment and nutrients reaching the NFMR, such as installing structures to reduce both agricultural and urban runoff; limiting cattle access to streams and installing alternative water sources for cattle; and using agricultural management practices that increase crop residue, such as no-till. IDNR also suggested that proper control of open agricultural animal feedlots will help prevent contaminated runoff from reaching streams, which in turn will reduce ammonia loading. Ongoing monitoring of this impaired stream segment will be used to periodically assess progress made toward attainment of the NFMR designated aquatic life uses.

3.8 Addressing Stormwater Flow in Connecticut's Eagleville Brook TMDL for Biological Impairment

Abstract

In 2004 Connecticut used biological assessment information to place Eagleville Brook on its 303(d) list of water quality limited (WQL) waters for failure to meet the brook's aquatic life uses. Before Total Maximum Daily Load (TMDL) development, the state conducted a stressor identification analysis that pointed to the complex array of pollutants transported by stormwater as the most likely cause of impairment. A statewide study that correlated impervious cover (IC) with benthic macroinvertebrate data collected from wadeable streams was conducted, and results showed that the designated aquatic life use was not supported when IC was more than 12 percent of the watershed area. A TMDL was developed in 2007 using a target of 12 percent IC—the first in the nation to use IC as a surrogate for stormwater. Objectives to reduce IC were established for each waterbody segment, and progress toward attainment of the designated aquatic life use will be evaluated by monitoring the condition of the benthic macroinvertebrate community in conjunction with ongoing chemical assessments.

Eagleville Brook has a 2.4-square-mile drainage area, and the watershed drains a portion of the University of Connecticut (UCONN) campus and the town of Mansfield. The brook is designated as a Class A waterbody, but fisheries sampling in 2002 showed that the waterbody was not meeting its aquatic life uses, with low fish density and large areas with no fish. Additionally, benthic macroinvertebrate sampling in 2003 showed low total abundance and species diversity, documenting that the waterbody was in nonattainment of the state's narrative biological criteria for Class A waters. In 2004 Connecticut added Eagleville Brook to its list of impaired waters for cause unknown on the basis of the biological assessment results.

Stressor Identification and Total Maximum Daily Load Development

Before Total Maximum Daily Load (TMDL) development, Connecticut conducted a stressor identification (SI) analysis to evaluate the potential stressors and determine the most likely causes of impairment. The SI study concluded that biological impairments were most likely from a combination of pollutants related to stormwater runoff from developed areas and other related stressors (such as the physical impacts of stormwater flows). There are no other known point source discharges in this small watershed. The major source of stormwater is runoff from the impervious surfaces in the watershed (e.g., roads in Mansfield and UCONN campus). A statewide study of the impact of impervious cover (IC) on aquatic habitats was also conducted; Connecticut's Rapid Biological Assessment Protocol III data from 125 small (< 50 square miles) watersheds showed that no stream monitoring location with more than 12 percent IC in the upstream watershed meets Connecticut's biological criteria for full support of aquatic life use.

In 2007 Connecticut developed the TMDL with a loading capacity (TMDL target) of 12 percent IC. The 12 percent TMDL target was chosen on the basis of the threshold observed for applicable Connecticut streams in the statewide study. In the TMDL, Eagleville Brook was partitioned into three segments, and the IC was calculated for each. For each segment, a TMDL implementation objective was also developed (Table 3-7).

Table 3-7. Summary of TMDL analysis for Eagleville Brook.

Waterbody segment	TMDL target	IC	Implementation objective
From the mouth at Eagleville Pond upstream to the confluence with Kings Brook, Mansfield	12%	5%	Antidegradation
The confluence with Kings Brook to headwaters near UCONN campus	12%	14%	21% reduction in the percent IC
Unnamed pond on UCONN campus	12%	27%	59% reduction in the percent IC

The targets apply at all times (instantaneously, daily, monthly, seasonally, and annually) and will achieve reductions in stormwater runoff volume in all storm events whenever they occur (e.g., on any day) throughout the year. The reductions associated with the implementation objectives were to be accomplished by improved stormwater management. The Connecticut Department of Environmental Protection (CT DEP) provided general and specific implementation recommendations in the TMDL and recommended using an adaptive management approach toward reducing stormwater impacts and improving water quality.

TMDL Implementation

Progress toward attainment of the aquatic life use will be evaluated by CT DEP's monitoring the macroinvertebrate and fish communities and assessing surface water chemistry according to an existing rotating basin sampling schedule. UCONN, the Town of Mansfield, and the Willimantic River Alliance have pledged support for TMDL implementation. EPA and CT DEP have funded a project using section 319 NPS funds to map locations and identify ways to reduce the effect of IC as required by the TMDL. The project also examined the estimated costs of such actions and developed initial engineering sketches for a *top ten* list for recommended retrofit management actions that are most cost-effective, primarily in the upper watershed. In addition, other projects have been completed on the UCONN campus to reduce IC, including installation of two green roofs and parking lots with pervious asphalt and concrete. The Town of Mansfield has received technical guidance on local land use regulations and practices, primarily in the lower watershed. Low-impact development concepts are expected to be incorporated into future development. An overall watershed management plan that supports a framework to pursue high-priority projects to reduce the effect of IC has been developed. Considerable stakeholder input has crafted a consensus approach to seize opportunities to reduce the effect of IC as situations arise during normal maintenance operations at UCONN and Mansfield. A tiered system to track progress will focus in the short term on close tracking of the area of new and disconnected IC, as well as flow monitoring to determine whether changes in IC will improve the hydrologic regime of Eagleville Brook. The TMDL has led to an increase in dialog among stakeholders and has led to changes in how people think about managing IC in the Eagleville Brook watershed. Additional information on the implementation of the Eagleville Brook TMDL can be found at http://clear.uconn.edu/projects/tmdl/index.htm.This site, hosted by UCONN, provides additional information and will be used to track the progress of TMDL implementation over time.

3.9 Vermont's Use of Biological Assessments to List Impaired Waters and to Support NPDES Permit Modification and Wastewater Treatment Facility Upgrades

Abstract

In the 1990s, the Vermont Department of Environmental Conservation's biological assessment of the Dog River showed aquatic life use impairments downstream of a wastewater treatment facility. Whole effluent toxicity and biological assessment data were used to support revisions to National Pollutant Discharge Elimination System permits for dischargers, and subsequent management actions at the facilities resulted in the segment's meeting its designated aquatic life use and its removal from the 303(d) listing for water impairment.

Biological Assessments Detect Impairment and Support Permit Modifications

Between 1993 and 1995, biological assessments of Vermont's Dog River showed that the river was not meeting its aquatic life use according to changes in the aquatic community typically associated with toxicity stress and moderate phosphorus pollution. In 1996, Vermont Department of Environmental Conservation (VT DEC) listed the Dog River on the state's 303(d) list of impaired waters, based on the biological assessment information, for cause unknown. Further investigation indicated two factors contributing to the degraded instream water quality. First, the Northfield Wastewater Treatment Facility (WWTF) had reached its design life and was no longer able to function properly and reliably meet National Pollutant Discharge Elimination System (NPDES) permit limits. Second, wastewater influent to the facility from two industrial textile facilities had high concentrations of metals and possibly surfactants. In WWTF effluent samples, metal concentrations were high and predicted to exceed water quality criteria at permitted flows. Whole effluent toxicity (WET) testing confirmed significant toxic effects at effluent concentrations greater than 12 percent. Through a toxicity identification evaluation (TIE) study, copper was identified as the most significant metal of concern in the WWTF effluent, with a maximum copper concentration of 184 micrograms per liter (µg/L). This level would have resulted in an instream concentration of 36 µg/L copper at 7Q10 (i.e., the lowest 7-day, consecutive low flow period occurring over the preceding 10-year period) permitted flows. Copper levels correlated with the level of toxicity found in the WET testing.

In 1999 pretreatment discharge permits with compliance schedules were issued to the textile facilities. The pretreatment permits established copper limitations for those influent waste streams that required the installation of pretreatment systems for the removal of copper (see Table 3-8). Although the systems were operational in 2000, biological assessments conducted between 2000 and 2003 showed continued aquatic life use impairment in the river. That monitoring showed a shift in the benthic macroinvertebrate community that, in addition to chemical data, indicated that phosphorus pollution had become the most likely cause of the aquatic life impairment. Specifically, the macroinvertebrate community was significantly higher in density and dominated by nutrient-tolerant taxa relative to previous sampling results. To measure this increase in nutrient-tolerant taxa, VT DEC used a ratio that compares the proportion of pollution- sensitive benthic macroinvertebrate species to more pollutant-tolerant species, the EPT/EPTc ratio. This reflects the ratio of generally pollution-sensitive species (e.g., **E**phemeroptera [mayflies], **P**lecoptera [stone flies] and **T**richoptera [caddisflies]) compared to the more pollutant-tolerant species (Chironomids [midges/flies]). A low threshold indicates dominance of midges

(EPTc) that have been observed in streams with significant levels of nitrogen, phosphorus, or other pollutants. Additionally, the higher biological index value reflected the increase in the midges and provides complementary information.

Table 3-8. Permit limitations for two textile facilities.

Facility	Flow monthly average	Copper	
		Monthly average	Daily maximum
Facility A	150,000 gal/day	0.027 lb/day	0.038 lb/day
Facility B	35,000 gal/day	0.007 lb/day	0.0125 lb/day

In January 2003, VT DEC issued a compliance schedule to the Village of Northfield to upgrade its WWTF, and the upgraded facility became operational in November 2004. The upgraded WWTF process consists of upgraded headworks, two sequential batch reactors, a surge tank, and an upgraded chlorination and dechlorination system. Phosphorus removal was required to comply with the requirements of the Lake Champlain TMDL and Vermont regulations (10 VSA 1266a). To achieve that, permit limits for a 1.0-mg/day discharge of phosphorus were set at 6.78 lb/day, at concentration of 0.8 mg/L monthly average. Northfield treatment plant copper effluent limitations were also established at 0.26 lb/day monthly average and 0.36 lb/max daily at a pH of between 6.5 and 8.5. Improved sludge management was also incorporated into the upgraded WWTF, including refurbishing the existing digester, adding a new digester, and adding a centrifuge for dewatering. Water quality and habitat improvements were observed, but the aquatic system's recovery was further complicated by a chlorine spill from the WWTF's temporary disinfection system during the upgrade in July 2004, leading to a further short-term decline in EPT.

Conclusion

Despite the short-term adverse effects from the 2004 chlorine spill, the compliance schedules and changes to both predischarge and the WWTF permits have resulted in changes in facility operations that, in turn, have resulted in improvements in water quality. Biological assessments showed improvement only after copper was reduced and wastewater treatment of phosphorus was improved. These combined efforts enabled a site that was classified as fair-poor to recover to excellent condition. Biological assessments in 2005 and 2006 showed that the Dog River was meeting its aquatic life uses, with specific measures, or metrics, showing density to be moderate; richness, EPT, and EPT/EPTc ratio to be high; and biological index (BI) to be lower relative to previous sampling. Chemical monitoring has documented that the applicable chemical water quality criteria were being met, and WET test results have shown that the effluent is nontoxic (i.e., no significant toxicity to test organisms using 100 percent effluent). The biological assessment information documents that the stream macroinvertebrate community is now dominated by water-quality-sensitive taxa more typical of its *natural* expectation—with recovery of sensitive species and a more balanced community. (Data from sampling between 1993 and 2006 are shown in Table 3-9.) As a result, in 2006 Vermont removed Dog River from its impaired waters list.

Table 3-9. Macroinvertebrate assessments for Dog River—Northfield WWTF.

Date	1993	1994	1995	2000	2001	2003	2004	2005	2006
Assess (criteria)	Fair	Fair	Fair	Fair-Poor	Poor	Poor	Poor	Very Good	Excellent
Density (> 300)	1,862	3,282	1,037	4,556	5,640	4,264	668	2,160	5,870
Richness (> 30)	39	43	41	50	50	62	34	51	62
EPT (> 18)	12	16	16	14	11	22	12	28	33
BI (< 5.00)	4.73	4.74	4.61	5.51	6.00	5.26	5.12	4.38	3.48
Ept/EptC (> 0.45)	0.029	0.50	0.52	0.29	0.07	0.22	0.14	0.89	0.89

Milestones:
2000 – Metals removed.
2004 – Chlorine spill late summer; WWTF upgrade with phosphorus removal completed in November.
2005 – First year of river meeting designated aquatic life use.
2006 – Second year of river meeting aquatic life use; stream removed from impaired waters listing.

3.10 Restoration of Red Rock Creek by the Grand Portage Band of Lake Superior Chippewa

Abstract

For the past 15 years, the Grand Portage Band of Lake Superior Chippewa (tribe) has led efforts to restore one of the Band's most impaired waters—Red Rock Creek. Biological assessment information has played a central role in establishing and assessing whether biological, chemical, and physical targets for restoration are being met. To date, the tribe has implemented multiple and interrelated restoration activities that have resulted in significant water quality improvements, as demonstrated by periodic sampling of the creek's benthic macroinvertebrate and plant communities.

Background

Over the past decade, the Grand Portage Band of Lake Superior Chippewa (tribe) has been leading restoration efforts to improve the physical, chemical, and biological integrity of one of the Band's impaired waters—Red Rock Creek. To date, biological assessment information has played a central role in defining biological goals for restoration in concert with chemical and physical targets that have also been established. The tribe has implemented restoration activities that have resulted in water quality improvements, as shown in sampling of both the benthic macroinvertebrate and plant communities.

Red Rock Creek Impairment

The Red Rock Creek watershed encompasses approximately 1,200 acres in Minnesota north of Lake Superior. While the upper reaches of the watershed are in relatively pristine condition, the creek flows through an abandoned gravel pit located approximately one-half mile from Lake Superior. Past gravel mining activities—most notably the removal of riparian (streamside) vegetation and cutting of a portion of the stream bank—have adversely affected the stream, resulting in severe sedimentation. This has resulted in a net loss of fish species and benthic macroinvertebrate communities. For instance, by 2006, steelhead trout, chinook salmon, coho salmon, and coaster brook trout were found only near the mouth of the stream, rather than their previous habitation along several miles of the stream. Gravel extraction has also caused the stream to leave its former channel and to spread into the gravel pit area. Notably, beaver damming has exacerbated problems associated with braiding and flow and has led to clogging of Red Rock Creek.

Monthly sampling of Red Rock Creek began in 1997. Turbidity measurements were high, with a mean concentration of 12.3 nephelometric turbidity units (NTUs). Gravel mining activities ceased in 1998, and in 2000 the Tribe reported that water quality was impaired based on biological and chemical assessments. Specifically, monitoring showed low dissolved oxygen concentrations, high turbidity, and low benthic macroinvertebrate densities and species abundance. In the impacted portion of the creek, mean dissolved oxygen concentrations were 6.3 mg/L—more than 2 mg/L lower than the concentrations measured in unimpacted upstream reaches. A total of27 macroinvertebrates were collected in the impacted stream reach, with a large proportion of pollution/sediment-tolerant diptera (e.g., Chironomides [midges]) present but no pollution-sensitive EPT taxa (e.g., **E**phemeroptera [mayflies], **P**lecoptera [stone flies] and **T**richoptera [caddisflies])). However, in 2004, 6 years after the cessation of gravel mining operations, over 100 macroinvertebrates were collected. Possible explanations for this improvement in macroinvertebrate density might be the subsequent regrowth of some of the stream's riparian buffer and instream habitat (Table 3-10). However, only 27 percent of the total taxa were EPT taxa, which is much lower than the 60–75 percent proportion of EPT taxa expected in unimpacted or minimally impacted streams in this area. Increases in EPT taxa are expected with continued restoration and allowing time for the aquatic system to recover natural flow and habitat conditions.

In addition to benthic macroinvertebrates, the tribe also assesses plant communities to evaluate the biological health of its waterways. To measure the natural quality of the area, the tribe uses a Floristic Quality Index (FQI),[17] a weighted species richness index that can be calculated by identifying all plant species in a given plot or transect. To evaluate streams, the Grand Portage Tribe uses an FQI score ≥ 20, the presence of at least 20 plant taxa, no exotic invasive plant species, and at least 5 sensitive or rare plant taxa. In 2004, Red Rock Creek had a total of 13 plant taxa, an FQI score of 14, 3 invasive exotic plant species, and no sensitive or rare plant taxa (Table 3-11).

Restoration Efforts

The tribe set biological, chemical, and physical goals for improving overall water quality in Red Rock Creek (Table 3-10). Restoration goals were established for increased dissolved oxygen concentrations, reduced turbidity, reduced diptera taxa to less than 5 percent of macroinvertebrates collected, and increased proportion of pollution-sensitive macroinvertebrate taxa. Restoration efforts began in 2006 with the removal of the beaver dam and installation of sediment traps. Monitoring results conducted immediately following restoration showed a mean turbidity concentration of 10.3 NTUs, dissolved oxygen concentrations that continued to be approximately 2 mg/L less than those in undisturbed reaches of the stream, and changes in the benthic macroinvertebrate community. Although sampling of the macroinvertebrate community showed a dramatic increase in the number of organisms collected (350), only 9.8 percent of the total insects collected were EPT taxa and 22 percent were diptera—similar to pre-restoration sampling results. In 2008 additional restoration measures were completed, including reinforcement of banks upstream of the sediment basin using live fascines and stakes, physical removal of excess sediment from the basin, and seeding and tree planting to further stabilize the banks and restore riparian vegetation.

Results

Monitoring results from 2008 and 2009 show that the restoration goals for Red Rock Creek have been exceeded for most biological, chemical, and physical measures of water quality (Tables 3-10 and 3-11). Dissolved oxygen concentrations and turbidity levels are comparable to those expected in unimpacted conditions with improvements in both benthic and floristic assessments of biological condition, though the continued presence of invasive plant species remains a challenge. The tribe will continue to maintain the sediment ponds and bank stabilization projects in order to achieve the restoration goal for percent EPT taxa. Regular removal of excess sediment from the basin, efforts to reestablish native vegetation in the riparian zone, and potential removal of invasive species from the basin will be considered in an adaptive management approach to fully achieve biological restoration goals.

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[17] Anthropogenic stressors can be manifest changes in plant communities through displacement and competition from exotic invasive species. The FQI is the calculation of the plant communities' mean coefficient of conservatism multiplied by the square root of the number of species. The coefficient of conservatism is a measure of an individual species' fidelity to natural habitats and communities.

Table 3-10. Sampling to assess progress toward restoration goals.

Parameter	Pre-restoration sampling results (year)	Restoration goal	Post-restoration sampling results (year)
Turbidity	12.3 NTU (1997)	50% reduction	2.4 NTU (2009)
Dissolved oxygen	6.3 mg/L (2000)	2 mg/L increase	9.6 mg/L (2009)
Number of macroinvertebrates	27 (2000) 10 (2004)	200	350 (2008)
% diptera	29.6% (2004)	Reduction to 5% of total	1.3% (2008)
% EPT species	27% (2004)	Increase to 60% of total	30% (2009)

Table 3-11. Plant sampling results.

Parameter	2004	2008
Number of plant taxa	13	21
FQI score	14	19
Number of invasive plant species	3	3
Number of sensitive or rare taxa	0	3

3.11 Using Biological Assessment Data to Show Impact of NPS Controls in Michigan

Abstract

In the 1990s biological assessments of Carrier Creek in Eaton County, Michigan, showed that the waterbody was not attaining its designated aquatic life uses, resulting in its inclusion on the state's 303(d) list in 1996 for cause unknown. Subsequent surveys indicated that stream biota was affected by urban runoff, poor instream habitat, and sediment deposition. In 2002 a Total Maximum Daily Load for biota was completed. Watershed partners are conducting several stream restoration projects to improve aquatic life use attainment. The restoration activities stabilized the stream channel and its hydrology, reduced stream bank erosion, and improved aquatic habitat. Improvements in fish and macroinvertebrate communities have been documented.

Background

Carrier Creek, a tributary to the Grand River, flows through a rapidly developing area in Eaton County near Lansing, Michigan. Historical channelization and more recent urban runoff resulted in eroding stream banks, high sedimentation rates, and degraded aquatic habitat for fish and macroinvertebrate communities. In 1996 Michigan included a 4-mile segment of the creek—from its confluence with the Grand River upstream to where it flows under Interstate 496—on its 303(d) list of impaired waters based on biological assessment information used to interpret its narrative standard that all surface waters of the state are "designated for and shall be protected for … aquatic life and wildlife." The Michigan Department of Environmental Quality (MDEQ) determined that the quality of the aquatic biota in that segment of the creek was reduced by urban runoff, poor instream habitat, and excessive sediment deposition. MDEQ completed a Total Maximum Daily Load (TMDL) for Carrier Creek biota in 2002. As noted in the TMDL, achievement of the water quality standards (WQS) for designated uses for Carrier Creek will be demonstrated by assessing the macroinvertebrate community and the instream habitat as it relates to sediment.

Stream Restoration

Between 2000 and 2006, state and local agencies and volunteer groups partnered in various stream restoration projects designed to achieve the TMDL goals. For example, in 2000 local agencies and volunteers stabilized and restored 5 miles of channel. The projects increased channel stability, improved instream habitat, and reconnected the channel to its floodplain. The upstream end of the channel was narrowed, and the stream pattern was reestablished to promote meandering. In some locations, the project team removed dredge spoils that were separating the stream from its natural floodplain.

In 2002 project partners created a 32-acre wetland in the headwaters of the watershed to intercept stormwater runoff and decrease stream flashiness. In 2004 the Perrin Chapter of Trout Unlimited installed structures along the creek to provide shelter and resting points for fish. In addition, the Eaton County Drain Commissioner is enhancing stormwater detention and flow control throughout the upper portion of the watershed to stabilize the channel, reduce the velocity of the flow, reduce erosion downstream, and reduce the amount of flooding. That work is ongoing.

Results

Biological assessment data have been used to assess the project's progress. The State of Michigan and the Eaton County Drain Commission collected data on fish, macroinvertebrates, and aquatic habitat quality at two locations in the project area, both before (2000) and after (2006) the restoration activities occurred. A consultant for the Eaton County Drain Commission collected additional fish data in 2007.

As of 2006, aquatic habitat was unchanged at one site and had improved at the other, but macroinvertebrate populations had not responded. However, by 2009, both macroinvertebrate and habitat quality scores had improved at all sites. The improvement in habitat scores was due to continued stream restoration activities that provided meandering channels and suitable instream habitat for the aquatic biota, such as fish and benthic macroinvertebrates. In fact, the 2007 fish data show that the number of fish taxa increased at both locations following restoration activities, more than doubling at one site and quadrupling at the other. There is another encouraging signal of improvement to date: a single slippershell mussel (*Alasmidonta viridis*) was found during an informal inspection of the restored reach in 2007. The slippershell is listed on the state's threatened list by the Michigan Natural Features Inventory and had not been observed in the stream before restoration. MDEQ will conduct further monitoring in the fall of 2011.

The restoration activities conducted to date have stabilized the stream channel and its hydrology, reduced stream bank erosion, and improved aquatic habitat. Fish communities are recovering, and future monitoring should show further improvements in the biota and eventually result in removing Carrier Creek from the list of impaired waters based on assessing the macroinvertebrate community and the instream habitat as it relates to sediment.

3.12 Using Biological Assessment as Evidence of Damage and Recovery Following a Pesticide Spill in Maryland and the District of Columbia

Abstract

In response to a fish kill in a tributary of the Potomac River in 2000, biological assessment data were used to show the impact of a pesticide spill and to document the waterbody's recovery. Sampling data collected before the spill provided a baseline of the expected aquatic community in the waterbody. Data from biological assessments before the spill were compared with sampling data collected immediately after the fish kill and several months later. The data were used to support enforcement actions and to support criminal charges against the polluter.

Problem Overview

In the spring of 2000 a fish kill (estimated to be 150,000 fish) was observed along an 8-mile stretch of Rock Creek, a major tributary of the Potomac River in Maryland and the District of Columbia. Responding to the kill, the Maryland Department of the Environment (MDE) sampled the water column and sediments and found high concentrations of the insecticides cypermethrin and bifenthrin, both of which are highly toxic to fish. Concentrations were especially high in a storm drain entering the stream from the parking lot of a pest control company, suggesting that a pesticide spill had occurred.

The case was investigated by EPA's Criminal Investigation Division with assistance from the State of Maryland, Montgomery County, the National Park Service, and the District of Columbia. Within 2 weeks, a coordinated, multiagency effort sampled sediments, fish, and benthic macroinvertebrates upstream and downstream of the outfall. Fish sampling was repeated after 5 months, and sediments were retested 9 months after the spill.

Data Collection and Analysis

Samples were analyzed in three time frames—before the spill occurred, just after the fish kill was observed, and some months afterward. Samples were also categorized by location; before and upstream samples served as controls for the suspected effects of the spill. Several hours after the fish kill was first observed, cypermethrin and bifenthrin concentrations in downstream waters were near the acute toxicity thresholds for fish and invertebrates. Pesticide concentrations in the storm drain were many times greater than the acute toxicity levels. Sediments tested 2 weeks after the fish kill showed elevated levels of cypermethrin and bifenthrin below the storm drain when compared to levels above the storm drain. When retested 9 months later, cypermethrin and bifenthrin concentrations in all sediment samples were below detection limits.

Fish and benthic macroinvertebrates were collected from 11 stations, including 4 above and 7 below the storm drain. Several sites had been sampled before the spill in routine monitoring programs by the District of Columbia and Montgomery County. Historical data from 1996–1998 were available for three stations below the outfall, and one site well below the spill had been sampled several times weeks before the spill. Just after the spill, both fish and macroinvertebrate communities showed severe degradation when compared to upstream controls and, for fish only, when compared to downstream samples taken before the kill event.

Decreases in numbers of fish and the number of fish species were observed, with a reduction in the fish index of biotic integrity at all sites below the spill. On average, 20 macroinvertebrate taxa, of 46 taxa found upstream, were absent from downstream sites. After 5 months, most minnow species had returned to the affected sites. Overall, the fish community had recovered to approximately 75 percent of upstream species composition.

Conclusion

Biological assessment provided a powerful tool for documenting stream degradation and stream recovery following the toxic spill. Evidence was further strengthened by baseline data collected in routine monitoring programs. Comparison of the post-spill samples to samples taken before the spill provided a quantitative assessment of the biological impact and evidence of stream recovery. In November 2001, the owner and an employee of the pest control firm were charged with violations of the Clean Water Act and the Federal Insecticide, Fungicide, and Rodenticide Act. Ongoing biological assessments, in conjunction with bioassays and chemical and physical assessments, can assist enforcement agencies in assessing damage, levying fair and reasonable damage assessments on those proven responsible for toxic spills, and determining the rate and level of stream recovery.

3.13 Support for Dredge and Fill Permitting in Ohio

Abstract

Ohio uses biological assessments to help inform its decisions about certifying permits for dredge and fill activities and to ensure that the impacts of those activities on aquatic habitats do not violate Ohio water quality standards (WQS). Ohio's tiered aquatic life uses, in conjunction with antidegradation policies and numeric biological criteria adopted into the state's WQS, enable Ohio to better assess the potential impact of dredge and fill activities and to make management decisions on the basis of its designated aquatic life uses. Ohio's designated aquatic life uses are based on the relationship of habitat and the resident biota. It is presumed that if critical aquatic habitat is present or can be restored, the aquatic life associated with the habitat can be supported. Additionally, when implementing nationwide permits, Ohio has been able to include additional conditions to protect high-quality waters as revealed by biological assessments.

Dredge and Fill Permitting

States use Clean Water Act (CWA) section 401 to regulate activities that might impact aquatic habitats. Those wanting to modify a stream in a way that will result in the discharge of dredge or fill material into waters of the United States must obtain a section 404 permit from the U.S. Army Corps of Engineers and a section 401 water quality certification from the state. The state must certify that the proposed activities will comply with and not violate water quality standards (WQS) or waive such certification. Ohio's designated aquatic life use classes, which are based on the relationship of habitat and the attendant numeric biological criteria adopted into the WQS, make that linkage a valid tool for evaluating the effects of habitat alterations that are covered under the CWA. In essence, the habitat tools employed are sufficiently predictive to serve the purpose of reviewing proposed stream habitat modification activities.

Ohio EPA used more than 20 years of data to develop habitat stressor gradients along several aspects of habitat quality at both the site and watershed scales, including overall habitat quality as measured by a habitat quality index, the Qualitative Habitat Evaluation Index (QHEI), and for specific attributes such as substrate and channel condition (Rankin 1989, 1995). This allows for sufficient predictive relationships such that this habitat tool can be used to help determine the attainability of the Ohio biological criteria.

Ohio's designated aquatic life uses for surface waters have enabled a range of management responses to dredge and fill projects related to the quality and sensitivity of the waterbody in the context of the CWA goal to protect aquatic life. Ohio's use classification system is tiered along a gradient of quality with the highest use class supporting pollution-sensitive, naturally occurring communities of benthic macroinvertebrates and fish (Exceptional Warmwater Habitat [EWH] Aquatic Life Use). A second class along the gradient (Warmwater Habitat [WWH]) also supports a community of pollution-sensitive, naturally occurring benthic macroinvertebrates and fish species that are consistent with least impacted reference conditions.

Nationwide permits are designed to minimize site-specific oversight where ecological risks are assumed to be low. Frequently, however, in reviewing the criteria where nationwide permits can apply, high-quality waters can be overlooked, leading to their unwarranted alteration and impairment. Small streams such as headwater streams are particularly vulnerable to not being properly assessed under nationwide permit conditions. The Ohio EWH use designation requires high-quality habitat and stable hydrological regimes (especially in headwater and wadeable streams). Because those essential attributes can be altered by direct modifications to the stream channel and other habitat features, Ohio requires individual reviews of projects that occur in such high-quality streams. Under a general use system, those sites would be lumped with all other streams under the nationwide permit system. In addition, antidegradation provisions for high-quality WWH and Coldwater Habitat (CWH) streams are also applied.

Mitigation Standards

The attention gained by biologically defined habitat impacts has prompted the development of mitigation standards, in conjunction with a process for rigorous validation, that will take Ohio's aquatic life uses into account and require enhancement or restoration wherever feasible. The stressor-response relationships that have been developed between biological assemblages and key habitat attributes have been applied to the 401 program in Ohio for more than 20 years. For nationwide permits, a series of general and specific exclusions and conditions that vary with the state's tiered uses have been derived (USACE 2002). They include a general exclusion (of nationwide permits) for streams that are EWH and for certain high-quality antidegradation tiers (State Resource Waters and Outstanding State Resource Waters, Superior High-Quality Waters), the delineation of which was based primarily on the same biological assemblage attributes on which the designated use classes are based.

Ohio's integrated approach for designating aquatic life uses, implementing antidegradation, and establishing biological criteria is based on relationships between the aquatic biota and critical aquatic habitat.

3.14 Virginia INSTAR Model for Watershed Protection

Abstract

The Virginia Department of Conservation and Recreation and Virginia Commonwealth University Center for Environmental Studies are collaborating in developing and implementing a statewide Healthy Waters program to identify and protect healthy streams. The Interactive Stream Assessment Resource (INSTAR) is an online, interactive database application that evaluates the ecological integrity of Virginia's streams using biological and habitat data. The Web-mapping application is available to the public as a free resource to help planners, advocacy groups, and individuals to support wise land use decision making.

In 2003 Virginia Commonwealth University's Center for Environmental Studies, Virginia Department of Conservation and Recreation (VA DCR), the Virginia Department of Environmental Quality, Virginia Coastal Zone Management Program, and other state agencies began collaboration on Interactive Stream Assessment Resource (INSTAR). INSTAR is an online, interactive database application that evaluates the ecological integrity of Virginia's streams using biological assessments and habitat data. INSTAR was developed as part of and to support Virginia's Healthy Waters Initiative. That initiative is an effort to raise awareness of the importance of stream ecological condition and how healthy it is and to make certain that conservation efforts are broad enough to include healthy streams and rivers, making them and restoration efforts a priority. The approach is complementary to water quality programs that focus on repairing degraded streams.

INSTAR is used to identify healthy streams using data that include information about fish and macroinvertebrates, instream habitat, and riparian borders. Users can access and manipulate the view of a comprehensive database representing more than 2,000 aquatic (stream and river) collections statewide. INSTAR was established to develop complementary, synoptic, and geospatial database for fish and macroinvertebrate community composition and abundance at stream locations throughout the state. INSTAR, and the extensive aquatic resources database on which it runs, supports a wide variety of stream assessment, management, and conservation activities aimed at restoring and protecting aquatic living resources throughout Virginia.

INSTAR was primarily designed as a tool that could be used for regional and local planning by providing support for making land use decisions and help in prioritizing stream protection and mitigation efforts. Advocacy groups and individuals might also want to use INSTAR to identify healthy streams in their communities and encourage their protection. INSTAR can support regional approaches to transportation, priority habitat corridor identification, greenways, zoning, and land conservation priorities. It can also be used to identify healthy streams vulnerable to development and those already protected. Locally, INSTAR can help raise awareness about the location of healthy waters and identify priority areas during comprehensive planning. Measures of the composition of the naturally expected benthic macroinvertebrate community provide a benchmark for determining a healthy stream.

INSTAR generates a Virtual Stream Assessment (VSA) score for each stream studied using data collected by biologists along a 150- to 500-meter length or reach of stream, depending on its width. Information collected includes the types and number of fish and aquatic macroinvertebrates, instream habitat (e.g., vegetation, rocks, fallen logs), and riparian vegetation. The information is compared statistically to a model reference stream that represents ideal conditions of biology and habitat for streams in that geographic region. How closely a stream compares to an appropriate model reference stream determines its VSA score and ranking. That information can help identify a range of condition, from streams that have exceptional health to streams that are good candidates for restoration. INSTAR also classifies Virginia's 1,275 small watersheds using a modified index of biological integrity (mIBI) that is based on occurrences of selected aquatic species found in each watershed.

With INSTAR, a user can generate stream data and mapping information at the local, regional, or statewide level. Searches can be done by locality, stream name, watershed, or drainage area, and specific locations can be pinpointed using global positioning system (GPS) coordinates or street addresses. Users can also access information about fish, macroinvertebrates, and habitat for a specific stream location and can turn on topographical views, road maps, wetland overlays, and aerial photos. Users can also measure, outline, and highlight areas; add and edit text; and generate customized maps and reports. INSTAR is available to the public through a free, user-friendly website: http://instar.vcu.edu.

Application of INSTAR in Richmond County

The Richmond County Local Tributary Strategy Pilot Project, funded through grants from the National Fish and Wildlife Foundation and VA DCR, focused on the capacity of stakeholders to develop and support a local program to implement statewide strategies to mitigate nutrient and sediment pollution delivered to local waters and the Chesapeake Bay. The project approach identified aspects of local/regional planning and implementation programs where consideration of strategies to meet regional water quality goals could lead to improved condition or improved protection of natural resources. The best outcome would be that implementation would affect local needs and the broader Chesapeake Bay goals. County-comprehensive planning and agricultural best management practice (BMP) implementation programs are examples of local programs that vary greatly in how they are managed and have regional impact. Central to success in the project was identifying a way to link such varied efforts so that their strategies might align with regional goals. The project worked to establish that link through a focus on linking land use to water quality or stream health. The link was defined by two data-collection efforts. A countywide INSTAR stream assessment was conducted, and a countywide chemical water assessment was conducted.

The stream health assessment became a central theme for the project as the data were reviewed under several different contexts.

1. The project participated in the county-comprehensive plan review and revision process as a partner in an extensive community engagement process. Work sessions were held to specifically discuss the link among land use, management and planning, stream health and natural resource conditions and trends, and a host of other social and economic sector interests. The stream health assessment was an important component of the natural resource workshop.
2. INSTAR-identified healthy stream sites were included as a component of secondary considerations in the local Soil and Water Conservation District Agricultural BMP Cost Share Program guidance.
3. The INSTAR stream assessment was used in combination with the chemical water quality and agricultural BMP implementation data to correlate stream health and the level of BMP implementation or the percentage of land treated in a site's drainage area. The map displays an enhanced view of INSTAR data that includes sites identified as Important Fisheries Resources

and their spatial distribution against the level of BMP implementation in corresponding watersheds.

4. The INSTAR stream assessment was used to review the health of streams that received drainage from the main urbanized area affecting the county's jurisdiction. The data allowed for prioritizing sites where improved stormwater management could affect local conditions and regional implementation goals.
5. The comprehensive nature of the stream assessment provides a baseline condition for the local effort to measure progress, impacts, identify threats, or conservation priorities.

The regional strategies developed under Virginia's initial Tributary Strategies and revisited in the development of the Chesapeake Bay Total Maximum Daily Load (TMDL) do not provide local data to assist with implementation planning. The INSTAR stream assessment is a way to fill that data gap.

3.15 Examination of Climate Change Trends in Utah

Abstract

U.S. Environmental Protection Agency and the Utah Department of Environmental Quality (UT DEQ) are partnering in analysis of long-term biological assessment data to evaluate the potential impact of global climatic trends on the aquatic biota in Utah's streams. UT DEQ's objective is to develop a defensible approach to account for systematic bias that these impacts might have on its biological assessment and biological criteria program. Reference condition (e.g., natural or near natural condition) provides a baseline for comparison between expected conditions and test sites so it is important for states to understand and, where possible, quantify the shifts in the *steady state* of local reference communities due to global climatic shifts, regardless of whether they are natural or human-induced. For example, test sites should not be expected to exhibit communities that no longer exist at reference sites. UT DEQ's objective is to quantify the proportion of variation attributed to temperature-driven effects.

U.S. Environmental Protection Agency (EPA) Office of Research and Development (2010c) analyzed biological assessment data from Utah to determine whether past climate trends could be detected and to characterize the vulnerabilities of the biological assessment program to future climate conditions. In particular, the Utah Department of Environmental Quality (UT DEQ) was concerned that systematic changes in the physical or biological characteristics of streams would bias biological assessment scores, leading to errors in its integrated report. The availability of long-term stream invertebrate data at four reference stations, in two ecoregions, formed the basis for the analyses.

Long-term declines in richness or abundance of cold-preference taxa was detectable (i.e., from statistically significant temporal trends) at the two longest-term (> 15 years) Utah reference stations—one in the Wasatch-Uinta ecoregion and the other in the Colorado Plateau. That response was supported by significant associations between declining richness or abundance of cold-preference taxa and increasing temperature. Fairly predictable losses in a metric considered sensitive to pollution and disturbance, EPT taxa richness, were observed with increasing temperatures at the locations, which represent both high- and low-elevation ecoregions. The EPT metric is a measure of the presence of generally pollution-sensitive species (e.g., **E**phemeroptera (mayflies), **P**lecoptera (stone flies) and **T**richoptera (caddisflies)) in a sample. The response of EPT taxa was largely driven by losses of coldwater-preference EPT taxa, but in some cases it was also influenced by gains in warm-preference EPT taxa.

From those results, it was estimated that a 25 - 40 percent loss of EPT taxa could occur with current scenarios of temperature increases by 2050 (USEPA 2010c). Should such substantial losses of EPT taxa due to climate change occur, it would confound measures of ecological condition and decisions regarding attainment of aquatic life uses in many state monitoring programs. The Utah results suggest that relative elevation is a contributing factor driving the temperature trait composition of regional benthic communities (USEPA 2010c), with a greater proportion of cold-preference taxa in the higher elevation ecoregions and a greater proportion of warm-preference taxa in low-elevation ecoregions. Higher elevation regions with a greater proportion of cold-preference taxa might have a greater vulnerability to temperature-driven effects on traditional, taxonomically based indicators of biological condition. However, with the results of these studies and others, temperature-modified metrics can be used to characterize the contribution of climate changes in temperature to the observed trends, which would minimize both false-positive and false-negative decisions about aquatic life use support.

UT DEQ uses a mathematical model, River Invertebrate Prediction and Classification System (RIVPACS), to predict the expected composition of benthic macroinvertebrate species inhabiting streams from observations made at numerous streams that are relatively unimpacted by anthropogenic stress. The expected composition provides the baseline against which a test stream is compared. The results of the study show that changes in climate-related parameters used as predictor variables in the model will potentially alter the model's precision. The model needs to be calibrated for the climate-sensitive parameters so that effects from global climate change (regardless of whether they are natural or enhanced by anthropogenic sources of carbon to the atmosphere) and effects from anthropogenic stress (e.g., toxic discharges, stormwater flows, nutrient enrichment) can be distinguished. UT DEQ recalibrates the model every 2 years for Integrated Report purposes. Recalibration includes new reference sites, updated data from existing reference sites, and new environmental predictor variables and data. Therefore, as part of its existing program, Utah is able to accommodate and adjust for changes to predictor variables due to climate change, provided that it is aware of the potential for systematic bias.

To continue support of the effort, UT DEQ intends to collect additional data at long-term reference sites. Using the initial 2006 RIVPACS model as baseline, which includes most historical data from reference sites, at least five sites from each of the eight biologically similar groups will be sampled. A site will be sampled when the basin rotation monitoring plan is implemented for that basin (six-basin rotation). The sites encompass various levels of elevation, watershed size, latitude, and such, which can provide clues where climate-change effects are most pronounced. The RIVPACS model will be recalibrated every 2 years including new reference sites and updated predictor variable data. These recalibrated models will then be applied to data collected from the revisited trend reference sites to quantify several measures of long-term biological changes, including observed/expected (O/E) trends sites, changes in biological group membership, and taxon-level changes within group membership, including patterns in trait-based community composition. Site-specific results from these recalibrated models will also be compared to historical results to evaluate the extent to which climate trends would have altered decisions regarding support or non-support of aquatic life uses if climate-related biases were not accounted for in the analyses.

3.16 Applications of Biological Assessment at Multiple Scales in Coral Reef, Estuarine, and Coastal Programs

Abstract

Biological assessments provide useful information on the cumulative impacts of multiple stressors on biological conditions. As integrators, biological assessments can also evaluate the effects of landscape and ecological processes on aquatic life. By applying biological assessments at multiple spatial scales and multiple levels of biological organization in large and spatially complex waterbodies such as estuaries, coral reefs, or large braided river networks, U.S. Environmental Protection Agency hopes to expand its ability to understand first the interactions of biological communities with the large-scale processes that define ecosystems and second the cumulative effects of multiple stressors over larger spatial scales and over decadal time periods. Approaches combining biological assessments at several scales and levels are being developed for estuaries in the National Estuary Program and for coral reefs.

Background

Biological assessments can be conducted at many spatial scales and at many levels of biological organization. *Spatial scale* refers to the area considered in a biological assessment and can range from a shoreline or stream reach to an entire waterbody, region, state, or nation. Level of biological organization makes note that biology self-organizes into levels of order or structure such as organism, population, community, biotope, bioregion, or biome. Each level is generally associated with a physical space, such as habitat, landscape, watershed, or region. For example, biological assessment is a valuable tool to examine a single stream reach by considering the biological community within a defined habitat or a consolidated group of habitats in the stream (USEPA 1990, 1999). Such habitat-specific community-level biological assessments can also be conducted at local, state, and national spatial scales. U.S. Environmental Protection Agency's (EPA's) National Coastal Assessments (2001–2006) and National Coastal Condition Assessment (2010)[18]—programs designed to assess the condition of the nation's estuaries and coastal waters—conduct habitat-specific community-level biological assessments (hereafter referred to as habitat-level assessments) at the national scale. Habitat-level assessments are consistent with the definition of biological integrity as the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a composition and diversity comparable to those of natural habitats of the region (Frey 1975; modified by Karr and Dudley 1981).

At a different level of biological organization, several methods for biological assessment that are specific to the aquatic landscape or to landscape-level processes have been developed. These methods can be useful tools in spatially complex waterbodies that are defined by interconnections among biological communities and among many distinct environments or habitats. Landscape-level concepts can be applied to all waterbody types and provide particular insights for watershed management. They are potentially very helpful as evaluative tools in waterbodies that appear as intertwined, patchy (and often shifting) mosaics of environments that support different biota and respond differently to different stressors.

[18] For more information, see http://water.epa.gov/type/oceb/assessmonitor/nccr/index.cfm.

Coral Reef Biological Assessments

The concept of biological integrity at the landscape level has, for example, been identified as important in developing biological criteria for coral reefs. Coral reefs are spatially complex habitats that are inextricably intertwined with a larger set of adjacent habitats (e.g., mangroves and seagrasses). Coral reef biota have evolved life history strategies that rely on the availability of those adjacent habitats (Christensen et al. 2003; Mumby et al. 2004, 2008; Aguilar-Perera and Appeldoorn 2007; McField and Kramer 2007; Meynecke et al. 2008; Sale et al. 2008). EPA's Coral Reef Biological Criteria document (Bradley et al. 2010) points out that "[b]iological integrity also means that reef organisms...have a clean, healthy environment to support them, including habitats for propagation, nurseries, and refugia. In this context, a fully functioning coral reef ecosystem may include adjacent supporting ecosystems such as seagrasses and mangroves." That document also recommends area measures of coral reef extent (e.g., square meters) as a first-order method for biological assessment of coral reefs that is relevant to landscape-scale evaluations. While most monitoring programs portray coral quantity as two-dimensional (2-D) live coral cover, EPA has developed a rapid survey procedure for estimating three-dimensional (3-D) total coral cover, which more realistically characterizes coral structure available as community habitat (Fisher 2007; Fisher, Davis, et al. 2007; Fisher, Fore, et al. 2008).

In conjunction with National Oceanic and Atmospheric Administration (NOAA) and other partners, scientists from EPA's Atlantic and Gulf Ecology Divisions (Narragansett and Gulf Breeze) are exploring the use of biological assessments to describe the coral reef and fish community along a gradient of stress in Guánica Bay, Puerto Rico. This effort may expand to include other critical coastal habitats in the future, e.g., sea grass beds and mangrove forests. Scientists will examine the pollution sensitivity of different taxa, presence or absence of native species, and other ecological response variables and then map the changes in these variables along a gradient of increasing stress—a Biological Condition Gradient (BCG) (see Chapter 2, Tool #2). Additionally, if there is sufficient quality and quantity of field data available, the BCG can provide a framework for relating well documented numeric stressor-response relationships to biological condition and thereby more precisely define stressor concentrations that support a waterbody's designated aquatic life use. Establishing this relationship could involve two steps. One step is establishing a numeric biological threshold that corresponds to the desired level of biological condition. For example, State and Tribal programs often develop numeric biological thresholds based on reference site conditions using an index of biotic integrity (IBI) or modeling the ratio of observed to expected species (O/E). Quantifying the relationship between BCG tier assignments and IBI or O/E scores for sampling sites along a gradient of stress provides a mechanism to link the scores to different levels of biological condition. The other step is quantifying the relationship between the IBI or O/E values and the stressor/parameter of interest such as nitrogen or phosphorus. Once a significant relationship between the IBI or O/E values and the stressor is documented, numeric water quality criteria (NWQC) for nitrogen or phosphorous could potentially be derived by selecting the stressor value that corresponds to the selected biological threshold (USEPA 2010a). This process facilitates the development of NWQC for nitrogen or phosphorus that are explicitly associated with levels of biological condition supportive of designated aquatic life uses. Developing these relationships at multiple scales including landscape-scale biological assessments will facilitate linking state and tribal water quality standards with both watershed and national estuary programs (Cicchetti and Greening 2011, USEPA In draft).

Biological Assessment at Multiple Scales in Estuaries and Coastal Waters

A large body of estuarine work has been done in index development and in application of habitat-level biological assessments. For example, approaches have been developed for salt marshes, soft-bottom benthic invertebrate communities and seagrass beds (USEPA 2000b). As a supplement to these efforts, several environmental programs such as EPA's national estuary programs (NEPs) are working together with U.S. Environmental Protection Agency (EPA) Office of Research and Development to develop landscape-scale biological assessment tools to evaluate and understand large-scale changes that have occurred to multiple habitats over long time periods and to integrate them into management in conjunction with existing habitat-level biological assessment tools. Specifically, the Tampa Bay, Narragansett Bay, and Mobile Bay Estuary programs are evaluating complementary application of the BCG to estuaries at the individual habitat level of biological assessment and at the landscape level of biological assessment, for managing estuaries and watersheds at the spatial scale of the entire waterbody.

Definitions:

- Habitat-level biological assessments—Evaluations of biological condition that consider biological communities within a defined habitat or suite of habitats (see Frey 1975; Karr and Dudley 1981).
- Landscape-level biological assessments—Evaluations of biological condition that consider and attempt to integrate biological processes, multiple biological habitats, or multiple biological communities within a defined landscape, waterbody, watershed, or waterbody type. The extent or arrangement (or both) of multiple biological habitats in a defined waterbody type.

✓ Both of these types of assessments can apply at a wide range of spatial scales, from a single area or subembayment to a larger waterbody, state, region, or nation.

As an example of landscape level assessment, one method in development considers the habitat landscape or biotope mosaic. A *biotope* is an area that is relatively uniform in physical structure and is identified by a dominant biota (Madden et al. 2009; Davies et al. 2004). Biotopes in estuaries include seagrass beds, salt marshes, coral reefs, clam flats, and more. Biotopes are a foundation of many recent habitat classification schemes, including the Coastal and Marine Ecological Classification Standard, which has been sponsored by the Federal Geographic Data Committee, and the European Nature Information System (Davies et al. 2004). Arrangements of biotopes provide species with spawning grounds, nurseries, refuge, sustenance, and other vital needs; such arrangements are particularly critical for larger mobile species and for species that move among biotopes at different stages of their life. The areas and arrangements of biotopes in a waterbody are affected by the full range of anthropogenic stressors, including nitrogen and phosphorus pollution, toxics, shoreline development, and sediment loads. Because biotopes are inherently a biological component, NEPs are developing approaches for biological assessment that consider areas and distributions of biotopes and biotope landscapes at the whole-estuary scale, combining the landscape-level tools with more resolved habitat-level tools. Tampa Bay, Narragansett Bay, and other NEPs are working on these multi-level BCG approaches. Additionally, the Mobile Bay NEP is exploring how to incorporate the concept of ecosystem services in development of a Biological Condition Gradient for the estuary. Current efforts in Tampa Bay and Narragansett Bay are briefly discussed below.

Tampa Bay Estuary Program

The Tampa Bay Estuary Program (TBEP) initiated a system-wide management framework in the 1990s that developed estuarine habitat restoration and protection goals to support estuarine-dependent species and the habitat landscapes they require (e.g., the extent of seagrass beds, mangrove forests, *Spartina* marshes, *Salicornia* marshes, and low-salinity marshes). Although the term *biotope* was not used, the framework employed the basic concepts of biotope extent and distribution to evaluate condition of the waterbody, comparing current condition to a more naturally occurring condition that existed at a relatively undisturbed point in the past. This information supported the development of environmental protection and restoration goals for the waterbody and watershed that move the estuary closer to those more naturally occurring conditions. This approach was combined with habitat-level work, including water quality modeling to predict seagrass health, benthic macroinvertebrate surveys, and more. Tampa Bay has recovered many hundreds of acres of high-value biotopes (Cloern 2001; Duarte 2009). TBEP is now working with other NEPs to develop those approaches into transferable biological assessment tools using concepts from the BCG. The methods used by TBEP, together with their application to biological assessment at landscape scales, are discussed in Cicchetti and Greening (2011).

Narragansett Bay Estuary Program

The Narragansett Bay Estuary Program (NBEP) and partners, benefiting from the Tampa Bay experience, are developing a suite of biological assessment tools to apply on a range of biological levels and spatial scales. A pilot program in Greenwich Bay, a sub-estuary of Narragansett Bay, has examined macroinvertebrate communities and biotopes in the context of the BCG using historical documentation of early stressor levels and ecosystem conditions to recreate a biological baseline. The project is especially pertinent to highly altered systems where it is often impossible to find undisturbed or minimally disturbed conditions. To characterize the biological responses to increasing stress, the study identified current, recent and historical stressors to Greenwich Bay benthos, including water quality (e.g., hypoxia), sediment metals, nutrients (i.e., nitrogen-loading), and hydrodynamics (including dredging and shoreline modification), terrestrial runoff, storms, and temperature. Changes in these parameters through time were summarized. A critical but challenging aspect of the project was to establish a reference level, or minimally disturbed endpoint. Target reference levels derived from historical baselines can be problematic because (1) they are difficult to calibrate with current ecosystem status, (2) ecosystems were as dynamic in the past as they are today, and (3) climate change and the degree of anthropogenic influence can render these endpoints unattainable. However, Greenwich Bay is fortunate in having available a significant amount of cultural and scientific historical data; although much of the information is qualitative, even qualitative differences in the biological indicators can be useful for defining a minimally disturbed endpoint. Ecological timeline data were overlaid with a detailed cultural timeline in order to associate changes in biological indicators with changes in human activities. Records of significant storms and climate trends gave broader context to ecological observations. The combined cultural and ecological timeline suggest when thresholds in the biological indicators may have been exceeded.

Because nutrient pollution is a major stressor in Narragansett Bay, the tools consider habitats and landscapes that are sensitive to (and diagnostic of) nutrient stress. At the habitat scale, NBEP and EPA's Atlantic Ecology Division (Narragansett) are developing approaches for biological assessment of macroinvertebrates in deeper subtidal areas, camera-based approaches to examine biology in deeper subtidal areas, and approaches for evaluating seagrass and microalgae as tools to better manage nutrient inputs to the waterbody and watershed. The overall project goal is to develop an estuarine framework that can apply at multiple scales and levels using several methods of biological assessment, all brought together with the "common language" of the BCG.

Transferability to Freshwater Aquatic Ecosystems

By performing biological assessments and developing BCGs at multiple spatial scales and levels of biological organization in estuaries and coral reef ecosystems, EPA, NOAA, and their NEP partners will better understand the interactions among biological communities with system-level processes that define and regulate ecosystems, and will be able to assess the cumulative effects of multiple stressors over large spatial scales and over longer periods of time (e.g., decadal). The results of this work are expected to be adapted to large and complex freshwater systems, such as braided river networks, lakes, and large rivers and their attendant watersheds. In river systems, for example, EPA's Ecological Exposure Research Division (Cincinnati) is developing geographic information system- (GIS-) based tools to classify and characterize natural variability in watersheds and concurrently developing watershed-scale models integrating habitat and landscape biological assessments of classified river systems, incorporating main channel and lateral slackwaters (bays, side channels, and backwaters) with the floodscape (isolated oxbows, lakes, wetlands, and usually dry alluvial floodplains). A major component of this work focuses on defining critical ecological thresholds, or tipping points, of ecological condition and function in river systems in response to multiple stressors in watersheds at multiple spatial and temporal scales.

Tools such as these could support watershed and basin wide management and planning, enabling state, tribal and local resource managers to: 1) account for more of the natural variability within and across river systems, watershed and regions; 2) relate changes in stressors exposure to changes in biological (and functional) condition at both a watershed and system-wide level; and, 3) facilitate the extrapolation of findings from one system and/or watershed to other similarly located or functioning systems.

3.17 Partnerships in the Protection of Oregon's Coho Salmon

Abstract

Assessment of biological conditions in Oregon's Coast Coho Evolutionarily Significant Unit (ESU) has provided state agencies with valuable information that can be used to improve protection of coho salmon. Oregon Department of Environmental Quality and Oregon Department of Fish and Wildlife are using monitoring data to examine several indicators—temperature and fine sediments—that have been identified as potential causes of coho population decline in the state. Findings show that the two monitoring areas with the highest biological condition also showed the lowest evidence of stress from temperature and fine sediment. National Oceanic and Atmospheric Administration's Fisheries Division has also been able to use biological information to support a decision to list coho as *threatened* and to designate the Oregon Coast Coho ESU as a critical habitat.

Introduction

For more than a decade, state and federal agencies have been working to halt the decline of coho salmon in Oregon. In 1997 Oregon implemented the Oregon Plan for Salmon and Watersheds, a step toward reversing the decline of coho salmon in Oregon coastal streams. In response, Oregon Department of Environmental Quality (ODEQ) and Oregon Department of Fish and Wildlife (ODFW) began expanded monitoring in Oregon coastal streams to gather information on the status of water quality and watershed health indicators identified as potential causes for declining populations of Oregon coastal coho salmon (State of Oregon 1997).

In 2005 ODEQ and ODFW assessed the information collected on the factors for the decline of coho and evaluated the relative importance of each factor to the continued viability of Oregon's coastal coho runs into the future. Specifically, ODEQ and ODFW assessed data for the Oregon Coast Coho Evolutionarily Significant Unit (ESU). The Oregon Coast Coho ESU is in western Oregon, spanning approximately three-quarters of the coastline with the Pacific Ocean and contains more than 9,000 miles of rivers and streams. Most of the stream miles (more than 80 percent) are small, wadeable streams (1^{st} through 3^{rd} order). Two hundred and eighty-three randomly selected sites were characterized throughout the ESU, ranging from 61 to 86 sites per monitoring area. Specifically, data were analyzed for four monitoring areas nested within the ESU (North Coast, Mid-Coast, Mid-South Coast, and Umpqua).

In 2007 ODFW released the final draft of the *Oregon Coast Coho Conservation Plan* (State of Oregon 2007), which outlines Oregon's strategy to ensure the continued viability of threatened coastal coho salmon runs. Part of the plan identifies the need for higher-resolution monitoring of water quality and macroinvertebrates in the Oregon Coast Coho ESU (Lawson et al. 2007). Because of the ability of macroinvertebrates to integrate the effects of water quality and habitat stressors—and limited resources for comprehensive monitoring—ODEQ and ODFW agreed that macroinvertebrates would be used to relate water quality and overall watershed condition in the ESU. In 2008, National Oceanic and Atmospheric Administration (NOAA) Fisheries Division used the information in its final decision to re-list Oregon coastal coho as *threatened* under the Endangered Species Act.

Assessment of Biological Condition

In 2006–2007 ODEQ and ODFW jointly collected and analyzed macroinvertebrate data in the ESU. They evaluated biological condition for each of four monitoring areas in the ESU. Macroinvertebrates were also used as a screening tool to determine the relative contributions of temperature and fine sediment as stressors to biological condition.

A multivariate predictive model, PREDATOR, was used to assess the biological condition of wadeable streams throughout Oregon (Hubler 2008). The model compares observed taxa with expected taxa to generate an observed/expected (O/E) taxa ratio. Scores of less than 1.0 have fewer taxa at a site than were predicted by the model, representing a loss of native reference taxa richness. Benchmarks based on the distribution of O/E scores at reference sites were used to classify the samples into one of the three following biological condition classes: least disturbed, moderately disturbed, and most disturbed (Table 3-12).

Table 3-12. Biological benchmarks.

Biological condition class	O/E	Taxa loss
Least disturbed	> 0.91	8% or less
Moderately disturbed	0.86–0.91	9%–14%
Most disturbed	< 0.86	15% or more

Subsequent monitoring showed that approximately 50 percent of the streams could be classified as least disturbed (equivalent to reference), while almost 40 percent of streams in the ESU had macroinvertebrates in most disturbed conditions (missing a considerable amount of reference taxa). The four monitoring units showed different relative proportions of condition classes. The Mid-Coast monitoring area had the largest proportion of sites in highest biological condition with 69 percent of sites in least disturbed condition and 17 percent of sites in most disturbed condition. The Umpqua monitoring unit showed only about one-quarter of sites in least disturbed conditions and approximately two-thirds of sites in most disturbed conditions. That information, along with stressor information for each monitoring unit, became very important in developing the stressor-response model. The information was used to try to identify the relative importance of two key (NPS) stressors to macroinvertebrate conditions in the Oregon Coastal Coho ESU.

Stressor-Response Model

The relationships among macroinvertebrate abundances and environmental variables (seasonal maximum temperature and percent fines) were used to model the optimum conditions for each taxon. These optimal conditions were then used to infer the overall assemblage preference for temperature and fine sediments of any site using a macroinvertebrate sample alone (Huff et al. 2006). Benchmarks were established to identify sites where temperature or fine sediments or both can be at levels considered to be stressful to the macroinvertebrate assemblages. Temperature stress (TS) values above 18 °C were considered temperature stressed, as it relates directly to the WQS set to protect salmon and trout rearing and migration. Fine sediment stress (FSS) values above 10 percent were considered sediment stressed because that value has been shown to negatively affect macroinvertebrates in mountain streams (Bryce et al. 2010).

The North Coast monitoring area showed the lowest levels of TS (36 percent of sites) and FSS (22 percent). The Mid-Coast monitoring area showed approximately half of the sites as stressed for both temperature and fine sediment, despite showing the highest percentage of sites in least disturbed biological condition. Both the Mid-South and Umpqua monitoring areas showed two-thirds or more of the sites to be stressed for both temperature and fine sediment. Apart from the North Coast, stresses to the macroinvertebrate assemblages from temperature and fine sediments appear to be equivalent.

Conclusions

Biological data and stressor-response relationships were used as the basis for several findings. First, NOAA was able to make a decision to list coho as *threatened* and to designate the Oregon Coast ESU as a critical habitat. Second, several general trends were observed in the assessment of the macroinvertebrate data collected and assessed. The two monitoring areas with the highest biological condition (North Coast and Mid-Coast) showed the lowest evidence of stress from temperature and fine sediment. The Mid-South Coast and Umpqua monitoring areas showed higher levels of stress and lower biological condition (substantially so in the Umpqua). That information can be used in developing management plans for ESU monitoring areas or basins. Much emphasis has been placed on improving the temperature conditions in Oregon’s streams and rivers, while less work has gone into developing sediment management plans. The data presented here suggest that excess fine sediments are affecting biological conditions in the ESU on a scale similar to that of temperature.

Finally, the monitoring project is an example of two state agencies working together to implement a monitoring program that is cost-effective by addressing both agencies’ needs for information. For ODFW, the random macroinvertebrate, water quality, and habitat sampling protocol provides critical information on water quality and habitat conditions, which have been identified as limiting factors to coho salmon viability. For ODEQ, the macroinvertebrate sampling in conjunction with the water quality and habitat monitoring provides valuable information on attainment of the designated aquatic life uses for streams.

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Glossary

aquatic assemblage	An association of interacting populations of organisms in a given waterbody; for example, fish assemblage or a benthic macroinvertebrate assemblage.
aquatic community	An association of interacting assemblages in a waterbody, the biotic component of an ecosystem.
aquatic life use	A beneficial use designation in which the waterbody provides, for example, suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms.
attribute	The measurable part or process of a biological system.
benthic macroinvertebrates or benthos	Animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard no. 30 sieve (28 meshes per inch, 0.595-mm openings); also referred to as benthos, infauna, or macrobenthos.
best management practice	An engineered structure or management activity, or combination of those, that eliminates or reduces an adverse environmental effect of a pollutant.
biological assessment or bioassessment	An evaluation of the biological condition of a waterbody using surveys of the structure and function of a community of resident biota.
biological criteria or biocriteria	Narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions; as such, biological criteria serve as an index of aquatic community health.
biological indicator or bioindicator	An organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions.
biological integrity	The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in a region.
biological monitoring or biomonitoring	Use of a biological entity as a detector and its response as a measure to determine environmental conditions; ambient biological surveys and toxicity tests are common biological monitoring methods.
biological survey or biosurvey	Collecting, processing, and analyzing a representative portion of the resident aquatic community to determine its structural and/or functional characteristics.

biotope	An area that is relatively uniform in physical structure and that is identified by a dominant biota.
Clean Water Act	The act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 *et seq*.
Clean Water Act 303(d)	This section of the act requires states, territories, and authorized tribes to develop lists of impaired waters for which applicable WQS are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that the jurisdictions establish priority rankings for waters on the lists and develop TMDLs for the waters. States, territories, and authorized tribes are to submit their lists of waters on April 1 in every even-numbered year.
Clean Water Act 305(b)	Biennial reporting requires description of the quality of the nation's surface waters, evaluation of progress made in maintaining and restoring water quality, and description of the extent of remaining problems.
criteria	Elements of state water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.
designated uses	Those uses specified in WQS for each waterbody or segment whether or not they are being attained.
disturbance	Human activity that alters the natural state and can occur at or across many spatial and temporal scales.
ecological integrity	The condition of an unimpaired ecosystem as measured by combined chemical, physical (including physical habitat), and biological attributes. Ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact.
ecoregion	A relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.
function	Processes required for normal performance of a biological system (may be applied to any level of biological organization).
guild	A group of organisms that exhibit similar habitat requirements and that respond in a similar way to changes in their environment.

historical data	Data sets from previous studies, which can range from handwritten field notes to published journal articles.
index of biological/biotic integrity	An integrative expression of site condition across multiple metrics; an IBI is often composed of at least seven metrics.
invasive species	A species whose presence in the environment causes economic or environmental harm or harm to human health. Native species or nonnative species can show invasive traits, although that is rare for native species and relatively common for nonnative species. (Note that this term is not included in the biological condition gradient [BCG].)
least disturbed condition	The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a waterbody within a class or region. Such waters have the least amount of human disturbance in comparison to others in the waterbody class, region, or basin. Least disturbed conditions can be readily found but can depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition can change significantly over time as human disturbances change.
maintenance of populations	Sustained population persistence; associated with locally successful reproduction and growth.
metric	A calculated term or enumeration that represents some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.
minimally disturbed condition	The physical, chemical, and biological conditions of a waterbody with very limited, or minimal, human disturbance.
multimetric index	An index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score before being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition. See **index of biological/biotic integrity (IBI).**
narrative biological criteria	Written statements describing the structure and function of aquatic communities in a waterbody that support a designated aquatic life use.
native	An original or indigenous inhabitant of a region; naturally present.

nonnative or intentionally introduced species	With respect to an ecosystem, any species that is not found in that ecosystem; species introduced or spread from one region of the United States to another outside their normal range are nonnative or non-indigenous, as are species introduced from other continents.
numeric biological criteria	Specific quantitative measures of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use.
periphyton	A broad organismal assemblage composed of attached algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates.
rapid bioassessment protocols	Cost-effective techniques used to survey and evaluate the aquatic community to detect aquatic life impairments and their relative severity.
reference condition (biological integrity)	The condition that approximates natural, unaffected conditions (biological, chemical, physical, and such) for a waterbody. Reference condition (biological integrity) is best determined by collecting measurements at a number of sites in a similar waterbody class or region undisturbed by human activity, if they exist. Because undisturbed conditions can be difficult or impossible to find, minimally or least disturbed conditions, combined with historical information, models, or other methods can be used to approximate reference condition as long as the departure from natural or ideal is understood. Reference condition is used as a benchmark to determine how much other waterbodies depart from this condition because of human disturbance. See definitions for minimally and least disturbed condition
reference site	A site selected for comparison with sites being assessed. The type of site selected and the types of comparative measures used will vary with the purpose of the comparisons. For the purposes of assessing the ecological condition of sites, a reference site is a specific locality on a waterbody that is undisturbed or minimally disturbed and is representative of the expected ecological integrity of other localities on the same waterbody or nearby waterbodies.
refugia	Accessible microhabitats or regions in a stream reach or watershed where adequate conditions for organism survival are maintained during circumstances that threaten survival; for example, drought, flood, temperature extremes, increased chemical stressors, habitat disturbance.

sensitive taxa	Taxa intolerant to a given anthropogenic stress; first species affected by the specific stressor to which they are *sensitive* and the last to recover following restoration.
sensitive or regionally endemic taxa	Taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often because of unique life history requirements. Can be long-lived, late-maturing, low-fecundity, limited-mobility, or require mutualist relation with other species. Can be among listed endangered/threatened or special concern species. Predictability of occurrence often low; therefore, requires documented observation. Recorded occurrence can be highly dependent on sample methods, site selection, and level of effort.
sensitive - rare taxa	Taxa that naturally occur in low numbers relative to total population density but can make up large relative proportion of richness. Can be ubiquitous in occurrence or can be restricted to certain micro-habitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or coldwater obligates; commonly k-strategists (populations maintained at a fairly constant level; slower development; longer life span). Can have specialized food resource needs or feeding strategies. Generally intolerant to significant alteration of the physical or chemical environment; are often the first taxa observed to be lost from a community.
sensitive - ubiquitous taxa	Taxa ordinarily common and abundant in natural communities when conventional sample methods are used. Often having a broader range of thermal tolerance than sensitive or rare taxa. These are taxa that constitute a substantial portion of natural communities and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.
stressors	Physical, chemical, and biological factors that adversely affect aquatic organisms.
structure	Taxonomic and quantitative attributes of an assemblage or community, including species richness and relative abundance structurally and functionally redundant attributes of the system and characteristics, qualities, or processes that are represented or performed by more than one entity in a biological system.
taxa	A grouping of organisms given a formal taxonomic name such as species, genus, family, and the like.

taxa of intermediate tolerance	Taxa that compose a substantial portion of natural communities; can be r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics). Can be eurythermal (having a broad thermal tolerance range). Can have generalist or facultative feeding strategies enabling utilization of relatively more diversified food types. Readily collected with conventional sample methods. Can increase in number in waters with moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration.
tolerant taxa	Taxa that compose a small proportion of natural communities. They are often tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution- or habitat-induced stresses. They can increase in number (sometimes greatly) in the absence of competition. Commonly r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), able to capitalize when stress conditions occur; last survivors.
total maximum daily load	The sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources; the calculated maximum amount of a pollutant a waterbody can receive and still meet WQS and an allocation of that amount to the pollutant's source.
toxicity identification evaluation	A set of procedures to identify the specific chemicals responsible for effluent toxicity.
toxicity reduction evaluation	A site-specific study conducted in a stepwise process designed to identify the causative agents of effluent toxicity, isolate the sources of toxicity, evaluate the effectiveness of toxicity control options, and then confirm the reduction in effluent toxicity.
water quality management (nonregulatory)	Decisions on management activities relevant to a water resource, such as problem identification, need for and placement of best management practices, pollution abatement actions, and effectiveness of program activity.
water quality standard	A law or regulation that consists of the designated use or uses of a waterbody, the narrative or numerical water quality criteria (including biological criteria) that are necessary to protect the use or uses of that waterbody, and an antidegradation policy.

whole effluent toxicity	The aggregate toxic effect of an aqueous sample (e.g., whole effluent wastewater discharge) as measured by an organism's response after exposure to the sample (e.g., lethality, impaired growth or reproduction); WET tests replicate the total effect and actual environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants.

Abbreviations and Acronyms

ADEQ	Arizona Department of Environmental Quality
BCG	biological condition gradient
BMIBI	benthic macroinvertebrate index of biotic integrity
BMP	best management practice
CADDIS	Causal Analysis/Diagnosis Decision Information System
CT DEP	Connecticut Department of Environmental Protection
CWA	Clean Water Act
CWH	coldwater habitat
EPA	U.S. Environmental Protection Agency
EPT	ephemeroptera, plecoptera, trichoptera taxa
ESU	evolutionarily significant unit
EV	exceptional value (Pennsylvania)
EWH	exceptional warmwater habitat
FIBI	fish index of biotic integrity
FQI	Floristic Quality Index
FSS	fine sediment stress
GIS	geographic information system
GPS	global positioning system
HQ	high-quality (Pennsylvania)
HUC	hydrologic unit code
IBI	index of biological/biotic integrity
IC	impervious cover
ICI	invertebrate community index
IDNR	Iowa Department of Natural Resources
INSTAR	Interactive Stream Assessment Resource
IRG	Integrated Reporting Guidance
LRW	limited resource water
LWH	limited warmwater habitat
MDE	Maryland Department of the Environment
MDEQ	Michigan Department of Environmental Quality
MDNR	Maryland Department of Natural Resources
ME DEP	Maine Department of Environmental Protection
mIBI	modified index of biological integrity
MIwb	modified index of well-being
MPCA	Minnesota Pollution Control Agency
MWH	modified warmwater habitat
NARS	National Aquatic Resource Surveys
NAWQA	National Water-Quality Assessment
NBEP	Narragansett Bay Estuary Program

NEP	National Estuary Program
NFMR	North Fork Maquoketa River
NJ DEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NTU	nephelometric turbidity unit
NWQC	numeric water quality criteria
O/E	observed over expected
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ONRW	Outstanding National Resource Water
ORD	Office of Research and Development (U.S. Environmental Protection Agency)
PA DEP	Pennsylvania Department of Environmental Protection
PREDATOR	PREDictive Assessment Tool for Oregon
QHEI	qualitative habitat evaluation index
RIVPACS	River Invertebrate Prediction and Classification System
SI	stressor identification
SSH	seasonal salmonid habitat
TBEP	Tampa Bay Estuary Program
TIE	toxicity identification evaluation
TMDL	Total Maximum Daily Load
TRE	toxicity reduction evaluation
TS	temperature stress
UAA	use attainability analysis
UCONN	University of Connecticut
USGS	U.S. Geological Survey
UT DEQ	Utah Department of Environmental Quality
VA DCR	Virginia Department of Conservation and Recreation
VSA	Virtual Stream Assessment
VT DEC	Vermont Department of Environmental Conservation
WET	whole effluent toxicity
WQL	water quality limited
WQS	water quality standards
WWH	warmwater habitat
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant

Appendix A. Additional Resources

Biological Assessment and Biological Criteria: Technical Guidance

Biological assessment and biological criteria	Description/summary
Biological Criteria: National Program for Surface Waters (EPA 440-5-90-004) Source: U.S. Environmental Protection Agency Date of Publication: 1990	This document provides EPA regions, states and others with the conceptual framework and assistance necessary to develop and implement narrative and numeric biological criteria and to promote national consistency in application.
http://www.epa.gov/bioindicators/pdf/EPA-440-5-90-004Biologicalcriterianationalprogramguidanceforsurfacewaters.pdf	
Policy on the Use of Bioassessments and Criteria in the Water Quality Program Source: U.S. Environmental Protection Agency Date of Publication: 1991	This document provides policy guidance on integration of biological surveys, assessments, and criteria with chemical-specific analysis and whole effluent and ambient toxicity testing methods in the water quality program.
http://www.epa.gov/bioiweb1/pdf/PolicyonBiologicalAssessmentsandCriteria.pdf	
Coral reefs	**Description/summary**
Stony Coral Rapid Bioassessment Protocol (EPA 600-R-06-167) Source: U.S. Environmental Protection Agency Date of Publication: 2007	The principal purpose of the *Stony Coral Rapid Bioassessment Protocol* is to introduce a simple and rapid coral survey method that provides multiple biological indicators to characterize coral condition. The document offers insight on indicator relevance to ecosystem services (societal values), reef condition, and sustainability. It provides information regarding regulatory programs, and it presents a few examples describing how biological assessment indicators can be incorporated into a regulatory biological criteria program to conserve coral resources.
http://www.epa.gov/bioindicators/pdf/EPA-600-R-06-167StonyCoralRBP.pdf	
Coral Reef Biological Criteria: Using the Clean Water Act to Protect a National Treasure (EPA-600-R-10-054) Source: U.S. Environmental Protection Agency Date of Publication: 2010	Coral reef resource managers can use this document as a guide for developing and implementing biological criteria as part of water quality standards. Biological criteria are complementary to chemical and physical criteria and, once established, carry the same regulatory authority. The document introduces the role of biological criteria under the Clean Water Act and describes the process for identifying metrics, establishing reference values, designing a long-term monitoring program, and integrating biological criteria with existing management programs. It includes sections that link biological criteria to high-visibility issues such as ecosystem services, climate change, and ocean acidification.
http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=223392	
Estuaries and coastal waters	**Description/summary**
Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance (EPA 822-B-00-024) Source: U.S. Environmental Protection Agency Date of Publication: 2000	This technical guidance provides an extensive collection of methods and protocols for conducting biological assessments in estuarine and coastal marine waters and the procedures for deriving biological criteria from the results. See also *National Coastal Condition Reports* (2001, 2004 and 2008) under *National Aquatic Resource Surveys* listed below.
http://www.epa.gov/waterscience/biocriteria/States/estuaries/estuaries.pdf	

Lakes and reservoirs	**Description/summary**
Lakes and Reservoir Bioassessment and Biocriteria Technical Guidance Document (EPA 841-B-98-007) Source: U.S. Environmental Protection Agency Date of Publication: 1998	This guidance is intended to provide managers and field biologists with functional methods and approaches that will facilitate the implementation of viable lake biological assessment and biological criteria programs that meet their needs and resources. Procedures for program design, reference condition determination, field biological surveys, biological criteria development, and data analysis are detailed. In addition, the document provides information on the application and effectiveness of lake biological assessment to existing EPA and state/tribal programs such as the Clean Lakes Program, 305(b) assessments, NPDES permitting, risk assessment, and watershed management. See also *National Lakes Assessment Report* (2010) under *National Aquatic Resource Surveys* listed below.
http://www.epa.gov/owow/monitoring/tech/lakes.html	
Non-wadeable streams and rivers	**Description/summary**
Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers (EPA 600-R-06-127) Source: U.S. Environmental Protection Agency Date of Publication: 2006	This document provides a framework for the development of biological assessment programs and biological criteria for large rivers. It helps states establish or refine their large river protocols for field sampling, laboratory sample processing, data management and analysis, and assessment and reporting.
http://www.epa.gov/eerd/rivers/non-wadeable_full_doc.pdf	
Streams and wadeable rivers	**Description/summary**
Biological Criteria: Technical Guidance for Streams and Small Rivers (EPA 822-B-96-001) Source: U.S. Environmental Protection Agency Date of Publication: 2001	The goal of this document is to help states develop and use biological criteria for streams and small rivers. It includes a general strategy for biological criteria development, identifies steps in the process, and provides technical guidance on how to complete each step, using the experience and knowledge of existing state, regional, and national surface water programs. See also *Wadeable Streams Assessment Report* (2006) under *National Aquatic Resource Surveys* listed below.
http://www.epa.gov/bioindicators/pdf/EPA-822-B-96-001BiologicalCriteria-TechnicalGuidanceforStreamsandSmallRivers-revisededition1996.pdf	
Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd ed. (EPA 841-B-99-002) Source: U.S. Environmental Protection Agency Date of Publication: 1999	This document is a practical technical reference for conducting cost-effective biological assessments of lotic systems. The Rapid Bioassessment Protocols (RBPs) are a blend of existing methods used by various states to sample biological assemblages and assess physical habitat.
http://www.epa.gov/owow/monitoring/rbp/download.html	

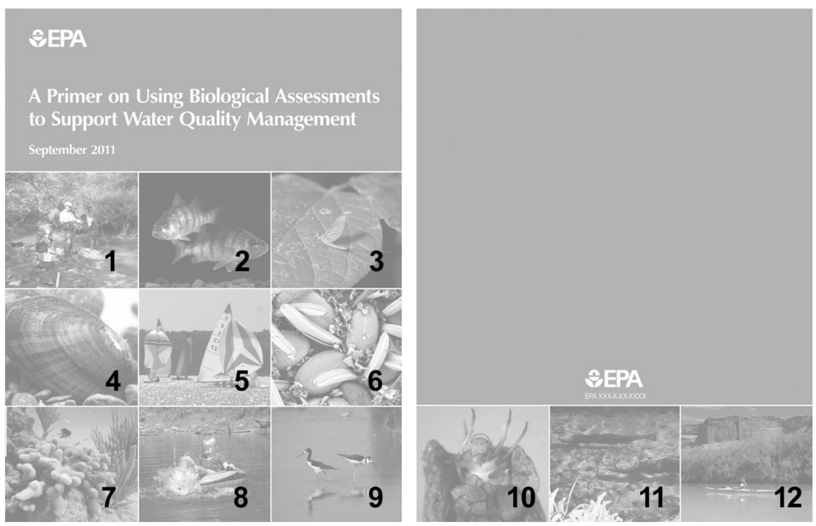
Other Relevant Water Program Guidance

Listing and TMDLs	Description/summary
Memorandum: Clarification of the Use of Biological Data and Information in the 2002 Integrated Water Quality Monitoring and Assessment Report Guidance Source: U.S. Environmental Protection Agency Date of Publication: 2002	This memorandum modified the 2002 *Integrated Water Quality Monitoring and Assessment Report Guidance* to provide clarity and promote consistency in the manner in which states use biological data and information in developing their submissions.
http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/biochange20302.cfm	
Guidance for 1994 Section 303(d) Lists Source: U.S. Environmental Protection Agency Date of Publication: 1994	This memorandum clarified how biological data can be used to support listing of a waterbody on the section 303(d) list.
http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/1994guid.cfm	
Recovery Potential Screening Source: U.S. Environmental Protection Agency Date of Publication: 2012	The Recovery Potential Screening website is a user-driven, flexible approach for comparing relative differences in restorability among impaired waters. The screening process uses ecological, stressor, and social indicators to evaluate and compare waters and reveal factors that may explain the relative restorability of waters. This technical method and website are intended to assist in complex planning and prioritizing decisions, provide a systematic and transparent comparison approach, reveal underlying environmental and social factors that affect restorability, and better inform restoration strategies to help achieve results. The website provides step-by-step directions in the screening process, downloadable tools for calculating indices and displaying results, summaries of indicators and their measurement from common data sources, a recovery literature database, and several case studies and related links.
http://www.epa.gov/recoverypotential/	

Monitoring and assessment	Description/summary
Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act Source: U.S. Environmental Protection Agency Date of Publication: 2005	This guidance is for states, territories, authorized tribes, and interstate commissions that help prepare and submit section 305(b) reports (referred to as *jurisdictions*). It outlines the development of biennial Integrated Reports, which that would support EPA's strategy for achieving a broad-scale, national inventory of water quality conditions. The objective of this guidance is to provide jurisdictions (1) a recommended reporting format and (2) suggested content to be used in developing a single document that integrates the reporting requirements of CWA sections 303(d), 305(b), and 314. (Pursuant to the CWA, jurisdictions report to EPA biannually on the condition of waters within their boundaries.)
http://www.epa.gov/owow/tmdl/2006IRG/report/2006irg-report.pdf	
Elements of a State Water Monitoring and Assessment Program (EPA 841-B-03-003) Source: U.S. Environmental Protection Agency Date of Publication: 2003	This document recommends 10 basic elements of a state water monitoring program and serves as a tool to help EPA and states determine whether a monitoring program meets the prerequisites of CWA section 106(e)(1).
http://www.epa.gov/owow/monitoring/elements/	
Consolidated Assessment and Listing Methodology (CALM): Toward a Compendium of Best Practices Source: U.S. Environmental Protection Agency Date of Publication: 2002	CALM provides a framework for states and other jurisdictions to document how they collect and use water quality data and information for environmental decision making. The primary purposes of the data analyses are to determine the extent to which all waters are attaining water quality standards, to identify waters that are impaired and need to be added to the 303(d) list, and to identify waters that can be removed from the list because they are attaining standards.
http://www.epa.gov/owow/monitoring/calm.html	
Biological Criteria: Technical Guidance for Survey Design and Statistical Evaluation of Biosurvey Data (EPA 822-B97-002) Source: U.S. Environmental Protection Agency Date of Publication: 1997	The emphasis of this guidance is on the practical application of basic statistical concepts to the development of biological criteria for surface water resource protection, restoration, and management.
http://www.epa.gov/bioindicators/pdf/EPA-822-B-97-002BiologicalCriteria-TechnicalGuidanceforSurveyDesignandStatisticalEvaluationofBiosurveyData.pdf	
Generic Quality Assurance Project Plan Guidance for Programs Using Community Level Biological Assessment in Wadeable Streams and Rivers (EPA 841-B-95-004) Source: U.S. Environmental Protection Agency Date of Publication: 1995	This document represents generic guidance for development of QAPPs for specific biological assessment projects or programs. It has been specifically designed for use by states using biological assessment protocols that focus on community-level responses as indicated by a multimetric approach and taxonomy to the genus/species level.
http://www.epa.gov/bioindicators/pdf/EPA-841-B-95-004GenericQualityAssuranceProjectPlanBioassessment.pdf	

National Aquatic Resource Surveys: *National Coastal Condition Report*. (2001) EPA-620/R-01/005 *National Coastal Condition Report II*. (2004) EPA-620/R-03/002 *Wadeable Streams Assessment.* (2006) EPA-841-B-06-002 *National Coastal Condition Report III*. (2008) EPA/842-R-08-002 *National Lakes Assessment*. (2010) EPA-841-R-09-001 Source: U.S. Environmental Protection Agency Dates of Publication: see above	The surveys are conducted using a statistical survey design to yield unbiased, statistically representative estimates of the biological condition of the whole water resource (e.g., wadeable streams, lakes, rivers). Data are collected, processed, and analyzed through EPA-state collaboration to assess and report on the condition of the nation's waters with documented confidence. Surveys collect a suite of indicators relating to the biological/physical habitat and water quality of the resource to assess the resource condition and determine the percentage meeting the goals of the CWA. Surveys collect information on biological and abiotic factors at 30–50 sites on an ecoregion level II scale for each resource.
http://www.epa.gov/owow/monitoring/nationalsurveys.html http://www.epa.gov/owow/oceans/nccr/ http://www.epa.gov/owow/streamsurvey/ http://www.epa.gov/owow/lakes/lakessurvey/	
Predictive Tools	**Description/summary**
Landscape and Predictive Tools: A Guide to Spatial Analysis for Environmental Assessment (draft) (EPA-100-R-11-002) Source: U.S. Environmental Protection Agency Date of Publication: In process of finalization. Release expected 2012.	This methods manual describes the purpose, rationale, and basic steps for using landscape and predictive tools for Clean Water Act monitoring, assessment, and management purposes such as filling monitoring gaps and prioritizing protection and rehabilitation actions. This guidance stresses simultaneous use of matched (or paired) landscape and in situ data for empirical modeling to enhance predictive capabilities and encourage science-based targeting and priority setting. Example and potential applications include criteria and standards development, problem identification and prevention, prioritization and targeting of rehabilitation, and advancing science, education, and society's ability to effectively manage aquatic and terrestrial resources. This methods guidance is organized into four sections: (I) Introduction to Landscape and Predictive Tools; (II) Geographic Frameworks, Spatial Data, and Analysis Tools; (III) Examples and Case Studies; and (IV) Gaps and Needs for Research and Applications; plus an extensive Toolbox providing links to and short descriptions of a wide range of easily accessed data sets and analytical tools. Wider application of these tools and approaches should yield better protection for high-quality waters and quicker, more cost-effective restoration of impaired waters.
http://www.epa.gov/raf/pubecological.htm	
Stressor Response	
Causal Analysis/Diagnosis Decision Information System (CADDIS) Source: U.S. Environmental Protection Agency Date: Last updated September 23, 2010	The Causal Analysis/Diagnosis Decision Information System, or CADDIS, is a website developed to help scientists and engineers in the Regions, States, and Tribes conduct causal assessments in aquatic systems. It is organized into five volumes: • Volume 1: Stressor Identification • Volume 2: Sources, Stressors & Responses • Volume 3: Examples & Applications • Volume 4: Data Analysis • Volume 5: Causal Databases
http://www.epa.gov/caddis	

Using Stressor-response Relationships to Derive Numeric Nutrient Criteria (EPA-820-2-10-001) Source: U.S. Environmental Protection Agency Date of Publication: 2010	This document provides guidance on statistical methods for estimating stressor-response relationships between changes in nutrient concentrations and changes in biological response variables. The document also provides guidance on methods for interpreting these relationships to derive numeric nutrient criteria. Other specific topics discussed include selecting appropriate covariates to improve the accuracy of estimated relationships, and methods for accounting for uncertainty in estimated relationships when deriving criteria.
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/finalstressor2010.pdf	
Water quality-based toxics control	**Description/summary**
Technical Support Document for Water Quality-based Toxics Control (EPA-5052-90-001) Source: U.S. Environmental Protection Agency Date of Publication: 1991	This document provides technical guidance for assessing and regulating discharge of toxic substances to waters of the United States. It was issued in support of EPA regulations and policy initiatives involving the application of biological assessment and chemical techniques to control toxic pollution to surface waters.
http://www.epa.gov/npdes/pubs/owm0264.pdf	
Watershed Protection	**Description/summary**
Identifying and Protecting Healthy Watersheds: A Technical Guide (draft) Source: U.S. Environmental Protection Agency Date of Publication: In process of finalization. Release expected 2012.	This draft technical document provides an overview of the key concepts behind an approach to identify and protect healthy watersheds, examples of assessments of healthy watershed components, an integrated assessment framework for identifying healthy watersheds, examples of management approaches, sources of national data, and key assessment tools. It contains numerous examples and case studies from across the country. The intended audience for this document is aquatic resource scientists and managers at the state, tribal, regional, and local levels; non-governmental organizations; and federal agencies. It will also benefit local government land use managers and planners as they develop protection priorities.
http://water.epa.gov/polwaste/nps/watershed/index.cfm	



Front cover:

1. Sampling in Rich Fork Creek, Davidson County, NC; Credit: Tetra Tech, Inc.
2. Yellow Perch, *P. flavescens*; Credit: U.S. Department of Agriculture
3. Adult Mayfly, Order: Ephemeroptera; Credit: Extension Entomology, Texas A&M University
4. Appalachian elktoe; Credit: Dick Biggins**,** U.S. Fish and Wildlife Service
5. Sailing in Carlyle Lake, IL; Credit: U.S. Army Corps of Engineers
6. Micrograph of freshwater diatoms; Credit: Algal Ecology Laboratory, Bowling Green State University
7. Coral Reef, St. Croix, USVI; Credit: Wayne Davis, U.S. Environmental Protection Agency
8. North River, Mount Crawford, VA; Credit: Tetra Tech, Inc.
9. Black-necked Stilt (*Himantopus mexicanus*), Maui, HI;
   Credit: John J. Mosesso, National Biological Information Infrastructure

Back cover:

10. Caddisfly; Credit: Rick Levey, Vermont Department of Environmental Conservation
11. California, salmon resting in a pool before resuming migration;
    Credit: U.S. Department of Agriculture, National Resources Conservation Service
12. Green River, UT; Credit: Scott T. Eblen, Medical University of South Carolina

EPA 810-R-11-01

7050.0222 SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION.

Subpart 1. **General.**

A. The numeric and narrative water quality standards in this part prescribe the qualities or properties of the waters of the state that are necessary for the aquatic life and recreation designated public uses and benefits. If the standards in this part are exceeded in waters of the state that have the Class 2 designation, it is considered indicative of a polluted condition which is actually or potentially deleterious, harmful, detrimental, or injurious with respect to the designated uses.

B. Standards for metals are expressed as total metal in this part, but must be converted to dissolved metal standards for application to surface waters. Conversion factors for converting total to dissolved metal standards are listed in subpart 9. The conversion factor for metals not listed in subpart 9 is one. The dissolved metal standard equals the total metal standard times the conversion factor. Water quality-based effluent limits for metals are expressed as total metal.

C. The tables of standards in this part include the following abbreviations and acronyms:

*	an asterisk following the FAV and MS values or double dashes (–) means subpart 7, item E, applies
(c)	means the chemical is assumed to be a human carcinogen
°C	means degrees Celsius
CS	means chronic standard, defined in part 7050.0218, subpart 3
–	double dashes means there is no standard
°F	means degrees Fahrenheit
FAV	means final acute value, defined in part 7050.0218, subpart 3
HH	in the "basis" column means the standard is human health-based
MS	means maximum standard, defined in part 7050.0218, subpart 3
NA	means not applicable
su	means standard unit. It is the reporting unit for pH
TH	means total hardness in milligrams per liter, which is the sum of the calcium and magnesium concentrations expressed as $CaCO_3$
Tox	in the "basis" column means the standard is toxicity-based

D. Important synonyms or acronyms for some chemicals are listed in parentheses below the primary name.

Subp. 2. **Class 2A waters; aquatic life and recreation.** The quality of Class 2A surface waters shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water. Abbreviations, acronyms, and symbols are explained in subpart 1.

Substance, Characteristic, or Pollutant (Class 2A)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Acenaphthene	µg/L	20	HH	56	112	Tox
Acetochlor	µg/L	3.6	Tox	86	173	Tox
Acrylonitrile (c)	µg/L	0.38	HH	1,140*	2,281*	Tox
Alachlor (c)	µg/L	3.8	HH	800*	1,600*	Tox
Aluminum, total	µg/L	87	Tox	748	1,496	Tox
Ammonia un-ionized as N	µg/L	16	Tox	–	–	NA

The percent un-ionized ammonia can be calculated for any temperature and pH by using the following equation taken from Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston, Aqueous ammonia equilibrium calculations; effect of pH and temperature. Journal of the Fisheries Research Board of Canada 32: 2379-2383 (1975):

$$f = \frac{1}{10^{(pk_a - pH)} + 1} \times 100$$

where: f = the percent of total ammonia in the un-ionized state

pk_a = 0.09 + (2730/T) (dissociation constant for ammonia)

T = temperature in degrees Kelvin (273.16° Kelvin = 0° Celsius)

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Anthracene	µg/L	0.035	Tox	0.32	0.63	Tox
Antimony, total	µg/L	5.5	HH	90	180	Tox
Arsenic, total	µg/L	2.0	HH	360	720	Tox
Atrazine (c)	µg/L	3.4	HH	323	645	Tox
Benzene (c)	µg/L	5.1	HH	4,487*	8,974*	Tox
Bromoform	µg/L	33	HH	2,900	5,800	Tox
Cadmium, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.7852[ln(total hardness mg/L)]-3.490)

The MS in µg/L shall not exceed: exp.(1.128[ln(total hardness mg/L)]-3.828)

The FAV in µg/L shall not exceed: exp.(1.128[ln(total hardness mg/L)]-3.1349)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total cadmium standards for five hardness values:

TH in mg/L	50	100	200	300	400
Cadmium, total					
CS µg/L	0.66	1.1	2.0	2.7	3.4
MS µg/L	1.8	3.9	8.6	14	19
FAV µg/L	3.6	7.8	17	27	37

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Carbon tetrachloride (c)	µg/L	1.9	HH	1750*	3500*	Tox
Chlordane (c)	ng/L	0.073	HH	1200*	2400*	Tox
Chloride	mg/L	230	Tox	860	1720	Tox
Chlorine, total residual	µg/L	11	Tox	19	38	Tox

Chlorine standard applies to conditions of continuous exposure, where continuous exposure refers to chlorinated effluents that are discharged for more than a total of two hours in any 24-hour period.

Chlorobenzene (Monochlorobenzene)	µg/L	20	HH	423	846	Tox
Chloroform (c)	µg/L	53	HH	1,392	2,784	Tox
Chlorpyrifos	µg/L	0.041	Tox	0.083	0.17	Tox
Chromium +3, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+1.561)

The MS in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+3.688)

The FAV in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+4.380)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total chromium +3 standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Chromium +3, total					

CS µg/L	117	207	365	509	644
MS µg/L	984	1,737	3,064	4,270	5,405
FAV µg/L	1,966	3,469	6,120	8,530	10,797

Substance, Characteristic, or Pollutant (Class 2A)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Chromium +6, total	µg/L	11	Tox	16	32	Tox
Cobalt, total	µg/L	2.8	HH	436	872	Tox
Color value	Pt/Co	30	NA	–	–	NA
Copper, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.620[ln(total hardness mg/L)]-0.570)

The MS in µg/L shall not exceed: exp.(0.9422[ln(total hardness mg/L)]-1.464)

The FAV in µg/L shall not exceed: exp.(0.9422[ln(total hardness mg/L)]-0.7703)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total copper standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Copper, total					
CS µg/L	6.4	9.8	15	19	23
MS µg/L	9.2	18	34	50	65
FAV µg/L	18	35	68	100	131

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Cyanide, free	µg/L	5.2	Tox	22	45	Tox
DDT (c)	ng/L	0.11	HH	550*	1100*	Tox
1,2-Dichloroethane (c)	µg/L	3.5	HH	45,050*	90,100*	Tox
Dieldrin (c)	ng/L	0.0065	HH	1,300*	2,500*	Tox
Di-2-ethylhexyl phthalate (c)	µg/L	1.9	HH	–*	–*	NA
Di-n-octyl phthalate	µg/L	30	Tox	825	1,650	Tox
Endosulfan	µg/L	0.0076	HH	0.084	0.17	Tox
Endrin	µg/L	0.0039	HH	0.090	0.18	Tox
Escherichia (E.) coli	See below	See below	HH	See below	See below	NA

Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Ethylbenzene	µg/L	68	Tox	1,859	3,717	Tox

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV

Eutrophication standards for Class 2A lakes and reservoirs.

Designated lake trout lakes in all ecoregions (lake trout lakes support natural populations of lake trout, *Salvelinus namaycush*):

Phosphorus, total	µg/L	12	NA	–	–	NA
Chlorophyll-a	µg/L	3	NA	–	–	NA
Secchi disk transparency	meters	No less than 4.8	NA	–	–	NA

Designated trout lakes in all ecoregions, except lake trout lakes:

Phosphorus, total	µg/L	20	NA	–	–	NA
Chlorophyll-a	µg/L	6	NA	–	–	NA
Secchi disk transparency	meters	No less than 2.5	NA	–	–	NA

Additional narrative eutrophication standards for Class 2A lakes and reservoirs are found under subpart 2a.

Eutrophication standards for Class 2A rivers and streams.

North River Nutrient Region:

Phosphorus, total	µg/L	less than or equal to 50
Chlorophyll-a (seston)	µg/L	less than or equal to 7
Diel dissolved oxygen flux	mg/L	less than or equal to 3.0
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 1.5

Central River Nutrient Region:

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 18
Diel dissolved oxygen flux	mg/L	less than or equal to 3.5
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 2.0

South River Nutrient Region:

Phosphorus, total	µg/L	less than or equal to 150
Chlorophyll-a (seston)	µg/L	less than or equal to 35
Diel dissolved oxygen flux	mg/L	less than or equal to 4.5
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 3.0

Additional narrative eutrophication standards for Class 2A rivers and streams are found under subpart 2b.

Substance, Characteristic, or Pollutant (Class 2A)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Fluoranthene	µg/L	1.9	Tox	3.5	6.9	Tox
Heptachlor (c)	ng/L	0.10	HH	260*	520*	Tox
Heptachlor epoxide (c)	ng/L	0.12	HH	270*	530*	Tox
Hexachlorobenzene (c)	ng/L	0.061	HH	–*	–*	Tox
Lead, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-4.705)

The MS in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-1.460)

The FAV in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-0.7643)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total lead standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Lead, total					
CS µg/L	1.3	3.2	7.7	13	19
MS µg/L	34	82	197	331	477
FAV µg/L	68	164	396	663	956

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Lindane (c) (Hexachlorocyclohexane, gamma-)	µg/L	0.0087	HH	1.0*	2.0*	Tox
Mercury, total in water	ng/L	6.9	HH	2,400*	4,900*	Tox
Mercury, total in edible fish	mg/kg ppm	0.2	HH	NA	NA	NA
Methylene chloride (c) Dichloromethane)	µg/L	45	HH	13,875*	27,749*	Tox
Metolachlor	µg/L	23	Tox	271	543	Tox
Naphthalene	µg/L	65	HH	409	818	Tox
Nickel, total	µg/L	equation	Tox/HH	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS shall not exceed the human health-based standard of 297 µg/L. For waters with total hardness values less than 212 mg/L, the CS in µg/L is toxicity-based and shall not exceed: exp.(0.846[ln(total hardness mg/L)]+1.1645)

The MS in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/L)]+3.3612)

The FAV in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/L)]+4.0543)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total nickel standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Nickel, total					
CS µg/L	88	158	283	297	297

MS µg/L	789	1,418	2,549	3,592	4,582
FAV µg/L	1,578	2,836	5,098	7,185	9,164

Substance, Characteristic, or Pollutant (Class 2A)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Oil	µg/L	500	NA	5,000	10,000	NA
Oxygen, dissolved	mg/L	See below	NA	–	–	NA

7.0 mg/L as a daily minimum. This dissolved oxygen standard requires compliance with the standard 50 percent of the days at which the flow of the receiving water is equal to the $7Q_{10}$.

Parathion	µg/L	0.013	Tox	0.07	0.13	Tox
Pentachlorophenol	µg/L	0.93	HH	equation	equation	Tox

The MS and FAV vary with pH and are calculated using the following equations:

The MS in µg/L shall not exceed: exp.(1.005[pH]-4.830)

The FAV in µg/L shall not exceed: exp.(1.005[pH]-4.1373)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For pH values less than 6.0, 6.0 shall be used to calculate the standard and for pH values greater than 9.0, 9.0 shall be used to calculate the standard.

Example of pentachlorophenol standards for five pH values:

pH su	6.5	7.0	7.5	8.0	8.5
Pentachlorophenol					
CS µg/L	0.93	0.93	0.93	0.93	0.93
MS µg/L	5.5	9.1	15	25	41
FAV µg/L	11	18	30	50	82

Substance, Characteristic, or Pollutant (Class 2A)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
pH, minimum	su	6.5	NA	–	–	NA
pH, maximum	su	8.5	NA	–	–	NA
Phenanthrene	µg/L	3.6	Tox	32	64	Tox
Phenol	µg/L	123	Tox	2,214	4,428	Tox
Polychlorinated biphenyls, total (c)	ng/L	0.014	HH	1,000*	2,000*	Tox
Radioactive materials	NA	See below	NA	See below	See below	NA

Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as permitted by the appropriate authority having control over their use.

Selenium, total	µg/L	5.0	Tox	20	40	Tox
Silver, total	µg/L	0.12	Tox	equation	equation	Tox

The MS and FAV vary with total hardness and are calculated using the following equations:

The MS in µg/L shall not exceed: exp.(1.720[ln(total hardness mg/L)]-7.2156)

The FAV in µg/L shall not exceed: exp.(1.720[ln(total hardness mg/L)]-6.520)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of silver standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Silver, total					
CS µg/L	0.12	0.12	0.12	0.12	0.12

MS µg/L	1.0	2.0	6.7	13	22
FAV µg/L	1.2	4.1	13	27	44

Substance, Characteristic, or Pollutant (Class 2A)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Temperature	°C or °F	No material increase	NA	–	–	NA
1,1,2,2-Tetrachloroethane (c)	µg/L	1.1	HH	1,127*	2,253*	Tox
Tetrachloroethylene (c)	µg/L	3.8	HH	428*	857*	Tox
Thallium, total	µg/L	0.28	HH	64	128	Tox
Toluene	µg/L	253	Tox	1,352	2,703	Tox
Toxaphene (c)	ng/L	0.31	HH	730*	1,500*	Tox
1,1,1-Trichloroethane	µg/L	329	Tox	2,957	5,913	Tox
1,1,2-Trichloroethylene (c)	µg/L	25	HH	6,988*	13,976*	Tox
2,4,6-Trichlorophenol	µg/L	2.0	HH	102	203	Tox
Total suspended solids (TSS)	mg/L	10	NA	–	–	NA
TSS standards for Class 2A may be exceeded for no more than ten percent of the time. This standard applies April 1 through September 30						
Vinyl chloride (c)	µg/L	0.17	HH	–*	–*	NA
Xylene, total m,p,o	µg/L	166	Tox	1,407	2,814	Tox
Zinc, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+0.7615)

The MS in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+0.8604)

The FAV in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+1.5536

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of zinc standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Zinc, total					
CS µg/L	59	106	191	269	343
MS µg/L	65	117	211	297	379
FAV µg/L	130	234	421	594	758

Subp. 2a. **Narrative eutrophication standards for lakes and reservoirs.**

A. Eutrophication standards for lakes and reservoirs are compared to summer-average data. Exceedance of the total phosphorus and either the chlorophyll-a or Secchi disk transparency standard is required to indicate a polluted condition.

B. It is the policy of the agency to protect all lakes and reservoirs from the undesirable effects of cultural eutrophication. Lakes and reservoirs with a baseline quality better than the numeric eutrophication standards in subpart 2 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, and the protection of lake or reservoir resources, including, but not limited to:

(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;

(2) the phosphorus effluent limits for point sources, where applicable in chapter 7053;

(3) the requirements for feedlots in chapter 7020;

(4) the requirements for individual sewage treatment systems in chapter 7080;

(5) the requirements for control of storm water in chapter 7090;

(6) county shoreland ordinances; and

(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients.

C. Lakes and reservoirs with a baseline quality that is poorer than the numeric eutrophication standards in subpart 2 must be considered to be in compliance with the standards if the baseline quality is the result of natural causes. The commissioner shall determine baseline quality and compliance with these standards using data and the procedures in part 7050.0150, subpart 5.

D. When applied to reservoirs, the eutrophication standards in this subpart and subpart 2 may be modified on a site-specific basis to account for characteristics unique to reservoirs that can affect trophic status, such as water temperature, variations in hydraulic residence time, watershed size, and the fact that reservoirs may receive drainage from more than one ecoregion. Information supporting a site-specific standard can be provided by the commissioner or by any person outside the agency. The commissioner shall evaluate all data in support of a modified standard and determine whether a change in the standard for a specific reservoir is justified. Any total phosphorus effluent limit determined to be necessary based on a modified standard shall only be required after the discharger has been given notice of the specific proposed effluent limits and an opportunity to request a hearing as provided in part 7000.1800.

E. Eutrophication standards applicable to lakes and reservoirs that lie on the border between two ecoregions or that are in the Red River Valley (also referred to as Lake Agassiz Plains), Northern Minnesota Wetlands, or Driftless Area Ecoregion must be applied on a case-by-case basis. The commissioner shall use the standards applicable to adjacent ecoregions as a guide.

Subp. 2b. **Narrative eutrophication standards for rivers and streams.**

A. Eutrophication standards for rivers and streams are compared to summer-average data or as specified in subpart 2. Exceedance of the total phosphorus levels and chlorophyll-a (seston), five-day biochemical oxygen demand (BOD_5), diel dissolved oxygen flux, or pH levels is required to indicate a polluted condition.

B. Rivers and streams that exceed the phosphorus levels but do not exceed the chlorophyll-a (seston), five-day biochemical oxygen demand (BOD_5), diel dissolved oxygen flux, or pH levels meet the eutrophication standard.

C. For chlorophyll-a (periphyton), the standard is exceeded if concentrations exceed 150 mg/m^2 more than one year in ten.

D. It is the policy of the agency to protect all rivers and streams from the undesirable effects of cultural eutrophication. Rivers and streams with a baseline quality better than the numeric eutrophication standards in subpart 3 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, including:

(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;

(2) the phosphorus effluent limits for point sources, where applicable, in chapter 7053;

(3) the requirements for feedlots in chapter 7020;

(4) the requirements for individual sewage treatment systems in chapter 7080;

(5) the requirements for control of storm water in chapter 7090;

(6) county shoreland ordinances; and

(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients.

E. Rivers and streams with a baseline quality that does not meet the numeric eutrophication standards in part 7050.0150, subpart 5b, are in compliance with the standards if the baseline quality is the result of natural causes. The commissioner must determine baseline quality and compliance with these standards using data and the procedures in part 7050.0150, subpart 5.

Subp. 3. **Class 2Bd waters.** The quality of Class 2Bd surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water. The applicable standards are given below. Abbreviations, acronyms, and symbols are explained in subpart 1.

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Acenaphthene	µg/L	20	HH	56	112	Tox
Acetochlor	µg/L	3.6	Tox	86	173	Tox
Acrylonitrile (c)	µg/L	0.38	HH	1,140*	2,281*	Tox
Alachlor (c)	µg/L	4.2	HH	800*	1,600*	Tox
Aluminum, total	µg/L	125	Tox	1,072	2,145	Tox
Ammonia un-ionized as N	µg/L	40	Tox	–	–	NA

The percent un-ionized ammonia can be calculated for any temperature and pH by using the following equation taken from Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston, Aqueous ammonia equilibrium calculations; effect of pH and temperature. Journal of the Fisheries Research Board of Canada 32: 2379-2383 (1975):

$$f = 1/(10^{(pka-pH)} + 1) \times 100$$

where: f = the percent of total ammonia in the un-ionized state

pk_a = 0.09 + (2730/T) (dissociation constant for ammonia)

T = temperature in degrees Kelvin (273.16° Kelvin = 0° Celsius)

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Anthracene	µg/L	0.035	Tox	0.32	0.63	Tox
Antimony, total	µg/L	5.5	HH	90	180	Tox
Arsenic, total	µg/L	2.0	HH	360	720	Tox
Atrazine (c)	µg/L	3.4	HH	323	645	Tox
Benzene (c)	µg/L	6.0	HH	4,487*	8,974*	Tox
Bromoform	µg/L	41	HH	2,900	5,800	Tox
Cadmium, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.7852[ln(total hardness mg/L)]-3.490)

The MS in µg/L shall not exceed: exp.(1.128[ln(total hardness mg/L)]-1.685)

The FAV in µg/L shall not exceed: exp.(1.128[ln(total hardness mg/L)]-0.9919)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total cadmium standards for five hardness values:

TH in mg/L	50	100	200	300	400
Cadmium, total					
CS µg/L	0.66	1.1	2.0	2.7	3.4

MS µg/L	15	33	73	116	160
FAV µg/L	31	67	146	231	319

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Carbon tetrachloride (c)	µg/L	1.9	HH	1,750*	3,500*	Tox
Chlordane (c)	ng/L	0.29	HH	1,200*	2,400*	Tox
Chloride	mg/L	230	Tox	860	1,720	Tox
Chlorine, total residual	µg/L	11	Tox	19	38	Tox

Chlorine standard applies to conditions of continuous exposure, where continuous exposure refers to chlorinated effluents that are discharged for more than a total of two hours in any 24-hour period.

Chlorobenzene (Monochlorobenzene)	µg/L	20	HH	423	846	Tox
Chloroform (c)	µg/L	53	HH	1,392	2,784	Tox
Chlorpyrifos	µg/L	0.041	Tox	0.083	0.17	Tox
Chromium +3, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+1.561)

The MS in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+3.688)

The FAV in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+4.380)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total chromium +3 standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Chromium +3, total					
CS µg/L	117	207	365	509	644
MS µg/L	984	1,737	3,064	4,270	5,405
FAV µg/L	1,966	3,469	6,120	8,530	10,797

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Chromium +6, total	µg/L	11	Tox	16	32	Tox
Cobalt, total	µg/L	2.8	HH	436	872	Tox
Copper, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.620[ln(total hardness mg/L)]-0.570)

The MS in µg/L shall not exceed: exp.(0.9422[ln(total hardness mg/L)]-1.464)

The FAV in µg/L shall not exceed: exp.(0.9422[ln(total hardness mg/L)]-0.7703)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total copper standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Copper, total					
CS µg/L	6.4	9.8	15	19	23
MS µg/L	9.2	18	34	50	65
FAV µg/L	18	35	68	100	131

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Cyanide, free	µg/L	5.2	Tox	22	45	Tox
DDT (c)	ng/L	1.7	HH	550*	1,100*	Tox
1,2-Dichloroethane (c)	µg/L	3.8	HH	45,050*	90,100*	Tox
Dieldrin (c)	ng/L	0.026	HH	1,300*	2,500*	Tox
Di-2-ethylhexyl phthalate (c)	µg/L	1.9	HH	–*	–*	NA
Di-n-octyl phthalate	µg/L	30	Tox	825	1,650	Tox
Endosulfan	µg/L	0.029	HH	0.28	0.56	Tox
Endrin	µg/L	0.016	HH	0.090	0.18	Tox
Escherichia (E.) coli	See below	See below	HH	See below	See below	NA

Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

Substance, Characteristic, or Pollutant (Class 2Bd)	Units	CS	Basis for CS	MS	FAV	Basis for MS, FAV
Ethylbenzene	µg/L	68	Tox	1,859	3,717	Tox

Substance, Characteristic, or Pollutant (Class 2Bd) Units CS Basis for CS MS FAV Basis for MS, FAV

Eutrophication standards for Class 2Bd lakes, shallow lakes, and reservoirs.

Lakes, Shallow Lakes, and Reservoirs in Northern Lakes and Forest Ecoregion

Phosphorus, total	µg/L	30	NA	–	–	NA
Chlorophyll-a	µg/L	9	NA	–	–	NA
Secchi disk transparency	meters	Not less than 2.0	NA	–	–	NA

Lakes and Reservoirs in North Central Hardwood Forest Ecoregion

Phosphorus, total	µg/L	40	NA	–	–	NA
Chlorophyll-a	µg/L	14	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.4	NA	–	–	NA

Lakes and Reservoirs in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions

Phosphorus, total	µg/L	65	NA	–	–	NA
Chlorophyll-a	µg/L	22	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.9	NA	–	–	NA

Shallow Lakes in North Central Hardwood Forest Ecoregion

Phosphorus, total	µg/L	60	NA	–	–	NA
Chlorophyll-a	µg/L	20	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.0	NA	–	–	NA

Shallow Lakes in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions

Phosphorus, total	µg/L	90	NA	–	–	NA
Chlorophyll-a	µg/L	30	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.7	NA	–	–	NA

Additional narrative eutrophication standards for Class 2Bd lakes, shallow lakes, and reservoirs are found under subpart 3a.

Eutrophication standards for Class 2Bd rivers and streams.

North River Nutrient Region

Phosphorus, total	µg/L	less than or equal to 50

Chlorophyll-a (seston)	µg/L	less than or equal to 7
Diel dissolved oxygen flux	mg/L	less than or equal to 3.0
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 1.5

Central River Nutrient Region

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 18
Diel dissolved oxygen flux	mg/L	less than or equal to 3.5
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 2.0

South River Nutrient Region

Phosphorus, total	µg/L	less than or equal to 150
Chlorophyll-a (seston)	µg/L	less than or equal to 35
Diel dissolved oxygen flux	mg/L	less than or equal to 4.5
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 3.0

Additional narrative eutrophication standards for Class 2Bd rivers and streams are found under subpart 3b.

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Fluoranthene	µg/L	1.9	Tox	3.5	6.9	Tox
Heptachlor (c)	ng/L	0.39	HH	260*	520*	Tox
Heptachlor epoxide (c)	ng/L	0.48	HH	270*	530*	Tox
Hexachlorobenzene (c)	ng/L	0.24	HH	–*	–*	Tox
Lead, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-4.705)

The MS in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-1.460)

The FAV in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-0.7643)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total lead standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Lead, total					
CS µg/L	1.3	3.2	7.7	13	19
MS µg/L	34	82	197	331	477
FAV µg/L	68	164	396	663	956

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Lindane (c) (Hexachlorocyclohexane, gamma-)	µg/L	0.032	HH	4.4*	8.8*	Tox
Mercury, total in water	ng/L	6.9	HH	2,400*	4,900*	Tox
Mercury, total in edible fish tissue	mg/kg ppm	0.2	HH	NA	NA	NA
Methylene chloride (c) (Dichloromethane)	µg/L	46	HH	13,875*	27,749*	Tox
Metolachlor	µg/L	23	Tox	271	543	Tox
Naphthalene	µg/L	81	Tox	409	818	Tox
Nickel, total	µg/L	equation	Tox/HH	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS shall not exceed the human health-based standard of 297 µg/L. For waters with total hardness values less than 212 mg/L, the CS in µg/L is toxicity-based and shall not exceed: exp.(0.846[ln(total hardness mg/L)]+1.1645)

The MS in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/L)]+3.3612)

The FAV in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/L)]+4.0543)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total nickel standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Nickel, total					
CS µg/L	88	158	283	297	297
MS µg/L	789	1,418	2,549	3,592	4,582
FAV µg/L	1,578	2,836	5,098	7,185	9,164

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Oil	µg/L	500	NA	5,000	10,000	NA
Oxygen, dissolved	mg/L	See below	NA	–	–	NA

5.0 mg/L as a daily minimum. This dissolved oxygen standard may be modified on a site-specific basis according to part 7050.0220, subpart 7, except that no site-specific standard shall be less than 5 mg/L as a daily average and 4 mg/L as a daily minimum. Compliance with this standard is required 50 percent of the days at which the flow of the receiving water is equal to the $7Q_{10}$.

Parathion	µg/L	0.013	Tox	0.07	0.13	Tox
Pentachlorophenol	µg/L	1.9	HH	equation	equation	Tox

The MS and FAV vary with pH and are calculated using the following equations:

The MS in µg/L shall not exceed: exp.(1.005[pH]-4.830)

The FAV in µg/L shall not exceed: exp.(1.005[pH]-4.1373)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For pH values less than 6.0, 6.0 shall be used to calculate the standard and for pH values greater than 9.0, 9.0 shall be used to calculate the standard.

Example of pentachlorophenol standards for five pH values:

pH su	6.5	7.0	7.5	8.0	8.5
Pentachlorophenol					
CS µg/L	1.9	1.9	1.9	1.9	1.9
MS µg/L	5.5	9.1	15	25	41
FAV µg/L	11	18	30	50	82

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
pH, minimum	su	6.5	NA	–	–	NA
pH, maximum	su	9.0	NA	–	–	NA
Phenanthrene	µg/L	3.6	Tox	32	64	Tox
Phenol	µg/L	123	Tox	2,214	4,428	Tox
Polychlorinated biphenyls, total (c)	ng/L	0.029	HH	1,000*	2,000*	Tox
Radioactive materials	NA	See below	NA	See below	See below	NA

Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as permitted by the appropriate authority having control over their use.

Selenium, total	µg/L	5.0	Tox	20	40	Tox
Silver, total	µg/L	1.0	Tox	equation	equation	Tox

The MS and FAV vary with total hardness and are calculated using the following equations:

The MS in µg/L shall not exceed: exp.(1.720[ln(total hardness mg/L)]-7.2156)

The FAV in µg/L shall not exceed: exp.(1.720[ln(total hardness mg/L)]-6.520)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total silver standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Silver, total					
CS µg/L	1.0	1.0	1.0	1.0	1.0
MS µg/L	1.0	2.0	6.7	13	22
FAV µg/L	1.2	4.1	13	27	44

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Temperature	°F	See below	NA	–	–	NA

5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperatures, except in no case shall it exceed the daily average temperature of 86°F.

1,1,2,2-Tetrachloroethane (c)	µg/L	1.5	HH	1,127*	2,253*	Tox
Tetrachloroethylene (c)	µg/L	3.8	HH	428*	857*	Tox
Thallium, total	µg/L	0.28	HH	64	128	Tox
Toluene	µg/L	253	Tox	1,352	2,703	Tox
Toxaphene (c)	ng/L	1.3	HH	730*	1,500*	Tox
1,1,1-Trichloroethane	µg/L	329	Tox	2,957	5,913	Tox
1,1,2-Trichloroethylene (c)	µg/L	25	HH	6,988*	13,976*	Tox
2,4,6-Trichlorophenol	µg/L	2.0	HH	102	203	Tox

Total suspended solids (TSS)						
North River Nutrient Region	mg/L	15	NA	-	-	NA
Central River Nutrient Region	mg/L	30	NA	-	-	NA
South River Nutrient Region	mg/L	65	NA	-	-	NA
Red River mainstem - headwaters to border	mg/L	100	NA	-	-	NA
TSS standards for the Class 2Bd North, Central, and South River Nutrient Regions and the Red River mainstem may be exceeded for no more than ten percent of the time. This standard applies April 1 through September 30						
Total suspended solids (TSS), summer average						
Lower Mississippi River mainstem - Pools 2 through 4	mg/L	32	NA	-	-	NA
Lower Mississippi River mainstem below Lake Pepin	mg/L	30	NA	-	-	NA
TSS standards for the Class 2Bd Lower Mississippi River may be exceeded for no more than 50 percent of the time. This standard applies June 1 through September 30						

Substance, Characteristic, or Pollutant (Class 2Bd)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Vinyl chloride (c)	µg/L	0.18	HH	–*	–*	NA
Xylene, total m,p,o	µg/L	166	Tox	1,407	2,814	Tox
Zinc, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+0.7615)

The MS in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+0.8604)

The FAV in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+1.5536)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total zinc standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Zinc, total					
CS µg/L	59	106	191	269	343
MS µg/L	65	117	211	297	379
FAV µg/L	130	234	421	594	758

Subp. 3a. **Narrative eutrophication standards for Class 2Bd lakes, shallow lakes, and reservoirs.**

A. Eutrophication standards applicable to lakes, shallow lakes, and reservoirs that lie on the border between two ecoregions or that are in the Red River Valley (also referred to as Lake Agassiz Plains), Northern Minnesota Wetlands, or Driftless Area Ecoregion must be applied on a case-by-case basis. The commissioner shall use the standards applicable to adjacent ecoregions as a guide.

B. Eutrophication standards are compared to summer-average data. Exceedance of the total phosphorus and either the chlorophyll-a or Secchi disk transparency standard is required to indicate a polluted condition.

C. It is the policy of the agency to protect all lakes, shallow lakes, and reservoirs from the undesirable effects of cultural eutrophication. Lakes, shallow lakes, and reservoirs with a baseline quality better than the numeric eutrophication standards in subpart 3 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, and the protection of lake, shallow lake, and reservoir resources, including, but not limited to:

(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;

(2) the phosphorus effluent limits for point sources, where applicable in chapter 7053;

(3) the requirements for feedlots in chapter 7020;

(4) the requirements for individual sewage treatment systems in chapter 7080;

(5) the requirements for control of storm water in chapter 7090;

(6) county shoreland ordinances; and

(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients.

D. Lakes, shallow lakes, and reservoirs with a baseline quality that is poorer than the numeric eutrophication standards in subpart 3 must be considered to be in compliance with the standards if the baseline quality is the result of natural causes. The commissioner shall determine baseline quality and compliance with these standards using data and the procedures in part 7050.0150, subpart 5.

E. When applied to reservoirs, the eutrophication standards in this subpart and subpart 3 may be modified on a site-specific basis to account for characteristics of reservoirs that can affect trophic status, such as water temperature, variations in hydraulic residence time, watershed size, and the fact that reservoirs may receive drainage from more than one ecoregion. Information supporting a site-specific standard can be provided by the commissioner or by any person outside the agency. The commissioner shall evaluate all data in support of a modified standard and determine whether a change in the standard for a specific reservoir is justified. Any total phosphorus effluent limit determined to be necessary based on a modified standard shall only be required after the discharger has been given notice of the specific proposed effluent limits and an opportunity to request a hearing as provided in part 7000.1800.

Subp. 3b. **Narrative eutrophication standards for rivers, streams, and navigational pools.**

A. Eutrophication standards for rivers, streams, and navigational pools are compared to summer-average data or as specified in subpart 3. Exceedance of the total phosphorus levels and chlorophyll-a (seston), five-day biochemical oxygen demand (BOD_5), diel dissolved oxygen flux, or pH levels is required to indicate a polluted condition.

B. Rivers, streams, and navigational pools that exceed the phosphorus levels but do not exceed the chlorophyll-a (seston), five-day biochemical oxygen demand (BOD_5), diel dissolved oxygen flux, or pH levels meet the eutrophication standard.

C. A polluted condition also exists when the chlorophyll-a (periphyton) concentration exceeds 150 mg/m^2 more than one year in ten.

D. It is the policy of the agency to protect all rivers, streams, and navigational pools from the undesirable effects of cultural eutrophication. Rivers, streams, and navigational pools with a baseline quality better than the numeric eutrophication standards in subpart 3 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources including:

(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;

(2) the phosphorus effluent limits for point sources, where applicable, in chapter 7053;

(3) the requirements for feedlots in chapter 7020;

(4) the requirements for individual sewage treatment systems in chapter 7080;

(5) the requirements for control of storm water in chapter 7090;

(6) county shoreland ordinances; and

(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients.

E. Rivers, streams, and navigational pools with a baseline quality that does not meet the numeric eutrophication standards in part 7050.0150, subpart 5b, are in compliance with the standards if the baseline quality is the result of natural causes. The commissioner must determine baseline quality and compliance with these standards using data and the procedures in part 7050.0150, subpart 5.

Subp. 4. **Class 2B waters.** The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface water is not protected as a source of drinking water. The applicable standards are given below. Abbreviations, acronyms, and symbols are explained in subpart 1.

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Acenaphthene	µg/l	20	HH	56	112	Tox
Acetochlor	µg/L	3.6	Tox	86	173	Tox
Acrylonitrile (c)	µg/l	0.89	HH	1,140*	2,281*	Tox
Alachlor (c)	µg/L	59	Tox	800	1,600	Tox
Aluminum, total	µg/L	125	Tox	1,072	2,145	Tox
Ammonia un-ionized as N	µg/L	40	Tox	–	–	NA

The percent un-ionized ammonia can be calculated for any temperature and pH by using the following equation taken from Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston, Aqueous ammonia equilibrium calculations; effect of pH and temperature. Journal of the Fisheries Research Board of Canada 32: 2379-2383 (1975):

$$f = 1/(10^{(pka-pH)} + 1) \times 100$$

where: f = the percent of total ammonia in the un-ionized state

$pk_a = 0.09 + (2730/T)$ (dissociation constant for ammonia)

T = temperature in degrees Kelvin (273.16° Kelvin = 0° Celsius)

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Anthracene	µg/L	0.035	Tox	0.32	0.63	Tox
Antimony, total	µg/L	31	Tox	90	180	Tox

Arsenic, total	µg/L	53	HH	360	720	Tox
Atrazine (c)	µg/L	10	Tox	323	645	Tox
Benzene (c)	µg/L	98	HH	4,487	8,974	Tox
Bromoform	µg/L	466	HH	2,900	5,800	Tox
Cadmium, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.7852[ln(total hardness mg/L)]-3.490)

The MS in µg/L shall not exceed: exp.(1.128[ln(total hardness mg/L)]-1.685)

The FAV in µg/L shall not exceed: exp.(1.128[ln(total hardness mg/L)]-0.9919)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total cadmium standards for five hardness values:

TH in mg/L	50	100	200	300	400
Cadmium, total					
CS µg/L	0.66	1.1	2.0	2.7	3.4
MS µg/L	15	33	73	116	160
FAV µg/L	31	67	146	231	319

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Carbon tetrachloride (c)	µg/L	5.9	HH	1,750*	3,500*	Tox
Chlordane (c)	ng/L	0.29	HH	1,200*	2,400*	Tox
Chloride	mg/L	230	Tox	860	1,720	Tox
Chlorine, total residual	µg/L	11	Tox	19	38	Tox

Chlorine standard applies to conditions of continuous exposure, where continuous exposure refers to chlorinated effluents that are discharged for more than a total of two hours in any 24-hour period.

Chlorobenzene (Monochlorobenzene)	µg/L	20	HH	423	846	Tox
Chloroform (c)	µg/L	155	Tox	1,392	2,784	Tox
Chlorpyrifos	µg/L	0.041	Tox	0.083	0.17	Tox
Chromium +3, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations

The CS in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+1.561)

The MS in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+3.688)

The FAV in µg/L shall not exceed: exp.(0.819[ln(total hardness mg/L)]+4.380)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total chromium +3 standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Chromium +3, total					
CS µg/L	117	207	365	509	644
MS µg/L	984	1,737	3,064	4,270	5,405
FAV µg/L	1,966	3,469	6,120	8,530	10,797

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**

Chromium +6, total	µg/L	11	Tox	16	32	Tox
Cobalt, total	µg/L	5.0	Tox	436	872	Tox
Copper, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.6200[ln(total hardness mg/L)]-0.570)

The MS in µg/L shall not exceed: exp.(0.9422[ln(total hardness mg/L)]-1.464)

The FAV in µg/L shall not exceed: exp.(0.9422[ln(total hardness mg/L)]-0.7703)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total copper standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Copper, total					
CS µg/L	6.4	9.8	15	19	23
MS µg/L	9.2	18	34	50	65
FAV µg/L	18	35	68	100	131

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Cyanide, free	µg/L	5.2	Tox	22	45	Tox
DDT (c)	ng/L	1.7	HH	550*	1,100*	Tox
1,2-Dichloroethane (c)	µg/L	190	HH	45,050*	90,100*	Tox
Dieldrin (c)	ng/L	0.026	HH	1,300*	2,500*	Tox
Di-2-ethylhexyl phthalate (c)	µg/L	2.1	HH	–*	–*	NA

Di-n-octyl phthalate	µg/L	30	Tox	825	1,650	Tox
Endosulfan	µg/L	0.031	HH	0.28	0.56	Tox
Endrin	µg/L	0.016	HH	0.090	0.18	Tox
Escherichia (E.) coli	See below	See below	HH	See below	See below	NA

Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

Ethylbenzene	µg/L	68	Tox	1,859	3,717	Tox

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**

Eutrophication standards for Class 2B lakes, shallow lakes, and reservoirs.

Lakes, Shallow Lakes, and Reservoirs in Northern Lakes and Forest Ecoregions

Phosphorus, total	µg/L	30	NA	–	–	NA
Chlorophyll-a	µg/L	9	NA	–	–	NA
Secchi disk transparency	meters	Not less than 2.0	NA	–	–	NA

Lakes and Reservoirs in North Central Hardwood Forest Ecoregion

Phosphorus, total	µg/L	40	NA	–	–	NA
Chlorophyll-a	µg/L	14	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.4	NA	–	–	NA

Lakes and Reservoirs in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions

Phosphorus, total	µg/L	65	NA	–	–	NA
Chlorophyll-a	µg/L	22	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.9	NA	–	–	NA

Shallow Lakes in North Central Hardwood Forest Ecoregion

Phosphorus, total	µg/L	60	NA	–	–	NA
Chlorophyll-a	µg/L	20	NA	–	–	NA
Secchi disk transparency	meters	Not less than 1.0	NA	–	–	NA

Shallow Lakes in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions

Phosphorus, total	µg/L	90	NA	–	–	NA
Chlorophyll-a	µg/L	30	NA	–	–	NA
Secchi disk transparency	meters	Not less than 0.7	NA	–	–	NA

Additional narrative eutrophication standards for Class 2B lakes, shallow lakes, and reservoirs are found in subpart 4a.

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**

Eutrophication standards for Class 2B rivers and streams.

North River Nutrient Region

Phosphorus, total	µg/L	less than or equal to 50
Chlorophyll-a (seston)	µg/L	less than or equal to 7
Diel dissolved oxygen flux	mg/L	less than or equal to 3.0
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 1.5

Central River Nutrient Region

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 18
Diel dissolved oxygen flux	mg/L	less than or equal to 3.5
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 2.0

South River Nutrient Region

Phosphorus, total	µg/L	less than or equal to 150
Chlorophyll-a (seston)	µg/L	less than or equal to 40
Diel dissolved oxygen flux	mg/L	less than or equal to 5.0
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 3.5

Site-specific standards for specified river reaches or other waters are:

Mississippi River Navigational Pool 1 (river miles 854.1 to 847.7 reach from Fridley to Ford Dam in St. Paul)

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 35

Mississippi River Navigational Pool 2 (river miles 847.7 to 815.2 reach from Ford Dam to Hastings Dam)

Phosphorus, total	µg/L	less than or equal to 125
Chlorophyll-a (seston)	µg/L	less than or equal to 35

Mississippi River Navigational Pool 3 (river miles 815.2 to 796.9 reach from Hastings Dam to Red Wing Dam)

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 35

Mississippi River Navigational Pool 4 (river miles 796.9 to 752.8 reach from Red Wing Dam to Alma Dam). Lake Pepin occupies majority of Pool 4 and Lake Pepin site-specific standards are used for this pool.

Mississippi River Navigational Pools 5 to 8 (river miles 752.8 to 679.1 Alma Dam to Genoa Dam)

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 35

Lake Pepin

Phosphorus, total	µg/L	less than or equal to 100
Chlorophyll-a (seston)	µg/L	less than or equal to 28

Crow Wing River from confluence of Long Prairie River to the mouth of the Crow Wing River at the Mississippi River

Phosphorus, total	µg/L	less than or equal to 75
Chlorophyll-a (seston)	µg/L	less than or equal to 13
Diel dissolved oxygen flux	mg/L	less than or equal to 3.5
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 1.7

Crow River from the confluence of the North Fork of the Crow River and South Fork of the Crow River to the mouth of the Crow River at the Mississippi River

Phosphorus, total	µg/L	less than or equal to 125
Chlorophyll-a (seston)	µg/L	less than or equal to 27
Diel dissolved oxygen flux	mg/L	less than or equal to 4.0
Biochemical oxygen demand (BOD_5)	mg/L	less than or equal to 2.5

Additional narrative eutrophication standards for Class 2B rivers and streams are found in subpart 4b.

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Fluoranthene	µg/L	1.9	Tox	3.5	6.9	Tox
Heptachlor (c)	ng/L	0.39	HH	260*	520*	Tox
Heptachlor epoxide (c)	ng/L	0.48	HH	270*	530*	Tox

Hexachlorobenzene (c)	ng/L	0.24	HH	–*	–*	Tox
Lead, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-4.705)

The MS in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-1.460)

The FAV in µg/L shall not exceed: exp.(1.273[ln(total hardness mg/L)]-0.7643)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total lead standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Lead, total					
CS µg/L	1.3	3.2	7.7	13	19
MS µg/L	34	82	197	331	477
FAV µg/L	68	164	396	663	956

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Lindane (c) (Hexachlorocyclobenzene, gamma-)	µg/L	0.036	HH	4.4*	8.8*	Tox
Mercury, total in water	ng/L	6.9	HH	2,400*	4,900*	Tox
Mercury, total in edible fish tissue	mg/kg ppm	0.2	HH	NA	NA	NA
Methylene chloride (c) (Dichloromethane)	µg/L	1,940	HH	13,875	27,749	Tox
Metolachlor	µg/L	23	Tox	271	543	Tox

Naphthalene	µg/L	81	Tox	409	818	Tox
Nickel, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/L)]+1.1645)

The MS in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/L)]+3.3612)

The FAV in µg/L shall not exceed: exp.(0.846[ln(total hardness mg/l)]+4.0543)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total nickel standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Nickel, total					
CS µg/L	88	158	283	399	509
MS µg/L	789	1,418	2,549	3,592	4,582
FAV µg/L	1,578	2,836	5,098	7,185	9,164

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Oil	µg/l	500	NA	5,000	10,000	NA
Oxygen, dissolved	mg/L	See below	NA	–	–	NA

5.0 mg/L as a daily minimum. This dissolved oxygen standard may be modified on a site-specific basis according to part 7050.0220, subpart 7, except that no site-specific standard shall be less than 5 mg/L as a daily average and 4 mg/L as a daily minimum. Compliance with this standard is required 50 percent of the days at which the flow of the receiving water is equal to the $7Q_{10}$. This standard applies to all Class 2B waters except for those portions of the Mississippi River from the outlet of the Metro Wastewater

Treatment Works in Saint Paul (River Mile 835) to Lock and Dam No. 2 at Hastings (River Mile 815). For this reach of the Mississippi River, the standard is not less than 5 mg/L as a daily average from April 1 through November 30, and not less than 4 mg/L at other times.

Parathion	µg/L	0.013	Tox	0.07	0.13	Tox
Pentachlorophenol	µg/L	equation	Tox/HH	equation	equation	Tox

The CS, MS, and FAV vary with pH and are calculated using the following equations:

For waters with pH values greater than 6.95, the CS shall not exceed the human health-based standard of 5.5 µg/L.

For waters with pH values less than 6.96, the CS in µg/L shall not exceed the toxicity-based standard of exp.(1.005[pH]-5.290)

The MS in µg/L shall not exceed: exp.(1.005[pH]-4.830)

The FAV in µg/L shall not exceed: exp.(1.005[pH]-4.1373)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For pH values less than 6.0, 6.0 shall be used to calculate the standard and for pH values greater than 9.0, 9.0 shall be used to calculate the standard.

Example of pentachlorophenol standards for five pH values:

pH su	6.5	7.0	7.5	8.0	8.5
Pentachlorophenol					
CS µg/L	3.5	5.5	5.5	5.5	5.5
MS µg/L	5.5	9.1	15	25	41
FAV µg/L	11	18	30	50	82

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
pH, minimum	su	6.5	NA	–	–	NA
pH, maximum	su	9.0	NA	–	–	NA
Phenanthrene	µg/L	3.6	Tox	32	64	Tox

Phenol	µg/L	123	Tox	2,214	4,428	Tox
Polychlorinated biphenyls, total (c)	ng/L	0.029	HH	1,000*	2,000*	Tox
Radioactive materials	NA	See below	NA	See below	See below	NA

Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as permitted by the appropriate authority having control over their use.

Selenium, total	µg/L	5.0	Tox	20	40	Tox
Silver, total	µg/L	1.0	Tox	equation	equation	Tox

The MS and FAV vary with total hardness and are calculated using the following equations:

The MS in µg/L shall not exceed: exp.(1.720[ln(total hardness mg/L)]-7.2156)

The FAV in µg/L shall not exceed: exp.(1.720[ln(total hardness mg/L)]-6.520

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total silver standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Silver, total					
CS µg/L	1.0	1.0	1.0	1.0	1.0
MS µg/L	1.0	2.0	6.7	13	22
FAV µg/L	1.2	4.1	13	27	44

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Temperature	°F	See below	NA	–	–	NA

5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperatures, except in no case shall it exceed the daily average temperature of 86°F.

1,1,2,2-Tetrachloroethane (c)	µg/L	13	HH	1,127	2,253	Tox
Tetrachloroethylene (c)	µg/L	8.9	HH	428	857	Tox
Thallium, total	µg/L	0.56	HH	64	128	Tox
Toluene	µg/L	253	Tox	1,352	2,703	Tox
Toxaphene (c)	ng/L	1.3	HH	730*	1,500*	Tox
1,1,1-Trichloroethane	µg/L	329	Tox	2,957	5,913	Tox
1,1,2-Trichloroethylene (c)	µg/L	120	HH	6,988	13,976	Tox
2,4,6-Trichlorophenol	µg/L	2.0	HH	102	203	Tox
Total suspended solids (TSS)						
North River Nutrient Region	mg/L	15	NA	–	–	NA
Central River Nutrient Region	mg/L	30	NA	–	–	NA
South River Nutrient Region	mg/L	65	NA	–	–	NA
Red River mainstem - headwaters to border	mg/L	100	NA	–	–	NA
TSS standards for the Class 2B North, Central, and South River Nutrient Regions and the Red River mainstem may be exceeded for no more than ten percent of the time. This standard applies April 1 through September 30						
Total suspended solids (TSS), summer average						
Lower Mississippi River mainstem - Pools 2 through 4	mg/L	32	NA	–	–	NA

Lower Mississippi River mainstem below Lake Pepin	mg/L	30	NA	–	–	NA
TSS standards for the Class 2B Lower Mississippi River may be exceeded for no more than 50 percent of the time. This standard applies June 1 through September 30						

Substance, Characteristic, or Pollutant (Class 2B)	**Units**	**CS**	**Basis for CS**	**MS**	**FAV**	**Basis for MS, FAV**
Vinyl chloride (c)	µg/L	9.2	HH	–*	–*	NA
Xylene, total m,p,o	µg/L	166	Tox	1,407	2,814	Tox
Zinc, total	µg/L	equation	Tox	equation	equation	Tox

The CS, MS, and FAV vary with total hardness and are calculated using the following equations:

The CS in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+0.7615)

The MS in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+0.8604)

The FAV in µg/L shall not exceed: exp.(0.8473[ln(total hardness mg/L)]+1.5536)

Where: exp. is the natural antilogarithm (base e) of the expression in parenthesis.

For hardness values greater than 400 mg/L, 400 mg/L shall be used to calculate the standard.

Example of total zinc standards for five total hardness values:

TH in mg/L	50	100	200	300	400
Zinc, total					
CS µg/L	59	106	191	269	343
MS µg/L	65	117	211	297	379
FAV µg/L	130	234	421	594	758

Subp. 4a. **Narrative eutrophication standards for Class 2B lakes, shallow lakes, and reservoirs.**

A. Eutrophication standards applicable to lakes, shallow lakes, and reservoirs that lie on the border between two ecoregions or that are in the Red River Valley (also referred to as Lake Agassiz Plains), Northern Minnesota Wetlands, or Driftless Area Ecoregion must be applied on a case-by-case basis. The commissioner shall use the standards applicable to adjacent ecoregions as a guide.

B. Eutrophication standards are compared to summer-average data. Exceedance of the total phosphorus and either the chlorophyll-a or Secchi disk transparency standard is required to indicate a polluted condition.

C. It is the policy of the agency to protect all lakes, shallow lakes, and reservoirs from the undesirable effects of cultural eutrophication. Lakes, shallow lakes, and reservoirs with a baseline quality better than the numeric eutrophication standards in subpart 4 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, and the protection of lake, shallow lake, and reservoir resources, including, but not limited to:

(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;

(2) the phosphorus effluent limits for point sources, where applicable in chapter 7053;

(3) the requirements for feedlots in chapter 7020;

(4) the requirements for individual sewage treatment systems in chapter 7080;

(5) the requirements for control of storm water in chapter 7090;

(6) county shoreland ordinances; and

(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients.

D. Lakes, shallow lakes, and reservoirs with a baseline quality that is poorer than the numeric eutrophication standards in subpart 4 must be considered to be in compliance with the standards if the baseline quality is the result of natural causes. The commissioner shall determine baseline quality and compliance with these standards using data and the procedures in part 7050.0150, subpart 5.

E. When applied to reservoirs, the eutrophication standards in this subpart and subpart 4 may be modified on a site-specific basis to account for characteristics of reservoirs that can affect trophic status, such as water temperature, variations in hydraulic residence time, watershed size, and the fact that reservoirs may receive drainage from more than one ecoregion. Information supporting a site-specific standard can be provided by the commissioner or by any person outside the agency. The commissioner shall evaluate all data in support of a modified standard and determine whether a change in the standard for a specific reservoir is justified. Any total phosphorus effluent limit determined to be necessary based on a modified standard shall only be required after the discharger has been given notice of the specific proposed effluent limits and an opportunity to request a hearing as provided in part 7000.1800.

Subp. 4b. **Narrative eutrophication standards for Class 2B rivers and streams.**

A. Eutrophication standards for rivers and streams are compared to summer-average data or as specified in subpart 4. Exceedance of the total phosphorus levels and chlorophyll-a (seston), five-day biochemical oxygen demand (BOD_5), diel dissolved oxygen flux, or pH levels is required to indicate a polluted condition.

B. Rivers and streams that exceed the phosphorus levels but do not exceed the chlorophyll-a (seston), five-day biochemical oxygen demand (BOD_5), diel dissolved oxygen flux, or pH levels meet the eutrophication standard.

C. A polluted condition also exists when the chlorophyll-a (periphyton) concentration exceeds 150 mg/m^2 more than one year in ten

D. It is the policy of the agency to protect all rivers, streams, and navigational pools from the undesirable effects of cultural eutrophication. Rivers, streams, and navigational pools with a baseline quality better than the numeric eutrophication standards in subpart 4 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, including:

(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;

(2) the phosphorus effluent limits for point sources, where applicable in chapter 7053;

(3) the requirements for feedlots in chapter 7020;

(4) the requirements for individual sewage treatment systems in chapter 7080;

(5) the requirements for control of storm water in chapter 7090;

(6) county shoreland ordinances; and

(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients.

E. Rivers, streams, and navigational pools with a baseline quality that does not meet the numeric eutrophication standards in subpart 4 are in compliance with the standards if the baseline quality is the result of natural causes. The commissioner must determine baseline quality and compliance with these standards using data and the procedures in part 7050.0150, subpart 5.

Subp. 5. **Class 2C waters.** The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life, and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable. The standards for Class 2B waters listed in subparts 4 and 4a shall apply to these waters except as listed below:

Substance, Characteristic, or Pollutant

Escherichia (E.) coli. Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

Oxygen, dissolved. 5 mg/L as a daily minimum. This dissolved oxygen standard may be modified on a site-specific basis according to part 7050.0220, subpart 7, except that no site-specific standard shall be less than 5 mg/L as a daily average and 4 mg/L as a daily minimum. Compliance with this standard is required 50 percent of the days at which the flow of the receiving water is equal to the $7Q_{10}$.

This dissolved oxygen standard applies to all Class 2C waters except for those portions of the Mississippi River from the outlet of the metro wastewater treatment works in Saint Paul (River Mile 835) to Lock and Dam No. 2 at Hastings (River Mile 815) and except for the reach of the Minnesota River from the outlet of the Blue Lake wastewater treatment works (River Mile 21) to the mouth at Fort Snelling. For this reach of the Mississippi River the standard is not less than 5 mg/L as a daily average from April 1 through November 30, and not less than 4 mg/L at other times. For the specified reach of the Minnesota River the standard shall be not less than 5 mg/L as a daily average year-round.

Temperature. 5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature, except in no case shall it exceed the daily average temperature of 90°F.

Subp. 6. **Class 2D waters; wetlands.**

A. The quality of Class 2D wetlands shall be such as to permit the propagation and maintenance of a healthy community of aquatic and terrestrial species indigenous to wetlands, and their habitats. Wetlands also add to the biological diversity of the landscape.

These waters shall be suitable for boating and other forms of aquatic recreation for which the wetland may be usable. The standards for Class 2B waters listed under subpart 4 shall apply to these waters except as listed below:

Substance, Characteristic, or Pollutant	Class 2D Standard
Oxygen, dissolved	If background is less than 5.0 mg/L as a daily minimum, maintain background
pH	Maintain background
Temperature	Maintain background

B. "Maintain background," as used in this subpart, means the concentration of the water quality substances, characteristics, or pollutants shall not deviate from the range of natural background concentrations or conditions such that there is a potential significant adverse impact to the designated uses.

C. Activities in wetlands which involve the normal farm practices of planting with annually seeded crops or the utilization of a crop rotation seeding of pasture grasses or legumes, including the recommended applications of fertilizer and pesticides, are excluded from the standards in this subpart and the wetland standards in parts 7050.0224, subpart 4; 7050.0225, subpart 2; and 7050.0227. All other activities in these wetlands must meet water quality standards.

Subp. 7. **Additional standards; Class 2 waters.** The following additional standards and requirements apply to all Class 2 waters.

A. No sewage, industrial waste, or other wastes from point or nonpoint sources shall be discharged into any of the waters of this category so as to cause any material change in any other substances, characteristics, or pollutants which may impair the quality of the waters of the state or the aquatic biota of any of the classes in subparts 2 to 6 or in any manner render them unsuitable or objectionable for fishing, fish culture, or recreational uses. Additional selective limits or changes in the discharge bases may be imposed on the basis of local needs.

B. To prevent acutely toxic conditions, concentrations of toxic pollutants from point or nonpoint sources must not exceed the FAV as a one-day average at the point of discharge or in the surface water consistent with parts 7050.0210, subpart 5, item D; 7053.0215, subpart 1; 7053.0225, subpart 6; and 7053.0245, subpart 1.

If a discharge is composed of a mixture of more than one chemical, and the chemicals have the same mode of toxic action, the commissioner has the option to apply an additive model to determine the toxicity of the mixture using the following equation:

$$\frac{C_1}{FAV_1} + \frac{C_2}{FAV_2} + \ldots\ldots + \frac{C_n}{FAV_n}$$ equals a value of one or more, an acutely toxic condition if indicated

where: C_1 .... C_n is the concentration of the first to the n^{th} toxicant.
FAV_1 .... FAV_n is the FAV for the first to the n^{th} toxicant.

C. To prevent chronically toxic conditions, concentrations of toxic pollutants must not exceed the applicable CS or CC and MS or MC in surface waters outside allowable mixing zones as described in part 7050.0210, subpart 5. The CS or CC and MS or MC will be averaged over the following durations: the MS or MC will be a one-day average; the CS or CC, based on toxicity to aquatic life, will be a four-day average; and the CS or CC, based on human health and applied in water or wildlife toxicity, will be a 30-day average.

D. Concentrations of noncarcinogenic or nonlinear carcinogenic (NLC) chemicals in water or fish tissue from point or nonpoint sources, singly or in mixtures, must be below levels expected to produce known adverse effects. This is accomplished through the application of an additive noncancer health risk index using common health risk index endpoints or health endpoints. Mixtures of chemicals with listed CS or site-specific CC are evaluated using the following approach:

Chemicals must be grouped according to medium (water or fish) and each health endpoint. Chemicals for which no health endpoint is specified are not grouped. Chemicals that are also linear carcinogens must be grouped as described under item E. Using the following equation, a noncancer health risk index must be determined for each group of two or more chemicals that have a common health endpoint listed in this part. To meet the protection objectives in part 7050.0217, the noncancer health risk index must not exceed a value of one.

$$\text{Noncancer health risk index by common health endpoint} = \frac{C_1}{CS_1 \text{ or } CC_1} + \frac{C_2}{CS_2 \text{ or } CC_2} + \ldots + \frac{C_n}{CS_n \text{ or } CC_n} \leq 1$$

where: C_n is the concentration of the first to the n^{th} chemical by common health endpoint and medium

CS_1 ... CS_n is the drinking water plus fish consumption and recreation chronic standard (CS_{dfr} or CS_{dev}), fish consumption and recreation chronic standard (CS_{fr}), or fish tissue chronic standard (CS_{ft}) for the first to n^{th} chemical by common health endpoint

CC_1 ... CC_n is the drinking water plus fish consumption and recreation chronic criterion (CC_{dfr} or CC_{dev}), fish consumption and recreation chronic criterion (CC_{fr}), or fish tissue chronic criterion (CC_{ft}) for the first to n^{th} chemical by common health endpoint

E. Concentrations of carcinogenic chemicals from point or nonpoint sources, singly or in mixtures, must not exceed an incremental or additional excess risk level of one in 100,000 (10^{-5}) in surface waters or fish tissue. Carcinogenic chemicals will be considered additive in their effect according to the following equation unless an alternative model is supported by available scientific evidence. The additive equation applies to chemicals that have a human health-based chronic standard (CS) or site-specific chronic criterion (CC) calculated with a cancer potency slope factor. To meet the protection objectives in part 7050.0217, the cancer health risk index must not exceed a value of one.

$$\text{Cancer health risk index} = \frac{C_1}{CS_1 \text{ or } CC_1} + \frac{C_2}{CS_2 \text{ or } CC_2} + \ldots + \frac{C_n}{CS_n \text{ or } CC_n} \leq 1$$

where: C_1 .... C_n is the concentration of the first to the n^{th} carcinogen in water or fish tissue

CS_1 ... CS_n is the drinking water plus fish consumption and recreation chronic standard (CS_{dfr}), fish consumption and recreation chronic standard (CS_{fr}), or fish tissue chronic standard (CS_{ft}) for the first to n^{th} carcinogenic chemical

CC_1 .... CC_n is the drinking water plus fish consumption and recreation chronic criterion (CC_{dfr}) fish consumption and recreation chronic criterion (CC_{fr}), or fish tissue chronic criterion (CC_{ft}) for the first to n^{th} carcinogenic chemical

F. When monitoring indicates that chemical breakdown products or environmental degradates are present in surface water or fish tissue, those products must be considered when meeting the objectives for toxic pollutants in part 7050.0217. When no human health-based CS or other MDH health-based guidance is available for the chemical breakdown product, the CS or CC for the parent chemical must be applied for that product. The parent CS or CC must also be applied to evaluate mixtures of chemicals.

G. This item applies to maximum standards (MS), final acute values (FAV), and double dashes (–) in this part and part 7050.0220 marked with an asterisk (*). For carcinogenic or highly bioaccumulative chemicals with BCFs greater than 5,000 or log K_{ow} values greater than 5.19, the human health-based chronic standard (CS) may be two or more orders of magnitude smaller than the acute toxicity-based MS.

If the ratio of the MS to the CS is greater than 100, the CS times 100 must be substituted for the applicable MS, and the CS times 200 must be substituted for the applicable FAV. Any effluent limit derived using the procedures of this item must only be required after the discharger has been given notice of the specific proposed effluent limits and an opportunity to request a hearing as provided in part 7000.1800.

Subp. 8. [Repealed, 32 SR 1699]

Subp. 9. **Conversion factors for dissolved metal standards.**

Metal	Conversion Factor for CS	Conversion Factor for MS and FAV
Cadmium	0.909 1.1017-[(ln TH, mg/L) (0.0418)]	0.946 1.1367-[(ln TH, mg/L) (0.0418)]
Chromium +3	0.860	0.316
Chromium +6	0.962	0.982
Copper	0.960	0.960
Lead	0.791 1.4620-[(ln TH, mg/L) (0.1457)]	0.791 1.4620-[(ln TH, mg/L) (0.1457)]
Mercury	1.0	0.850
Nickel	0.997	0.998
Silver	0.850	0.850
Zinc	0.986	0.978

Conversion factors for cadmium and lead are hardness (TH) dependent. The factors shown in the table above are for a total hardness of 100 mg/L only. Conversion factors for cadmium and lead for other hardness values shall be calculated using the equations included in the table. The dissolved standard is the total standard times the conversion factor.

Statutory Authority: *MS s 14.06; 115.03; 115.44; 116.07*

History: *18 SR 2195; 19 SR 1310; 24 SR 1105; 27 SR 1217; 32 SR 1699; 39 SR 154; 39 SR 1344*

Published Electronically: *March 24, 2015* tained (including attainment of the objective of this chapter) from achieving such limitation.

(B) Reasonable progress

The Administrator, with the concurrence of the State, may issue a permit which modifies the effluent limitations required by subsection (a) of this section for toxic pollutants for a single period not to exceed 5 years if the applicant demonstrates to the satisfaction of the Administrator that such modified requirements (i) will represent the maximum degree of control within the economic capability of the owner and operator of the source, and (ii) will result in reasonable further progress beyond the requirements of section 1311(b)(2) of this title toward the requirements of subsection (a) of this section.

(c) Delay in application of other limitations

The establishment of effluent limitations under this section shall not operate to delay the application of any effluent limitation established under section 1311 of this title.

(June 30, 1948, ch. 758, title III, § 302, as added Pub. L. 92–500, § 2, Oct. 18, 1972, 86 Stat. 846; amended Pub. L. 100–4, title III, § 308(e), Feb. 4, 1987, 101 Stat. 39.)

AMENDMENTS

1987—Subsec. (a). Pub. L. 100–4, § 308(e)(2), inserted ''or as identified under section 1314(*l*) of this title'' after ''Administrator'' and ''public health,'' after ''protection of''.

Subsec. (b). Pub. L. 100–4, § 308(e)(1), amended subsec. (b) generally. Prior to amendment, subsec. (b) read as follows:

''(1) Prior to establishment of any effluent limitation pursuant to subsection (a) of this section, the Administrator shall issue notice of intent to establish such limitation and within ninety days of such notice hold a public hearing to determine the relationship of the economic and social costs of achieving any such limitation or limitations, including any economic or social dislocation in the affected community or communities, to the social and economic benefits to be obtained (including the attainment of the objective of this chapter) and to determine whether or not such effluent limitations can be implemented with available technology or other alternative control strategies.

''(2) If a person affected by such limitation demonstrates at such hearing that (whether or not such technology or other alternative control strategies are available) there is no reasonable relationship between the economic and social costs and the benefits to be obtained (including attainment of the objective of this chapter), such limitation shall not become effective and the Administrator shall adjust such limitation as it applies to such person.''

§ 1313. Water quality standards and implementation plans

(a) Existing water quality standards

(1) In order to carry out the purpose of this chapter, any water quality standard applicable to interstate waters which was adopted by any State and submitted to, and approved by, or is awaiting approval by, the Administrator pursuant to this Act as in effect immediately prior to October 18, 1972, shall remain in effect unless the Administrator determined that such standard is not consistent with the applicable requirements of this Act as in effect immediately prior to October 18, 1972. If the Administrator makes such a determination he shall, within three months after October 18, 1972, notify the State and specify the changes needed to meet such requirements. If such changes are not adopted by the State within ninety days after the date of such notification, the Administrator shall promulgate such changes in accordance with subsection (b) of this section.

(2) Any State which, before October 18, 1972, has adopted, pursuant to its own law, water quality standards applicable to intrastate waters shall submit such standards to the Administrator within thirty days after October 18, 1972. Each such standard shall remain in effect, in the same manner and to the same extent as any other water quality standard established under this chapter unless the Administrator determines that such standard is inconsistent with the applicable requirements of this Act as in effect immediately prior to October 18, 1972. If the Administrator makes such a determination he shall not later than the one hundred and twentieth day after the date of submission of such standards, notify the State and specify the changes needed to meet such requirements. If such changes are not adopted by the State within ninety days after such notification, the Administrator shall promulgate such changes in accordance with subsection (b) of this section.

(3)(A) Any State which prior to October 18, 1972, has not adopted pursuant to its own laws water quality standards applicable to intrastate waters shall, not later than one hundred and eighty days after October 18, 1972, adopt and submit such standards to the Administrator.

(B) If the Administrator determines that any such standards are consistent with the applicable requirements of this Act as in effect immediately prior to October 18, 1972, he shall approve such standards.

(C) If the Administrator determines that any such standards are not consistent with the applicable requirements of this Act as in effect immediately prior to October 18, 1972, he shall, not later than the ninetieth day after the date of submission of such standards, notify the State and specify the changes to meet such requirements. If such changes are not adopted by the State within ninety days after the date of notification, the Administrator shall promulgate such standards pursuant to subsection (b) of this section.

(b) Proposed regulations

(1) The Administrator shall promptly prepare and publish proposed regulations setting forth water quality standards for a State in accordance with the applicable requirements of this Act as in effect immediately prior to October 18, 1972, if—

(A) the State fails to submit water quality standards within the times prescribed in subsection (a) of this section.

(B) a water quality standard submitted by such State under subsection (a) of this section is determined by the Administrator not to be consistent with the applicable requirements of subsection (a) of this section.

(2) The Administrator shall promulgate any water quality standard published in a proposed

regulation not later than one hundred and ninety days after the date he publishes any such proposed standard, unless prior to such promulgation, such State has adopted a water quality standard which the Administrator determines to be in accordance with subsection (a) of this section.

(c) Review; revised standards; publication

(1) The Governor of a State or the State water pollution control agency of such State shall from time to time (but at least once each three year period beginning with October 18, 1972) hold public hearings for the purpose of reviewing applicable water quality standards and, as appropriate, modifying and adopting standards. Results of such review shall be made available to the Administrator.

(2)(A) Whenever the State revises or adopts a new standard, such revised or new standard shall be submitted to the Administrator. Such revised or new water quality standard shall consist of the designated uses of the navigable waters involved and the water quality criteria for such waters based upon such uses. Such standards shall be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this chapter. Such standards shall be established taking into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes, and also taking into consideration their use and value for navigation.

(B) Whenever a State reviews water quality standards pursuant to paragraph (1) of this subsection, or revises or adopts new standards pursuant to this paragraph, such State shall adopt criteria for all toxic pollutants listed pursuant to section 1317(a)(1) of this title for which criteria have been published under section 1314(a) of this title, the discharge or presence of which in the affected waters could reasonably be expected to interfere with those designated uses adopted by the State, as necessary to support such designated uses. Such criteria shall be specific numerical criteria for such toxic pollutants. Where such numerical criteria are not available, whenever a State reviews water quality standards pursuant to paragraph (1), or revises or adopts new standards pursuant to this paragraph, such State shall adopt criteria based on biological monitoring or assessment methods consistent with information published pursuant to section 1314(a)(8) of this title. Nothing in this section shall be construed to limit or delay the use of effluent limitations or other permit conditions based on or involving biological monitoring or assessment methods or previously adopted numerical criteria.

(3) If the Administrator, within sixty days after the date of submission of the revised or new standard, determines that such standard meets the requirements of this chapter, such standard shall thereafter be the water quality standard for the applicable waters of that State. If the Administrator determines that any such revised or new standard is not consistent with the applicable requirements of this chapter, he shall not later than the ninetieth day after the date of submission of such standard notify the State and specify the changes to meet such requirements. If such changes are not adopted by the State within ninety days after the date of notification, the Administrator shall promulgate such standard pursuant to paragraph (4) of this subsection.

(4) The Administrator shall promptly prepare and publish proposed regulations setting forth a revised or new water quality standard for the navigable waters involved—

(A) if a revised or new water quality standard submitted by such State under paragraph (3) of this subsection for such waters is determined by the Administrator not to be consistent with the applicable requirements of this chapter, or

(B) in any case where the Administrator determines that a revised or new standard is necessary to meet the requirements of this chapter.

The Administrator shall promulgate any revised or new standard under this paragraph not later than ninety days after he publishes such proposed standards, unless prior to such promulgation, such State has adopted a revised or new water quality standard which the Administrator determines to be in accordance with this chapter.

(d) Identification of areas with insufficient controls; maximum daily load; certain effluent limitations revision

(1)(A) Each State shall identify those waters within its boundaries for which the effluent limitations required by section 1311(b)(1)(A) and section 1311(b)(1)(B) of this title are not stringent enough to implement any water quality standard applicable to such waters. The State shall establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters.

(B) Each State shall identify those waters or parts thereof within its boundaries for which controls on thermal discharges under section 1311 of this title are not stringent enough to assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife.

(C) Each State shall establish for the waters identified in paragraph (1)(A) of this subsection, and in accordance with the priority ranking, the total maximum daily load, for those pollutants which the Administrator identifies under section 1314(a)(2) of this title as suitable for such calculation. Such load shall be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

(D) Each State shall estimate for the waters identified in paragraph (1)(B) of this subsection the total maximum daily thermal load required to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife. Such estimates shall take into account the normal water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters or parts thereof. Such estimates shall include a calculation of the maximum heat input that can be made into each such part and shall include a margin of safety which takes into account any lack of knowledge concerning the development of thermal water quality criteria for such protection and propagation in the identified waters or parts thereof.

(2) Each State shall submit to the Administrator from time to time, with the first such submission not later than one hundred and eighty days after the date of publication of the first identification of pollutants under section 1314(a)(2)(D) of this title, for his approval the waters identified and the loads established under paragraphs (1)(A), (1)(B), (1)(C), and (1)(D) of this subsection. The Administrator shall either approve or disapprove such identification and load not later than thirty days after the date of submission. If the Administrator approves such identification and load, such State shall incorporate them into its current plan under subsection (e) of this section. If the Administrator disapproves such identification and load, he shall not later than thirty days after the date of such disapproval identify such waters in such State and establish such loads for such waters as he determines necessary to implement the water quality standards applicable to such waters and upon such identification and establishment the State shall incorporate them into its current plan under subsection (e) of this section.

(3) For the specific purpose of developing information, each State shall identify all waters within its boundaries which it has not identified under paragraph (1)(A) and (1)(B) of this subsection and estimate for such waters the total maximum daily load with seasonal variations and margins of safety, for those pollutants which the Administrator identifies under section 1314(a)(2) of this title as suitable for such calculation and for thermal discharges, at a level that would assure protection and propagation of a balanced indigenous population of fish, shellfish, and wildlife.

(4) LIMITATIONS ON REVISION OF CERTAIN EFFLUENT LIMITATIONS.—

(A) STANDARD NOT ATTAINED.—For waters identified under paragraph (1)(A) where the applicable water quality standard has not yet been attained, any effluent limitation based on a total maximum daily load or other waste load allocation established under this section may be revised only if (i) the cumulative effect of all such revised effluent limitations based on such total maximum daily load or waste load allocation will assure the attainment of such water quality standard, or (ii) the designated use which is not being attained is removed in accordance with regulations established under this section.

(B) STANDARD ATTAINED.—For waters identified under paragraph (1)(A) where the quality of such waters equals or exceeds levels necessary to protect the designated use for such waters or otherwise required by applicable water quality standards, any effluent limitation based on a total maximum daily load or other waste load allocation established under this section, or any water quality standard established under this section, or any other permitting standard may be revised only if such revision is subject to and consistent with the antidegradation policy established under this section.

(e) Continuing planning process

(1) Each State shall have a continuing planning process approved under paragraph (2) of this subsection which is consistent with this chapter.

(2) Each State shall submit not later than 120 days after October 18, 1972, to the Administrator for his approval a proposed continuing planning process which is consistent with this chapter. Not later than thirty days after the date of submission of such a process the Administrator shall either approve or disapprove such process. The Administrator shall from time to time review each State's approved planning process for the purpose of insuring that such planning process is at all times consistent with this chapter. The Administrator shall not approve any State permit program under subchapter IV of this chapter for any State which does not have an approved continuing planning process under this section.

(3) The Administrator shall approve any continuing planning process submitted to him under this section which will result in plans for all navigable waters within such State, which include, but are not limited to, the following:

(A) effluent limitations and schedules of compliance at least as stringent as those required by section 1311(b)(1), section 1311(b)(2), section 1316, and section 1317 of this title, and at least as stringent as any requirements contained in any applicable water quality standard in effect under authority of this section;

(B) the incorporation of all elements of any applicable area-wide waste management plans under section 1288 of this title, and applicable basin plans under section 1289 of this title;

(C) total maximum daily load for pollutants in accordance with subsection (d) of this section;

(D) procedures for revision;

(E) adequate authority for intergovernmental cooperation;

(F) adequate implementation, including schedules of compliance, for revised or new water quality standards, under subsection (c) of this section;

(G) controls over the disposition of all residual waste from any water treatment processing;

(H) an inventory and ranking, in order of priority, of needs for construction of waste treatment works required to meet the applicable requirements of sections 1311 and 1312 of this title.

(f) Earlier compliance

Nothing in this section shall be construed to affect any effluent limitation, or schedule of compliance required by any State to be implemented prior to the dates set forth in sections 1311(b)(1) and 1311(b)(2) of this title nor to preclude any State from requiring compliance with any effluent limitation or schedule of compliance at dates earlier than such dates.

(g) Heat standards

Water quality standards relating to heat shall be consistent with the requirements of section 1326 of this title.

(h) Thermal water quality standards

For the purposes of this chapter the term ''water quality standards'' includes thermal water quality standards.

(i) Coastal recreation water quality criteria

(1) Adoption by States

(A) Initial criteria and standards

Not later than 42 months after October 10, 2000, each State having coastal recreation waters shall adopt and submit to the Administrator water quality criteria and standards for the coastal recreation waters of the State for those pathogens and pathogen indicators for which the Administrator has published criteria under section 1314(a) of this title.

(B) New or revised criteria and standards

Not later than 36 months after the date of publication by the Administrator of new or revised water quality criteria under section 1314(a)(9) of this title, each State having coastal recreation waters shall adopt and submit to the Administrator new or revised water quality standards for the coastal recreation waters of the State for all pathogens and pathogen indicators to which the new or revised water quality criteria are applicable.

(2) Failure of States to adopt

(A) In general

If a State fails to adopt water quality criteria and standards in accordance with paragraph (1)(A) that are as protective of human health as the criteria for pathogens and pathogen indicators for coastal recreation waters published by the Administrator, the Administrator shall promptly propose regulations for the State setting forth revised or new water quality standards for pathogens and pathogen indicators described in paragraph (1)(A) for coastal recreation waters of the State.

(B) Exception

If the Administrator proposes regulations for a State described in subparagraph (A) under subsection (c)(4)(B) of this section, the Administrator shall publish any revised or new standard under this subsection not later than 42 months after October 10, 2000.

(3) Applicability

Except as expressly provided by this subsection, the requirements and procedures of subsection (c) of this section apply to this subsection, including the requirement in subsection (c)(2)(A) of this section that the criteria protect public health and welfare.

(June 30, 1948, ch. 758, title III, § 303, as added Pub. L. 92–500, § 2, Oct. 18, 1972, 86 Stat. 846; amended Pub. L. 100–4, title III, § 308(d), title IV, § 404(b), Feb. 4, 1987, 101 Stat. 39, 68; Pub. L. 106–284, § 2, Oct. 10, 2000, 114 Stat. 870.)

REFERENCES IN TEXT

This Act, referred to in subsecs. (a)(1), (2), (3)(B), (C) and (b)(1), means act June 30, 1948, ch. 758, 62 Stat. 1155, prior to the supersedure and reenactment of act June 30, 1948 by act Oct. 18, 1972, Pub. L. 92–500, 86 Stat. 816. Act June 30, 1948, ch. 758, as added by act Oct. 18, 1972, Pub. L. 92–500, 86 Stat. 816, enacted this chapter.

AMENDMENTS

2000—Subsec. (i). Pub. L. 106–284 added subsec. (i).

1987—Subsec. (c)(2). Pub. L. 100–4, § 308(d), designated existing provision as subpar. (A) and added subpar. (B).

Subsec. (d)(4). Pub. L. 100–4, § 404(b), added par. (4).

§ 1313a. Revised water quality standards

The review, revision, and adoption or promulgation of revised or new water quality standards pursuant to section 303(c) of the Federal Water Pollution Control Act [33 U.S.C. 1313(c)] shall be completed by the date three years after December 29, 1981. No grant shall be made under title II of the Federal Water Pollution Control Act [33 U.S.C. 1281 et seq.] after such date until water quality standards are reviewed and revised pursuant to section 303(c), except where the State has in good faith submitted such revised water quality standards and the Administrator has not acted to approve or disapprove such submission within one hundred and twenty days of receipt.

(Pub. L. 97–117, § 24, Dec. 29, 1981, 95 Stat. 1632.)

REFERENCES IN TEXT

The Federal Water Pollution Control Act, referred to in text, is act June 30, 1948, ch. 758, as amended generally by Pub. L. 92–500, § 2, Oct. 18, 1972, 86 Stat. 816. Title II of the Act is classified generally to subchapter II (§ 1281 et seq.) of this chapter. For complete classification of this Act to the Code, see Short Title note set out under section 1251 of this title and Tables.

CODIFICATION

Section was enacted as part of the Municipal Wastewater Treatment Construction Grant Amendments of 1981, and not as part of the Federal Water Pollution Control Act which comprises this chapter.

§ 1314. Information and guidelines

(a) Criteria development and publication

(1) The Administrator, after consultation with appropriate Federal and State agencies and other interested persons, shall develop and publish, within one year after October 18, 1972 (and from time to time thereafter revise) criteria for water quality accurately reflecting the latest scientific knowledge (A) on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water, including ground water; (B) on the concentration and dispersal of pollutants, or their byproducts, through biological, physical, and chemical processes; and (C) on the effects of pollutants on biological community diversity, productivity, and stability, including information on the factors affecting rates of eutrophication and rates of organic and inorganic sedimentation for varying types of receiving waters.

(2) The Administrator, after consultation with appropriate Federal and State agencies and other interested persons, shall develop and pub-

115.44 CLASSIFICATION OF WATERS; STANDARDS OF QUALITY AND PURITY.

Subdivision 1. **Variable factors.** It is recognized that, due to variable factors, no single standard of quality and purity of the waters is applicable to all waters of the state or to different segments of the same waters.

Subd. 2. **Classification and standards.** In order to attain the objectives of sections 115.41 to 115.53, the agency after proper study, and after conducting public hearing upon due notice, shall, as soon as practicable, group the designated waters of the state into classes, and adopt classifications and standards of purity and quality therefor. Such classification shall be made in accordance with considerations of best usage in the interest of the public and with regard to the considerations mentioned in subdivision 3 hereof.

Subd. 3. **Adoption of classification.** In adopting the classification of waters and the standards of purity and quality above mentioned, the agency shall give consideration to:

(a) the size, depth, surface area covered, volume, direction and rate of flow, stream gradient and temperature of the water;

(b) the character of the district bordering said waters and its peculiar suitability for the particular uses, and with a view to conserving the value of the same and encouraging the most appropriate use of lands bordering said waters, for residential, agricultural, industrial, or recreational purposes;

(c) the uses which have been made, are being made, or may be made of said waters for transportation, domestic and industrial consumption, bathing, fishing and fish culture, fire prevention, the disposal of sewage, industrial wastes and other wastes or other uses within this state, and, at the discretion of the agency, any such uses in another state on interstate waters flowing through or originating in this state;

(d) the extent of present defilement or fouling of said waters which has already occurred or resulted from past discharges therein;

(e) the need for standards for effluent from disposal systems entering waters of the state;

(f) such other considerations as the agency deems proper.

Subd. 4. **Standards.** The agency, after proper study, and in accordance with chapter 14, shall adopt and design standards of quality and purity for each classification necessary for the public use or benefit contemplated by the classification. The standards shall prescribe what qualities and properties of water indicate a polluted condition of the waters of the state which is actually or potentially deleterious, harmful, detrimental, or injurious to the public health, safety, or welfare; to terrestrial or aquatic life or to its growth and propagation; or to the use of the waters for domestic, commercial and industrial, agricultural, recreational, or other reasonable purposes, with respect to the various classes established pursuant to subdivision 2. The standards may also contain other provisions that the agency deems proper. Wherever practicable and advisable, the agency shall establish standards for effluent of disposal systems entering classified waters.

Subd. 5. **Factors.** (a) In establishing such standards, consideration should be given to the following factors:

(1) the extent, if any, to which floating solids may be permitted in the water;

(2) the extent to which suspended solids, colloids or a combination of solids with other substances suspended in water, may be permitted;

(3) the extent to which organism of the coliform group (intestinal bacilli) or any other bacteriological organisms may be permitted in the water;

(4) the extent of the oxygen demand which may be permitted in the receiving waters;

(5) such other chemical or biological properties necessary for the attainment of the objectives of this chapter and, with respect to pollution of the waters of the state, chapter 116.

(b) Wherever deemed practicable and advisable by the agency, standards specifying the quality and purity, or maximum permissible pollutional content, of effluent entering waters of the state may be established without respect to water quality standards; provided, however, that whenever the owner or operator of any point source, after opportunity for public hearing, can demonstrate to the satisfaction of the agency that any effluent limitation proposed for the control of the heat component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of fish and wildlife in and on the body of water into which the discharge is to be made, the agency may impose an effluent limitation for such plan, with respect to the heat component of such discharge, taking into account the interaction of such heat component with other pollutants, that will assure the protection and propagation of a balanced, indigenous population of fish and wildlife in and on that body of water; and provided further that notwithstanding any other provision of this chapter and, with respect to the pollution of the waters of the state, chapter 116, any point source of a discharge having a heat component, the modification of which point source is commenced after May 20, 1973, and which, as modified, meets applicable effluent limitations, and which effluent limitations will assure protection and propagation of a balanced, indigenous population of fish and wildlife in or on the water into which the discharge is made, shall not be subject to any more stringent effluent limitation with respect to the heat component of its discharge during a ten-year period beginning on the date of completion of such modification or during the period of depreciation or amortization of such facility for the purpose of section 167 or 169, or both, of the Internal Revenue Code of 1954, whichever period ends first.

Subd. 6. **Modification of standards.** The adoption, alteration, or modification of the standards of quality and purity in subdivision 4 shall be made by the agency in accordance with chapter 14.

Subd. 7. **Rule notices.** For rules authorized under this section, the notices required to be mailed under sections 14.14, subdivision 1a, and 14.22 must also be mailed to the governing body of each municipality bordering or through which the waters for which standards are sought to be adopted flow.

Subd. 8. **Waiver.** If the agency finds in order to comply with the Federal Water Pollution Control Act or any other federal law or rule or regulation promulgated thereunder that it is impracticable to comply with the requirements of this section in classifying waters or adopting standards or in meeting any of the requirements thereof, compliance with the requirements of such section are waived to the extent necessary to enable the agency to comply with federal laws and rules and regulations promulgated thereunder. The agency may classify waters and adopt criteria and standards in such form and based upon such evidence as it may deem necessary and sufficient for the purposes of meeting requirements of such federal laws, notwithstanding any provisions in this chapter or any other state law to the contrary. In the event waters are classified and criteria and standards are adopted to meet the requirements of federal law, the agency shall thereafter proceed to otherwise comply with the provisions of this section which were waived as rapidly as is practicable. This authority shall extend to proceedings pending before the agency on May 20, 1973.

Notwithstanding the provisions of subdivision 4, wherever advisable and practicable the agency may establish standards for effluent or disposal systems discharging into waters of the state regardless of whether such waters are or are not classified.

Subd. 9. **Annual report.** (a) By January 15 each year, the commissioner shall post on the Pollution Control Agency's Web site a report on the agency's activities the previous calendar year to implement standards and classification requirements into national pollutant discharge elimination system and state disposal system permits held by municipalities. The report must include:

(1) a summary of permits issued or reissued over the previous calendar year, including any changes to permitted effluent limits due to water quality standards adopted or revised during the previous permit term;

(2) highlights of innovative approaches employed by the agency and municipalities to develop and achieve permit requirements in a cost-effective manner;

(3) a summary of standards development and water quality rulemaking activities over the previous calendar year, including economic analyses;

(4) a summary of standards development and water quality rulemaking activities anticipated for the next three years, including economic analyses;

(5) a process and timeframe for municipalities to provide input to the agency regarding their needs based on the information provided in the report; and

(6) a list of anticipated permitting initiatives in the next calendar year that may impact municipalities and the agency's plan for involving the municipalities throughout the planning and decision-making process. The plan must include opportunities for input and public comment from municipalities on rulemaking initiatives prior to preparation of a statement of need and reasonableness required under section 14.131. The commissioner must ensure the agency's plan under this clause is implemented.

(b) For the purposes of this section, "economic analyses" must include assessments of the potential costs to regulated municipalities associated with water quality standards or rules proposed by the agency.

History: *1963 c 874 s 6; 1967 c 203 s 1; 1969 c 9 s 21; 1969 c 931 s 8,9; 1973 c 374 s 15,16; 1993 c 180 s 1-3; 1994 c 465 art 1 s 9; 2008 c 277 art 1 s 97; 1Sp2015 c 4 art 4 s 101*

115.03 POWERS AND DUTIES.

Subdivision 1. **Generally.** The agency is hereby given and charged with the following powers and duties:

(a) to administer and enforce all laws relating to the pollution of any of the waters of the state;

(b) to investigate the extent, character, and effect of the pollution of the waters of this state and to gather data and information necessary or desirable in the administration or enforcement of pollution laws, and to make such classification of the waters of the state as it may deem advisable;

(c) to establish and alter such reasonable pollution standards for any waters of the state in relation to the public use to which they are or may be put as it shall deem necessary for the purposes of this chapter and, with respect to the pollution of waters of the state, chapter 116;

(d) to encourage waste treatment, including advanced waste treatment, instead of stream low-flow augmentation for dilution purposes to control and prevent pollution;

(e) to adopt, issue, reissue, modify, deny, or revoke, enter into or enforce reasonable orders, permits, variances, standards, rules, schedules of compliance, and stipulation agreements, under such conditions as it may prescribe, in order to prevent, control or abate water pollution, or for the installation or operation of disposal systems or parts thereof, or for other equipment and facilities:

(1) requiring the discontinuance of the discharge of sewage, industrial waste or other wastes into any waters of the state resulting in pollution in excess of the applicable pollution standard established under this chapter;

(2) prohibiting or directing the abatement of any discharge of sewage, industrial waste, or other wastes, into any waters of the state or the deposit thereof or the discharge into any municipal disposal system where the same is likely to get into any waters of the state in violation of this chapter and, with respect to the pollution of waters of the state, chapter 116, or standards or rules promulgated or permits issued pursuant thereto, and specifying the schedule of compliance within which such prohibition or abatement must be accomplished;

(3) prohibiting the storage of any liquid or solid substance or other pollutant in a manner which does not reasonably assure proper retention against entry into any waters of the state that would be likely to pollute any waters of the state;

(4) requiring the construction, installation, maintenance, and operation by any person of any disposal system or any part thereof, or other equipment and facilities, or the reconstruction, alteration, or enlargement of its existing disposal system or any part thereof, or the adoption of other remedial measures to prevent, control or abate any discharge or deposit of sewage, industrial waste or other wastes by any person;

(5) establishing, and from time to time revising, standards of performance for new sources taking into consideration, among other things, classes, types, sizes, and categories of sources, processes, pollution control technology, cost of achieving such effluent reduction, and any nonwater quality environmental impact and energy requirements. Said standards of performance for new sources shall encompass those standards for the control of the discharge of pollutants which reflect the greatest degree of effluent reduction which the agency determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. New sources shall encompass buildings, structures, facilities, or in-

stallations from which there is or may be the discharge of pollutants, the construction of which is commenced after the publication by the agency of proposed rules prescribing a standard of performance which will be applicable to such source. Notwithstanding any other provision of the law of this state, any point source the construction of which is commenced after May 20, 1973, and which is so constructed as to meet all applicable standards of performance for new sources shall, consistent with and subject to the provisions of section 306(d) of the Amendments of 1972 to the Federal Water Pollution Control Act, not be subject to any more stringent standard of performance for new sources during a ten-year period beginning on the date of completion of such construction or during the period of depreciation or amortization of such facility for the purposes of section 167 or 169, or both, of the Federal Internal Revenue Code of 1954, whichever period ends first. Construction shall encompass any placement, assembly, or installation of facilities or equipment, including contractual obligations to purchase such facilities or equipment, at the premises where such equipment will be used, including preparation work at such premises;

(6) establishing and revising pretreatment standards to prevent or abate the discharge of any pollutant into any publicly owned disposal system, which pollutant interferes with, passes through, or otherwise is incompatible with such disposal system;

(7) requiring the owner or operator of any disposal system or any point source to establish and maintain such records, make such reports, install, use, and maintain such monitoring equipment or methods, including where appropriate biological monitoring methods, sample such effluents in accordance with such methods, at such locations, at such intervals, and in such a manner as the agency shall prescribe, and providing such other information as the agency may reasonably require;

(8) notwithstanding any other provision of this chapter, and with respect to the pollution of waters of the state, chapter 116, requiring the achievement of more stringent limitations than otherwise imposed by effluent limitations in order to meet any applicable water quality standard by establishing new effluent limitations, based upon section 115.01, subdivision 13, clause (b), including alternative effluent control strategies for any point source or group of point sources to insure the integrity of water quality classifications, whenever the agency determines that discharges of pollutants from such point source or sources, with the application of effluent limitations required to comply with any standard of best available technology, would interfere with the attainment or maintenance of the water quality classification in a specific portion of the waters of the state. Prior to establishment of any such effluent limitation, the agency shall hold a public hearing to determine the relationship of the economic and social costs of achieving such limitation or limitations, including any economic or social dislocation in the affected community or communities, to the social and economic benefits to be obtained and to determine whether or not such effluent limitation can be implemented with available technology or other alternative control strategies. If a person affected by such limitation demonstrates at such hearing that, whether or not such technology or other alternative control strategies are available, there is no reasonable relationship between the economic and social costs and the benefits to be obtained, such limitation shall not become effective and shall be adjusted as it applies to such person;

(9) modifying, in its discretion, any requirement or limitation based upon best available technology with respect to any point source for which a permit application is filed after July 1, 1977, upon a showing by the owner or operator of such point source satisfactory to the agency that such modified requirements will represent the maximum use of technology within the economic capability of the owner or operator and will result in reasonable further progress toward the elimination of the discharge of pollutants; and

(10) requiring that applicants for wastewater discharge permits evaluate in their applications the potential reuses of the discharged wastewater;

(f) to require to be submitted and to approve plans and specifications for disposal systems or point sources, or any part thereof and to inspect the construction thereof for compliance with the approved plans and specifications thereof;

(g) to prescribe and alter rules, not inconsistent with law, for the conduct of the agency and other matters within the scope of the powers granted to and imposed upon it by this chapter and, with respect to pollution of waters of the state, in chapter 116, provided that every rule affecting any other department or agency of the state or any person other than a member or employee of the agency shall be filed with the secretary of state;

(h) to conduct such investigations, issue such notices, public and otherwise, and hold such hearings as are necessary or which it may deem advisable for the discharge of its duties under this chapter and, with respect to the pollution of waters of the state, under chapter 116, including, but not limited to, the issuance of permits, and to authorize any member, employee, or agent appointed by it to conduct such investigations or, issue such notices and hold such hearings;

(i) for the purpose of water pollution control planning by the state and pursuant to the Federal Water Pollution Control Act, as amended, to establish and revise planning areas, adopt plans and programs and continuing planning processes, including, but not limited to, basin plans and areawide waste treatment management plans, and to provide for the implementation of any such plans by means of, including, but not limited to, standards, plan elements, procedures for revision, intergovernmental cooperation, residual treatment process waste controls, and needs inventory and ranking for construction of disposal systems;

(j) to train water pollution control personnel, and charge such fees therefor as are necessary to cover the agency's costs. All such fees received shall be paid into the state treasury and credited to the Pollution Control Agency training account;

(k) to impose as additional conditions in permits to publicly owned disposal systems appropriate measures to insure compliance by industrial and other users with any pretreatment standard, including, but not limited to, those related to toxic pollutants, and any system of user charges ratably as is hereby required under state law or said Federal Water Pollution Control Act, as amended, or any regulations or guidelines promulgated thereunder;

(l) to set a period not to exceed five years for the duration of any national pollutant discharge elimination system permit or not to exceed ten years for any permit issued as a state disposal system permit only;

(m) to require each governmental subdivision identified as a permittee for a wastewater treatment works to evaluate in every odd-numbered year the condition of its existing system and identify future capital improvements that will be needed to attain or maintain compliance with a national pollutant discharge elimination system or state disposal system permit; and

(n) to train subsurface sewage treatment system personnel, including persons who design, construct, install, inspect, service, and operate subsurface sewage treatment systems, and charge fees as necessary to pay the agency's costs. All fees received must be paid into the state treasury and credited to the agency's training account. Money in the account is appropriated to the agency to pay expenses related to training.

The information required in clause (m) must be submitted in every odd-numbered year to the commissioner on a form provided by the commissioner. The commissioner shall provide technical assistance if requested by the governmental subdivision.

The powers and duties given the agency in this subdivision also apply to permits issued under chapter 114C.

Subd. 2. **Hearing or investigation.** In any hearing or investigation conducted pursuant to this chapter and chapters 114C, 116, and 116F, any employee or agent thereto authorized by the agency, may administer oaths, examine witnesses and issue, in the name of the agency, subpoenas requiring the attendance and testimony of witnesses and the production of evidence relevant to any matter involved in any such hearing or investigation. Witnesses shall receive the same fees and mileage as in civil actions.

Subd. 3. **Contempt of court.** In case of contumacy or refusal to obey a subpoena issued under this section, the district court of the county where the proceeding is pending or in which the person guilty of such contumacy or refusal to obey is found or resides, shall have jurisdiction upon application of the agency or its authorized member, employee or agent to issue to such person an order requiring the person to appear and testify or produce evidence, as the case may require, and any failure to obey such order of the court may be punished by said court as a contempt thereof.

Subd. 4. **Building permits.** It is unlawful for any person to issue or grant a building permit for, or otherwise permit, the construction, enlargement, or relocation of a commercial or industrial building to be used as the place of employment of more than 12 persons, or any other commercial or industrial building to house a process producing industrial or other wastes, unless the sewage or industrial or other waste originating in such buildings is or will be discharged into a disposal system for which a permit has first been granted by the agency unless the agency has cause not to apply this requirement, provided that this subdivision shall not apply to building permits issued for buildings, which have an estimated value of less than $500,000, located or to be located within an incorporated municipality. After January 1, 1975, such permits shall be acted upon by the agency within 90 days after submitted, provided that the agency, for good cause, may order said 90-day period to be extended for a reasonable time.

Subd. 4a. **Section 401 certifications.** (a) The following definitions apply to this subdivision:

(1) "section 401 certification" means a water quality certification required under section 401 of the federal Clean Water Act, United States Code, title 33, section 1341; and

(2) "nationwide permit" means a nationwide general permit issued by the United States Army Corps of Engineers and listed in Code of Federal Regulations, title 40, part 330, appendix A.

(b) The agency is responsible for providing section 401 certifications for nationwide permits.

(c) Before making a final decision on a section 401 certification for regional conditions on a nationwide permit, the agency shall hold at least one public meeting outside the seven-county metropolitan area.

(d) In addition to other notice required by law, the agency shall provide written notice of a meeting at which the agency will be considering a section 401 certification for regional conditions on a nationwide permit at least 21 days before the date of the meeting to the members of the senate and house of representatives environment and natural resources committees, the senate Agriculture and Rural Development Committee, and the house of representatives Agriculture Committee.

Subd. 5. **Agency authority; national pollutant discharge elimination system.** Notwithstanding any other provisions prescribed in or pursuant to this chapter and, with respect to the pollution of waters of the state, in chapter 116, or otherwise, the agency shall have the authority to perform any and all acts minimally necessary including, but not limited to, the establishment and application of standards, procedures, rules, orders, variances, stipulation agreements, schedules of compliance, and permit conditions, consistent with and, therefore not less stringent than the provisions of the Federal Water Pollution Control Act, as amended, applicable to the participation by the state of Minnesota in the national pollutant discharge elimination system (NPDES); provided that this provision shall not be construed as a limitation on any powers or duties otherwise residing with the agency pursuant to any provision of law.

Subd. 5a. **Public notice for national pollutant discharge elimination system permit application.** The commissioner must give public notice of a completed national pollutant discharge elimination system permit application for new municipal discharges in the official county newspaper of the county where the discharge is proposed.

Subd. 5b. [Repealed, 2003 c 128 art 1 s 120]

Subd. 5c. **Regulation of storm water discharges.** (a) The agency may issue a general permit to any category or subcategory of point source storm water discharges that it deems administratively reasonable and efficient without making any findings under agency rules. Nothing in this subdivision precludes the agency from requiring an individual permit for a point source storm water discharge if the agency finds that it is appropriate under applicable legal or regulatory standards.

(b) Pursuant to this paragraph, the legislature authorizes the agency to adopt and enforce rules regulating point source storm water discharges. No further legislative approval is required under any other legal or statutory provision whether enacted before or after May 29, 2003.

(c) The agency shall develop performance standards, design standards, or other tools to enable and promote the implementation of low-impact development and other storm water management techniques. For the purposes of this section, "low-impact development" means an approach to storm water management that mimics a site's natural hydrology as the landscape is developed. Using the low-impact development approach, storm water is managed on site and the rate and volume of predevelopment storm water reaching receiving waters is unchanged. The calculation of predevelopment hydrology is based on native soil and vegetation.

Subd. 6. **Certification statement; pollution control equipment loan.** (a) In addition to its other powers and duties, the agency shall prepare the certification statement required to be submitted by an applicant for a pollution control equipment loan under the provisions of section 7(g) of the Small Business Act and section 8 of the Federal Water Pollution Control Act, as amended.

(b) The agency certification shall state whether the loan applicant's proposed additions to, or alterations in, equipment facilities or methods of operation are necessary and adequate to comply with the requirements established under the Federal Water Pollution Control Act, as amended. The agency's certification statement shall comply with the requirements of Code of Federal Regulations, title 40, part 21.

(c) The agency may identify small businesses eligible for loans under section 7(g) of the Small Business Act and section 8 of the Federal Water Pollution Control Act, as amended and assist in the preparation of loan application.

(d) No fee shall be required of an applicant for any assistance provided under this subdivision.

Subd. 7. **Pollution control facility revenue bonds.** In addition to its other powers and duties, the agency shall disseminate information and provide assistance regarding the small business administration program to guarantee payments or rentals on pollution control facility revenue bonds pursuant to Public Law 94-305 (June 4, 1976). The agency shall also encourage and assist governmental units to coordinate the joint or cooperative issuance of bonds guaranteed under this program to the end that the total amount of the bonds is sufficient in size to allow convenient sale.

Subd. 8. **Exemptions for aboveground storage tanks.** The commissioner may not adopt rules under this section that regulate the use of the following aboveground storage tanks:

(1) farm or residential tanks of 1,100 gallons or less capacity used for storing motor fuel for non-commercial purposes;

(2) tanks of 1,100 gallons or less capacity used for storing heating oil for consumptive use on the premises where stored;

(3) tanks used for storing liquids that are gaseous at atmospheric temperature and pressure; or

(4) tanks used for storing agricultural chemicals regulated under chapter 18B, 18C, or 18D.

Subd. 8a. **Permit duration for major aboveground storage facilities.** Agency permits for major aboveground storage facilities may be issued for a term of up to ten years.

Subd. 8b. **Permit duration; state disposal system permits; feedlots.** State disposal system permits that are issued without a national pollutant discharge elimination system permit to feedlots shall be issued for a term of ten years. A feedlot with a permit under this subdivision is required to be in compliance with agency rules. A facility or operation change may require a permit modification if required under agency rules.

Subd. 9. **Future costs of wastewater treatment; update of 1995 report.** The commissioner shall, by January 15, 1998, and each even-numbered year thereafter, provide the chairs of the house of representatives and senate committees with primary jurisdiction over the agency's budget with the following information:

(1) an updated list of all wastewater treatment upgrade and construction projects the agency has identified to meet existing and proposed water quality standards and regulations;

(2) an estimate of the total costs associated with the projects listed in clause (1), and the projects' priority ranking under Minnesota Rules, chapter 7077. The costs of projects necessary to meet existing standards must be identified separately from the costs of projects necessary to meet proposed standards;

(3) the commissioner's best estimate, developed in consultation with the commissioner of employment and economic development and affected permittees, of the increase in sewer service rates to the residents in the municipalities required to construct the projects listed in clause (1) resulting from the cost of these projects; and

(4) a list of existing and proposed state water quality standards which are more stringent than is necessary to comply with federal law, either because the standard has no applicable federal water quality criteria, or because the standard is more stringent than the applicable federal water quality criteria.

Subd. 10. **Pollutant loading offset.** (a) The Pollution Control Agency may issue or amend permits to authorize pollutant discharges to a receiving water and may authorize reductions in loading from other sources to the same receiving water, if together the changes achieve a net decrease in the pollutant loading to the receiving water. A point source participating in a water quality offset authorized by this subdivision must have pollutant load reduction requirements for the traded pollutants based on water quality based effluent limits or wasteload allocations in place prior to the offset. The pollutant load reduction requirements in place prior to the offset must meet the requirements of this chapter and Minnesota Rules, parts 7050.0150, subpart 8; 7053.0205; and 7053.0215, including, but not limited to, requirements related to pollutant form, spatial loading, and temporal loading. The agency must require significant offset ratios for offsets between permitted sources and nonpermitted sources and must demonstrate how nonpermitted source offset credits make progress toward ensuring attainment of water quality standards. The agreement of a source to participate in an offset is voluntary. The agency shall track the pollutant offsets or "trades" implemented under this subdivision.

(b) The legislature intends this subdivision to confirm and clarify the authority of the Pollution Control Agency to issue the authorized permits under prior law. The subdivision must not be construed as a legislative interpretation within the meaning of section 645.16, clause (8), or otherwise as the legislature's intent that the agency did not have authority to issue such a permit under prior law.

Subd. 11. **Aquatic application of pesticides.** (a) The agency may issue under requirement of the federal government national pollutant discharge elimination system permits for pesticide applications for the following designated use patterns:

(1) mosquitoes and other flying insect pests;

(2) forest canopy pests;

(3) aquatic nuisance animals; and

(4) vegetative pests and algae.

If the federal government no longer requires a permit for a designated use pattern, the agency must immediately terminate the permit. The agency shall not require permits for aquatic pesticide applications other than those designated use patterns required by the federal government.

(b) The agency shall not regulate or require permits for the terrestrial application of pesticides or any other pesticide related permit except as provided in paragraph (a).

History: *1945 c 395 s 3; 1969 c 9 s 21; 1969 c 931 s 6; 1973 c 374 s 7-9; 1973 c 412 s 12; 1976 c 76 s 1; 1979 c 147 s 1; 1984 c 597 s 41; 1985 c 248 s 70; 1Sp1985 c 13 s 229; 1986 c 444; 1987 c 186 s 15; 1989 c 335 art 1 s 127; art 4 s 33; 1992 c 601 s 2; 1993 c 87 s 1; 1993 c 186 s 8; 1996 c 437 s 9,10; 1996 c 462 s 38; 1997 c 216 s 93; 2000 c 370 s 1; 1Sp2001 c 2 s 120; 2003 c 128 art 1 s 120,121; 1Sp2003 c 4 s 1; 2006 c 251 s 10; 2009 c 37 art 1 s 37; 2009 c 109 s 14; 2011 c 107 s 79; 2012 c 150 art 1 s 4; 2014 c 237 s 4,5*

THE USE OF THE TIERED AQUATIC USE (TALU) FRAMEWORK TO DESIGNATE BENEFICIAL LIFE USES FOR DRAINAGE DITCHES AND ALTERED WATERCOURSES

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Minnesota Pollution Control Agency

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Executive Summary

The proposed adoption of Tiered Aquatic Life Use (TALU) designations to better protect aquatic life in Minnesota lakes and streams raises several questions about legal authority and the application of TALU designations to certain waterbodies such as drainage ditches and altered watercourses. This paper answers the following questions:

- What are TALU standards?
- What federal and state legal authority supports creating TALU standards?
- If adopted in Minnesota, what waterbodies can TALU standards cover?
- How do other states apply TALU?
- How do federal Clean Water Act (CWA) agricultural exemptions interact with state-adopted TALU standards?

The TALU framework establishes water quality standards (WQS) with tiers based on distinctions in aquatic life. TALU standards achieve the CWA goal of protecting the biological integrity of our nation's waters. By delineating tiers based on a waterbody's potential ability to support aquatic life, TALU standards offer a refined and practical approach to achieving water quality goals.

Both the CWA and Minnesota statutes authorize Minnesota to adopt WQS including TALU standards. The Minnesota Pollution Control Agency (MPCA) is responsible for implementing the Clean Water Act goal of protecting the quality of Minnesota's waters, including their chemical, physical, and biological integrity.

Minnesota's WQS apply to all waters within the scope of the Minnesota statutory definition of "waters of the State." Minnesota proposes to apply TALU designations to "waters of the State" to protect Class 2 aquatic life beneficial uses. Other states, such as Ohio, successfully incorporated TALU standards into their water quality standards by also applying TALU to all "waters of the State."

Minnesota's proposed TALU standards would apply to drainage ditches and altered watercourses because they fall within Minnesota's definition of "waters of the State." The CWA exempts some agricultural activities from CWA requirements. However, the CWA does not constrain a state's statutory authority to define "waters of the State" for that state's application of WQS. Minnesota has long applied a broad definition of "waters of the State" and expects those waters, including drainage ditches, to support aquatic life and recreation. The TALU framework will assign more specific aquatic life beneficial uses that best reflect the aquatic life each waterbody is capable of supporting.

I. Introduction

A. Document Purpose

Minnesota regularly reviews and revises its water quality standards (WQS) as required by the Clean Water Act (CWA)[1] and federal rules.[2] Minnesota proposes to revise its water quality standards to incorporate tiered aquatic life use (TALU) designations. A TALU framework improves the protection of aquatic life, such as fish and invertebrates (e.g., insects, crayfish, mussels), by grouping rivers and streams into "tiers." These tiers are based on the types of fish and invertebrates expected in healthy rivers and streams of each tier. The incorporation of TALU tiers into WQS allows for more customized management of streams for the protection of fish and invertebrates.

This paper provides information on the legal authority to incorporate a TALU framework into state WQS, and explores how other states use TALU designations. The paper also discusses how the TALU framework applies to various waterbodies, such as drainage ditches and altered watercourses, and reviews the scope of the CWA as it relates to drainage ditches[3] and altered watercourses.[4] Finally, the paper considers the application of the TALU framework in Minnesota.

While adopting the TALU framework also has technical, cultural, and political implications, this paper does not explore those aspects.

[1] 33 U.S.C. § 1251 et seq. (2011).

[2] 33 U.S.C. § 1313(c) (2011); 40 C.F.R. § 131.20 (2010).

[3] There are a number of definitions and interpretations of what constitutes a drainage ditch. Except when the term is used in the Minnesota context, this paper uses the term "drainage ditch" to mean any human-made or human-modified watercourse designed and used to move or remove water from one location to another. It includes not only artificially created watercourses but also otherwise natural watercourses that have been artificially manipulated or modified. When discussing Minnesota law, this paper uses terms as they are defined in Minnesota law. Minnesota drainage law defines a ditch as "an open channel to conduct the flow of water." MINN. STAT. § 103E.005(8) (2014). "Drainage systems" is another term used both in an informal manner and in a legal context. Informally, drainage systems are generally comprised of structures on private property (e.g., swales, underground tile drainage systems) which move water into larger structures (e.g., public drainage ditches), and which ultimately discharge into lakes and streams. Minnesota drainage law supplies a specific legal definition for a drainage system which hinges on the creation of the drainage system by a legally established drainage authority: "'Drainage system' means a system of ditch or tile, or both, to drain property, including laterals, improvements, and improvements of outlets, established and constructed by a drainage authority. 'Drainage system' includes the improvement of a natural waterway used in the construction of a drainage system and any part of a flood control plan proposed by the United States or its agencies in the drainage system." MINN. STAT. § 103E.005 (2014).

[4] Minnesota water law provides specific statutory definitions for the terms "altered natural watercourse," "artificial watercourse," and "natural watercourse." Those definitions are: "'Altered natural watercourse' means a former natural watercourse that has been affected by artificial changes to straighten, deepen, narrow, or widen the original channel;" "'Artificial watercourse' means a watercourse artificially constructed by human beings where a natural watercourse was not previously located;" and "'Natural watercourse' means a natural channel that has definable beds and banks capable of conducting confined runoff from adjacent land." MINN. STAT. § 103G.005 (2014).

B. Introduction to TALU

The TALU framework is a method of classifying rivers and streams based on the fish and invertebrate assemblages expected to live in healthy rivers and streams.[5] The framework uses a tool authorized in Minnesota law called the index of biological integrity (IBI)[6] to measure the health of fish and invertebrate communities in streams. Biologists collect fish and invertebrates from a stream and count the number of each fish or invertebrate species. These counts are converted into an IBI score, which is then compared to reference IBI scores from streams of the same type with healthy fish and invertebrate assemblages.

A low IBI score indicates a compromised stream where the biological health, or biological integrity, of the stream is low.[7] A high IBI score indicates a healthy stream where the biological integrity of the stream is high.[8] An IBI score below Minnesota's aquatic life use threshold or biological criterion means that a stream is not meeting minimum state water quality standards. All waters of the state – including drainage ditches and altered watercourses – that support or may support fish and other aquatic life are assigned to beneficial use Class 2 unless otherwise designated.[9] Class 2 standards protect water quality to support the aquatic life in the water and for recreation uses.[10]

The aquatic life potential for streams, as expressed in IBI scores, form the basis for tiered Class 2 uses. The proposed TALU framework divides streams into categories, or tiers: Exceptional, General, and Modified uses.[11] Exceptional use streams are high quality waters with fish and invertebrate assemblages at or near undisturbed conditions.[12] General use streams are waters with the ability to support fish and invertebrate assemblages that meet minimum goals.[13] Modified use streams are waters with legally altered habitat that prevents fish and invertebrate assemblages from meeting minimum goals.[14] Each

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[5] *See* U.S. ENVTL. PROT. AGENCY, CASE STUDIES- SETTING ECOLOGICALLY-BASED WATER QUALITY GOALS OHIO'S TIERED AQUATIC LIFE USE DESIGNATIONS TURN 20 YEARS OLD (2013) [hereinafter EPA CASE STUDIES]; U.S. ENVTL. PROT. AGENCY, FRAMEWORK FOR IMPLEMENTATION OF TIERED AQUATIC LIFE USES IN CONNECTICUT (2007); BOUCHARD JR., R. WILLIAM, ET AL., *A NOVEL APPROACH FOR THE DEVELOPMENT OF TIERED USE BIOLOGICAL CRITERIA FOR RIVERS AND STREAMS IN AN ECOLOGICALLY DIVERSE LANDSCAPE*, 188 ENVIRONMENTAL MONITORING AND ASSESSMENT, 196 (FEB. 27, 2016).

[6] For over a decade, MINN. R. 7050.0150(6) (2013) has authorized the use of IBIs "In evaluating whether the narrative standards in subpart 3, which prohibit serious impairment of the normal fisheries and lower aquatic biota upon which they are dependent and the use thereof, material alteration of the species composition, material degradation of stream beds, and the prevention or hindrance of the propagation and migration of fish and other biota normally present, are being met, the commissioner will consider all readily available and reliable data and information for the following factors of use impairment…" MINN. R. 7050.0150(4)(L) (2013) defines IBI. ("'Index of biological integrity' or 'IBI' means an index developed by measuring attributes of an aquatic community that change in quantifiable and predictable ways in response to hum disturbance, representing the health of that community.")

[7] *See* EPA CASE STUDIES, *supra* note 5.

[8] *Ibid.*

[9] MINN. R. 7050.0140(3); MINN. R. 7050.0430 (2013).

[10] MINN. R. 7050.0140(3).

[11] MINN. POLLUTION CONTROL AGENCY, TIERED AQUATIC LIFE USE (TALU) FRAMEWORK (2015).

[12] *Ibid.*

[13] *Ibid.*

[14] *Ibid.*

tier has specific expectations and biological criteria for fish and invertebrates.[15] These tiers do not represent a wholesale change, but instead refine the expected uses.

II. Federal and State Water Quality Regulatory Framework

Federal and state law work hand in hand to protect water quality in a scheme known as "cooperative federalism." As the opening section of the CWA declares, "[i]t is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources . . . ."[16] The MPCA's responsibilities under the CWA include setting WQS to meet the CWA goals for each Minnesota waterbody. MPCA works closely with the EPA to ensure that Minnesota complies with the CWA's provisions to protect and enhance water quality. Furthermore, MPCA is charged with enforcing Minnesota's state laws and rules that protect water quality, including administering state water quality permits.[17]

This section reviews the scope of both the CWA's authority directing the restoration and maintenance of the chemical, physical, and biological integrity of waters and Minnesota's independent legal authority to protect water quality. This section also analyzes the extent of the CWA's federal coverage under recent court decisions and the EPA final rule on the definition of "waters of the United States."

A. Minnesota Has Independent Legal Authority for State Water Quality Standards and the CWA Requires Their Development

Minnesota has both federal and independent state authority to create WQS for its "waters of the State." Minnesota was at the forefront of water protection in the 20th century, pioneering new policies to advance water quality and inspiring action at the federal level.[18] In 1963, the Minnesota legislature mandated the adoption of water quality standards for all public waters in the state.[19] Because Minnesota has a broadly inclusive definition of public waters, the water quality standards that were adopted affected many of the state's watercourses.[20] Congress followed Minnesota's lead two years later, led by Congressman Blatnik of Minnesota's Eighth Congressional District. Congress amended the Federal Water Pollution Control Act of 1948 to require states to develop ambient WQS through a process closely mirroring the process that Minnesota used in adopting its WQS.[21] In 1967, the Minnesota legislature recognized the need for an agency to administer the growing number of pollution

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[15] *Ibid.*

[16] 33 U.S.C. § 1251(b) (2011).

[17] The Minnesota Supreme Court recognized the state's power to enforce state discharge permits along with federal NPDES permits in MPCA v. U.S. Steel Corp, noting that the CWA places "primary responsibility" for controlling and preventing water pollution with the states. Minnesota Pollution Control Agency v. U.S. Steel Corp., 307 Minn. 374, 382–83 (Minn. 1976).

[18] *See* SHERRY A. ENZLER ET AL., *FINDING A PATH TO SUSTAINABLE WATER MANAGEMENT: WHERE WE'VE BEEN, WHERE WE NEED TO GO*, 39 WM. MITCHELL L. REV. 842, 890–92 (2013).

[19] *Id*. at 892.

[20] *Ibid.*

[21] *Id*. at 892–93.

control laws and created the Minnesota Pollution Control Agency (MPCA).[22] This move was particularly forward-thinking because the federal CWA was passed five years later in 1972.[23] Minnesota quickly incorporated the CWA's National Pollutant Discharge Elimination System (NPDES) permitting scheme into state statutes after receiving program authorization, and has done similarly with subsequent CWA amendments.[24]

The CWA applies to waters that fall within the definition of "waters of the United States," over which Congress can exert power as discussed below in part II.B. States can include more waters, but cannot include fewer waters, than the federal scope.[25] The CWA serves as a floor for protection of the nation's waters, but does not preempt states from imposing greater protections on other waterbodies.[26]

Under the CWA, each state is required to adopt WQS applicable to its "waters of the state."[27] The scope of coverage varies from state to state.[28] Minnesota defines its "waters of the state" broadly.[29] Minnesota law charges MPCA with the duty and power to, "establish and alter such reasonable pollution standards for *any waters of the state* in relation to the public use to which they are or may be put as it shall deem necessary . . . "[30]

Minnesota WQS are located in Minnesota Rules ch. 7050, Waters of the State.[31] The purpose of the standards is to "protect and maintain surface waters in a condition which allows for the maintenance of all existing beneficial uses."[32] The standards are exceeded in a particular water body when pollution levels cause the loss of beneficial uses for that water body.[33] The standards in chapter 7050 protect all waters of the State and apply to point and nonpoint sources of pollution and to the physical alteration of wetlands.[34] Rule 7050.0140 divides waters of the State into seven classifications based on the suitability of that water for specific beneficial uses.[35] Minn. Rules 7050.0221-7050.0227 contain narrative and numeric standards for each class and subclass of water body.[36] For the purposes

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[22] *Id*. at 893.

[23] *Id.* at 893–94.

[24] *Id*. at 894–95.

[25] *Ibid.*

[26] 33 U.S.C. § 1370.

[27] 40 C.F.R. § 131.10.

[28] *See* R. Steven Brown & Christopher Woodhouse*, The States' Definitions of "Waters of the State*,*"* ENVTL. COUNCIL OF THE STATES (2009).

[29] MINN. STAT. § 115.01(22) (2014) ("'Waters of the state' means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems and all other bodies or accumulations of water, surface or underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state or any portion thereof.")

[30] MINN. STAT. § 115.03(c) (2014) (emphasis added).

[31] Additional standards that apply to the Lake Superior Basin only are in MINN. R. 7052 (2013).

[32] MINN. R. 7050.0150(1) (2013).

[33] *Ibid.*

[34] MINN. R. 7050.0110 (2013).

[35] MINN. R. 7050.0140 (2013) (noting that beneficial use classifications are: Class 1- domestic consumption; Class 2 - aquatic life and recreation; Class 3 - industrial consumption; Class 4 - agriculture and wildlife; Class 5 - aesthetic enjoyment and navigation; Class 6 - other uses and protection of border waters; Class 7- limited resource values waters).

[36] *E.g.,* MINN. R. 7050.0222(2) (2013) (explaining that Class 2A waters, protected for aquatic life and recreation, must meet both narrative and numeric standards). The narrative standard states "the quality of Class 2A surface

of TALU, the most important beneficial use classification is the Class 2 use protections for aquatic life and recreation.[37]

1. Requirements in Implementing the CWA

Under EPA regulations, WQS are a required part of state implementation of the CWA.[38] State WQS describe the goals and acceptable conditions for a state's water resources. The WQS adopted by states must include three elements:

1. **Designated beneficial uses that establish water quality goals.**[39] Each state program divides the waters of its state into classes. Each class is defined by designated beneficial uses, such as the protection of aquatic life and recreation. The designated beneficial uses must be protected and restored under a state program. Most surface waters in Minnesota are protected for aquatic life and recreation uses as part of a Class 2 beneficial use classification.[40]

2. **Chemical, physical, and biological water quality criteria that define the minimum conditions necessary to protect the designated beneficial uses.**[41] Water quality criteria identify the conditions needed to support the designated beneficial use, and are either narrative descriptions or numeric limits for specific pollutants or properties (e.g., benzene or pH).[42]

3. **Antidegradation requirements that protect high water quality.**[43] Antidegradation requirements ensure that existing uses are maintained and that high quality waters and waters of outstanding resource value are protected from degradation.

Together these three elements form the core of state WQS.

Though the EPA is responsible for implementing the CWA, the CWA requires states to develop and administer WQS.[44] Oversight of state programs and approval of state water quality standards resides with the EPA.[45]

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waters shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water." *Id.* This narrative is followed by a long list of numeric standards for a wide range of pollutants, including aluminum, chloride, cyanide, DDT, and mercury. *Id.*

[37] *Id.*

[38] 40 C.F.R. § 131.1 (2011).

[39] 40 C.F.R. § 131.10 (2011).

[40] MINN. R. 7050.0140(3) (2013) (establishing Class 2 waters); MINN. R. 7050.0430 (classifying waters as Class 2B unless otherwise listed); 7050.0470 (2013) (listing surface waters with other classifications).

[41] 40 C.F.R. § 131.11 (2011).

[42] The minimum conditions necessary to protect designated beneficial uses are referred to in federal law as "water quality criteria" and referred to in Minnesota law as "standards."

[43] 40 C.F.R. § 131.12 (2011).

[44] 40 C.F.R. § 131.4 (2011).

[45] 40 C.F.R. § 131.5 (2011).

2. The Clean Water Act Authorizes Use of TALU Through its Goal of Protecting the Biological Integrity of Waters

The CWA's objective is to "restore and maintain the chemical, physical, and *biological integrity* of the Nation's waters."[46] The CWA further provides that the goal of the act is developing water quality standards that provide protection for fish, shellfish, and wildlife, and that those standards are achieved wherever attainable.[47] The CWA goals and policies direct the restoration and maintenance of not only water chemistry but also the physical and biological integrity of our waters. The TALU framework helps to accomplish these goals and policies.

The EPA, as the CWA implementing agency, interprets the CWA objective to mean that WQS must be protective and restorative of the full spectrum of aquatic life that can be supported in a particular waterbody.[48] Aquatic life broadly includes algae, macro-invertebrates, and shellfish, as well as fish species.[49] EPA expressly authorizes creation of sub-categories of uses, including differentiating between aquatic life that a waterbody can support.[50] At least three states have formally adopted the TALU framework in developing aspects of their WQS.[51] States that adopt WQS using the TALU framework must submit the WQS to EPA for approval.[52]

Through its protection of biological integrity, the CWA authorizes states to use biological assessment for all three elements of WQS: designating aquatic life uses; establishing criteria to protect the designated uses; and protecting high water quality through antidegradation requirements. A TALU framework creates a structure of designated aquatic life uses, then defines classes and subclasses of water bodies in accordance with their ecological attributes.[53] TALU-based biological criteria, or "biocriteria," are numeric values or narrative descriptions established to protect aquatic life in waterbodies that are classified based on attainable biological condition.[54] Through these tools, the TALU framework ensures that states protect the biological integrity of waters and ensures that each stream has standards appropriate to its potential to support aquatic life.

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[46] 33 U.S.C. § 1251(a) (2011) (emphasis added).

[47] *Ibid.*

[48] 40 C.F.R. § 131.10(a); BIOLOGICAL CRITERIA: NATIONAL PROGRAM GUIDANCE FOR SURFACE WATERS, U.S. ENVTL. PROT. AGENCY (1990) at vii, 3; *see* U.S. ENVTL. PROT. AGENCY, NATIONAL RECOMMENDED WATER QUALITY CRITERIA (2014) ("Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States."); U.S. ENVTL. PROT. AGENCY, WATER QUALITY CRITERIA (2014), available at http://water.epa.gov/scitech/swguidance/standards/criteria ("Criteria are developed for the protection of *aquatic life* as well as for *human health*.").

[49] *See* U.S. ENVTL. PROT. AGENCY, WATER QUALITY STANDARDS HANDBOOK, Table 2-1 (2014).

[50] 40 C.F.R. § 131.10(c).

[51] FRAMEWORK AND IMPLEMENTATION RECOMMENDATIONS FOR TIERED AQUATIC LIFE USES: MINNESOTA RIVERS AND STREAMS, Midwest Biodiversity Institute (2011) at 13; U.S. ENVTL. PROT. AGENCY, DRAFT USE OF BIOLOGICAL INFORMATION TO BETTER DEFINE DESIGNATED AQUATIC LIFE USES IN STATE AND TRIBAL WATER QUALITY STANDARDS: TIERED AQUATIC LIFE USES, 15 (2005).

[52] 33 U.S.C. § 1313 (2011); 40 C.F.R. § 131 (2011).

[53] FRAMEWORK AND IMPLEMENTATION RECOMMENDATIONS FOR TIERED AQUATIC LIFE USES: MINNESOTA RIVERS AND STREAMS, Midwest Biodiversity Institute (2011) at xix.

[54] *Id.* at 1.

B. Federal and State Jurisdiction

This section examines the differences in the authority between federal and state regulatory authority. While the Clean Water Act is limited to waters over which Congress has authority and legislation, states received power at their creation over all the waters within their jurisdiction. As shown below, this divergence is significant for the applicability of water quality standards.

1. Federal Jurisdiction Is Limited to "Waters of the United States"

Federal jurisdiction over waters is limited by the Commerce Clause of the U.S. Constitution, which provides that Congress shall have the power to regulate commerce among states.[55] The clause provides federal jurisdiction for waters that may affect interstate commerce, including navigation. Navigable waters, in turn, are defined in the CWA as "waters of the United States, including the territorial seas."[56] The phrase "waters of the United States" is not further defined by law, leaving the term open to interpretation. Federal courts and EPA have both attempted to define the term.

a. Tests for Determining Whether a Waterbody Is Covered as a "Water of the United States"

On its face, the word "navigable" could be read to have its plain meaning—those waters that are navigable-in-fact, commonly called "traditional" navigable waters. The CWA gave "navigable" a different definition when it defined "navigable waters" as "waters of the United States." The U.S. Supreme Court examined this in 1985 , when it commented that by adopting this definition, the term "navigable" in the Act has only "limited import."[57] The court found the term "waters of the United States" must include more than just waters that are navigable-in-fact. In 2006, the U.S. Supreme Court examined the issue again in *Rapanos*.[58] The *Rapanos* decision was a plurality decision, in which there is no majority opinion. Two tests for CWA jurisdiction resulted: Justice Kennedy's "significant nexus" test and Justice Scalia's plurality test.

Justice Kennedy's significant nexus test states that a waterbody is covered under the CWA when it, "either alone or in combination with similarly situated lands in the region, significantly affect[s] the chemical, physical, and biological integrity of other covered waters more readily understood as 'navigable.'"[59] In other words, the water must have a "significant nexus" with waters that are navigable-in-fact. Justice Scalia's plurality test states a water[60] must be adjacent to a channel of a water of the United States and there must be a *continuous surface connection* to the adjacent water.[61] The dissent in *Rapanos* took the view that CWA jurisdiction should be found when a water feature meets *either* the significant nexus test or the plurality test. While the *Rapanos* case was a wetlands case, its applicability

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[55] U.S. CONST. Art. 1, § 8, cl. 3.

[56] 33 U.S.C. § 1362 (2011).

[57] United States v. Riverside Bayview Homes, Inc., 474 U.S. 121, 133 (1985).

[58] Rapanos v. United States, 547 U.S. 715 (2006).

[59] *Id.* at 755, 780 (Kennedy, J., concurring).

[60] The decision's plurality clarified that the term "waters of the United States" includes, "only those relatively permanent, standing or continuously flowing bodies of water 'forming geographic features' that are described in ordinary parlance as 'streams[,] . . . oceans, rivers, [and] lakes.'" *Id.* at 739 (plurality opinion).

[61] *Id.* at 742 ("[O]nly those wetlands with a continuous surface connection to bodies that are 'waters of the United States' in their own right, so that there is no clear demarcation between the two, are 'adjacent' to such waters and covered by the Act.").

is not limited to just wetlands. The *Rapanos* tests can be applied to make determinations about CWA jurisdiction over virtually any type of water feature.[62]

The significant nexus test appears more inclusive, but each test includes at least one type of water or discharge the others do not. For example, the significant nexus test supported CWA jurisdiction over waterbodies without a continuous surface connection to "waters of the United States," which the plurality test does not.[63] The plurality test covers small, continuous discharges into "waters of the United States," even if they did not significantly impact the "waters of the United States." The significant nexus test might not cover those discharges.[64]

Lower courts remain split on which test is the controlling test for finding jurisdiction. Some of the federal circuit courts have adopted the view that the significant nexus test is the only proper test, some have decided there is jurisdiction under either test, and some have remained silent.[65] No federal circuit court has used the plurality test without also allowing use of the significant nexus test, so the significant nexus test has become the most widely used part of the decision; at the same time, the plurality test is still relied upon in some areas and circumstances.[66] The Eighth Circuit, which includes Minnesota, decided that CWA jurisdiction exists if a water feature can meet either the significant nexus test or the plurality test.[67]

b. EPA's "Waters of the United States" Rule

Because of uncertainty over the scope of "waters of the United States,"[68] the EPA attempted to clarify the definition in 2002. That definition change was found invalid and the definition reverted back to a 1973 rule.[69]

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[62] *See, e.g.*, Envtl. Prot. Info. Ctr. v. Pac. Lumber Co., 469 F. Supp. 2d 803, 823 (N.D. Cal. 2007) (using the significant nexus test to analyze the jurisdictionality of a tributary of a navigable water).

[63] *See, e.g.*, N. California River Watch v. City of Healdsburg, 496 F.3d 993, 1000 (9th Cir. 2007) ("There is accordingly a substantial nexus between the Basalt Pond and covered waters sufficient to confer jurisdiction under the Act pursuant to Justice Kennedy's substantial nexus test. With respect to the physical effect on the River, there is an actual surface connection between Basalt Pond and the Russian River *when the River overflows the levee and the two bodies of water commingle*. There is also an underground hydraulic connection between the two bodies, so a change in the water level in one immediately affects the water level in the other." (emphasis added) (citations omitted)); *see also* Rapanos v. United States, 547 U.S. 715, 782 (2006) (Kennedy, J., concurring) (explaining that when the government seeks to regulate wetlands adjacent to navigable-in-fact waters, it may rely on adjacency to establish jurisdiction, but when the government seeks to regulate waterbodies adjacent to nonnavigable tributaries, it must establish a significant nexus on a case-by-case basis).

[64] United States v. Johnson, 467 F.3d 56, 64 (1st Cir. 2006) ("[I]n cases where there is a small surface water connection to a stream or brook, the plurality's jurisdictional test would be satisfied, but Justice Kennedy's balancing of interests might militate against finding a significant nexus.").

[65] *See* United States v. Donovan, 661 F.3d 174 (3d Cir. 2011); Precon Dev. Corp. v. U.S. Army Corps of Engineers, 633 F.3d 278 (4th Cir. 2011); United States v. Cundiff, 555 F.3d 200 (6th Cir. 2009); United States v. Bailey, 571 F.3d 791 (8th Cir. 2009); United States v. Lucas, 516 F.3d 316 (5th Cir. 2008); United States v. Robinson, 521 F.3d 1319 (11th Cir. 2008); Northern California River Watch v. City of Healdsburg, 496 F.3d 993 (9th Cir. 2007); United States v. Johnson, 467 F.3d 56 (1st Cir. 2006); United States v. Gerke, 464 F.3d 723 (7th Cir. 2006).

[66] *Id.*

[67] United States v. Bailey, 571 F.3d 791 (8th Cir. 2009).

[68] *See generally* United States v. Riverside Bayview Homes, Inc., 474 U.S. 121, 133 (1985) ("In adopting this definition of 'navigable waters,' Congress evidently intended to repudiate limits that had been placed on federal regulation by earlier water pollution control statutes and to exercise its powers under the Commerce Clause to

After the decision in *Rapanos*, uncertainty remained over what could be considered a "water of the United States" and thus regulated under the CWA.[70] In response to the confusion, on April 21, 2014, the EPA proposed a rule to clarify the definition.[71] EPA announced on May 27, 2015, that it would adopt a final rule.[72] The rule defines with more specificity which waterbodies are covered under the definition and which are not. It incorporates Justice Kennedy's significant nexus test for determining the jurisdictional status of certain types of waters that require a case-by-case assessment of jurisdiction.[73] It also sets out a comprehensive list of definitions to clarify which waters can be considered "waters of the United States" without going through a case-by-case jurisdictional analysis.[74] The rule defines in regulation the terms "adjacent," "neighboring," "tributary," and "significant nexus."[75] A list of waters excluded from the definition of "waters of the United States," over which the agencies have generally not asserted CWA jurisdiction, is also expressed in the rule.[76]

EPA makes clear in the preamble to the rule and supporting documentation that ditches meeting the definition of "tributary" are considered waters of the United States.[77] The rule's technical support document notes that numerous courts of appeals have held ditches to be "tributaries," even if they are human-made structures.[78] EPA relies on a peer-reviewed scientific report that describes the significance of smaller waterbodies, including ditches, on the chemical, physical, and biological integrity of waters that are navigable-in-fact.[79]

In combination with the list of excluded waters, the EPA definitions clarify how close physically or how closely hydrologically connected to traditional "navigable waters" a waterbody must be to receive coverage under the CWA. The rule defines "waters of the United States"[80] and explains that a significant nexus exists if a water, "either alone or in combination with other similarly situated waters in the region significantly affect[] the chemical, physical, or biological integrity of" a navigable, interstate, or territorial water.[81] In an effort to reduce administrative burdens, the rule also includes both

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regulate at least some waters that would not be deemed 'navigable' under the classical understanding of that term." (citations omitted)).

[69] Am. Petroleum Inst. v. Johnson, 541 F. Supp. 2d 165 (D.D.C. 2008) ("EPA failed to offer a rational explanation for its new definition of "navigable waters," rendering it arbitrary and capricious under the APA . . . Court concludes that EPA's promulgation of the new definition of "navigable waters" violated the APA."); 73 Fed. Reg. 71941-01.

[70] *E.g.,* Adrienne Froelich Sponberg, *US Struggles to Clear Up Confusion Left in the Wake of* Rapanos, AM. INST. BIOLOGICAL SCIENCES (2009).

[71] Definition of "Waters of the United States" Under the Clean Water Act, 79 Fed. Reg. 22,187 (proposed Apr. 21, 2014) (to be codified at 33 C.F.R. pt. 328).

[72] "Clean Water Rule Protects Streams and Wetlands Critical to Public Health, Communities, and Economy," U.S. EPA, May 27, 2015, available at http://yosemite.epa.gov/opa/admpress.nsf/0/62295CDDD6C6B45685257E52004FAC97.

[73] 80 Fed. Reg. 37.058 (June 29, 2015).

[74] *Id.* at 37,104.

[75] *Id.* at 37,104-37,105.

[76] *Id.* at 37,105.

[77] *Id.* at 37,069; TECHNICAL SUPPORT DOCUMENT FOR THE CLEAN WATER RULE, U.S. EPA (May 27, 2015) at 257.

[78] TECHNICAL SUPPORT DOCUMENT FOR THE CLEAN WATER RULE, U.S. EPA (May 27, 2015) at 73.

[79] 80 Fed. Reg. 37,062.

[80] *See Id.* at 37,105 (defining neighboring based on distances from waters determined to be waters of the United States).

[81] 80 Fed. Reg. 37,106.

tributaries and adjacent waters in its definition of "waters of the United States."[82] Together, adjacent waters and tributaries include waters located within the floodplain of a "water of the United States." Certain waters are excluded, including ditches that were not originally tributaries and that have ephemeral or intermittent flow.[83] Also excluded are gullies, rills, and ephemeral features that are not within the definition of tributary.[84]

The "waters of the United States" rule authorizes federal CWA authority over traditional navigable waters, their tributaries, and their adjacent waters, even if they are human-made or altered. It adopts Justice Kennedy's significant nexus test for finding jurisdiction over waters that may significantly affect those traditional navigable waters.[85] Waters not clearly within those categories or excluded require a case-by-case analysis to determine whether the relationship is significant.[86] In other words, a waterbody may fall within CWA federal jurisdiction if it has a close enough relationship with a "water of the United States" to justify a federal interest.

(Note: As of the date of this document, the "waters of the United States" rule is the subject of multiple legal challenges. Because of pending litigation, the Sixth Circuit Court of Appeals issued a nationwide stay on implementation.[87] In response to this stay, EPA and the U.S. Army Corp of Engineers are implementing the definitions as they were prior to August 27, 2015.[88])

c. Clean Water Act Exemptions

Section 404(f) of the CWA provides exemptions from permitting requirements in certain circumstances.[89] Permitting exemptions provided by Section 404(f) are narrow and limited in scope to: "normal" farming and agricultural practices that include minor drainage;[90] and the construction or maintenance of farm irrigation ditches or drainage ditches.[91] Under these exemptions, farmers can maintain existing drainage ditches, but they cannot construct new ditches or "improve" existing ditches without a permit.[92] To qualify as exempt from permitting requirements, the activities must be "part of an established, ongoing operation" and avoid conversion of wetlands to dry land.[93]

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[82] *Id.* at 37,080.

[83] *Id.* at 37,097.

[84] *Id.* at 37,098.

[85] *Id.* at 37,060.

[86] *Id.* at 37,086.

[87] State of Ohio, et al. v. U.S. Army Corps of Eng'rs, et al., ORDER OF STAY (6th Cir. Oct. 9, 2015)

[88] MEMORANDUM REGARDING ADMINISTRATION OF CLEAN WATER PROGRAMS IN LIGHT OF THE STAY OF THE CLEAN WATER RULE; IMPROVING TRANSPARENCY AND STRENGTHENING COORDINATION, U.S.EPA, U.S.ACE, (Nov. 16, 2015).

[89] 33 U.S.C. § 1344(f) (2011).

[90] 33 U.S.C. § 1344(f)(1)(A) (2011).

[91] 33 U.S.C. § 1344(f)(1)(C) (2011).

[92] *Id.*; Benjamin H. Grumbles, *Section 404(f) of the Clean Water Act: Trench Warfare over Maintenance of Agricultural Drainage Ditches*, 17 WM. MITCHELL L. REV. 1021, 1025 (1991).

[93] Section 404(f) provides:

Non-prohibited discharge of dredged or fill material.

(1) Except as provided in paragraph (2) of this subsection, the discharge of dredged or fill material—

(A) *from normal farming, silviculture, and ranching activities such as plowing, seeding, cultivating, minor drainage*, harvesting for the production of food, fiber, and forest products, or upland soil and water conservation practices;

Beyond the permitted discharge of dredge and fill material under section 404, the CWA does not authorize any other contaminant to enter a water of the United States (including drainage ditches that meet the newly-revised definition). In addition, the CWA does not exempt a drainage ditch from meeting or achieving applicable water quality standards. Thus, whether the water is in a constructed drainage ditch or a natural watercourse, the quality of the water is within the jurisdiction of the CWA. Importantly, section 404 of the CWA, with the exception of the dredge or fill material specified, does not exempt the water being transported in a drainage ditch from any other water quality requirements of the Act.

Permits are not required for agricultural stormwater or irrigation return flow, as these are excluded from the definition of point sources that triggers the permit requirement.[94]

Even considering its exclusions and exemptions, the federal definition of "waters of the United States" includes certain drainage ditches and altered watercourses that have a significant nexus to traditional navigable waters. The requirement to demonstrate a nexus to interstate commerce ultimately limits federal coverage over some smaller tributaries. This requirement distinguishes federal jurisdiction from that of the states.

2. State Jurisdiction

Where federal law is restricted to waters with a nexus to interstate activity, state interests have no such restriction. States, including Minnesota, have sought to protect public health, recreation, and aquatic life by exercising control over a broader scope of waters.

a. Minnesota's Waters of the State

When Minnesota was granted statehood in 1858, it obtained title to all waters and beds underlying those waters that were commercially navigable at the time of Minnesota's entry to the Union.[95] In 1897, Minnesota adopted its state definition of "waters of the State" for purposes of state

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(B) *for the purpose of maintenance, including emergency reconstruction* of recently damaged parts, of currently serviceable structures such as dikes, dams, levees, groins, riprap, breakwaters, causeways, and bridge abutments or approaches, and transportation structures;

(C*) for the purpose of* construction or maintenance of farm or stock ponds or irrigation ditches, or the *maintenance of drainage ditches*;

(D) for the purpose of construction of temporary sedimentation basins on a construction site which does not include placement of fill material into the navigable waters;

(E) for the purpose of construction or maintenance of farm roads or forest roads, or temporary roads for moving mining equipment, where such roads are constructed and maintained, in accordance with best management practices, to assure that flow and circulation patterns and chemical and biological characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized;

(F) resulting from any activity with respect to which a State has an approved program under section 1288(b)(4) of this title which meets the requirements of subparagraphs (B) and (C) of such section, *is not prohibited by or otherwise subject to regulation under this section or section 1311(a) or 1342* of this title (except for effluent standards or prohibitions under section 1317 of this title.

33 U.S.C. § 1344(f) (2011) (emphasis added); *see also* Larry R. Bianucci & Rew R. Goodenow, *The Impact of Section 404 of the Clean Water Act on Agricultural Land Use*, 10 UCLA J. ENVTL. L. & POL'Y 41, 52–54 (1991).

[94] 33 U.S.C. § 1362 (2011).

[95] Daniel Ball, 77 U.S. 557 (1870). *E.g.,* Martin v. Waddell, 41 U.S. 367, 410 (1842).

regulatory authority and public use.[96] The current statutory definition of "waters of the State" determines whether a water body is subject to pollution control and other forms of regulation, and it encompasses nearly every waterbody type in the state:

> *'Waters of the state' means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems and all other bodies or accumulations of water, surface or underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state or any portion thereof.*[97]

Since the early days of statehood, Minnesota has considered a waterbody regulated if it is used "for the ordinary purposes of life," including recreation, domestic, and agricultural use.[98] Minnesota's definition of "waters of the State" represents a much broader scope of regulation than the federal test's focus on commercial navigation,[99] demonstrating how Minnesota views its abundant water bodies as a fundamental public good.[100]

b. Minnesota Authority to Adopt WQS for Waters of the State

Minnesota has the authority, independent from federal law, to regulate any body of water included in its definition of "waters of the State."[101] In assigning powers and duties to MPCA, the legislature authorized MPCA to protect "any of the waters of the state."[102] State law does not have the exemptions for upland ditches contained in the EPA's rule, and instead expressly includes drainage systems as a water of the state.[103] It follows that Minnesota has authority to regulate drainage ditches,[104] even if they may be exempt under federal law.[105] The Clean Water Act does not limit state

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96 MINN. DEPT. NAT. RES., HISTORY OF WATER PROTECTION (2015).

97 1963 MINN. LAWS ch. 874, sec. 2 (codified at MINN. STAT. § 115.01(22) (2014)).

98 Nelson v. De Long, 213 Minn. 425, 431, 7 N.W. 2d 342, 346 (Minn. 1942).

99 PPL Montana, LLC v. Montana, 132 S. Ct. 1215, 1233 (2012) ("Navigability must be assessed as of the time of statehood, and it concerns the river's usefulness for "'trade and travel'") (internal citation omitted).

100 Lamprey v. Metcalf, 53 N.W. 1139, 1143 (Minn. 1893) (noting that many of the state's lakes cannot or will not be used for commercial navigation, but are used by the public for many purposes, including recreation, domestic, and agricultural, and that handing over all these lakes to private ownership, "under any old or narrow test of navigability, would be a great wrong upon the public for all time, the extent of which cannot, perhaps, be now even anticipated").

101 MINN. STAT. §§ 115.03, 115.01(22) (2014).

102 MINN. STAT. § 115.03(a) (2014).

103 *See* MINN. STAT. § 115.01(22) (2014).

104 *Id.* For examples of other cases that apply state water quality standards to drainage ditches, *see Matter of McGowan*, 533 So.2d 999, 1003 (La. Ct. App. 1988) ("Unless specifically excepted by permit, the Louisiana Water Quality Standards apply to intermittent streams which may be dry during dry weather conditions, and to man-made water courses such as ditches or canals created specifically for drainage or water conveyance. Louisiana Water Quality Standards §§ V and VIII."); State v. Jones, 101 So.3d 1083, 1104 (La. App. 3 Cir. Nov. 7, 2012) ("Based on the fact that PDC initially obtained permits, an indication that the discharge was into the waters of the State, and the finding in McGowan that drainage ditches are waters of the State, the State proved beyond a reasonable doubt that PDC discharged into the waters of the State from the North Mamou and East Side Subdivisions without a valid permit."); Morgan v. Natural Res. & Envtl. Prot. Cabinet, 6 S.W.3d 833, 839–42 (Ky. Ct. App. 1999) ("The drainage ditch does carry water during periods of rainfall and thereafter and intermittently constitutes a body of water with defined channels which . . . makes the discharge into this

authority to enforce standards more broadly: it specifically allows states to "adopt or enforce (A) *any standard or limitation* respecting discharges of pollutants, or (B) *any requirement* respecting control or abatement of pollution."[106] Therefore, even if certain drainage ditches are exempt from regulation under federal standards, Minnesota can assign WQS.

Minnesota drainage law, codified in chapter 103G, defines a subset of public waters relevant for drainage work. The chapter differentiates between "waters of the state" and "public waters," which require additional analysis to identify.[107] Categorization as a public water can trigger additional restrictions on drainage, use, and modification.[108] Thus, despite apparent similarity in terms, "public waters" and "waters of the state" address different categories of waterbodies. None of MPCA's duties or regulations for water quality standards are limited to the subset making up "public waters."

The only restriction on adoption of WQS is a federal prohibition against removing existing uses.[109] Any use that existed on or after November 28, 1975, cannot be removed under the Clean Water Act.[110] EPA regulations require existing uses to be maintained even if they are not included in WQS.[111]

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drainage ditch a discharge into 'waters of the Commonwealth' for purposes of the water quality program. . . . We believe this issue was thoroughly analyzed by both the hearing officer and the trial court. Further, the case law analyzed by the court was pertinent to the issue, and thoughtfully reviewed. We find no error in the trial court's resolution of the matter. We are mindful of KRS Chapter 224' s broad prohibition against water pollution, or the threat thereof, and believe the interpretation of both the statute and the regulations in this case serves the purpose of the water quality standards set out in KRS Chapter 224: 'to safeguard from pollution the uncontaminated waters of the Commonwealth; to prevent the creation of any new pollution of the waters of the Commonwealth; and to abate any existing pollution.'").

[105] *See* Spannaus v. Hoffman, 543 F.2d 1198, 1208 (Ct. App. Minn. 1976) ("[This language] prevents the Amendments from pre-empting the states from adopting higher pollution control standards than those established under the Amendments."); In re Cities of Annandale, 731 N.W. 2d 502, 510 (Minn. 2007) ("Water quality standards, which are promulgated by the states, generally establish the desired condition of a body of water. The CWA requires states to establish water quality standards sufficient to 'protect the public health or welfare, enhance the quality of water and serve the purposes of this chapter.' A state's water quality standards must be established 'taking into consideration [each body of water's] use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes, and also taking into consideration their use and value for navigation.' Water quality standards are 'aimed at translating the broad goals of the CWA into waterbody-specific objectives.'" (internal citations omitted)).

[106] 33 U.S.C. § 1370 (2012); *See* supra Part II.A.

[107] MINN. STAT. § 103G.005 subd. 15.

[108] MINN. STAT. §§ 103G.205, 103G.211, 103G.215.

[109] 40 C.F.R. § 131.10(g).

[110] *Ibid.*; 40 C.F.R. § 131.3(e).

[111] 40 C.F.R. § 131.3(e). Where higher uses are being attained than current designations require, those uses must be incorporated into the designation. 40 C.F.R. § 131.10(i).

III. Case Studies

Minnesota is not the first state to propose adding the TALU framework to its WQS. Three states have already transitioned from a single aquatic life use system to a tiered aquatic life use system in their WQS. Ohio's TALU approach is most similar to the approach Minnesota is proposing to adopt. Ohio adopted its TALU framework in 1978 and revised its approach in 1990.[112] While Illinois does not have a TALU framework in its WQS,[113] like Minnesota, Illinois defines waters of the state broadly to include drainage ditches.

A. Ohio's Water Quality Standards Incorporating TALU

Over the past three decades, Ohio has become a leading state in implementing TALU in its water quality standards. Ohio has incorporated the TALU framework into all of its WQS, which apply to all waters falling under its definition of "waters of the State."[114] Ohio law required the Ohio Environmental Protection Agency (OEPA) director to adopt WQS,[115] including WQS for the protection of fish and aquatic life.[116] TALU was adopted in Ohio Admin. Code 3745-1, pursuant to the Ohio Administrative Procedure Act.[117] The TALU framework includes exceptional warmwater, warmwater, limited warmwater, modified warmwater, seasonal salmonid, coldwater, trout, and native coldwater uses.[118]

Ohio law gave the OEPA the responsibility for ensuring that TALU standards are met.[119] . To carry out this responsibility OEPA issues NPDES permits for wastewater discharges and reviews plans for stream and ditch modifications under its CWA section 401/404 program to ensure that its WQS are met.[120] OEPA can reject any stream or ditch modification plan that does not achieve or protect its WQS.[121] At this time there are no reported cases of plans for drainage ditches being rejected for failure to meet water quality standards.

Ohio applies a TALU framework to drainage ditches.[122] Ohio's TALU framework applies to drainage ditches through its state definition of "waters of the State," which includes:

> *[A]ll streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and other bodies or accumulations of water, surface and underground, natural or artificial, regardless of the depth of the strata in which underground water is located, that are situated wholly or partly within, or border upon, this state, or are within its jurisdiction, except those private waters that do*

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[112] *See* EPA CASE STUDIES, *supra* note 5.

[113] ILL. ADMIN CODE TIT. 35, § 303.201 (2015).

[114] *See* OHIO ADMIN. CODE 3745-1 (2014) (outlining Ohio's water quality standards, including state TALU requirements).

[115] *Ibid.*

[116] OHIO REV. CODE ANN. § 6111.041 (West 2014).

[117] OHIO ADMIN. CODE 3745-1 (2010).

[118] *Id.* at 3745-1-07 (2010).

[119] OHIO REV. CODE ANN. § 6111.041 (West 2014).

[120] OHIO REV. CODE ANN. § 6111.

[121] OHIO REV. CODE ANN. § 6101.13

[122] OHIO ADMIN. CODE 3745-1 07(B)(1)(D) for modified warmwater habitat; OHIO ADMIN. CODE 3745-1-07(B)(1)(G)(II) for limited resource water.

> *not combine or effect a junction with natural surface or underground waters.*[123]

Like Minnesota, Ohio explicitly includes "drainage systems" in the statutory definition of "waters of the State," and no exemption from state water quality standards exists for water in drainage systems. Importantly, the definition includes natural and artificially created waterbodies just as Minnesota's does. Ohio's Class C primary contact recreation waters designation specifically contemplates and covers historically channelized watercourses.[124] Ditches are assigned aquatic life use designations.[125]

Ohio's TALU and bioassessment approaches have been upheld by the courts. Ohio's bioassessment and TALU approaches were reviewed and upheld by the Ohio Supreme Court in *Northeast Ohio Regional Sewer District v. Shank*.[126] In *Shank*, the use of biological data to determine and designate a use to a particular stretch of a river's WQS was questioned. The Ohio Supreme Court upheld the Warm Water Habitat (WWH) use designation, even though the river was not then in attainment, based on the biological data that indicated that the use could be attained in the river. *Shank* was the first clear decision that TALU designations were valid where biological data indicated that the water could support a higher use than it currently met. The *Shank* decision has not been challenged in any reported case in Ohio. Several subsequent Ohio cases have also upheld the application of TALU WQS.[127]

EPA Region 5 has reviewed and approved Ohio's TALU framework in its WQS.[128] In review of Ohio's TALU program, EPA Region 5 found it "fostered an effective and balanced approach to protecting, restoring, and enhancing the quality of Ohio streams and rivers."[129] EPA Region 5 also recognized that one of the key benefits to Ohio's TALU program is that the TALU framework provides appropriate and effective levels of protection for Ohio streams and rivers and sets reasonably attainable goals for the majority of Ohio's streams and rivers.[130] Furthermore, Ohio's TALU framework also recognizes that the CWA goal may not be feasibly attainable in the short-term in certain streams, and to deal with this obstacle it provides, "a reasonable and scientifically sound methodology for identifying waters where CWA goals are not immediately attainable."[131]

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[123] OHIO REV. CODE ANN. § 6111.01(H) (West 2014).

[124] OHIO ADMIN. CODE 3745-1-07 (B)(4)(b)(iii) (2010).

[125] *See* OHIO ADMIN. CODE 3745-1-08 Table 8-1 (2014).

[126] 567 N.E.2d 993 (Ohio 1991).

[127] *E.g.,* Columbus & Franklin Cty. Metro. Park Dist. v. Shank, 600 N.E.2d 1042, n.12 (Ohio 1992) ("Exceptional warmwater habitats were defined in Ohio Adm. Code 3645-1-07(A)(3) as follows: 'Exceptional warmwater'—these are waters capable of supporting exceptional or unusual populations of warmwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis.").

[128] "Case Studies- Setting Ecologically-Based Water Quality Goals Ohio's Tiered Aquatic Life Use Designations Turn 20 Years Old," last visited May 7, 2015, U.S. EPA, available at http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/aquaticlifeohio.cfm.

[129] U.S. ENVTL. PROT. AGENCY, MBI TECHNICAL REPORT: ASSESSMENT OF THE BIOLOGICAL ASSEMBLAGE CONDITION OF SMALL HEADWATER STREAMS IN OHIO SUBJECT TO THE PROPOSED GENERAL USE PROVISIONS OF OHIO'S WATER QUALITY STANDARDS (2011).

[130] *Id.*

[131] *Id.*

B. Illinois's Water Quality Standards

Illinois applies its WQS to waters of the state including drainage ditches. Though Illinois has not adopted a TALU framework, the potential benefits of the TALU system are particularly highlighted as applied to drainage ditches because drainage ditches are also within the scope of Illinois's definition of "waters of the State."[132] Since Illinois does not have a tiered approach, drainage ditches are held to the same general aquatic life standard as other waterbodies. There are no statutory provisions exempting water in drainage ditches from Illinois water quality standards.

The default designation in Illinois is general use unless otherwise classified, similar to Minnesota's approach. These general use standards provide no exception for waterbodies like some drainage ditches or other accumulations of water that are unable to attain the general use standards.[133] Unlike Ohio's TALU WQS, Illinois's WQS are the same for all waters, regardless of the variable levels of aquatic life or habitat that exist amongst features like ditches, lakes, rivers, and streams. Under a TALU approach, all "waters of the State" have WQS that are appropriately tiered to the aquatic life and habitat present in those waterbodies.

The Appellate Court of Illinois considered in *People v. A.J. Davinroy Contractors*[134] whether the discharge of raw sewage water into a drainage ditch violated the Illinois Environmental Protection Act's water pollution prevention measures, which prohibit discharges of pollutants to "waters of the State" without an NPDES permit.[135] The pollution to the drainage ditch was found to be pollution to the waters of the state of Illinois.[136] The court held that there was no exception granted by law to this discharge based on historic use and that the lack of alternative way to transport wastewater was not a defense.[137]

This case provides another example of a state regulating water quality pursuant to the CWA by using its own definition of "waters of the State." *Davinroy* demonstrates that states are free to regulate water quality pursuant to the CWA by using state law which may be more stringent than the federal law. The application of TALU standards to drainage ditches throughout the state of Minnesota is consistent with this principle.

C. Case Study Conclusions

Both Ohio and Illinois treat drainage ditches as "waters of the State," which are subject to WQS, and neither state creates a distinction between drainage ditches—whether artificially created or human altered—and other water bodies for purposes of coverage under state WQS. While both states categorize drainage ditches and altered watercourses as waterbodies falling within the scope of their WQS regulations, Ohio and Illinois treat ditches and altered watercourses differently under their

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[132] Illinois defines "waters of the State" as, "all accumulations of water, surface and underground, natural, and artificial, public and private, or parts thereof, which are wholly or partially within, flow through, or border upon the State of Illinois . . ." *Id.* at § 301.440.

[133] *Id.*

[134] 249 Ill.App.3d 788 (App. Ct. Ill. 1993).

[135] *Id.* at 789, 792–93 ("In summary, the State proved that Davinroy had discharged raw sewage, a contaminant, into Goose Lake Ditch . . . and that the sewage had caused unacceptable levels of pollution in the ditch past Davinroy's work sites that were not in existence in the ditch upstream of the work site.").

[136] *Id.* at 792.

[137] *Id.* at 794.

respective WQS schemes. Ohio's TALU approach allows the state to set appropriately tiered WQS based on the waterbody's ability to support aquatic life or habitat. Unlike Ohio, Illinois does not provide different WQS for ditches than for other waterbodies with different capacities for supporting aquatic life. Similar to Ohio's approach, the State of Minnesota, consistent with the CWA, and pursuant to the state definition of "waters of the State," has the right to regulate those drainage ditches that may be excluded under the federal standards under a TALU approach.

IV. Perceived Conflict with Drainage Law in Minnesota

Drainage law has a long history in Minnesota, dating back to the 19th century and regularly revised since then.[138] This history has often led to conflict with environmental interests due to differing purposes between the two. Where the intent of drainage is often to remove water from the landscape, environmental regulation is designed to restore the ecological function of the landscape.[139] Minnesota's drainage law does not address the relationship to the state's WQS, making only passing references to water quality considerations. This conflict has led to differing views on the application of WQS to drainage systems in Minnesota.

This section addresses the history of Minnesota laws that deal with agricultural drainage systems and past application of WQS to drainage ditches. This section also analyzes when WQS can be assigned to drainage ditches and altered watercourses.

A. History of Minnesota's Drainage Laws and Governmental Roles

In 1883, the Minnesota legislature laid the foundation for drainage law by authorizing county commissioners to construct public drainage ditches in the name of public health, welfare, and convenience.[140] In 1955, the state legislature enacted the Minnesota Watershed Act (MWA), allowing for the creation of watershed districts to address the negative consequences of drainage, among other things.[141] The MWA updated the drainage project approval process to be more thorough and comprehensive. The law was later updated to require county drainage authorities to consider conservation practices when developing drainage projects.[142] Further restrictions were placed on drainage of wetlands in 1991 with the passage of the Wetland Conservation Act.[143]

Minnesota's drainage laws have the primary purpose of removing excess water from land to allow agricultural activities.[144] Modern agriculture in Minnesota is substantially aided by these artificial drainage systems.[145] Minnesota's drainage law has an important role in the protection of Minnesota's

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[138] MINN. ASSOC. OF WATERSHED DISTS., INC., UNDERSTANDING MINNESOTA PUBLIC DRAINAGE LAW 2 (2002).

[139] *In re* Improvement of Murray Cnty. Ditch No. 34, 615 N.W. 2d 40, 45 (Minn. 2000) (citing Town of Vivian v. Town of Dunbar, 162 Minn. 491, 492 (Minn. 1925)); 33 U.S.C. § 1251(a)(2).

[140] Mark J. Hanson, *Damming Agricultural Drainage: The Effect of Wetland Preservation and Federal Regulation on Agricultural Drainage in Minnesota*, 13 WM. MITCHELL L. REV. 135, 144–47 (1987).

[141] MINN. BD. OF WATER & SOIL RES., ONE WATERSHED, ONE PLAN: AN EVOLUTION OF WATER PLANNING IN MINNESOTA 2 (2014).

[142] Tom Lutgen, MINN. DEPT. OF NATURAL RES., Minnesota Public Drainage Manual 2.4 (September 1991).

[143] 1991 MINN. LAWS ch. 354.

[144] *In re* Improvement of Murray Cnty. Ditch No. 34, 615 N.W. 2d 40, 45 (Minn. 2000) (citing Town of Vivian v. Town of Dunbar, 162 Minn. 491, 492 (Minn. 1925)).

[145] *Id.*

water resources due to the prevalence of agricultural drainage networks in the state. A large area of Minnesota crop land includes a network of drain tiles that remove water from the soil profile in crop fields and discharge into surface drainage ditches or other conveyances.[146] The current system of drainage has a significant impact on the state's water quality.[147] Under Minnesota drainage law, the drainage authority must now consider alternative measures to protect or improve water quality.[148] Additionally, the law restricts drainage and other actions affecting public waters that are regulated by the Department of Natural Resources.[149]

Agencies at all levels of government play a role in the development and approval of drainage systems in the state. At the federal level, any drainage project that discharges dredged or fill into waters of the United States requires a CWA §404 permit;[150] other discharges into waters of the United States require an NPDES permit.[151]

At the state level, the Minnesota Board of Water and Soil Resources (BWSR), Department of Natural Resources (DNR), and MPCA all play a role in drainage projects. BWSR partners with local organizations and private landowners to implement soil and water conservation programs, among other functions.[152] The DNR has the primary responsibility for managing public waters, including state-designated wetlands.[153] Any project that affects public waters, including drainage projects, must obtain a public waters work permit from the DNR.[154] Furthermore, as the state agency charged with enforcing and maintaining WQS, MPCA is involved in permitting for projects that may adversely affect a water body's compliance with standards.[155]

Local governmental bodies involved in drainage projects include soil and water conservation districts, counties, watershed districts, and joint drainage authorities. Soil and water conservation districts were created by statute to work with BWSR to implement best management practices and improve the conservation aspects of various water management projects.[156] When a drainage system is located within one county, the county board of commissioners has authority over the project.[157] These

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146 Gerald Von Korff & Tim Sime, *Water Project and Drainage Law in Minnesota*, Minnesota CLE, Foreword 3 (2010).

147 Dave Wall, NITROGEN IN MINNESOTA SURFACE WATERS, Minnesota Pollution Control Agency, at 5-9 (2013).

148 MINN. STAT. § 103E.015(2)(v) (2014).

149 MINN. STAT. § 103E.011 (2014).

150 33 U.S.C. § 1344 (2012).

151 33 U.S.C. § 1342 (2012).

152 *See About the Board of Water and Soil Resources*, MINN. BD. OF WATER & SOIL RES. (last visited Mar. 6, 2015), http://www.bwsr.state.mn.us/aboutbwsr/index.html.

153 ENVTL. LAW INST., STATE WETLAND PROTECTION: STATUS, TRENDS & MODEL APPROACHES, APPENDIX: STATE PROFILES: MINNESOTA 3–4 (2008). Minnesota Statute defines "public waters" very broadly, and the definition includes, but is not limited to, water bodies that are considered "navigable." Public waters include "natural and altered watercourses with a total drainage area greater than two square miles," designated trout streams, "meandered lakes," and "public waters wetlands." *See* MINN. STAT. § 103G.005(15) (2014).

154 MINN. STAT. § 103G.245.

155 *See* MINN. POLLUTION CONTROL AGENCY, WETLANDS IN MINNESOTA (2013). The CWA also requires that any federal permit or license authorizing discharge into the navigable waters must be certified by the state permitting agency (MPCA). 33 U.S.C. § 1341; *see* MINN. BD. OF WATER & SOIL RES., WETLANDS REGULATION IN MINNESOTA (2003).

156 MINN. STAT. § 103C.331 (2014).

157 MINN. STAT. §§ 103E.011, 103E.005 subd. 9.

are the most common systems in Minnesota.[158] When a drainage system crosses county lines, a joint county drainage authority has authority over the system, comprised of representatives from each county in which the system is located.[159] Watershed districts generally define their boundaries based on the watershed in which the district resides.[160] Because of this, jurisdictional authority over drainage projects is often transferred from the county to the watershed district.[161] Watershed districts perform a variety of functions, including monitoring water quality and groundwater levels, managing drainage systems, and providing for wildlife and recreation opportunities.[162]

The lengthy history of drainage law and variety of government entities has created a intricate structure of oversight and regulation. State WQS and the CWA add another layer of complexity to address state and federal water quality goals.

B. History of WQS Applied to Drainage Systems

Although state drainage law does not address WQS, many of these surface drainage ditches fall within the definition of "waters of the state" and state water quality standards have long applied to drainage ditches. When the Minnesota legislature first authorized the adoption of water quality standards in 1963, the standards were to apply to "waters of the state."[163] The definition of "waters of the state" at the time included drainage systems.[164] Since then, Minnesota has taken a number of actions to apply WQS to drainage ditches and altered natural watercourses.

1. Assessed and Impaired Waters

Drainage ditches and altered watercourses have been assessed by MPCA as waters of the state using the existing WQS. As noted in Table 1, some drainage ditches have been included on the state's 303(d) Impaired Waters list. The listing process requires assessment of the water applying the state's WQS, public notice and comment with the opportunity to challenge a listing, and review and approval by the EPA.[165] While some ditches have been listed as impaired, other ditches across the state have been found to support Class 2B aquatic life standards.[166]

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158 MINN. ASSOC. OF WATERSHED DISTS., INC., UNDERSTANDING MINNESOTA PUBLIC DRAINAGE LAW 4 (2002).

159 Minn. Stat. § 103E.235.

160 MINN. STAT. § 103D.205.

161 MINN. STAT. § 103D.701; *see* MINN. ASSOC. OF WATERSHED DISTS., INC., UNDERSTANDING MINNESOTA PUBLIC DRAINAGE LAW 4 (2002).

162 *What Do Watershed Districts Do?*, MINN. ASSOC. OF WATERSHED DISTS., INC. (last visited Mar. 6, 2015), http://www.mnwatershed.org/ (follow "What is a Watershed District" link on left, then follow "What Do Watershed Districts Do?" link in center of page).

163 1963 MINN. LAWS. Ch. 874, sec. 6.

164 *Id.*at sec. 2.

165 *See* 33 U.S.C. § 1313(d); 40 C.F.R. § 130.7.

166 *See*, *e.g.*, MINNESOTA RIVER BASIN ASSESSMENT OF STREAM WATER QUALITY, MPCA, Apr. 2014, available at http://www.pca.state.mn.us/index.php/view-document.html?gid=15228 (listing County Ditch 34, AUID 07020003-526, and County Ditch 12, AUID 07020004-552, as class 2 waters fully supporting aquatic life use).

Table 1. Ditches and altered watercourses listed as impaired for aquatic life.[167]

Reach name	Year listed	Basin [168]	River ID#	Impairment(s)
County Ditch 6	2002	UMiss	07010202-521	Macroinvertebrates & fish
Crooked Lake Ditch	2006	UMiss	07010202-552	Macroinvertebrates
Getchell Creek (County Ditch 2)	2006	UMiss	07010202-562	Macroinvertebrates
Unnamed ditch	2012	UMiss	07010202-666	Macroinvertebrates & fish
Jewitts Creek (County Ditch 19, 18, 17)	2002	UMiss	07010204-585	Macroinvertebrates & fish
County Ditch 17	2006	UMiss	07010206-557	Macroinvertebrates
Unnamed ditch	2006	UMiss	07010206-594	Macroinvertebrates
Judicial Ditch 10 (Wood Lake Creek)	2006	MnR	07020004-546	Fish
Judicial Ditch 8	2004	MnR	07020005-546	Fish
County Ditch 15	2012	MnR	07020005-690	Fish
Judicial Ditch 1	2006	MnR	07020010-548	Fish
County Ditch 6	2012	MnR	07020011-522	Macroinvertebrates
County Ditch 12	2012	MnR	07020011-558	Macroinvertebrates & fish
County Ditch 19	2012	MnR	07020011-608	Macroinvertebrates & fish
County Ditch 15-2	2012	MnR	07020011-609	Macroinvertebrates & fish
Mud Creek (County Ditch 10)	2002	StC	07030004-566	Macroinvertebrates & fish
Mud Creek (County Ditch 10)	2002	StC	07030004-567	Fish
Unnamed ditch	2012	StC	07030005-723	Fish

2. Alterations of Public Waters

Drainage law requires permits for certain alterations to public waters.[169] As discussed above in section II.B.2, "public waters" are a subset of "waters of the state." The legal alteration of a public water can change the ability of the waterbody to support aquatic life. Physical modification to a waterway or changes in flow could change the potential for the system to meet the WQS goals for aquatic life. As a result, public waters that were subject to ditching or other action may not be capable of meeting the Class 2B aquatic life standard.

Minnesota provides a method called a Use Attainability Analysis to reclassify waters that are not capable of meeting the Class 2B water quality standards.[170] These waters are reclassified as "limited resource value waters" without the same protections as Class 2 waters.[171] Each reclassification must be codified in rule.[172]

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[167] Minnesota Final 2012 Impaired Waters List, May 31, 2013.

[168] "UMiss" is Upper Mississippi Basin; "MnR" is Minnesota River Basin; "StC" is St. Croix Basin

[169] MINN. STAT. § 103G.245.

[170] MINN. R. 7050.0140 subp. 8.

[171] *Ibid.*

[172] MINN. R. 7050.0430, 7050.0470.

C. Authority to Apply WQS to Drainage Ditches and Altered Watercourses in Minnesota

As discussed above in part II.A, Minnesota has independent authority to set WQS and did so before the adoption of the Clean Water Act. As shown in II.B.2, Minnesota defines "waters of the state" broadly to include drainage systems and applies its WQS to waters of the state regardless of whether the waterbody is natural or artificial.

Standards to protect aquatic life (like those proposed in the TALU framework) can apply to drainage ditches because they are considered "waters of the State" – and in fact such standards already apply, as discussed in section IV.B. Minnesota applies its existing WQS to waters of the state without limitation. Existing rules apply the standards "to all waters of the state, both surface and underground."[173] Use classifications apply to "all surface waters"[174] and each use is assigned to any "waters of the state" capable of supporting the use.[175] The state assessment of water quality standards is based on "pollution of the waters of the state" to the extent that attainable uses are not met.[176] Even where a watercourse is "significantly altered by human activity and the effect is essentially irreversible," certain water quality standards apply.[177] Existing aquatic life protections presume that every waterbody can support aquatic life unless otherwise demonstrated.[178]

It is possible to meet both sets of requirements in drainage ditches and altered watercourses. Minnesota law requires that wherever possible, a law must be interpreted to avoid direct conflict with other statutes.[179] Though drainage law addresses different requirements from WQS, there is no direct conflict between the two chapters of law, and drainage law acknowledges the need to address multiple purposes – including water quality – before undertaking drainage work.[180] Where two laws are found to be irreconcilable, the later law controls.[181] Drainage law has a long history predating the environmental controls in the Clean Water Act and associated amendments. The broad definition of "waters of the state" and broad applicability of WQS encompass many drainage ditches that are publicly owned. Many of these drainage ditches are subject to the state's general aquatic life standards, despite lacking the physical characteristics to support such a degree of aquatic life.

The TALU framework will provide a set of goals that better reflects the ability of altered waters and ditches in the state to support some level of aquatic life. Currently, waters that will not support the full Class 2B aquatic life uses are either listed as impaired or reclassified as "limited use" (i.e., Class 7

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173 MINN. R. 7050.0110.

174 *Ibid.*

175 MINN. R. 7050.0140.

176 MINN. R. 7050.0150.

177 MINN. R. 7050.0140 subp. 8(A).

178 MINN. R. 7050.0430.

179 Minn. Stat. § 645.26 subd. 1 (2014); *see* Erickson v. Sunset Memorial Park Ass'n, 259 Minn. 532 (1961) ("A statute is to be construed, where reasonably possible, so as to avoid irreconcilable difference and conflict with another statute."); *see also* Atchison, Topeka, & Santa Fe Railway Co. v. Buell, 480 U.S. 557, 566–67 (1986) ("[A]bsent an intolerable conflict between the two statutes, we are unwilling to read the RLA as repealing any part of the FELA.").

180 MINN. STAT. § 103E.015 subd. 6.

181 MINN. STAT. § 645.26 subd. 4; *see* Barton v. Moore, 558 N.W.2d 746 (Minn. 1997) ("The rules of statutory construction provide that when provisions enacted at different sessions of the legislature are irreconcilable, those provisions enacted at a later session are controlling over earlier provisions.")); *see also* cases cited *supra* note 179.

water) waters indicating no aquatic life support in the waterbody.[182] Creating a "modified" TALU aquatic life tier allows a more accurate representation of the ability of these waters to support aquatic life. Waters currently in Class 7 may never be able to fully support a healthy aquatic community, but some might support a limited aquatic community. Many drainage ditches support, or can support, aquatic life between the limited Class 7 use and the CWA minimum goals. There is currently, however, no protective option for these waters. Waterbodies already achieving the aquatic life standards, as some altered watercourses do today, will be protected to the same degree they are now.[183]

In adopting the TALU framework, the state standards can more accurately reflect the circumstances of legally altered waterways to support aquatic ecosystems. The TALU framework does not require reversal of past legal alterations. Instead, it accounts for the habitat changes resulting from those legal alterations by applying the appropriate tier of aquatic life use. Rather than placing ditches and altered watercourses on the state's impaired waters list indefinitely because full aquatic life is not currently achievable, the framework identifies the highest achievable use. Any restoration targets will then reflect achievable goals.

V. Minnesota Has Authority to Apply TALU Standards to Drainage Ditches and Altered Watercourses

Like the application of TALU to all other waters falling within Minnesota's definition of "waters of the State," the application of TALU to drainage ditches will assign biological standards for drainage ditches at levels appropriate for the waterbody's capability to support aquatic life. The CWA authorizes the use of a TALU framework in the development of state WQS to protect the biological integrity of water.[184] While there are some limited exceptions in the CWA for drainage ditches, these exceptions do not apply for purposes of state WQS.

Minnesota's TALU framework will provide appropriately adjusted water quality standards for the purpose of protecting and maintaining the biological integrity of both Minnesota's "waters of the State" and the "waters of the United States."[185] TALU standards offer a practical approach to regulating water quality by offering different tiers of water quality standards based on a waterbody's ability to support aquatic life.[186] TALU standards will be applied to all waters falling under the definition of "waters of the State."[187] Minnesota has both independent legal authority and authority under the CWA to create TALU designations, and other states, such as Ohio, have already implemented TALU standards successfully.[188] Similar to those TALU standards in Ohio, the TALU system proposed in Minnesota will be applied to all waters encompassed in Minnesota's definition of "waters of the State."[189]

Though agricultural exemptions exist in the CWA, those exemptions do not prevent Minnesota from applying WQS to waters of the state.[190] Minnesota has both independent authority and authority

[182] *See* MINN. R. 7050.0140.

[183] The Clean Water Act does not allow removal of existing uses. *See* 40 C.F.R. § 131.10(g).

[184] 40 C.F.R. § 131.10(c).

[185] *See supra* Part I.B and II.A–B.

[186] *See supra* Part I.B.

[187] *See supra* Part II.B.

[188] *See supra* Part II.A. and III.A–C.

[189] *See supra* Part II.B., and III.A.

[190] *See supra* Part II.A-B, and IV.A–C.

from the CWA to apply standards to all waters within the definition of "waters of the State," including waters such as drainage ditches and altered watercourses.[191] As the agency responsible for protecting water quality, the MPCA has the legal authority to implement TALU designations for its WQS.[192]

[191] *See supra* Part II.A–B and IV.A–C.

[192] *See supra* Part II.A-B.

7050.0430 UNLISTED WATERS.

All surface waters of the state that are not listed in part 7050.0470 and that are not wetlands as defined in part 7050.0186, subpart 1a, are hereby classified as Class 2B, 3C, 4A, 4B, 5, and 6 waters.

Statutory Authority: *MS s 115.03; 115.44*

History: *9 SR 914; 12 SR 1810; 18 SR 2195; 32 SR 1699*

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ASSESSING THE TMDL APPROACH TO WATER QUALITY MANAGEMENT

Committee to Assess the Scientific Basis of the Total Maximum
Daily Load Approach to Water Pollution Reduction

Water Science and Technology Board
Division on Earth and Life Studies

National Research Council

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COMMITTEE TO ASSESS THE SCIENTIFIC BASIS OF THE TOTAL MAXIMUM DAILY LOAD APPROACH TO WATER POLLUTION REDUCTION

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Preface

The Total Maximum Daily Load (TMDL) program, initiated in the 1972 Clean Water Act, recently emerged as a foundation for the nation's efforts to meet state water quality standards. A "TMDL" refers to the "total maximum daily load" of a pollutant that achieves compliance with a water quality standard; the "TMDL process" refers to the plan to develop and implement the TMDL. Failure to meet water quality standards is a major concern nationwide; it is estimated that about 21,000 river segments, lakes, and estuaries have been identified by states as being in violation of one or more standards. To address this problem, the U. S. Environmental Protection Agency (EPA) proposed an ambitious timetable for states to develop TMDL plans that will result in attainment of water quality standards. Given the reduction in pollutant loading from point sources such as sewage treatment plants over the last 30 years, the successful implementation of most TMDLs will require controlling nonpoint source pollution.

These two features, the ambitious timetable and nonpoint source controls, are probably the two most controversial of many issues that have been raised by those who have questioned the TMDL program. Behind and intertwined with these basic policy issues are important questions concerning the adequacy of the science in support of TMDLs.

In the last year, the TMDL program has become one of the most discussed and debated environmental programs in the nation, primarily because of the drafting of final rules for the program. These rules follow several years of intense activity, including the formation of a Federal Advisory Committee devoted to this topic. In October 2000, Congress suspended EPA's implementation of these rules until further information could be gathered on several aspects of the program. In particular, Congress requested that the National Research Council (NRC) examine the scientific basis of the TMDL program. In recognition of the urgent need to address water quality standard violations, Congress established an aggressive schedule for completion of the study that allowed only four months from start to finish—unprecedented for most NRC studies. The eight-member committee, constituted in January 2001, immediately conducted its first meeting. This three-day meeting included two days devoted to public comments and a third day focused on internal committee discussions. The ensuing three months was a period of intense activity filled with correspondence, writing, and two additional committee meetings.

The difficult challenges facing EPA and the states in the implementation of the TMDL program were immediately apparent to the committee. Because the committee faced a congressionally mandated deadline, a number of issues important to some stakeholders were not addressed comprehensively. These include bed sediment issues, atmospheric deposition, translating narrative standards into numeric criteria, and a full review of existing water quality models. Nonetheless, the committee found that substantial improvements can be made in a number of areas to strengthen the scientific basis of the TMDL program. Also of importance, the committee identified several policy issues that are restricting the use of the best science in the TMDL program. We urge Congress, EPA, and the states to give thoughtful attention to the recommendations made throughout this report so that resources can be more efficiently used to improve water quality.

We greatly appreciate the assistance of Don Brady and Françoise Brasier of the EPA Office of Water for their assistance in initiating the study and organizing the first committee meeting. We are also grateful to those who spoke with and educated our committee, including congressional staff, EPA scientists, state representatives, and the many individuals and organizations that submitted comments to the committee.

The committee recognizes the vital role of Water Science and Technology Board (WSTB) director Stephen Parker in making this study possible. The extremely short time period for this study created an enormous challenge for NRC study director Laura Ehlers, who was able to juggle her many responsibilities to keep us focused and provide invaluable assistance in crafting the text. Finally, it is fair to say that this study owes most thanks to Leonard Shabman (Virginia Polytechnic Institute and State University) who was working in the WSTB office as a visiting scholar during the study. Dr. Shabman’s insight was invaluable; he added immensely to committee discussion and correspondence, and he played a key role in drafting the text and developing the recommendations.

More formally, the report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC’s Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The reviews and draft manuscripts remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their participation in the review of this report: Richard A. Conway, consultant; Paul L. Freedman, Limno-Tech, Inc.; Donald R. F. Harleman, Massachusetts Institute of Technology (retired); Robert M. Hirsch, U.S. Geological Survey; Judith L. Meyer, University of Georgia; Larry A. Roesner, Colorado State University; Robert V. Thomann, Manhattan University (retired); and Robert C. Ward, Colorado State University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Frank H. Stillinger, Princeton University, and D. Peter Loucks, Cornell University. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the NRC.

Kenneth H. Reckhow,
Chair

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APPENDICES

Executive Summary

Over the last 30 years, water quality management in the United States has been driven by the control of point sources of pollution and the use of effluent-based water quality standards. Under this paradigm, the quality of the nation's lakes, rivers, reservoirs, groundwater, and coastal waters has generally improved as wastewater treatment plants and industrial dischargers (point sources) have responded to regulations promulgated under authority of the 1972 Clean Water Act. These regulations have required dischargers to comply with effluent-based standards for criteria pollutants, as specified in National Pollutant Discharge Elimination System (NPDES) permits issued by the states and approved by the U.S. Environmental Protection Agency (EPA). Although successful, the NPDES program has not achieved the nation's water quality goals of "fishable and swimmable" waters largely because discharges from other unregulated nonpoint sources of pollution have not been as successfully controlled. Today, pollutants such as nutrients and sediment, which are often associated with nonpoint sources and were not considered criteria pollutants in the Clean Water Act, are jeopardizing water quality, as are habitat destruction, changes in flow regimes, and introduction of exotic species. This array of challenges has shifted the focus of water quality management from effluent-based to ambient-based water quality standards.

This is the context in which EPA is obligated to implement the Total Maximum Daily Load (TMDL) program, the objective of which is attainment of ambient water quality standards through the control of both point and nonpoint sources of pollution. Although the TMDL program originated from Section 303d of the Clean Water Act, it was largely overlooked during the 1970s and 1980s as states focused on bringing point sources of pollution into compliance with NPDES permits. Citizen lawsuits during the 1980s forced EPA to develop guidance for the TMDL program, which is now considered to be pivotal in securing the nation's water quality goals. Under TMDL regulations promulgated in 1992, EPA requires states to list waters that are not meeting water quality criteria set for specific designated uses. For each impaired water, the state must identify the amount by which point and nonpoint sources of pollution must be reduced in order for the waterbody to meet its stated water quality standards. Meeting these requirements, many of which have been imposed by court order or consent decree, has become the most pressing and significant regulatory water quality challenge for the states since passage of the Clean Water Act.

Given the most recent lists of impaired waters submitted to EPA, there are about 21,000 polluted river segments, lakes, and estuaries making up over 300,000 river and shore miles and 5 million lake acres. The number of TMDLs required for these impaired waters is greater than 40,000. Under the 1992 EPA guidance or the terms of lawsuit settlements, most states are required to meet an 8- to 13-year deadline for completion of TMDLs. Budget requirements for the program are staggering as well, with most states claiming that they do not have the personnel and financial resources necessary to assess the condition of their waters, to list waters on 303d, and to develop TMDLs. A March 2000 report of the General Accounting Office (GAO) highlighted the pervasive lack of data at the state level available to set water quality standards, to determine what waters are impaired, and to develop TMDLs.

Subsequent to the GAO report and following issuance by EPA of updated TMDL regulations, Congress requested that the National Research Council (NRC) assess the *scientific basis* of the TMDL program, including:

- the information required to identify sources of pollutant loadings and their respective contributions to water quality impairment,
- the information required to allocate reductions in pollutant loadings among sources,
- whether such information is available for use by the states and whether such information, if available, is reliable, and
- if such information is not available or is not reliable, what methodologies should be used to obtain such information.

Of concern to the nation's lawmakers was the paucity of data and information available to the states to comply with program requirements and meet water quality standards. Indeed, as the TMDL program proceeds, the best available science, especially with regard to nonpoint sources of pollution, will be needed for regulatory and nonregulatory actions to be equitable and effective. Report recommendations are targeted (1) at those issues where science can and should make a significant contribution and (2) at barriers (regulatory and otherwise) to the use of science in the TMDL program. Chapters 2, 3, and 4 discuss the information required to set water quality standards, to list waters as impaired, and to develop TMDLs (including the identification of pollution sources), while Chapter 5 discusses the role of science in allocating pollutant loading among sources. Chapters 3 and 4 go into considerable detail about the monitoring, modeling, and statistical analysis methods needed to collect data and convert it to information, and to assess and reduce uncertainty.

This report represents the consensus opinion of the eight-member NRC committee assembled to complete this task. The committee met three times during a three-month period and heard the testimony of over 40 interested organizations and stakeholder groups. The NRC committee feels that the data and science have progressed sufficiently over the past 35 years to support the nation's return to ambient-based water quality management. Given reasonable expectations for data availability and the inevitable limits on our conceptual understanding of complex systems, statements about the science behind water quality management must be made with acknowledgment of uncertainties. The committee has concluded that there are creative ways to accommodate this uncertainty while moving forward in addressing the nation's water quality challenges. These broad conclusions are elaborated upon below.

TMDL PROGRAM GOALS

The TMDL program should focus first and foremost on improving the condition of waterbodies as measured by attainment of designated uses. Work on meeting the strict time demands within the budget constraints cited by most states has focused on administrative outcomes as measures of success for the TMDL program. However, the success of the nation's premier water quality program should not be measured by the number of TMDL plans completed and approved, nor by the number of NPDES permits issued or cost share dollars spent. Success is achieved when the condition of a waterbody supports its designated use. Adequate monitoring and assessment must be used to improve the listing of impaired waterbodies and to characterize the effectiveness of the actions taken to meet the designated use.

The program should encompass all stressors, both pollutants and pollution, that determine the condition of the waterbody[1]. Proposed regulations may limit the applicability of the program to only those water quality problems caused by chemical and physical pollutants. Given their demonstrated effectiveness, activities that can overcome the effects of "pollution" and bring about waterbody restoration—such as habitat restoration and channel modification—should not be excluded from consideration during TMDL plan implementation.

Scientific uncertainty is a reality within all water quality programs, including the TMDL program, that cannot be entirely eliminated. The states and EPA should move forward with decision-making and implementation of the TMDL program in the face of this uncertainty while making substantial efforts to reduce uncertainty. Securing designated uses is limited not only by a focus on administrative rather than water quality outcomes in the TMDL process, but also by unreasonable expectations for predictive certainty among regulators, affected sources, and stakeholders.

CHANGES TO THE TMDL PROCESS

This report focuses on how scientific data and information should be used within the TMDL program. Science plays a crucial role in the standards-setting process, in the decision to add waters to the 303d list, in the development of the TMDL plan, and in the allocation of

[1] This refers to the legal definitions of "pollutant" and "pollution," which are given in Box 1-1 of Chapter 1.

pollutant loads among various sources (although its importance relative to the role of policy decisions varies). The committee finds that although the state of the science is sufficient to develop TMDLs to meet ambient water quality goals in many situations, programmatic issues substantially hinder the use of the best available science. Thus, the following changes in the TMDL process are recommended, with an understanding that without such changes, the TMDL program will be unable to incorporate and improve upon the best available scientific information.

States should develop appropriate use designations for waterbodies in advance of assessment and refine these use designations prior to TMDL development. **Clean Water Act goals of fishable and swimmable waters are too broad to be operational as statements of designated uses. Thus, there should be greater stratification of designated uses at the state level (such as primary and secondary contact recreation). The appropriate designated use may not be the use that would be realized in the water's predisturbance condition. Sufficient science and examples exist for all states to inject this level of detail into their water quality standards. To ensure that designated uses are appropriate, use attainability analysis should be considered for all waterbodies before a TMDL is developed.**

EPA should approve the use of both a preliminary list and an action list instead of one 303d list. **Many waters now on state 303d lists were placed there without the benefit of adequate water quality standards, data, or waterbody assessment. These potentially erroneous listings contribute to a very large backlog of TMDL segments and foster the perception of a problem that is larger than it may actually be. States should be allowed to move those waters for which there is a lack of adequate water quality standards or data and analysis from the 303d list back to a preliminary list, as shown in Figure ES-1. This would provide the assurance that listed waters are indeed legitimate and merit the resources required to complete a TMDL. If no legal mechanism exists to bring this about, one should be created by Congress. The data requirements and other criteria that should be used to differentiate the preliminary list from the action list are discussed in the report. No waterbody should remain on the preliminary list for more than one rotating basin cycle.**

TMDL plans should employ adaptive implementation. As shown in Figure ES-2, adaptive implementation is a cyclical process in which TMDL plans are periodically assessed for their achievement of water quality standards including designated uses. If the implementation of the TMDL plan is not achieving attainment of the designated use, scientific data and information should be used to revise the plan. Adaptive implementation is needed to ensure that the TMDL program is not halted because of a lack of data and information, but rather progresses while better data are collected and analyzed with the intent of improving upon initial TMDL plans. Congress and EPA need to address the policy barriers that inhibit adoption of an adaptive implementation approach to the TMDL program, including the issues of future growth, the equitable distribution of cost and responsibility among sources of pollution, and EPA oversight.

USE OF SCIENCE IN THE TMDL PROGRAM

This report suggests changes in the data used and analytical methods employed that will support the revisions to the TMDL process recommended above. The following sections highlight the use of science in the TMDL program steps as illustrated in Figure ES-1. Additional recommendations about the scientific basis of the program not included in this executive summary are found throughout the report.

Water Quality Standards

The TMDL process is primarily a measurement process and as such is significantly impacted by the setting of water quality standards. Water quality standards consist of two parts: a specific desired use appropriate to the waterbody, termed a *designated use*, and a *criterion* that can be measured to establish whether the designated use is being achieved.

The criterion used to measure whether the condition of a waterbody supports its designated use can be positioned at different points along the causal chain connecting stressors (such as land use activities) to biological responses in a waterbody. Positioning the criterion involves a trade-off between forecast error for the stressor–criterion relationship and the adequacy of the criterion as a measure (surrogate) for the designated use. Model results that

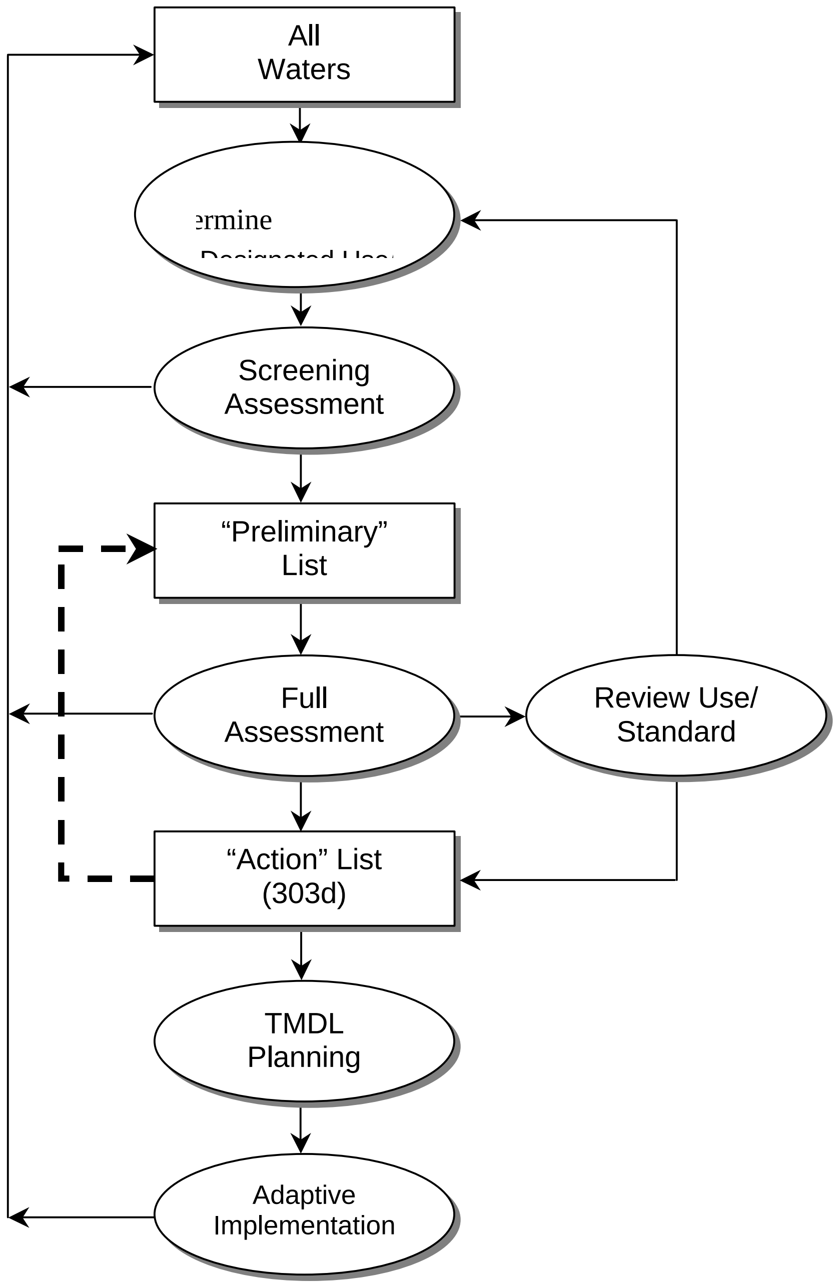

FIGURE ES-1 Framework for water quality management.

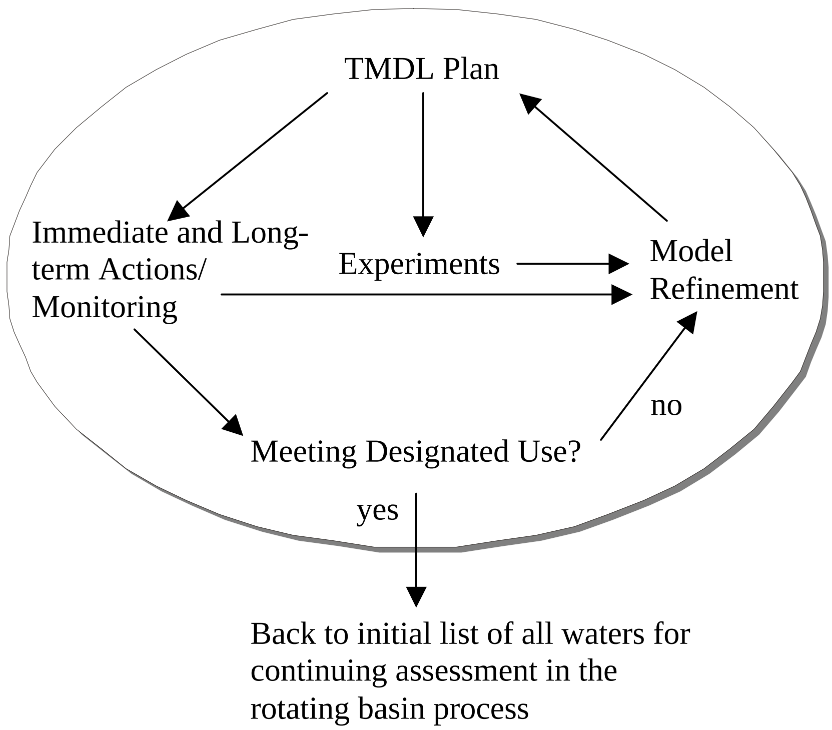

FIGURE ES-2 Adaptive implementation flowchart.

forecast the impact of the stressor on the criterion are likely to be more uncertain as the criterion is positioned farther from the stressor and closer to the designated use. On the other hand, positioning the criterion closer to the stressor and farther from the designated use is likely to mean that the criterion is a poorer measure or surrogate for the designated use.

Biological criteria should be used in conjunction with physical and chemical criteria to determine whether a waterbody is meeting its designated use. In general, biological criteria are more closely related to the designated uses of waterbodies than are physical or chemical measurements. However, guiding management actions to achieve water quality goals based on biological criteria also depends on appropriate modeling efforts.

All chemical criteria and some biological criteria should be defined in terms of magnitude, frequency, and duration. The frequency component should be expressed in terms of a number of allowed excursions in a specified period. Establishing these three dimensions of the criterion is crucial for successfully developing water quality standards and subsequently TMDLs.

Water quality standards must be measurable by reasonably obtainable monitoring data. In many states, there is a fundamental discrepancy between the criteria that have been chosen to determine whether a waterbody is achieving its designated use and the frequency with which water quality data are collected. This report gives examples of this phenomenon and makes suggestions for improvement.

Waterbody Assessment and Listing

Ambient monitoring and assessment programs should form the basis for determining whether waters are placed on the preliminary list or the action list.

EPA needs to develop a uniform, consistent approach to ambient monitoring and data collection across the states. The rotating basin approach used by several states is an excellent example of a framework than can be used to conduct waterbody assessments of varying levels of complexity, for example to support 305b reports, to place impaired waters on a preliminary list or action list, and to develop TMDLs. **In that regard, EPA should set the TMDL calendar in concert with each state's rotating basin program.**

Evidence suggests that limited budgets are preventing the states from monitoring for a full suite of indicators to assess the condition of their waters and from embracing a rotating basin approach to water quality management. Currently, EPA is assessing the sufficiency of state resources to develop and implement TMDLs. Depending on the results of that assessment, Congress might consider aiding the states, for example through matching grants to improve data collection and analysis.

Evaluated data and evidence of violation of narrative standards should not be exclusively used for placement of a waterbody on the action list, but is useful for placement on the preliminary list. EPA should develop guidance to help states translate narrative standards to numeric criteria for the purposes of 303d listing and TMDL calculation and implementation.

EPA should endorse statistical approaches to defining all waters, proper monitoring design, data analysis, and impairment assessment. For chemical parameters, these statistical approaches might include the binomial hypothesis test or other methods that can be more effective than the raw score approach in making use of the data collected to determine water quality impairment. For biological parameters, they might focus on improvement of sampling designs, more careful identification of the components of biology used as indicators, and analytical procedures that explore biological data as well as integrate biological information with other relevant data.

TMDL Development

The scientific basis of the latter half of the TMDL process revolves around a wide variety of models of varying complexity that are used to relate waterbody conditions to different land uses and other factors. Models are a required element of developing TMDLs because water quality standards are probabilistic in nature. However, although models can aid in the decision-making process, they do not eliminate the need for informed decision-making.

Uncertainty must be explicitly acknowledged both in the models selected to develop TMDLs and in the results generated by those models. Prediction uncertainty must be estimated in a rigorous way, models must be selected and rejected on the basis of a prediction error criterion, and guidance/software needs to be developed to support uncertainty analysis.

The TMDL program currently accounts for the uncertainty embedded in the modeling exercise by applying a margin of safety (MOS); EPA should end the practice of arbitrary selection of the MOS and instead require uncertainty analysis as the basis for MOS determination. Because reduction of the MOS can potentially lead to a significant reduction in TMDL implementation cost, EPA should place a high priority on selecting and developing TMDL models with minimal forecast error.

EPA should selectively target some postimplementation TMDL compliance monitoring for verification data collection so that model prediction error can be assessed. TMDL model choice is currently hampered by the fact that relatively few models have undergone thorough uncertainty analysis. Postimplementation monitoring at selected sites can yield valuable data sets to assess the ability of models to reliably forecast response.

EPA should promote the development of models that can more effectively link environmental stressors (and control actions) to biological responses. A first step will be the development of conceptual models that account for known system dynamics. Eventually, these should be strengthened with both mechanistic and empirical models, although empirical models are more likely to fill short-term needs. Such models are needed to promote the wider use of biocriteria.

Monitoring and data collection programs need to be coordinated with anticipated water quality and TMDL modeling requirements. For many parameters, there are insufficient data to have confidence in the results generated by some of the complex models used in practice today. Thus, EPA should not advocate detailed mechanistic models for TMDL development in data-poor situations. Either simpler, possibly judgmental, models should be used or, preferably, data needs should be anticipated so that these situations are avoided.

In order to carry out adaptive implementation, EPA needs to foster the use of strategies that combine monitoring and modeling and expedite TMDL development. This should involve the use of Bayesian techniques that can combine different types of information. Although the modeling framework proposed in this report calls for improvements in models, there are existing models that can be applied rapidly and effectively within an adaptive implementation framework.

FINAL THOUGHTS

Through the adoption and use of the preliminary list/action list approach, adequate monitoring and assessment approaches, sound selection of appropriate models, and adaptive implementation described in this report, the TMDL program will be capable of utilizing the best available scientific information. It is worth noting that the success of these approaches is directly related to the provision of adequate personnel and financial resources for data collection, management, and interpretation and for the development of sufficiently detailed and stratified water quality standards.

1
Introduction

THE RETURN TO AMBIENT-BASED WATER QUALITY MANAGEMENT

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), as supplemented by the Clean Water Act (CWA) of 1977 and the Water Quality Act of 1987, are the foundation for protecting the nation's water resources. Precursors to the Water Quality Act go back to the Rivers and Harbors Appropriations Act of 1899, often referred to as the Refuse Act, and the Water Pollution Control Acts of 1948 and 1965 (Rodgers, 1994). An important impetus for earlier water quality legislation was protection of public health. Over time, this purpose was supplemented by aesthetic and recreational purposes (fishable and swimmable) and then by the goal of restoring and maintaining the "chemical, physical, and biological integrity of the Nation's waters" (Section 101a of PL 92-500).

In practice, each of these general purposes must be restated in operational and measurable terms as *ambient* water quality standards, which are established by the states and are subject to federal approval. Section 303d of the CWA makes it a responsibility of the states to assess whether ambient standards are being achieved for individual waterbodies. If ambient standards are not being met, a water quality management program to achieve those standards is anticipated.

The data and analytical requirements for determining both the causes of a failure to meet ambient standards and the solutions to such problems have challenged water quality analysts for over half a century. Prior to the 1972 Water Pollution Control Act Amendments, states were expected to identify pollutant sources that were resulting in violations of ambient water quality standards. Once the sources of the problem were carefully identified, controls on polluting activities would be put in place. However, in even modestly complex watersheds, multiple sources of pollutants made it difficult to unambiguously determine which sources were responsible for the standard violation. One source might insist that the cause of the problem was the discharge from others, or at least that its own contribution to the problem was not as significant as the contributions of others. Neither the available monitoring data nor the analytical methods available at the time allowed the states to defensibly mandate differential load reduction requirements (Houck, 1999).

The 1972 Amendments recognized this analytical dilemma and shifted the focus of water quality management away from ambient standards. Instead, all dischargers of certain pollutants were expected to limit their discharges by meeting nationally established *effluent standards.* Effluent standards are specified in National Pollution Discharge Elimination System (NPDES) permits, issued by the states to certain pollutant sources and approved by the U.S. Environmental Protection Agency (EPA). Effluent standards were set at a national level based on available technologies for wastewater treatment appropriate to different industry groups (although in certain waterbodies effluent standards more stringent than the technology-based requirement have been required to meet local water quality goals). The shift to effluent standards eliminated the need to link required reductions at particular sources with the ambient condition of a waterbody. Instead, each regulated source was simply required to meet the effluent standard in its wastewater. In the intervening period since passage of PL 92-500, pollutants discharged by industry and municipal treatment plants have declined, and the ambient quality of many of the nation's lakes, rivers, reservoirs, groundwater, and coastal waters has improved.

There were consequences that followed the embracing of effluent-based standards instead of ambient-based standards. First, efforts to measure and communicate water quality accomplishments were often described in terms of compliance with wastewater permit conditions rather than the condition of the waters. Second, effluent standards could only apply to so-called point sources rather than to all sources of a pollutant or other forms of pollution (Box 1-1). Pollutants from nonpoint sources (derived from diffuse and hard-to-monitor origins such as land-disturbing agricultural, silvicultural, and construction activities) largely escaped oversight. Third, attention to chemical pollutants measured in discharge water came to dominate water quality policy, and the physical and biological determinants of the ambient condition of a waterbody were less frequently considered. A *pollutant* is defined as a substance added by humans or human activities. In many cases, the condition of a waterbody depends on more than the loads of particular pollutants from sources required to meet effluent standards. For example, changes in the hydrologic regime associated with development activities can destabilize streambanks, increase loads of sediment and nutrients, or eliminate key species or otherwise change the aquatic ecosystem. As shown in Box 1-1, biological, hydrologic, and physical changes to a waterbody that do not fit the definition of pollutant were encompassed in the 1987 act's definition of *pollution.*

Box 1-1 Pollution vs. Pollutant

Clean Water Act Section 502(6). The term "pollutant" means dredged spoil, solid waste, incinerator residue, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, salt, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. This term does not mean (A) "sewage from vessels" within the meaning of section 312 of this Act; or (B) water, gas, or the materials which are injected into a well to facilitate production of oil or gas, or water derived in association with oil or gas production and disposed of in a well, if the well used either to facilitate production or for disposal purposes is approved by authority of the State in which the well is located, and if such State determines that such injection or disposal will not result in the degradation of ground or surface water resources.

> **Clean Water Act Section 502(19).** The term "pollution" means the manmade or man-induced alteration of chemical, physical, biological, and radiological integrity of water.
>
> In the Clean Water Act, pollution includes pollutants (as described above) as well as other stressors such as habitat destruction, hydrologic modification, etc.

Present-day implementation of Section 303d of the Clean Water Act returns to the pre-1972 focus on ambient water quality standards, even though there are still requirements for meeting effluent standards. Section 303d requires states to identify waters not meeting ambient water quality standards, define the pollutants and the sources responsible for the degradation of each listed water, establish Total Maximum Daily Loads (TMDLs) necessary to secure those standards, and allocate responsibility to sources for reducing their pollutant releases. Therefore, for each impaired waterbody, the state must identify the amount by which both point and nonpoint source pollutants would need to be reduced in order for the waterbody to meet ambient water quality standards. Other alterations that do not fit the pollutant definition such as changes of habitat, flow alterations, channelization, and modification or loss of riparian habitat may need to be considered as a reason for not meeting standards. If TMDL language is strictly interpreted, however, these causes may fall outside the TMDL program.

Although Section 303d has been in place since the early 1970s, activity to comply with it was limited until the last decade. States were slow to submit inventories of impaired waters, and measures of water quality program success were often simply documentation of point source permit issuance and compliance. Few TMDLs were prepared, and they often did not incorporate both point and nonpoint source discharge controls (Houck, 1999). Action to meet Section 303d requirements accelerated in the 1990s primarily because of a series of citizen lawsuits against EPA. By 1992, EPA revised the TMDL regulations to require submission of states' lists of impaired water bodies every two years.

EPA estimates that from 3,800 to 4,000 TMDLs will need to be completed per year to meet the 8- to 13-year deadlines currently imposed on the process. From 1,000 to 1,800 would have to be completed per year to meet consent decree deadlines, while another 1,800 to 2,200 per year need to be resolved through settlement agreements. States have identified about 21,000 impaired river segments, lakes, and estuaries encompassing more than 300,000 river and shore miles and 5 million lake acres (Brady, 2001). Excess sediments, nutrients, and pathogens are leading reasons for listing according to state reports submitted to EPA. Federal, state, and local governments, regulated and potentially regulated communities, and concerned citizens throughout the nation claim that they face unrealistic deadlines and must use analytical and decision-making procedures that are largely untested. Proposed revisions to the TMDL regulations were submitted in 1999, with a final rule issued July 13, 2000. However, faced with expressions of concern about the practicality of the program, a congressional rider prohibited EPA from implementing the new rule until October 2001. As a result, the TMDL program continues under 1992 regulations and, in some cases, consent decrees.

The 303d focus on ambient water quality standards has returned the nation to a water quality program that was not considered implementable 35 years ago when there was a paucity of data and analytical tools for determining causes of impairment and assigning responsibility to various sources. Determining the pollutant load from a regulated point source is a relatively straightforward task, although isolating its effect in a complex waterbody remains a technical challenge. Such technical uncertainties in relating stresses on the waterbody to impairment are compounded when nonpoint sources of pollutants and other forms of pollution are considered.

Having returned the focus to ambient water quality conditions, are we better positioned today than we were years ago? Do we have more and better data and analytical methods? Do we have a better understanding of watershed events and processes responsible for water quality violations? These are the science questions facing the nation as we implement Section 303d of the Clean Water Act.

NATIONAL RESEARCH COUNCIL STUDY

Despite recent progress, the demands of the TMDL program weigh heavily on the limited resources of EPA and the states. The TMDL process requires high-quality data and sophisticated tools to analyze those data. States have reported having insufficient funds, inadequate monitoring programs, and limited staff to collect and analyze such data (GAO, 2000). According to the General Accounting Office (GAO), only six states have enough data to fully assess the condition of their waterbodies, while only 18 have enough data to place their waterbodies on the list of impaired waters (303d list). Forty states had sufficient high-quality data to determine TMDLs for waterbodies impaired primarily by point sources such as municipal sewage treatment plants, and 29 had sufficient high-quality data to implement these TMDLs. When states were asked about waterbodies impaired primarily by nonpoint sources, however, only three claimed to have sufficient data.

The GAO report outlined several critical issues for consideration by the states and EPA. Beyond questions of additional funding for data collection and staff, the states need assistance using watershed models; many reported being unclear where to go for such assistance. There appears to be no formalized process to capitalize on lessons learned, to transfer technology, and to share knowledge. Aside from the reported lack of data to comply with the TMDL regulations, when data are available, they are often not the type needed for source identification and TMDL analyses.

Subsequent to the GAO report, Congress requested that the National Research Council (NRC) analyze on a broad scale *the scientific basis of the TMDL program*. The NRC was asked to evaluate:

- the information required to identify sources of pollutant loadings and their respective contributions to water quality impairment,
- the information required to allocate reductions in pollutant loadings among sources,
- whether such information is available for use by the states and whether such information, if available, is reliable, and
- if such information is not available or is not reliable, what methodologies should be used to obtain such information.

While the GAO report was about data, the NRC was charged to focus on *reliable information* for making decisions. In presentations made to the NRC committee, the terms "data" and "information" often were used as synonyms, but data are not the same as information. Unanalyzed data do not constitute information. Data must be interpreted for their meaning through the filter of analytical techniques, and the result of such data analysis is information that can support decision-making. Knowing what data are needed and turning those data into information constitutes, in large part, the science behind a water quality management program. The techniques for transforming data into information include statistical inference methods, simulation modeling of complex systems, and, at times, simply the application of the best professional judgment of the analyst. In all these processes there will always be some uncertainty (and thus some "unreliability") about whether the resulting information accurately characterizes the water quality problem and the effectiveness of the solutions. Because uncertainty cannot be eliminated, determining whether the information generated from data analysis is reliable is a value judgment. Individuals and groups will have different opinions about whether and how to proceed with water quality management given a certain level of uncertainty.

To organize its deliberations, the committee considered the role of science at each step of the TMDL process, from the initial defining of all waters to the implementation of actions to control pollution; the report is structured around this organization. Report recommendations are targeted (1) at those issues where science can and should make a significant contribution and (2) at barriers (regulatory and otherwise) to the use of science in the TMDL program. Because of this broad scope, the content of the report extends beyond the confines of the charge in the bulleted items above. Chapters 2, 3, and 4 discuss the information (as defined above) required to set water quality standards, to list waters as impaired, and to develop TMDLs (including the identification of pollution sources); Chapter 5 comments on the role of science in allocating pollutant loading among sources. Because GAO (2000) already documents a widespread lack of data and information at the state level and because availability of information varies significantly from state to state, the committee did not devote substantial time to determining availability. As mentioned above, whether the information is reliable depends on the degree of uncertainty decision-makers are willing to accept when making regulatory or spending choices—a decidedly nonscientific matter. Chapters 3 and 4 describe in detail the monitoring, modeling, and statistical analysis methods needed to collect data and convert it to information, and to assess and reduce uncertainty. Chapter 5 describes an approach for making decisions in the face of uncertainty.

This report represents the culmination of three meetings over three months, including a two-day public session in which 30 presentations from a wide variety of stakeholders were made (see Appendix B). Given the information gathered during the study period and the collective experience of its members, the committee feels that the data and science have progressed sufficiently over the past 35 years to support the nation's return to ambient-based water quality management. In addition, the need for this approach is made apparent by the inability of a large percentage of the nation's water to meet water quality standards using point source controls alone. Given reasonable expectations for data availability and inevitable limits on our conceptual understanding of complex systems, statements about the science behind water quality management must be made with acknowledgment of uncertainties. Finally, the committee has concluded that there are creative ways to accommodate this uncertainty while moving forward in addressing the nation's water quality challenges. These broad conclusions are elaborated upon throughout this report.

CURRENT TMDL PROCESS AND REPORT ORGANIZATION

Section 303d requires that states identify waters that are not attaining ambient water quality standards (i.e., are impaired). (Although new rules are pending, at the request of Congress, this report focuses on the 1992 regulations that govern the current program.) States must then establish a priority ranking for such waters, taking into account the severity of the impairment and the uses to be made of such waters. For impaired waters, the states must establish TMDLs for pollutants necessary to secure applicable water quality standards. The CWA further requires that once water quality standards are attained they must be maintained.

Figure 1-1 depicts the basic steps in the TMDL process. These steps are described briefly below and are considered in greater detail throughout the report. At the beginning of the process are all waterbodies for the state and the development of water quality standards for each waterbody. Water quality standards are established outside the TMDL process and include designated uses for a waterbody and measurable water quality criteria designed to assure that each designated use is being achieved. Because water quality standards are the foundation on which the entire TMDL program rests, more detailed discussion of standard setting is provided in Chapters 2 and 3.

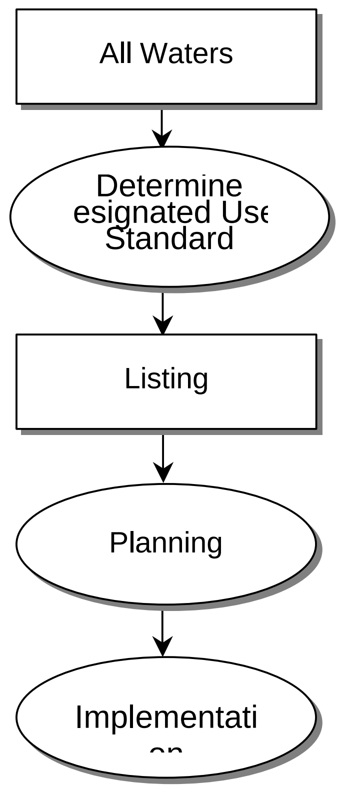

FIGURE 1-1 Conceptualized steps of the TMDL process.

The next step in the process is the listing of *impaired* waterbodies if evaluation of available data suggests that certain waterbodies are not meeting standards. According to Section 303d, all impaired waterbodies must be listed by the states or responsible agencies and submitted to EPA every two years. In addition, the states should provide priority ranking for the waterbodies on the 303d list. Following its submission, EPA must either approve or disapprove the list. Listing of a waterbody initiates a costly planning process and may lead to added costs to implement pollutant controls by point and nonpoint sources. The NRC committee heard testimony that many waterbodies have been listed based on limited or completely absent data and poorly conceived analytical techniques for data evaluation. Chapter 3 reviews the listing process and makes recommendations that will improve the reliability of the listing decision.

Once an impaired waterbody is listed, a planning step ensues. Section 303d specifies that those waters impaired by pollutants should undergo calculation of a TMDL. The term TMDL has essentially two meanings (EPA, 1991):

- The TMDL process is used for implementing state water quality standards—that is, it is a planning process that will lead to the goal of meeting the water quality standards.
- The TMDL is a numerical quantity determining the present and near future maximum load of pollutants from point and nonpoint sources as well as from background sources, to receiving waterbodies that will not violate the state water quality standards with an adequate margin of safety. The permissible load is then allocated by the state agency among point and nonpoint sources.

The calculation described above requires data collection and various forms of modeling in order to identify sources of pollution and background conditions, calculate the maximum load that will meet water quality standards with a margin of safety, and make allocations of responsibility for load reduction to point and nonpoint sources. Chapter 4 reviews modeling capability, data needs for model implementation, and the appropriate role of modeling in the TMDL planning process.

The last step in the process is implementation of the TMDL and the delisting of the waterbody. Implementation is the process of putting the actions envisioned in the TMDL plan in place. Such actions could include limitations on point sources beyond technology-based effluent standards. Also, using best management practices for nonpoint sources, as well as addressing pollution problems, might be part of implementation, although these actions are not required by Section 303d[2]. The results of implementation actions need to be assessed before a waterbody can be removed from the list. Monitoring in this phase is necessary to measure the success (or failure) of the plan. Chapter 5 discusses postimplementation monitoring and a strategy for assuring that the best available science is used in the TMDL implementation phase. When the monitoring proves that the implementation is successful (i.e., the water quality standards are met), the waterbody can be delisted.

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[2] Whether nonpoint source controls are required as part of the TMDL program is the source of much of the debate, especially with regard to the 2000 regulations that are now on hold. Under the current (1992) regulations, 303d is a planning exercise only. Implementation must be by some other provisions of the CWA or other programs. Also, states differ in their ability to enforce use of certain best management practices.

2

Conceptual Foundations for Water Quality Management

This chapter describes the analytical and related policy challenges of implementing an ambient-focused water quality management program, of which the Total Maximum Daily Load (TMDL) program is an example[3]. The goal of an ambient water quality management program is to measure the condition of a waterbody and then determine whether that waterbody is meeting water quality standards. By definition, this process is dependent on the setting of appropriate water quality standards. Although realistic standard setting must account for watershed (hydrologic, ecological, and land use) conditions, the corresponding need to make policy decisions in setting standards must also be recognized. In addition, ambient-based water quality management requires decision-making under uncertainty because the possibility for making assessment errors is always present. Properly executed statistical procedures can identify the magnitude and direction of the possible errors so that knowledge can be incorporated into the decisions made. In addition to uncertainties inherent in measuring the attainment of water quality standards, there are uncertainties in results from models used to determine sources of pollution, to allocate pollutant loads, and to predict the effectiveness of implementation actions on attainment of a standard. As part of the information needed in the TMDL program, this uncertainty must be understood and addressed as implementation decisions are made.

AMBIENT WATER QUALITY STANDARDS

Unlike an effluent standard, an ambient water quality standard applies to a specific spatial area—a defined waterbody—and is expected to be met over all areas of that waterbody. Thus, identifying the waterbody of interest, whether a lake, a stream segment, or areas of an estuary, is a first step in setting water quality standards. Waterbodies vary greatly in size—

[3] Although this discussion refers to the TMDL program, it is not meant to be a description of that program.

for example, from a small area such as a mixing zone below a point source discharge on a river to an estuary formed by a major river discharge.

Water quality standards themselves consist of two parts: a specific desired use appropriate to the waterbody, termed a *designated use*, and a *criterion* that can be measured to establish whether the designated use is being achieved. Barriers to achieving the designated use are the presence of pollutants and hydrologic and geomorphic alterations to the waterbody or watershed.

Appropriate Designated Uses

A designated use describes the goal of the water quality standard. For example, a designated use of human contact recreation should protect humans from exposure to microbial pathogens while swimming, wading, or boating. Other uses include those designed to protect humans and wildlife from consuming harmful substances in water, fish, and shellfish. Aquatic life uses are intended to promote the protection and propagation of fish, shellfish, and wildlife resources.

A designated use is stated in a written, qualitative form, but the description should be as specific as possible. Thus, more detail than “recreational support” or “aquatic life support” is needed. The general “fishable” and “swimmable” goals of the Clean Water Act constitute the beginning, rather than the end, of appropriate use designation. For example, a sufficiently detailed designated use might distinguish between beach use, primary water contact recreation, and secondary water contact recreation[4]. Similarly, rather than stating that the waterbody needs to be “fishable,” the designated use would ideally describe whether the waterbody is expected to support a desired fish population (e.g., salmon, trout, or bass)

[4] These uses are defined differently from state to state. In Ohio, primary contact recreation includes full body immersion activities such as swimming, canoeing, and boating. Such streams or rivers must have a depth of at least 1 meter. Secondary contact recreation includes activities such as wading, but where full body immersion is not practical because of depth limitations. The fecal bacteria criteria are less stringent for secondary contact recreation than for primary contact recreation.

and the relative invertebrate or other biological communities necessary to support that population. Although small headwater streams may have aesthetic values, they may not have the ability to support extensive recreational uses themselves (i. e., be "fishable" or "swimmable"). However, their condition may have an influence on the ability of a downstream area to achieve a particular designated use. In this case, the designated use for the smaller waterbody may be defined in terms of the achievement of the designated use of the larger downstream waterbody (as illustrated in the discussion of criteria below).

In many areas of the United States, human activities have radically altered the landscape and aquatic ecosystems, such that an appropriate designated use may not necessarily be the aquatic life condition that was present in a watershed's predisturbance condition, which may be unattainable. For example, a reproducing trout fishery in downtown Washington, D.C., may be desired, but may not be attainable because of the development history of the area or the altered hydrologic regime of the waterbody. Similarly, designating an area near the outfall of a sewage treatment plant for shellfish harvesting may be desired, but health considerations would designate it as a restricted shellfish harvest water. Furthermore, there may be a conscious decision to establish a designated use that would *not* have existed in the predisturbance condition. For example, construction of a lake for a warm water fishery is a use possible only as a result of human intervention.

Appropriate use designation for a state's waterbodies is a policy decision that can be informed by technical analysis. However, a final selection will reflect a social consensus made in consideration of the current condition of the watershed, its predisturbance condition, the advantages derived from a certain designated use, and the costs of achieving the designated use. Ideally, a statewide water quality management program should establish a detailed gradient of use designations for waterbodies. Box 2-1 describes the multiple tiers of designated uses developed for waters in Ohio.

Box 2-1 Appropriate Designated Uses: The Ohio Example

An approach to setting appropriately stratified or tiered designated uses for a state's waterbodies has been developed in Ohio. The state recognized early on that a stratified set of use designations for aquatic life, recreation, and water supply was needed to accurately reflect the potential quality of various waterbodies and to guide cost-effective expenditures for pollution controls and other restoration activities. In lieu of general use, more detailed designated uses were developed that reflect the "potential" of the aquatic ecosystem and account for the historical influence of broad-scale socioeconomic activities. Individual waterbodies are assigned the appropriate designated use based on a use attainability analysis (UAA) process that relies heavily on site-specific information about the waterbody. The information used in this process results from the systematic monitoring of waters via a rotating basin approach in which biological, chemical, and physical data are collected and analyzed. Aquatic life uses are based primarily on the biological criteria and physical habitat assessments that are calibrated with regard to the important regional and watershed-specific variables that determine the potentially sustainable aquatic assemblage. Recreational uses are designated based on the size of the waterbody, reflecting the ability of humans to use the water for swimming, boating, fishing, or wading.

The system of tiered aquatic life and recreational uses in the Ohio water quality standards was established in 1978, well before biological criteria were adopted for use (May 1990). Two newly proposed uses are now under study: one for urban streams, which would require a site-specific UAA, and one for primary headwater streams (<1 sq. mi. drainage area), which are outside of the practical resolution of the present biological criteria. (A readily accessible and detailed example of such designated uses for Ohio can be found at http://www.epa.state.oh.us/dsw/rules/3745-1.html.

Defining a Criterion

A water quality standard includes a criterion representing the condition of the waterbody that supports the designated use. Thus, the designated use is a description of a desired endpoint for the waterbody, and the criterion is a measurable indicator that is a surrogate for use attainment. The criterion may be positioned at *any* point in the causal chain of squares shown in Figure 2-1. Criteria in squares 2 and 3 are possible measures of ambient water quality condition. Square 2 includes measures of a water quality parameter such as dissolved oxygen (DO), pH, nitrogen concentration, suspended sediment, or temperature. Criteria closer to the designated use (e.g., square 3) include measures such as the condition of the algal community (chlorophyll *a*), a comprehensive index measure of the biological community as a whole, or a measure of contaminant concentration in fish tissue. In square 1, where the criterion is farther from the

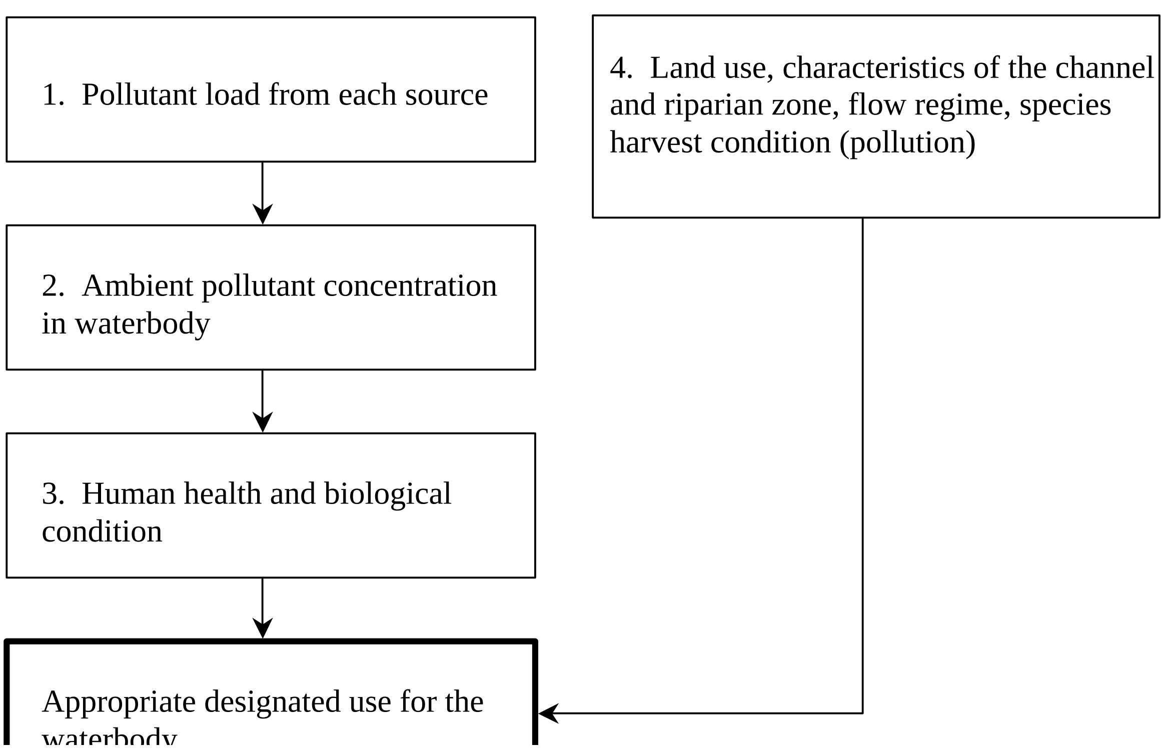

FIGURE 2-1 Types of water quality criteria and their position relative to designated uses.

designated use, are measures of the pollutant discharge from a treatment plant (e.g., biological oxygen demand, NH_3, pathogens, suspended sediments) or the amount of a pollutant entering the edge of a stream from runoff. A criterion at this position is referred to as an effluent standard. Finally, square 4 represents criteria that are associated with sources of pollution other than pollutants. These criteria might include measures such as flow timing and pattern (a hydrologic criterion), abundance of nonindigenous taxa, some quantification of channel modification (e.g., decrease in sinuosity), etc.

Because the designated use is stated in written and qualitative terms, the challenge is to logically relate the criterion to the designated use. Establishing this relationship is easier as the criterion moves closer to the designated use (Figure 2-1). In addition, the more precise the statement of the designated use, the more accurate the criterion will be as an indicator of that use. For example, the criterion of fecal coliform count may be used for determining if the use of water contact recreation is achieved, and the fecal count criterion may differ among waterbodies that have primary versus secondary water contact as their designated use.

Surrogate variables often are selected for use as criteria because they are easy to measure. Although the surrogate may have this appealing attribute, its usefulness can be limited if it cannot be logically related to a designated use. For example, chlorophyll *a* has been chosen as a biocriterion in some states because it is a surrogate for aesthetic conditions or the status of the larger aquatic ecosystem. In North Carolina, the ambient water quality standard of 40 μg/l for chlorophyll *a* was proposed for lakes, reservoirs, sounds, estuaries, and other slow-moving waters not designated as trout waters. However, a discussion of the appropriate designated uses for the waters of the state and how this criterion is logically related to those uses did not accompany the adoption of this criterion.

As with setting designated uses, the relationship among waterbodies and segments must be considered when determining criteria. For example, where a segment of a waterbody is designated as a mixing zone for a discharge, the criterion adopted should assure that the mixing zone use will not affect the attainment of the uses designated for the surrounding waterbody. In a similar vein, the desired condition of a small headwater stream may need to be chosen as it relates to other waterbodies in the watershed. Thus, an ambient nutrient criterion may be set in a small headwater stream to secure a designated use in a downstream estuary, even if there are no localized effects of the nutrients in the small headwater stream. Conversely, a higher fecal coliform criterion that supports only secondary contact recreation may be warranted for a waterbody with little likelihood of being a recreational resource—if the fecal load dissipates before the flow reaches an area designated for primary contact recreation.

DECISION UNCERTAINTY

Ambient-focused water quality management requires one to ask whether the designated use is being attained and, if not, the reasons for nonattainment and how the situation can be remedied. Neither of these questions, which make reference to the chosen criteria, can be answered with complete certainty. Determining use attainment requires making criterion measurements at different locations in the waterbody and at different times and comparing the measurements to the standard. Individual measurements of a single criterion constitute a sample, and statistical inference procedures use the sample data to test hypotheses about whether the actual condition in the water meets the criterion. Errors of inference are always possible in statistically valid hypothesis testing. It is possible to falsely conclude that a criterion is not being met when it is. It is also possible to conclude that a criterion is being met when in fact it is being violated. Chapter 3 includes recommendations for controlling and managing such uncertainty.

Water quality management also requires models to relate the criterion to activities that might control pollution. For example, a criterion requiring a certain DO level may be chosen to help meet the designated use of a trout fishery. Models will be required to relate a management practice, such as fertilizer control, to the DO criterion. These types of models can be broadly labeled as models that relate stressors (sources of pollutants and pollution) to responses—similar to models used in hazardous waste risk assessment and many other fields. Stressors include human activities likely to cause impairment, such as the presence of impervious surfaces in a watershed, cultivation of fields too close to the stream, over-irrigation of crops with resulting polluted return flows, the discharge of domestic and industrial effluent into waterbodies, dams and other channelization, introduction of nonindigenous taxa, and overharvesting of fishes. Indirect effects of humans include the clearing of natural vegetation in uplands that alters the rates of delivery of water and sediment to stream channels.

A careful review of direct and indirect effects of human activities suggests five major classes of environmental stressors: alterations in physical habitat, modifications in the seasonal flow of water, changes in the food base of the system, changes in interactions within the stream biota, and release of contaminants (conventional pollutants) (Karr, 1990; NRC, 1992). The presence of one of more of these in a landscape may be responsible for changes in a waterbody that result in failure to attain a designated use. Ideally, models designed to protect or restore water quality to ensure attainment of designated uses should include all five classes of pollution. The broad-based approach implicit in these five features is more likely to solve water resource problems because it requires a more integrative diagnosis of the cause of degradation (NRC, 1992).

Models that relate stressors to responses can be of varying levels of complexity (Chapter 4). Sometimes, models are simple conceptual depictions of the relationships among important variables and indicators of those variables, such as the statement "human activities in a watershed affect water quality including the condition of the river biota." More complicated models can be used to make predictions about the assimilative capacity of a waterbody, the movement of a pollutant from various point and nonpoint sources through a watershed, or the effectiveness of certain best management practices.

There are two significant sources of uncertainty in any water quality management program: epistemic and aleatory uncertainty (Stewart, 2000). Epistemic uncertainty—incomplete knowledge or lack of sufficient data to estimate probabilities—is a by-product of our reliance on models that relate sources of pollution to human health and biological responses. We are limited by incomplete conceptual understanding of the systems under study, by models that are necessarily simplified representations of the complexity of the natural and socioeconomic systems, as well as by limited data for testing hypotheses and/or simulating the systems. Limited conceptual understanding leads to parameter uncertainty. For example, at present there is scientific uncertainty about the parameters that can represent the fate and transfer of pollutants through watersheds and waterbodies. It is plausible to argue that more complete data and more work on model development can reduce epistemic uncertainty. Thus, a goal of water quality management should be to increase the availability of data, improve its reliability, and advance our modeling capabilities. Indeed, Chapter 4 describes ways in which improved data and modeling can narrow the band of uncertainty and ways to characterize the remaining uncertainty.

However, complete certainty in support of water quality management decisions cannot be achieved because of aleatory uncertainty—the inherent variability of natural processes. Aleatory uncertainty arises in systems characterized by randomness. For example, if a pair of dice is thrown, the outcome can be predicted to be between 2 and 12, although the exact outcome cannot be predicted. The example of the dice toss represents the best-case scenario of a system characterized by randomness, because it is a closed system in which we have complete confidence that the result will be between 2 and 12. Not only are waterbodies, watersheds, and their inhabitants characterized by randomness, but they are also open systems in which we cannot know in advance what the boundaries of possible biological outcomes will be.

Thus, uncertainty is a reality that water quality management must recognize and strive to assess and reduce when possible. It derives from the need to use models that relate actions taken to alter the stressors so that the desired criterion and designated use of a waterbody will be secured. Although the purpose of water quality modeling will change depending on how close to the designated use the criterion is positioned, the importance of modeling and the inevitable uncertainties of model results remain.

CONCLUSIONS AND RECOMMENDATIONS

The two major themes of this chapter represent areas in water quality management where science and public policy intersect. First, with respect to the setting of water quality standards, in order for designated uses to reflect the range of scientific information and social desires for water quality, there must be substantial stratification and refinement of designated uses. Information from science can and must be part of this process; however, there are unavoidable social and economic decisions to be made about the desired state for each waterbody. Second, although science should be one cornerstone of the program, an unwarranted search for scientific certainty is detrimental to the water quality management needs of the nation. Recognition of uncertainty and creative ways to make decisions under such uncertainty should be built into water quality management policy, as discussed in the remaining chapters.

1. Assigning tiered designated uses is an essential step in setting water quality standards. Clean Water Act goals (e.g., "fishable," "swimmable") are too broad to be operational as statements of designated use. However, designated uses will still remain narrative statements.

2. Once designated uses are defined, the criterion chosen to measure use attainment should be logically linked to the designated use. The criterion can be positioned anywhere along the causal chain connecting stressors (sources of pollution) to biological response. As the designated uses are expressed with more detail and are appropriately tiered, the criterion can be more readily related to the use. However, criteria should not be adopted based solely on the ease of measurement in making this link.

3. Expectations for the contribution of "science" to water quality management need to be tempered by an understanding that uncertainty cannot be eliminated. In both the assessment and planning processes, even the best available tools cannot banish uncertainty stemming from the variability of natural systems.

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3
Waterbody Assessment: Listing and Delisting

On July 27, 2000, the Assistant Administrator for Water at the U. S. Environmental Protection Agency (EPA) testified before a U.S. House committee that over 20,000 waterbodies across the United States were not meeting water quality standards according to Section 303d lists. Because of legal, time, and resource pressures placed upon the states and EPA, there is considerable uncertainty about whether many of the waters on the 1998 303d lists are truly impaired. In many instances, waters previously presented in a state's 305b report[5] or evaluated under the 319 Program[6] were carried over to the state's 303d list without *any* supporting water quality data [e.g., see Iowa Senate File 2371, Sections 7–12 (Credible Data Legislation)]. Meanwhile, some waters that may be impaired have yet to be identified and listed.

The creation of an accurate and workable list of impaired waters is dependent on the first three steps of the Total Maximum Daily Load (TMDL) process, as depicted in Figure 1-1. States need to decide what waters should be assessed in the first place, how to create water quality standards for those waters, and then how to determine exceedance of those standards. Ideally, all these activities are encompassed and coordinated under the umbrella of a holistic ambient water quality monitoring program, described in the next section. However, given resource constraints, the approaches currently used in most states to list impaired waters fall short of this ideal. In recognition of these constraints, the committee recommends changes to the TMDL program that would make the lists more accurate over the short and long terms. In addition, this chapter includes discussion on identifying waters to be assessed, defining measurable criteria for water quality standards, and interpreting monitoring results for making the listing (and delisting) decision.

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[5] The Clean Water Act Section 305b report—the National Water Quality Inventory Report—is the primary vehicle for informing Congress and the public about general water quality conditions in the United States. This document characterizes water quality, identifies widespread water quality problems of national significance, and describes various programs implemented to restore and protect our waters (http://www.epa.gov/305b/).

[6] Under the Clean Water Act Section 319 Nonpoint Source Management Program, States, Territories, and Indian Tribes receive grant money to support a wide variety of activities, including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects (http://www.epa.gov/owow/nps/cwact.html).

ADEQUATE AMBIENT MONITORING AND ASSESSMENT

The demands of an ambient-focused water quality management program, such as the TMDL program, require changing current approaches toward monitoring and assessment and subsequent decision-making. In many states, administrative performance measures (e.g., number of TMDLs developed, number of permits issued, and timeliness of actions) have been the principal measure of program effectiveness (Box 3-1). Such administrative measures are important, but reliance on such measures diverts attention and resources away from environmental indicators of waterbody condition—the principal measures of effectiveness and success. Rather, information for decision-making should be based on carefully collected and interpreted monitoring data (Karr and Dudley, 1981; Yoder, 1997; Yoder and Rankin, 1998). The committee recognizes that state ambient monitoring programs have multiple objectives beyond the TMDL program (e.g., 305b reports, trends and loads assessments, and other legal requirements), which are not addressed in this report. It is suggested that to make efficient use of resources, states evaluate the extent to which their present ambient monitoring programs are coordinated and collectively satisfy their objectives.

Ambient monitoring and assessment begins with the assignment of appropriate designated uses for waterbodies and measurable water quality criteria that can be used to determine use attainment (EPA, 1995a). The criteria, which may include biological, chemical, and physical measures, define the types of data to be collected and assessed. In response to the Government Performance and Results Act, the EPA Office of Water has developed national indicators for surface waters (EPA, 1995a) and a conceptual framework for using environmental information in decision-making (EPA, 1995b). EPA's Office of Research and Development recently published technical guidelines for the evaluation of ecological indicators (Jackson et al., 2000). One set of measurable parameters, termed indicators in Table 3-1, is offered for illustration. The core indicators include baseline biological, chemical, and physical parameters that comprise the basic attributes of aquatic ecosystems supplemented by specific chemical, physical, and bacteriological parameters from water, sediment, and tissue media, depending on the applicable designated use(s) and watershed-specific issues. Additional indicators not listed (e.g., biochemical markers and whole toxicity testing) may be appropriate as the situation dictates.

More than one criterion may be necessary to determine attainment of a designated use, and each criterion will have strengths and limitations. In many instances of impairment—for example when riparian and aquatic habitats have been modified or flow regimes altered—biological parameters are better than chemical parameters at reflecting the condition of the aquatic ecosystem (Box 3-2). This is because biological assemblages respond to and integrate all relevant chemical, physical, and biological factors in the environment whether of natural or anthropogenic origin. On the other hand, relying only on biological assessments would not allow precise enough determination of associated causes and sources of impairments to satisfy water quality management needs including TMDL development. Over the long term, a full complement of measured parameters must be the goal for water quality monitoring, assessing chemistry and biology in a complementary manner and in their most appropriate indicator role (Karr, 1991; ITFM 1992, 1993, 1995; Yoder, 1997; Yoder and Rankin, 1998).

Box 3-1 Ohio's Experience with TMDLs

In 1998, Ohio EPA's Division of Surface Water (DSW) made recommendations for a process to develop TMDLs (Ohio EPA, 1999). The impetus for developing a comprehensive TMDL strategy was (1) the national attention brought about by lawsuits filed by environmental organizations and (2) the potential for the TMDL process to address all relevant sources of pollution to a waterbody. Prior to realizing the importance of this issue, state water quality management efforts were focusing on point sources and National Pollution Discharge Elimination System (NPDES) permitting, although since 1996, the leading cause of waterbody impairment has been shown to be nonpoint pollution and habitat degradation (Ohio EPA, 2000; Section 305b report).

An agreement was reached between Ohio EPA and U.S. EPA Region V on a 15-year schedule for TMDL development. Ohio's 1998 303d list shows 881 of 5,000 waterbody segments as being impaired or threatened in 276 of the 326 watershed areas. Thus, completing TMDLs for all the currently listed segments by 2013 (in keeping with the 15-year schedule) will require an average of 18 watershed TMDLs per year assuming that no new watersheds are added to future revisions of the 303d lists. It is understood that this latter assumption is unrealistic because a good portion of the state's 5,000 waterbody segments has yet to be assessed, and it is a near certainty that additional waterbodies and watersheds will be listed. Ohio recognizes that the technical and management processes required to implement TMDLs will need to go beyond the purview of the past emphasis on NPDES permits and point sources.

At present, Ohio estimates it has sufficient resources available to develop only half of the TMDLs needed each year to produce the quality of product needed to meet various program expectations and expectations of stakeholders. Using 1998 as a baseline, approximately 16 percent of the DSW's resources were dedicated to efforts that directly support TMDL development (see pie chart below). Without increases in funding, the resources will need to be diverted from other programs, or the pace of TMDL development will slow to the point where the 15-year schedule will need to be significantly extended. Diverting resources from other programs is highly unlikely in that each program faces unique challenges, including reduction and elimination of NPDES permit backlogs and the growing need for new source permits, both of which place new burdens on the largest share of DSW resources. Devoting additional resources to TMDL development and implementation would require significant changes in water quality management emphasis on the national level, which seems unlikely given historical inertia and the emphasis placed on permitting programs by EPA and the states. Better coordination between competing programs as well as additional resources are needed to resolve the present TMDL resource shortfall dilemma. Focusing water quality management more on environmental results (as opposed to administrative accomplishments alone) should provide a framework to better unify the emphasis and direction of competing programs.

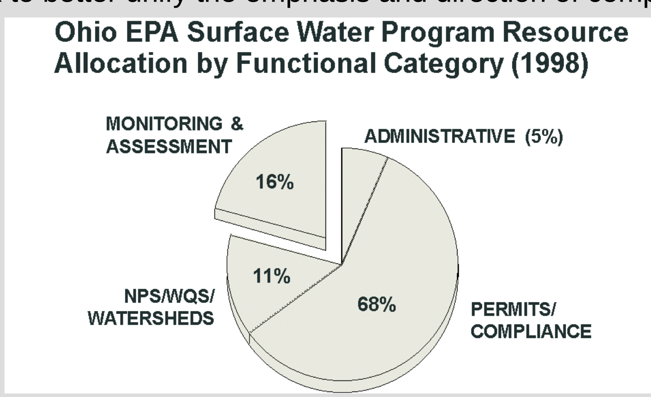

TABLE 3-1. Core and Supplemental Indicators and Parameters that Comprise the Elements of an Adequate State Monitoring and Assessment Framework (after ITFM, 1992, and Yoder, 1997).

Core Indicators				
Fish	**Macroinvertebrates**	**Periphyton**	**Physical habitat**	**Chemical quality**
• Use at least two assemblages			• Channel morphology • Flow regime • Substrate quality • Riparian condition	• pH • Temperature • Conductivity • DO

For Specific Designated Uses, add the following:				
	Aquatic Life	**Recreation**	*Water Supply*	*Human/Wildlife Consumption*
Base list	• Ionic strength • Nutrients, sediment	• Fecal bacteria • Ionic strength	• Fecal bacteria • Ionic strength • Nutrients, sediment	• Metals (in tissues) • Organics (in tissues)
Supplemental list	• Metals • Organics • Toxics	• Other pathogens • Organics	• Metals • Organics • Other pathogens	

Box 3-2 The Information Value of Monitoring Multiple Criteria

The tendency for misdiagnosis of impairment by relying on only one type of criterion was illustrated in a study of more than 2,500 paired stream and river sampling sites in Ohio (Ohio EPA, 1990; Rankin and Yoder, 1990). In 51.6 percent of the samples, the results from biomonitoring and chemical monitoring agreed—that is, they both detected either impairment or attainment of the water quality standard. This was particularly true for certain classes of chemicals (e.g., toxicants), where an exceedance as measured by the chemical parameter was always associated with a biocriteria impairment. However, in 41.1 percent of the samples, impairment was revealed by exceedance of the biocriteria but not by exceedance of the chemical criteria. These results suggest that impairment may go unreported in areas where only chemical measurements are made. Interestingly, in 6.7 percent of the samples, chemical assessment revealed impairment that was not detected by bioassessment (especially for parameters such as ammonia-N, dissolved oxygen (DO), and occasionally copper). This latter occurrence is likely related to the fact that biocriteria have been stratified to reflect regional or ecotype peculiarities, and the more generically derived chemical criteria have not. Both the under- and overprotective tendencies of a chemical-criteria-only approach to water quality management can be ameliorated by joint use of chemical criteria and biocriteria, each used within their most appropriate indicator roles and within an adequate monitoring and assessment framework.

> At present, monitoring resources available to some states often do not allow for collecting and interpreting data for such a comprehensive suite of parameters. Indeed, ITFM (1995) reported that of the funding allocated by state and federal agencies to water quality management activities, only 0.2 percent was devoted to ambient monitoring. GAO (2000) has also noted the lack of adequate state budgets for the collection of meaningful data and for data interpretation. In response to these resource shortfalls, the tendency has been to use only a single indicator of ambient conditions and often just a limited number of observations. Although some parameters can be monitored at lower costs than others, all monitoring can be costly (Yoder and Rankin, 1995).

After standards development, a second requirement is adoption of a strategic and consistent approach to sampling and assessment given limited data collection resources. Currently, the states use vastly different frameworks for monitoring and assessment, the net result of which is widely divergent estimates of the extent of impaired waters and of the proportion of waters that are fully assessed. This casts a great deal of uncertainty not only about what water quality problems are the most important, but also about the accuracy and completeness of their delineation. Errors in these estimates often become evident in the poor credibility of 303d listings.

A monitoring strategy that has promise in this limited-resource environment is the rotating basin approach, commonly referred to as a five-year basin approach (ITFM, 1995). As discussed in Box 3-3 for Florida, this approach is already followed by a number of states, at least in how ambient monitoring is accomplished[7]. As part of a rotating basin approach, individual waters are assessed at differing levels of complexity each year, allowing for localized problems to be identified and solutions to be developed. For example, whether an individual assessment consists of an initial screening to identify gross impairment or a full assessment with more serious consequences will depend on how the information is to be used (for 305b reports, 303d listing, or other water quality programs). Over time, different waterbodies are intensively studied as part of the rotation. Data collected can be used to support a number of different reporting and planning requirements, including a finding of attainment of water quality standards, a determination of impairment, or possible delisting if the waterbody is found not to be impaired. Initial assessments that identify a waterbody as *potentially* impaired could be followed up by more thorough assessment. The rotating basin approach is an iterative process where the end result is both continual improvement of water quality management tools and policies and the ability to respond to emerging issues.

Conclusions and Recommendations

1. To achieve the goal of ambient-based water quality management, monitoring and reporting must mature to focus on the condition of the environment as the principal measure of success rather than on administrative measures.

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[7] In some states, the rotating basin approach is considered to be part of the ambient monitoring program, while in others, it is a separate program. This report assumes the former throughout.

2. Biological parameters should be used in conjunction with physical and chemical parameters to assess the condition of waterbodies. The use of both biological and chemical parameters is needed because they provide different and complementary types of information about the source and extent of impairment.

3. Evidence suggests that limited budgets are preventing the states from monitoring for a full suite of indicators to assess the condition of their waters and from embracing a rotating basin approach to water quality management. Currently, EPA is assessing the sufficiency of state resources to develop and implement TMDLs. Depending on the results of that assessment, Congress might consider aiding the states, for example through matching grants to improve data collection and analysis. EPA would be instructed to develop guidelines for such a program, if needed, making eligibility contingent on an approved statewide monitoring and assessment strategy.

Box 3-3 The Rotating Basin Program in Florida

Settlement of a lawsuit brought by Earthjustice against EPA for its failure to enforce timely actions to accomplish TMDL-related activities in Florida occurred in June 1999. Under the consent decree's (CD) "Terms of the Agreement," nearly 2,000 TMDLs in 711 waterbody segments are to be completed by the year 2011. Florida Department of Environmental Protection (FDEP) has been named the lead agency to produce and adopt TMDLs, but its efforts must be coordinated with numerous other state and local agencies. In addition, the state has created opportunities for public participation throughout the TMDL generation and adoption process.

To address the challenge of conducting the TMDL program and to better allocate its available resources, on July 1, 2000, Florida moved to the rotating basin approach for watershed management. Florida's rotating basin approach has five phases (see below), with each phase taking about one year to complete. Further, FDEP has divided the state into 30 areas based on 8-digit hydrologic unit codes (HUCs), such that six areas representing approximately one-fifth of Florida will be in the TMDL adoption phase in any one year. To meet the timelines ordered in the CD for Florida, FDEP must limit the time, effort, and resources it can commit in any one phase or waterbody.

Because EPA has largely focused on addressing point source discharges through the NPDES permitting program, state and local governments have in many cases taken the lead in dealing with nonpoint source issues, usually outside of the TMDL program. These programs often provide a flexible option to the time and budget constraints mentioned above. Florida believes that if local stakeholders are willing to initiate substantive programs that can fully, or even partially, accomplish the goals of the TMDL program at an expedited pace, then state and federal agencies should be able to support these actions, rather than delay or resist them. For example, in southwest Florida, a group of concerned stakeholders combined to form a "Nitrogen Consortium" (NC) to reduce inputs of nitrogen from all sources to the waters of Tampa Bay. Working together with the Tampa Bay Estuary Program and the FDEP, the NC developed a plan designed to "hold the line" against future increases of nitrogen (Tampa Bay National Estuary Program, 1996). Specific load-reduction efforts have been identified within the basin that allow for anticipated growth to occur without resulting in a net increase in nitrogen loads to Tampa Bay. As would be anticipated under the conditions of a more formal TMDL, periodic reviews are made of the underlying assumptions and models used to further refine the nitrogen loads and associated goals. Although FDEP has not formally adopted

a TMDL for Tampa Bay, EPA has approved these “hold the line” limits as a TMDL for Tampa Bay.

4. To allow states to better target limited monitoring budgets, EPA should set the TMDL calendar in concert with each state's rotating basin program. The rotating basin approach used by several states is an excellent example of a rigorous approach to ambient monitoring and data collection that can be used to conduct waterbody assessments of varying levels of complexity. For example, this approach can be used to create 305b reports, to list impaired waters, and to develop TMDLs. Once TMDLs are developed, the rotating basin approach could allow state and local governments to issue permits and implement management programs based on the TMDLs in a coordinated manner.

Box 3-3 Continued

Florida's Basin Management Cycle: *5 phases*

	What happens in this phase?	*When does it occur?*
Phase I Preliminary Basin Assessment	Build basin management team Prepare Status Report - Document physical setting - Conduct water quality & TMDL assessments - Inventory existing & proposed management activities - Identify & prioritize management goals & objectives, & issues of concern - Develop Plan of Study	Years 1-2
Phase II Strategic Monitoring	Carry out strategic monitoring to collect additional data	Years 1-3
Phase III Data Analysis & TMDL Development	Compile & evaluate new data Finalize list of waters requiring TMDL Develop TMDL Identify additional data collection needs Report new findings	Years 2-4
Phase IV Management Action Plan	Finalize management goals & objectives Develop draft Management Action Plan Identify monitoring & management partnerships, needed rule changes, legislative actions, and funding opportunities Obtain participants' commitment to implement plan Develop Monitoring & Evaluation Plan	Years 4-5
Phase V Implementation	Implement Management Action Plan Secure project funding Carry out rule development/legislative action Transfer information to public & other agencies Conduct environmental education Monitor & evaluate implementation of plan	Year 5+

DEFINING ALL WATERS

As shown in Figure 1-1, the TMDL process begins with identification of all waters for which achievement of water quality standards is to be assessed. The proposed regulations for the TMDL program (EPA, 1999a) define a waterbody as "a geographically defined portion of navigable waters, waters of the contiguous zone, and ocean waters under the jurisdiction of the United States, including segments of rivers, streams, lakes, wetlands, coastal waters and ocean waters." The proposed regulations also require that states identify the geographic location of listed waterbodies using a "nationally recognized georeferencing system as agreed to by [the state] and the EPA." States identify listed waterbodies using a variety of georeferencing systems, including stream segments in the EPA's reach file system and watersheds in the U. S. Geological Survey (USGS) system of hydrologic drainage basins. The use of such systems for documenting the location of listed waters is convenient and provides a degree of national standardization to the TMDL process. However, the selection of a georeferencing system and a spatial scale for defining the totality of state waters is a more complicated issue (aside from the policy issue of national standardization).

The EPA's definition of waterbody implies that all state waters should be considered in the search for impaired waters and provides no guidance on a practical upstream limit or spatial scale to observe in that search. In theory, the hierarchy of tributaries in a watershed extends upstream indefinitely. In practice, however, the choice of a lower limit on spatial scale or stream size has a very large influence on the total number of stream miles and small lakes that are included in the definition of state waters and thus require some form of assessment. For example, RF1, the original version of the EPA's national reach file system (DeWald et al., 1985) contained approximately 65,000 stream reaches totaling approximately 1 million km of stream channels. Now considered by EPA to be inadequate for describing the nation's river and stream system, RF1 has been replaced by the National Hydrography Dataset (NHD) containing more than 3 million reaches totaling nearly 10 million km of channels. Moreover, a number of states have petitioned the EPA to add still lower-order reaches (i.e., smaller streams) to the NHD in order to document the location of waters assessed by local interest groups. Because of local pressure and the lack of a regulatory lower limit on the size of streams and lakes to be considered, and because Geographic Information Systems (GIS) can document the existence and location of very small streams and lakes, the task of accurately and comprehensively assessing state waters has become formidable. At the current NHD scale, states contain an average of about 70,000 stream reaches (>100,000 km), and given recent trends, that average is rising.

This raises the question of how large the region of validity (the spatial area over which the data apply) is for data gathered at a single monitoring station. The question is conceptually troubling to begin with because the variability of water quality is large and continuous in both space and time. In practice, moreover, the de facto valid region for monitoring stations is extremely large. Given the spatially detailed treatment of rivers and streams in the NHD, however, most states would need to gather data from more than a thousand stations per year to maintain an average "monitoring ratio" of 100 km per station (assuming the NHD approximately describes state waters). This distance is clearly greater than the valid region for monitoring stations on most surface waters, especially because most of the channel length in state waters is contributed by relatively small streams (e.g., drainage areas less than 100 km^2) where water quality conditions may vary greatly over short distances. Thus, a substantial portion of state waters would appear to be located outside of the valid monitoring region for a state monitoring program of 1,000 stations. These waters are either left out of the decision process and are deemed not impaired by default, or they are included in the decision process with higher error rates.

One solution to this problem is to avoid the concept of a valid region for individual monitoring stations entirely and replace it with an approach in which monitoring data are used to develop statistical models of water quality in state waters. Water quality conditions at monitoring sites can be statistically related to known factors that cause impairment in watersheds (the size and location of stressors, for example), thus enabling estimates of water quality conditions at other unmonitored locations. As discussed later, this approach may also benefit the listing process.

Conclusions and Recommendations

1. Each state should develop a catalogue of waterbodies based on the National Hydrography Dataset for the purposes of defining state waters and designing sampling and assessment programs.

2. States should attempt to move away from the concept of a region of validity of individual monitoring stations and instead consider a statistical modeling approach to assessing the condition of waters. **This approach would combine monitoring data with estimates of water quality based on statistical models.**

DESIRABLE CRITERIA

This section considers the desired features of chemical and biological criteria as surrogates for designated use. For listing and delisting purposes, numeric and measurable criteria should be logically derived from the designated use statement. Ideally, appropriate designated uses and associated criteria are assigned to each waterbody prior to an assessment. Realistically, the cost and effort involved in categorizing every waterbody in advance of an assessment may be prohibitive, and many states' programs for setting appropriate use designation are continuing efforts. As is noted in Chapter 5, it is advisable to conduct a site-specific review to refine the standard once a waterbody is listed and before a TMDL is initiated.

One desired feature of a criterion is that it must be measurable with available monitoring methods. Unfortunately, federal guidelines for water quality assessment (EPA, 1994) do not assure this feature. In many cases there may be a discrepancy between the formulation of water quality criteria and the frequency with which water quality data are gathered.

A criterion may not be a single number, but instead may be represented as a frequency, duration, and magnitude. In the context of a pollutant, the *magnitude* refers to how much of the pollutant can be allowed in the water while still achieving the designated use. The magnitude can be chosen to protect against either acute or chronic effects of a pollutant. *Duration* refers to the period of time over which measurements of the pollutant are considered. Pollutant levels may be averaged over some number of hours or days to determine that amount of the pollutant that can be present without a loss of the designated use. The allowable *frequency* at which the criterion can be violated (called an excursion) without a loss of the designated use also must be considered. Thus, in the case of a trout fishery, the criterion might specify a minimum DO (or maximum chlorophyll *a*) that can be realized for a period of time and the number of times this number can be violated before there is demonstrable harm to the designated use. It should be noted that these numbers are pollutant-specific, and they might vary with season depending on, for example, fish life-stage.

Establishing these three dimensions of the criterion is crucial for successfully developing water quality standards[8]. Currently, there are many cases where there are insufficient data collected in one or more of these three dimensions to evaluate attainment of water quality criteria. In addition, some standards are virtually impossible to comply with, especially when the frequency of allowable excursions is zero (called "no-exceedance" standards). Box 3-4 provides three examples of criteria that are either unmeasurable given current monitoring protocols or are exceedingly difficult to meet and thus constitute an intractable problem for the TMDL program. Careful consideration of the three dimensions of the criterion is also critical to the development of appropriate TMDLs. In the law, the letter "d" in TMDL refers to a *daily* load, which has been interpreted literally in some legal cases. However, for many pollutants, the load determined over a longer time period (e.g., a season or year) is more relevant to securing the designated use. Examples of this are nutrient and sediment criteria, where the duration component of the criterion is generally not stated as "daily."

A second desirable feature is that the measured criterion must be logically derived from the qualitative statement of the designated use. The closer the criterion is in the causal chain (Figure 2-1), the easier it is to make that connection. This has led to increased interest in biocriteria, particularly numeric measures of fish, benthic invertebrate, algal, and diatom assemblages. Recommendations to adopt biocriteria are often made because biocriteria integrate the effects of multiple stressors over time and space, thus minimizing the need for a large number of samples (Karr, 2000). A second advantage of using biocriteria is that, unlike chemical criteria, they are designed to be specific to certain regions and conditions. For example, a swamp forest will typically violate DO criteria, and waterbodies in mountain areas with heavy metal-bearing rocks may violate heavy metal criteria. Biocriteria that are regionally relevant would not show those conditions as violations.

Fecal coliform counts and algal community parameters such as chlorophyll *a* are a type of biocriteria, but they are not comprehensive measures of waterbody condition. To make bioassessment more comprehensive, index systems have been developed that focus on characteristics of the biota expected in the particular region where the waterbody is located, including desired fish species and other associated organisms (Box 3-5).

The scientific community measures integrity by describing the biological condition of waterbodies that, as much as possible, have not been altered by human activity. When "pristine" or "minimally disturbed" sites are used to define integrity, any site that has been altered by human actions must, by definition, lack integrity because its biota have changed in response to the actions of humans. For obvious reasons, reservoirs, farm ponds, and other waterbodies "created" by human actions cannot be assessed using this standard.

Box 3-4 Problems Associated with Standards

[8] Specifying the magnitude, frequency, and duration is critical for chemical criteria, but may not be necessary for certain biological criteria. For example, the fecal coliform standard is best defined with all three components. On the other hand, many biocriteria such as IBI are well defined by a single number because they integrate biological, chemical, and physical effects over time.

Unmeasurable Standards

By definition, the TMDL program requires that waterbodies meet water quality criteria daily, interpreted by some as meaning that the sampling frequency must be daily. This requires that a complete time series of grab or composite samples be taken daily without an interruption over a period of a minimum of three years. As one might expect, such time series of water quality data are almost never available for waterbody assessment (with the exception of the continuous monitoring for a few parameters such as DO or temperature). Samples are generally taken monthly for common parameters and annually or less often for some toxic chemicals that require expensive laboratory analytical methodology. Sediment sampling is done infrequently, perhaps once in a period of several years.

Similarly, the frequency/duration components of water quality criteria for contact recreation are generally infeasible to measure. Many states use fecal coliform count as an indicator for the contact recreation. The standards are usually compared to the geometric mean of at least five samples taken over 30 days. This standard is not defined in terms of allowable excursions; thus, there is no frequency component. With the exception of waterbodies used for water supply, monitoring data are rarely collected often enough to comply with such a standard.

No-Exceedance Standard

Many states require that a numeric standard be maintained at all times, which implies that all monitored values of a parameter should be below the criterion. Such a limitation is a statistical impossibility because there is always a chance—albeit remote—that a water parameter may reach a high but statistically possible value exceeding an established standard. In addition, this requirement would seem to provide an incentive to sample as little as possible in order to reduce the chance of collecting a sample that is in exceedance. For example, it is possible that if nine samples are taken over a period of three years, none of the samples would, by chance, result in an excursion. If 100 samples are taken in the same period, a few (e.g., five or less) may exceed the standard. The former sampling scheme would indicate that the waterbody is in compliance while the other would not. Stream concentrations represent statistical time series for which only infinitesimally large values of a standard would have a 100 percent statistical probability of not ever being exceeded.

Flow Restriction Standards

To make “no-exceedance” standards easier to comply with, EPA (1992) and many states incorporated a flow restriction into the standards. Thus, the standards must be maintained at all times except at flows that are less than some specified low flow value (one example is given below). Unfortunately, except for the “harmonic mean flow” (Singh and Ramamurthy, 1991), none of the critical low flows specified by EPA allow consideration of wet weather discharges (Novotny, 1999). Thus, under wet weather flows, the “no-exceedance” criterion is in effect. This ignores the fact that measured water quality parameters are naturally variable.

One type of flow restriction standard is based on hydrologically based design flows. To protect against acute effects, such water quality criteria must be met at all times except during the lowest daily flow occurring once every 10 years (referred to as 1Q10). To protect against chronic effects, water quality criteria must be met at all times except during the lowest flow occurring once every 10 years averaged over a 7-consecutive-day period (7Q10). This approach assumes that concentrations of pollutants of concern are decreasing as flows increase—likely to be true for the case of a continuous year-round discharge from a point source, but not for nonpoint sources. It should be noted that these design flows have “interim” status and were not recommended for general application with water quality standards. In addition, hydrologically based design flows vary from state to state.

However, it does *not* follow that a waterbody lacking integrity is impaired or that restoring biological integrity is either possible or desirable. A waterbody that is described as lacking "biological integrity" should not be assumed to be in a less-than-desirable state. Rather, when a bioassessment finds that a waterbody diverges from integrity, there must be a social decision about whether that divergence is acceptable. In short,

"The biota of minimally disturbed sites—those with integrity—provides a benchmark, a standard by which others are measured. The protection of that standard, or something very close to it, is likely to be the goal¾the end toward which effort is directed¾in relatively few places (e.g., national parks). The modern reality is that we are not able to preserve all areas in this benchmark condition. For example, restoring salmon to every Pacific Northwest stream is not realistic, yet a restoration goal that includes viable populations of cutthroat trout may be reasonable even in many urban or suburban streams. (Karr, 2000)

Measures of biological condition (e.g., IBI) inform society of the status of a water resource. But society must decide the desired designated use and then determine what level on the index numeric scale is, with reasonable certainty, likely to protect that designated use.

Recently, the EPA Office of Water has convened a working group of states and other supporting institutions to better define the gradient of biological condition from pristine to highly degraded and link this with operational measures such as numeric biocriteria in a manner that will ensure consistency across state programs. This is referred to as tiered aquatic life uses and is expressed as a biocondition axis. Examples of this framework already exist in Maine, Ohio, and Vermont. The expectation is that as states develop a more detailed system of tiered designated uses, they will also develop measurable biocriteria logically tied to those uses.

Conclusions and Recommendations

1. All chemical criteria and some biological criteria should be defined in terms of magnitude, frequency, and duration. Each of these three components is pollutant-specific and may vary with season. The frequency component should be expressed in terms of a number of allowed excursions in a specified period (return period) and not in terms of the low flow or an absolute "never to be exceeded" limit. The requirement of "no exceedances" for many water quality criteria is not achievable given natural variability alone, much less with the variability associated with discharges from point and nonpoint sources.

2. Water quality standards must be measurable by reasonably obtainable monitoring data. In many states, there is a fundamental discrepancy between the criteria that have been chosen to determine whether a waterbody is achieving its designated use and the frequency with which water quality data are collected.

3. Biological criteria should be used in conjunction with physical and chemical criteria to determine whether a waterbody is meeting its designated use. Biocriteria are more closely related to designated uses, they can be defined and measured, and they integrate the effects of multiple stressors over time and space.

Box 3-5 Index Systems for Bioassessment

During the past two decades, biological assessment—evaluating human-caused biotic changes apart from those occurring naturally—has become a part of water managers' tool kits. Two major approaches to ambient biological monitoring are used—the river invertebrate prediction and classification system (RIVPACS) and the multimetric index of biological integrity (IBI). Although their conceptual and analytical details differ, both RIVPACS and IBI (1) focus on biological endpoints to define waterbody condition, (2) use a concept of a regionally relevant reference condition as a benchmark, (3) organize sites into classes with similar environmental characteristics, (4) assess change and degradation caused by human effects, (5) require standardized sampling, laboratory, and analytical methods, (6) score sites numerically to reflect site condition, (7) define "bands," or condition classes, representing waterbody condition, and (8) furnish needed information for diverse management decisions (Karr and Chu, 2000).

RIVPACS was developed in England (Wright et al., 1989, 1997) with clones available for use in Australia (Norris et al., 1995) and Maine (Davies and Tsomides, 1997). IBI was developed in the United States (Karr, 1981; Karr et al., 1986; Karr and Chu, 1999) with clones applied by state and federal agencies (Ohio EPA, 1988; Davis et al., 1996; Barbour et al., 1999) and abroad (Hughes and Oberdorff, 1999). Although applications of RIVPACS are historically limited to invertebrates in rivers, IBI applications have been developed for diverse taxonomic groups and waterbody types. For example, a multimetric index (RFAI, reservoir fish assessment index) has been developed as a component of Tennessee Valley Authority's (TVA) "vital signs" monitoring program to assess fishery management success in reservoirs (Jennings et al., 1995; McDonough and Hickman, 1999).

As a general example, consider a minimally disturbed Pacific Northwest stream supporting self-sustaining populations of salmon and associated assemblages of invertebrates. With urban development, salmon decline and cutthroat trout become relatively more abundant, and certain invertebrate taxa (e.g., stoneflies) are reduced or eliminated. Tiered beneficial uses could in this case differentiate between streams supporting salmon vs. cutthroat trout, using an index based on the invertebrate assemblage as the biocriterion. Recent work in these streams suggests that a benthic index of biological integrity (B-IBI) of about 35 is a minimum required to maintain a healthy salmon population (Karr, 1998). If the IBI drops below 20 because of continued development, even the cutthroat trout will eventually disappear.

LISTING AND DELISTING IN A DATA-LIMITED ENVIRONMENT

As discussed at the beginning of this chapter, states are confronted with lengthy lists of impaired waters requiring TMDLs, many of which were judged against inadequate standards or were not fully assessed as part of a comprehensive ambient monitoring program. This section proposes a mechanism for managing the large number of waters requiring attention by dividing the listing process into multiple smaller steps, as shown in Figure 3-1.

Figure 3-1 illustrates a framework for water quality management that is more detailed than the conceptualized steps of the TMDL process shown in Figure 1-1. Figure 3-1 begins with the identification of all waters to be assessed and the determination of appropriate water quality standards as in the current TMDL program. Following this, however, waters to be assessed would next go through an initial screening assessment. This involves comparing available, and often limited, data on water quality conditions with the existing applicable water quality criterion. If based on this initial screening assessment the waterbody is considered a candidate for impairment, it is advanced to the “preliminary” list for further consideration. It should be relatively easy to get on the preliminary list, the consequences of which include additional and immediate investigation to determine the nature and reality of a suspected problem. The term “preliminary” indicates that waterbodies on this list may later be placed on an action list, but they may also be declared unimpaired. Such a preliminary list has been suggested or employed in some states (e.g., Florida).

Those waterbodies placed on the preliminary list are the object of a more complete assessment that would involve additional monitoring and appropriate analysis of new data to reduce the uncertainty about their condition. If the decision from the full assessment is that the waterbody is impaired, then it moves to an “action list.” One might think of the action list as the state’s impaired waters (303d) list. The word “impaired” is a term of art. Impaired waters under Section 303d are analogous to “water quality limited segment(s),” as defined in the federal regulations (40 CFR Section 130.2(j)). The consequence of advancing to the action list is that additional resources are needed to either review and update the existing standard or complete a TMDL. (For those cases in which the existing criteria are not appropriate to a waterbody, Figure 3-1 allows for review of the water quality standard for that waterbody. The process for completing that review—use attainability analysis—is discussed in Chapter 5.)

The organizing concept in this idealized process is continuous and concurrent progress toward improved monitoring and listing decisions. The process moves forward from a position of limited information to more information; from uncertainty to more certainty; and from inaction to progressively larger and possibly more costly actions. Were EPA to endorse the idealized process represented in Figure 3-1, the listing process would be improved. For example, at the current time, there are thousands of waters on state 303d lists that were not placed there using adequate data or information. Waters in this category should be moved back to the preliminary list, represented by the dashed return arrow in Figure 3-1, to allow a more complete evaluation to be made.

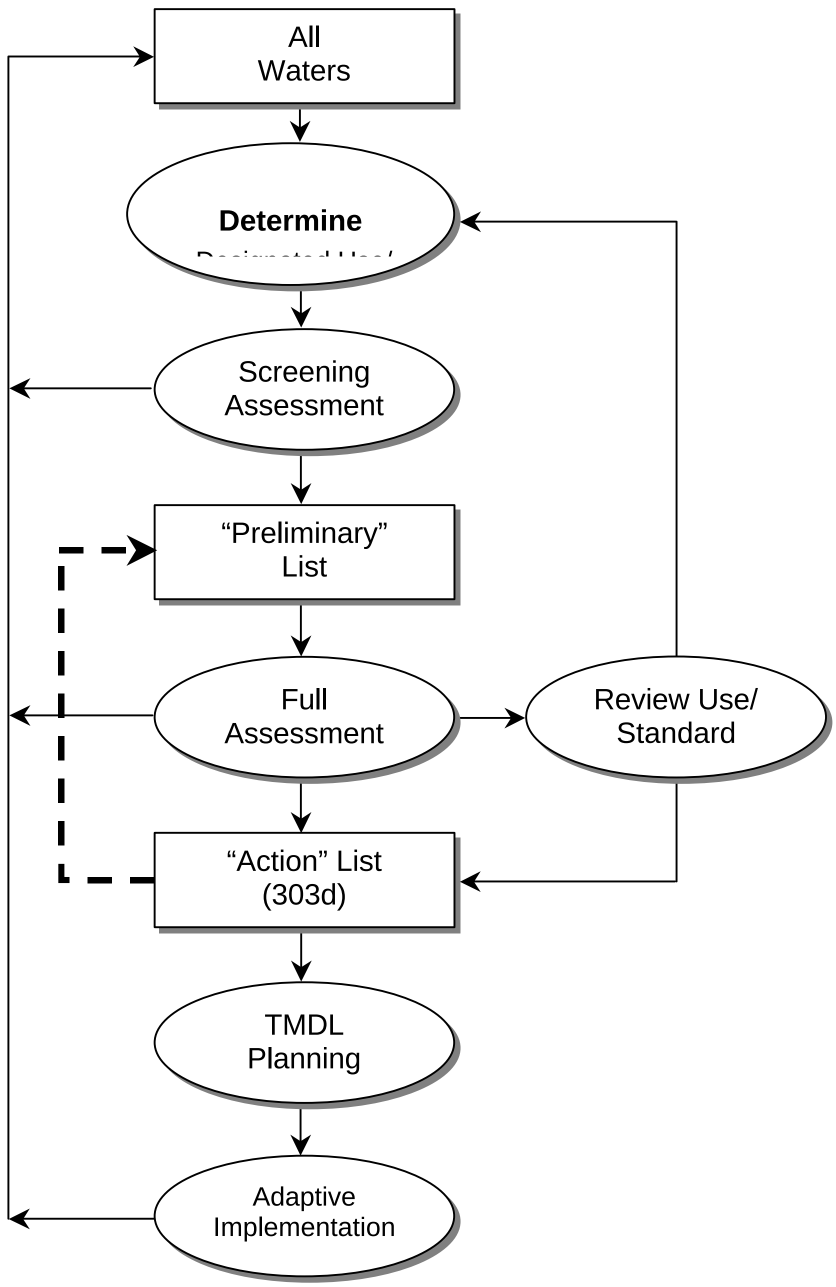

FIGURE 3-1 Framework for water quality management.

Creating the Preliminary List

Determining whether there should be some minimum threshold of data available when evaluating waterbodies for attainment of water quality standards is an issue of great concern to states. On the one hand, many call for using only the "best science" in making listing decisions, while others fear many impaired waters will not be identified in the wait for additional data. The existence of a preliminary list addresses these concerns by focusing attention on waters suspected to be impaired without imposing on stakeholders and the agencies the consequences of TMDL development, until additional information is developed and evaluated.

In many cases, biological and limited water quality surveys along with an inventory of existing sources of pollution may provide adequate information for a screening assessment of the waterbody. Evaluated data are also an important source of information for determining if a waterbody should be placed on the preliminary list. Evaluated data may take many forms (e.g., data older than a certain age, beach closures based on fixed rainfall thresholds, visual observations, and statistical inferences from small data sets) and have been described differently from state to state[9]. In contrast, monitored data are viewed as being more comprehensive, typically using data less than five years old, and may include a wide array of direct measurements of water quality, including physical, chemical, or biological measures. Use of evaluated data has been controversial in water quality assessments under the Clean Water Act. The controversy would be lessened if the use of evaluated data were limited to placing waters on the preliminary list.

The quality of the data used to list waterbodies as impaired is frequently a concern. Beyond the normal data entry, sampling, and laboratory errors, states must determine the reliability of the data coming from a wide range of sources (especially for evaluated data). Some states have responded to this uncertainty by strictly limiting the data used in making assessments to those collected by the state's lead environmental agency or some other select group of data providers (such as USGS). To overcome this uncertainty, and thereby expand the universe of reliable data, some states have required that associated meta data[10] be provided and entered into a central data repository (such as STORET).

Narrative criteria might also play a significant role in determining whether a waterbody should be placed on the preliminary list. Many water quality standards are characterized only by narrative criteria that express the desired target but do not allow comparison to a numeric value. For example, a typical narrative criterion for nutrients (nitrogen and phosphorus) in inland waters is "concentrations should be limited to the extent necessary to prevent nuisance growths of algae, weeds, and slimes" (as in New York State). Currently, violations based on interpretation of a narrative criterion may be a basis for placing a waterbody on the 303d list, even though such an evaluation is done without a numeric value of the criterion. EPA and the states have worked together over the last ten years to develop translators that will convert narrative standards to numeric criteria or guidance values (EPA, 1999b,c; NRC, 2000). While further progress is made

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[9] Evaluated data and/or information provides an indirect appraisal of water quality through such sources as information on historical adjacent land uses, aquatic and riparian health and habitat, location of sources, results from predictive modeling using input variables, and some surveys of fish and wildlife. Monitored data refers to direct measurements of water quality, including sediment measurements, bioassessments, and some fish tissue analyses. (EPA, 1998, 2000).

[10] Meta data is information about data and its usage, such as (1) what it is about, (2) where it is to be found, (3) how much it costs, (4) who can access it, (5) in what format it is available, (6) what the quality of the data is for a specified purpose, and (7) what spatial location and time period it covers.

in developing such translators, violations of narrative standards should be used to place waterbodies on the preliminary list.

The approaches to creating a preliminary list will vary from state to state. For example, in Florida, data and information used to place waters on the preliminary list have to meet certain basic QA/QC requirements as well as limited data sufficiency tests. Minimum sample sizes and confidence levels have been established, and both chemical and biological data are considered. States will have to decide upon and develop criteria for defining data sufficiency and analytical procedures for placing waterbodies on the preliminary list and the action list. EPA might be expected to assist in this process.

Moving Off the Preliminary List

Waters on the preliminary list should receive special monitoring attention. Movement from the preliminary list will be either back to the list of all waters *or* onto the action (303d) list. Movement off the preliminary list will demand a more analytically structured evaluation than was required for getting on the list. Each state should develop statistical procedures appropriate for testing attainment of each criterion. Sampling design, sample size, and QA/QC assurances for monitoring data would be defined, as would the appropriate tools for data analysis. If the data evaluated by the appropriate procedure indicate that there is no impairment, then delisting would follow. Delisting depends on analyses of sampling data and not on the implementation of a TMDL plan, although such a plan may be required to meet the criterion.

The process represented in Figure 3-1 is designed to improve the accuracy of the listing process. Placement of a waterbody on the preliminary list can serve as an indication to stakeholders that action should be taken soon to achieve water quality standards in order to avoid the costs associated with TMDL development. Because of the consequences of movement to the action list, there may be an incentive to keep waters on the preliminary list indefinitely. This incentive can be eliminated by requiring that a waterbody be automatically placed on the action (303d) list at the end of the next rotating basin cycle if additional analyses have not been undertaken. Such a requirement also may provide an incentive for point and nonpoint pollutant sources to contribute to the monitoring program in order to (potentially) avoid the consequences of a 303d listing.

Conclusions and Recommendations

1. EPA should approve the use of both a preliminary list and an action list instead of one 303d list. The two-list process would reduce the uncertainty that often accompanies a listing decision and would provide flexibility to the TMDL program.

2. If some waters on the current 303d list would be more appropriately catalogued on the preliminary list, EPA should allow states to move those waterbodies from the current 303d list to the preliminary list. If no legal mechanism exists to bring this about, Congress should create one. Many waters now on state 303d lists were placed there without the benefit of adequate data or waterbody assessment. These potentially erroneous listings contribute to a very large backlog of TMDL segments and foster the perception of a problem that is larger than it may actually be.

3. States should be allowed the flexibility to delist a waterbody without having to complete a TMDL if additional data or new information providing evidence of attainment of the water quality standard becomes available.

4. No waterbody should remain on the preliminary list for more than one rotating basin cycle. If the waterbody has not been removed from the preliminary list at the end of a rotating basin cycle, it should automatically be placed on the 303d list, unless EPA approves an exemption from such a requirement on a waterbody-by-waterbody basis. Criteria for granting exemptions could be developed by EPA.

5. To increase the reliability of the data used in listing waterbodies, EPA should require some limited amount of meta data for data submitted to STORET.

DATA EVALUATION FOR THE LISTING AND DELISTING PROCESS

Given finite monitoring resources, it is obvious that the number of sampling stations included in the state program will ultimately limit the number of water quality measurements that can be made at each station. Thus, in addition to the problem of defining state waters and designing the monitoring network to assess those waters, fundamental statistical issues arise concerning how to interpret limited data from individual sampling stations. Statistical inference procedures must be used on the sample data to test hypotheses about whether the actual condition in the waterbody meets the criterion. Thus, water quality assessment is a hypothesis-testing procedure.

A statistical analysis of sample data for determining whether a waterbody is meeting a criterion requires the definition of a null hypothesis; for listing a waterbody, the null hypothesis would be that the *water is not impaired*[11]. The analysis is prone to the possibility of both Type I error (a false conclusion that an unimpaired water is impaired) and Type II error (a false conclusion that an impaired water is not impaired). Different statistical analyses are needed depending on whether chemical or biological criteria are being assessed.

Statistical Approaches for Chemical Parameters

If chemical criteria—carefully designed to account for magnitude, frequency, and duration—are expected to be met, instantaneous measurements would be needed to determine compliance. Under current practice, however, even when states conduct frequent monitoring, sample sizes are limited, and so the possibility for false positive errors (Type I) and false negative errors (Type II) remains. As sample sizes increase, error rates can be better managed. For placement on the preliminary list, a small sample size may be acceptable. However,

[11] For delisting, the null hypothesis might be that the water is impaired.

placement on the action list would require an increase in the number of sample points used in order to reduce the uncertainty in the listing and delisting decisions.

The committee does not recommend any particular statistical method for analyzing monitoring data and for listing waters. However, one possibility is that the *binomial hypothesis test* could be required as a minimum and practical first step (Smith et al., 2001). The binomial method is not a significant departure from the current approach—called the *raw score approach*—in which the listing process treats all sample observations as binary values that either exceed the criterion or do not, and the binomial method has some important advantages. For example, one limitation of the raw score approach is that it does not account for the total number of measurements made. Clearly, 1 out of 6 measurements above the criterion is a weaker case for impairment than is 6 out of 36. The binomial hypothesis test allows one to take sample size into account. By using a statistical procedure, sample sizes can be selected and one can *explicitly* control and make trade-offs between error rates (see Smith et al., 2001, and Gibbons, in press, for guidance on managing the risk of false positive and false negative errors)[12]. Several states, including Florida and Virginia, are considering or are already using the binomial hypothesis test to list impaired waters. Detailed examples of how to apply this test are beyond the scope of this document, but can be found in Smith et al. (2001) and the proposed Chapter 62-303 of the Florida Administrative Code[13].

Whether the binomial or the raw score approach is used, there must be a decision on an acceptable frequency of violation for the numeric criterion, which can range from 0 percent of the time to some positive number. Under the current EPA approach, 10 percent of the sample measurements of a given pollutant made at a station may exceed the applicable criterion without having to list the surrounding waterbody. The choice of 10 percent is meant to allow for uncertainty in the decision process. Unfortunately, simply setting an upper bound on the percentage of measurements at a station that may violate a standard provides insufficient information to properly deal with the uncertainty concerning impairment.

The choice of acceptable frequency of violation is also supposed to be related to whether the designated use will be compromised, which is clearly dependent on the pollutant and on waterbody characteristics such as flow rate. A determination of 10 percent cannot be expected to apply to all water quality situations. In fact, it is inconsistent with federal water quality criteria for toxics that specify allowable violation frequencies of either one day in three years, four consecutive days in three years, or 30 consecutive days in three years (which are all less than 10 percent). Embedded in the EPA raw score approach is an implication that 10 percent is an acceptable violation rate, which it may not be in certain circumstances.

Both the raw score and binomial approaches require the analyst to “throw away” some of the information found in collected data. For example, if the criterion is 1.0, measurements of 1.1 and 10 are given equal importance, and both are treated simply as exceeding the standard. Thus,

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[12] The choice of a Type I error rate is based on the assessors willingness to falsely categorize a waterbody. It also is the case that, for any sample size, the Type II error rate decreases as the acceptable Type I error rate increases. The willingness to make either kind of mistake will depend on the consequences of the resulting actions (more monitoring, costs to do a TMDL plan, costs to implement controls, possible health risk) and who bears the cost (public budget, private parties, etc.). The magnitude and burden of a Type I versus Type II error depend on the statement of the null hypothesis and on the sample size. When choosing a Type I error rate, the assessor may want to explicitly consider these determinants of error rates.

[13] This proposed rule chapter was approved for adoption by the Florida Department of Environmental Protection’s Environmental Regulation Commission on April 26, 2001, but has not been officially filed for adoption by the Department because of a pending rule challenge before the Division of Administrative Hearings.

a potentially large amount of information about the likelihood of impairment is simply discarded. (The standard deviation can be used to set priorities for TMDL development or other restoration activities.) There are other approaches that are more effective at extracting information from a single monitoring sample, thereby reducing the number of samples needed to make a decision with the same level of statistical confidence. For example, Gibbons (in press) suggests testing the data for normality or log normality and then examining the confidence intervals surrounding the estimated 90^{th} percentile of the chosen distribution. When the data are neither normal nor lognormal, or when more than 50 percent of the observations are censored (below the detection limit), Gibbons suggests constructing a nonparametric confidence limit based on the binomial distribution of ranked data. Another approach that uses all the data to make a decision is "acceptance sampling by variables" (Duncan, 1974). In general, alternative statistical approaches transform questions about the proportion of samples that exceed a standard into questions about the center (or another parameter) of a continuous distribution. It should be noted that new approaches will bring new analytical requirements that must be taken into consideration. For example, if there is a requirement to specify a distribution, sufficient data must be available. In some cases, data from other similar sites may be needed to give an overall assessment of distribution type. Finally, as more powerful statistical procedures are used, water quality assessors will need to understand how to run the tests and also how to state hypotheses that clearly relate to the water quality criterion.

Statistical Approaches for Biological Parameters

Error bands exist with any sampled data, including bioassessment results. Thus, bioassessment procedures must also be designed to be statistically sound. The utility of any measure of stream condition depends on how accurately the original sample represents the condition in the stream—that is, how successful it is in avoiding statistical "bias." Protocols to for making such measurements are established in the technical literature (Karr and Chu, 1999) as well as in guidance manuals produced by EPA (Barbour et al., 1996, 1999; EPA, 1998a; Gibson et al., 2000).

There are three principal ways variability is dealt with in the process of deriving and using biocriteria (Yoder and Rankin, 1995). First, variability is compressed through the use of multimetric evaluation mechanisms such as IBI. Reference data for each metric are compressed into discrete scoring ranges (i.e., 5, 3, and 1). Second, variability is stratified via tiered uses, ecoregions, stream size categories (headwaters, wadable, boatable), and method of calibrating each metric (i.e., vectoring expectations by stream size). Third, variability is controlled through standardized operating procedures, data quality objectives (i.e., level of taxonomy), index sampling periods (to control for seasonal effects), replication of sampling, and training (Yoder and Rankin, 1995). One can, for example, avoid seasonal variation by carefully defining index sampling periods or variation among microhabitats by sampling the most representative microhabitat (Karr and Chu, 1999). Box 3-6 presents results of several studies in which the error around biological parameters was assessed.

Box 3-6 Understanding Sources of Variability in Bioassessment

Sources of error evaluated in one study of biological monitoring data from New England lakes (Karr and Chu, 1999) included three types of variance: interlake variability (differences among lakes); intralake variability (variability associated with sampling different sites within a lake as decided by the field crew), and lab error (error related to subsample work in the lab). The interlake variability was the effect of interest, and the goal was to determine if that source of variability was dominant. Distribution of variance varied as a function of biological metric selected. Those measures with reduced variance except for the context of interest (e.g., interlake variability) were selected for inclusion in IBI to increase the probability of detecting and understanding the pattern of interest.

Two other studies involved an examination not of the individual metrics, but of the overall IBI (i.e., after individual metrics were tested and integrated into an IBI). For Puget Sound streams, 9 percent of variation came from differences within streams and 91 percent was variability across streams (reported in Karr and Chu, 1999, Fig. 35). For a study in Grand Teton National Park, streams were grouped in classes reflecting different amounts of human activity in their watersheds. In this case, 89 percent of the variance came from differences among the groups, and 11 percent came from differences among members of the same group (reported in Karr and Chu, 1999).

In all these cases, the goal was to find ways of measuring that emphasize differences among watersheds with differing human influences, while keeping other sources of variation small. Success in these examples was based on the development of an earlier understanding of sources of variation and then establishing sampling protocols that avoid other irrelevant sources of variation (such as variation stemming from the differing abilities of personnel to select and use methods). If these sources of variation are controlled for, then the study can emphasize the kind of variation that is of primary interest (e.g., human influence gradients).

Conclusions and Recommendations

1. EPA should endorse statistical approaches to proper monitoring design, data analysis, and impairment assessment. For chemical parameters, these might include the binomial hypothesis test or other statistical approaches that can more effectively make use of the data collected to determine water quality impairment than does the raw score approach. For biological parameters, these might focus on improvement of sampling designs, more careful identification of the components of biology used as indicators, and analytical procedures that explore biological data as well as integrate biological information with other relevant data.

2. States should be required to report the statistical properties of the sample data analyses used to make listing determinations. Error rates, confidence limits, or other means of conveying uncertainty should be presented along with the rationale for a decision to list or delist a waterbody.

USE OF MODELS IN THE LISTING PROCESS

As stated in EPA guidance documents as well as the Federal Advisory Committee Act (FACA) report (EPA, 1998b), monitoring data are the preferred form of information for identifying impaired waters. Model predictions might be used in addition to or instead of monitoring data for two reasons: (1) modeling could be feasible in some situations where monitoring is not, and (2) integrated monitoring and modeling systems could provide better information than monitoring alone for the same total cost. EPA guidance and the FACA report explicitly recognize the obvious practicality of the first reason, but largely ignore the potential importance of the second. This section considers some of the ways in which modeling might be used as a complement to monitoring and points out some limitations of modeling in informing the listing process.

Often, in attempting to estimate the frequency of violation of a standard, the number of pollutant concentration measurements made in a waterbody is so small that it is difficult to avoid false negative error with the desired level of confidence. One way in which a simple statistical model may assist in interpreting monitoring data in such cases is by introducing a variable to the analysis that is correlated with pollutant concentration. One common correlate of many water quality time series is stream flow, which is measured continuously at many monitoring stations, including nearly all USGS stations. The statistical methods for taking advantage of correlated stream flow data are called record extension techniques, several of which have been described and compared by Hirsch (1982). By modeling pollutant concentration as a function of streamflow and using the resulting model to estimate a denser concentration time series, a better estimate of the frequency distribution of pollutant concentration may be obtained. The predicted concentration time series then may be tested for violation frequency using either the binomial approach (see above) or the quantile approach. The value of this modeling approach over using pollutant data alone is directly dependent on the level of correlation that exists between the pollutant concentration and stream flow. Further discussion of the specific extension technique called MOVE (Maintenance of Variance – Extension) appears in Helsel and Hirsch (1991).

The EPA guidance on 303d listing suggests that a simple, but useful, modeling approach that may be used in the absence of monitoring data is “dilution calculations,” in which the rate of pollutant loading from point sources in a waterbody (recorded as kg per day in NPDES permits, for example) is divided by the stream flow distribution to give a set of estimated pollutant concentrations that may be compared to the state standard. Simple dilution calculations assume conservative movement of pollutants through a watershed and ignore the fact that for most pollutants some loss of mass occurs during transport due to a variety of processes including evaporation, settling, or biochemical transformation (see, for example, Novotny and Olem, 1994). Thus, the use of dilution calculations will tend to bias the decision process toward false positive conclusions. Lacking a clear rationale for such a bias, a better approach would be to include a best estimate of the effects of loss processes in the dilution model.

Section 303d and related guidance from EPA emphasize the importance of searching for information on waterbodies that are suspected of violating water quality standards, which is understandable given the desire to limit the number of sites sampled and hence the cost of monitoring. Targeted monitoring will often increase the efficiency of the assessment process (i.e., reduce the total number of decision errors), but may have somewhat hidden effects on the balance of false positive and false negative errors. Targeted monitoring represents the informal use of a prior *probability distribution on impairment* to guide monitoring toward sites located in a particular region of the distribution. One of the most potentially valuable uses of modeling in relation to 303d listing would be to formalize the use of prior information on impairment probability in order to better organize the decision process. That is, modeling techniques such as SPARROW (Smith et al., 1997) could be used to estimate preliminary impairment distributions for all waterbodies in the state. These distributions would then be used to guide monitoring and control the rates of false positive and false negative error either through Bayesian or other methods of interpreting monitoring data. Limited monitoring resources generally could be focused on the sites where impairment was most *un*certain (i.e., where the estimated probability of impairment was neither very high nor very low), potentially improving the efficiency of monitoring. Sites at the extremes of the impairment distributions (i.e., extremely likely or unlikely to be impaired) would be less frequently monitored. Decisions for placing waters on a preliminary list might be made primarily on the basis of such modeling. (Formal placement of a waterbody on the 303d list would require additional monitoring.)

Conclusions and Recommendations

1. Models that can fill gaps in data have the potential to generate information that will increase the efficiency of monitoring and thus increase the accuracy of the preliminary listing process. For example, regression analyses that correlate pollutant concentration with some more easily measurable factor could be used to extend monitoring data for preliminary listing purposes. Models can also be used in a Bayesian framework to determine preliminary probability distributions of impairment that can help direct monitoring efforts and reduce the quantity of monitoring data needed for making listing decisions at a given level of reliability.

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4
Modeling to Support the TMDL Process

This chapter addresses the planning step (Figure 1-1) that occurs once a waterbody is formally listed as impaired. The main activity required during the planning step is an assessment of the relative contribution of different stressors (sources of pollution) to the impairment. For example, during this step Total Maximum Daily Loads (TMDLs) are calculated for the chemical pollutant (if there is one) causing the impairment, and the maximum pollutant loads consistent with achieving the water quality standard are estimated. Pollutant load limits alone may not secure the designated use, however, if other sources of pollution are present. Changes in the hydrologic regime (such as in the pattern and timing of flow) or changes in the biological community (such as in the control of alien taxa or riparian zone condition) may be needed to attain the designated use, as discussed in Chapter 2. As hydrologic, biological, chemical, or physical conditions change, the estimation of the TMDL can change.

Because they represent our scientific understanding of how stressors relate to appropriate designated uses, models play a central role in the TMDL program. Models are the means of making predictions—not only about the TMDL required to achieve water quality standards, but also about the effectiveness of different actions to limit pollutant sources and modify other stressors to reach attainment of a designated use. This chapter discusses the necessity for, and limitations of, models and other predictive approaches in the TMDL process. Thus, it directly addresses the committee's charge of evaluating the TMDL program's information needs and the methods used to obtain information.

MODEL SELECTION CRITERIA

Mathematical models can be characterized as empirical (also known as statistical) or mechanistic (process-oriented), but most useful models have elements of both types. An empirical model is based on a statistical fit to data as a way to statistically identify relationships between stressor and response variables. A mechanistic model is a mathematical characterization of the scientific understanding of the critical biogeochemical processes in the natural system; the only data input is in the selection of model parameters and initial and boundary conditions. Box 4-1 presents a simple explanation of the difference between the two types of models.

Water quality models for TMDL development are typically classified as either watershed (pollutant load) models or as waterbody (pollutant response) models. A watershed model is used to predict the pollutant load to a waterbody as a function of land use and pollutant discharge; a waterbody model is used to predict pollutant concentrations and other responses in the waterbody as a function of the pollutant load. Thus, the waterbody model is necessary for determining the TMDL that meets the water quality standard, and a watershed model is necessary for allocating the TMDL among sources. Some comprehensive modeling frameworks [e.g., BASINS (EPA, 2001) and Eutromod (Reckhow et al., 1992)] include both, but most water quality models are of one or the other type. Except where noted, the comments in this chapter reflect both watershed and waterbody models; examples presented may address one or the other model type as needed to illustrate concepts.

Although prediction typically is made with a mathematical model, there are certainly situations in which expert judgment can and should be employed. Furthermore, although in many cases a complex mathematical model can be developed, the model best suited for the situation may be relatively simple, as noted in examples described later in the chapter. Indeed, reliance on professional judgment and simpler modeling will be acceptable in many cases, and is compatible with the adaptive approach to TMDLs described in Chapter 5.

Highly detailed models are expensive to develop and apply and may be time consuming to execute. Much of the concern over costs of TMDLs appears to be based on the assumption that detailed modeling techniques will be required for most TMDLs. In the quest to efficiently allocate TMDL resources, states should recognize that simpler analyses can often support informed decision-making and that complex modeling studies should be pursued only if warranted by the complexity of the analytical problem. More complex modeling will not necessarily assure that uncertainty is reduced, and in fact can compound problems of uncertain predictions. As discussed below, accounting for uncertainty and representing watershed processes are two of the possible criteria that need to be considered when selecting an analytical model for TMDL development.

TMDLs, which are typically evaluated through predictive modeling, lead to decisions concerning controls on pollutant sources or other stressors. Thus, models used in TMDL analysis provide “decision support.” Box 4-2 lists *desirable* model selection/evaluation criteria in consideration of the decision support role of models in the TMDL process. The list is intended to characterize an ideal model. Given the limitations of existing models, it should not be viewed as a required checklist for attributes that all present-day TMDL models must have.

EPA has supported water quality model development for many years and, along with the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, and the U.S. Department of Agriculture, is responsible for most models currently being applied for TMDL development. Agency-wide, EPA has funded model development and technology transfer activities for a wide range of models. The greatest concentration of this effort has been at the Center for Exposure Assessment Modeling (CEAM). In contrast to the broad perspective found within EPA as a whole, CEAM has demonstrated a clear preference for mechanistic models, as evidenced by their adoption of the BASINS modeling system (EPA, 2001) as the primary TMDL modeling framework.

Models developed at the CEAM and incorporated into BASINS place high priority on correctly describing key processes, which is related to but different from model selection

Box 4-1 Mechanistic vs. Statistical Models

Suppose a teacher is conducting a lesson on measurements and sets out to measure and record the height and weight of ea`ch student. Unfortunately, the scale breaks after the first several children have been weighed. In order to proceed with the lesson (though on a somewhat different tack), a *mechanistically* inclined teacher might decide to use textbook data on the density of the human body, together with a variety of length measurements of each child (e.g., waist, leg, and arm dimensions), to estimate body volumes as the sum of the volumes of body parts. The teacher may then obtain the weights of the students as the product of density and volume. A *statistically* inclined teacher, on the other hand, might simply use the data obtained for the first several children in a regression model of weight on height that could then be used to predict the weights of the other students based on their height.

The accuracy and utility of each of these two approaches depend on both the details of the input data and the calculation procedures. If the mechanistic teacher has good information on tissue densities, for example, and has the time to make many length measurements, the results may be quite good. Conversely, the statistical approach may yield quite acceptable results at a fraction of the mechanistic effort if enough children had been weighed before the scale broke, and if those children were approximately representative of the whole class in terms of body build. Moreover, the regression model comes with error statistics for its predictions and parameters. Although the same statistical approach would work with other groups of students, additional weight measurements would be required for model calibration. Thus, the benefits of the statistical approach are that it is less costly and its reliability is known, but its use is dependent on data collected for the variable of interest (weight, in this case) under the circumstances of interest. The mechanistic approach has wider application and a clear rationality (the total equals the sum of the parts), but it requires more time and effort, and, unless some data are collected for the variable of interest under similar circumstances, its error characteristics are unknown.

Of course, in practice, mechanistic and statistical modelers often make considerable use of each other’s techniques. In the classroom analogy, for example, it would make sense for the statistically inclined teacher to make more detailed measurements of the weighed students’ dimensions and develop a multivariate regression model of weight as a function of torso volume, leg volume, etc., rather than height alone. The more complex model could be applied to a wider range of body builds. Moreover, the regression coefficients would represent the estimated densities of different parts of the body. These could be compared with the textbook values of body density as a test of the rationality of the model. Conversely, the mechanistic teacher might use body density data from the textbook to adjust the height–weight regression equations for use with different age and ethnic groups. This would eliminate the need for collecting additional weight data for these groups.

It is also worth distinguishing a third type of model termed *stochastic* that is widely used in engineering applications and that may have a useful role in TMDL modeling. The objective of stochastic modeling is to simulate the statistical behavior of a system by imposing random variability on one or more terms in the model. Such models are usually fundamentally mechanistic, but avoid mechanistic description of complex processes by using simpler randomized terms. Stochastic models generally require a large number of measurements of certain variables (e.g., inputs, state variables) in order to correctly characterize their random behavior. As an example, consider a mechanistic model of river water quality that includes randomly generated streamflow and pollutant loads. If the randomly generated inputs are realistic (both individually and in relation to each other), then the output may provide a very useful description of the variability to expect in the water quality of the river.

Box 4-2 Model Selection Criteria

A predictive model should be broadly defined to include both mathematical expressions and expert scientific judgment. A predictive model useful for TMDL decision support ideally should have the following characteristics:

1. *The model focuses on the water quality standard.* The model is designed to quantitatively link management options to meaningful response variables. This means that it is desirable to define the TMDL endpoints (e.g., pollutant sources and standard violation parameter) and incorporate the entire "chain" from stressors to response into the modeling analysis. This also means that the spatial/temporal scales of the problem and the model should be compatible.

2. *The model is consistent with scientific theory.* The model does not err in process characterization. Note that this is different from the often-stated goal that the model correctly represents processes, which, for terrestrial and aquatic ecosystems, cannot be achieved.

3. *Model prediction uncertainty is reported.* Given the reality of prediction errors, it makes sense to explicitly acknowledge the prediction uncertainty for various management options. This provides decision-makers with an understanding of the risks of options, and allows them to factor this understanding into their decisions. To do this, prediction error estimates are required.

4. *The model is appropriate to the complexity of the situation*. Simple water quality problems can be addressed with simple models. Complex water quality problems may or may not require the use of complex models (as discussed later in this chapter and in Chapter 5).

5. *The model is consistent with the amount of data available.* Models requiring large amounts of monitoring data should not be used in situations where such data are unavailable.

6. *The model results are credible to stakeholders.* Given the increasing role of stakeholders in the TMDL process, it may be necessary for modelers to provide more than a cursory explanation of the predictive model.

7. *Cost for annual model support is an acceptable long-term expense.* Given growth and change, water quality management will not end with the initial TMDL determination. The cost of maintaining and updating the model must be tolerable over the long term.

8. *The model is flexible enough to allow updates and improvements.* Research can be expected to improve scientific understanding, leading to refinements in models.

criterion #2 (see Box 4-2). It is important to recognize that placing priority on ultimate process description often will come at the expense of the other model selection criteria. For one thing, an emphasis on process description tends to favor complex mechanistic models over simpler mechanistic or empirical models and may result in analyses that are more costly than is necessary for effective decision-making. In addition, physical, chemical, and biological processes in terrestrial and aquatic environments are far too complex to be conceptually understood or fully represented in even the most complicated models. For the purposes of the TMDL program, the primary purpose of modeling should be to support decision-making. Our inability to completely describe all relevant processes can be accounted for by quantifying the uncertainty in the model predictions.

UNCERTAINTY ANALYSIS IN WATER QUALITY MODELS

The TMDL program currently accounts for the uncertainty embedded in the modeling exercise by applying a margin of safety (MOS). As discussed in Chapter 1, the TMDL can be represented by the following equation:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

This states that the TMDL is the sum of the present and near future load of pollutants from point sources and nonpoint and background sources to receiving waterbodies plus an adequate margin of safety (MOS) needed to attain water quality standards.

One possible metric for the point source waste load allocation (ΣWLA) and the nonpoint source load allocation (ΣLA) is mass per unit time, where time is expressed in days. However, other units of time may actually be more appropriate. For example, it may be better to use a season as the time unit when the TMDL is calculated for lakes and reservoirs, or a year when contaminated sediments are the main stressor.

EPA (1999) gives additional ways in which a TMDL can be expressed:

- the required reduction in percentage of the current pollution load to attain and maintain water quality standards,
- the required reduction of pollutant load to attain and maintain riparian, biological, channel, or morphological measures so that water quality standards are attained and maintained, or
- the pollutant load or reduction of pollutant load that results from modifying a characteristic of a waterbody (e.g., riparian, biological, channel, geomorphologic, or chemical characteristics) so that water quality standards are attained and maintained.

The MOS is sometimes a controversial component of the TMDL equation because it is meant to protect against potential water quality standard violations, but does so at the expense of possibly unnecessary pollution controls. Because of the natural variability in water quality parameters and the limits of predictability, a small MOS may result in nonattainment of the water quality goal; however, a large MOS may be inefficient and costly. The MOS *should* account for uncertainties in the data that were used for water quality assessment and for the variability of background (natural) water quality contributions. It should also reflect the reliability of the models used for estimating load capacity.

Under current practice, the MOS is typically an arbitrarily selected numeric safety factor. In other cases, a numeric value is not stated, and rather conservative choices are made about the models used and the effectiveness of best management practices. Consistent with our concerns, NRC (2000) notes that since parameters involved in the TMDL determination are probabilistic and the MOS is a measure of uncertainty, the MOS should be determined through a formal uncertainty and error propagation analysis. There is also a compelling practical reason for explicit and thorough quantification of uncertainty in the TMDL via the MOS—reduction of the MOS can potentially lead to a significant reduction in TMDL implementation cost. On this basis alone, EPA should place a high priority on estimating TMDL forecast uncertainty and on selecting and developing TMDL models with minimal forecast error.

Model prediction error can be assessed in two ways. First, Monte Carlo simulation can be used to estimate the effect of model parameter error, model equation error, and initial/boundary condition error on prediction error. This process is data-intensive and may be computationally unwieldy for large models. A second and simpler alternative is to compare predictions with observations, although the correct interpretation of this analysis is not as straightforward as it may seem. If a model is “overfitted” to calibration data and the test or “verification” data are not substantially different from the calibration data, the prediction–observation comparison will underestimate the prediction error. The best way to avoid this is to obtain independent verification data substantiated with a statistical comparison between calibration data and verification data.

To date, we are aware of no thorough error propagation studies with the mechanistic models favored by EPA (by thorough, we mean that all errors and error covariance terms are estimated and are plausible for the application). Further, the track record associated with even limited uncertainty analyses is not encouraging for water quality models in general. Among empirical models, only the relatively simple steady-state nutrient input–output models have undergone reasonably thorough error analyses. For example, Reckhow and Chapra (1979) and Reckhow et al. (1992) report prediction error of approximately 30 percent to 40 percent for cross-system models that predict average growing season total phosphorus or total nitrogen concentration based on measured annual loading. Prediction errors are likely to be higher for applications based on estimated or predicted loading. Prediction error will be higher still when these simple models are linked to statistical models to predict chlorophyll *a*, Secchi disk transparency, or an integrative measure of biological endpoints.

Most error analyses conducted on mechanistic water quality models have also focused on eutrophication, so relatively little is known of prediction error for toxic pollutants, microorganisms, or other important stressors. In one of the few relatively thorough error propagation studies, Di Toro and van Straten (1979) and van Straten (1983) used maximum likelihood to determine point estimates and covariances for parameters in a seasonal phytoplankton model for Lake Ontario. Of particular note, they found that prediction error decreased substantially when parameter covariances were included in error propagation, underscoring the importance of including covariance terms in error analyses. This result occurred because, while individual parameters might be highly uncertain, specific *pairs* of parameters (e.g., the half saturation constant and the maximum growth rate in the Michaelis–Menten model) may vary in a predictable way (expressed through covariance) and thus may be *collectively* less uncertain. Di Toro and van Straten found the prediction coefficient of variation to range from 8 percent (for nitrate-N) to 390 percent (for ammonia-N), with half of the values falling between 44 percent and 91 percent. Zooplankton prediction errors tended to be much higher. Beck (1987) found that the error levels cited in these studies are typical of those reported elsewhere. There is evidence to suggest that the current models of water quality, in particular, the larger models, are capable of generating predictions to which little confidence can be attached (Beck, 1987).

The need for understanding the prediction uncertainty of chosen models is not new. Indeed, recent TMDL modeling and assessment guidance from EPA often mentions the importance of formal uncertainty analysis in determining the MOS (EPA, 1999). However, EPA has consistently failed to either recommend predictive models that are amenable to thorough uncertainty analysis or provide adequate technical guidance for reliable estimation of prediction error.

Conclusions and Recommendations

1. EPA needs to provide guidance on model application so that thorough uncertainty analyses will become a standard component of TMDL studies. Prediction uncertainty should be estimated in a rigorous way, and models should be evaluated and selected considering the prediction error need. The limited error analysis conducted within the QUAL2E-UNCAS model (Brown and Barnwell, 1987) was a start, but there has been little progress at EPA in the intervening 14 years.

2. The TMDL program currently accounts for the uncertainty embedded in the modeling exercise by applying a margin of safety (MOS); EPA should end the practice of arbitrary selection of the MOS and instead require uncertainty analysis as the basis for MOS determination. Because reduction of the MOS can potentially lead to a significant reduction in TMDL implementation cost, EPA should place a high priority on selecting and developing TMDL models with minimal forecast error.

3. Given the computational difficulties with error propagation for large models, EPA should selectively target some postimplementation TMDL compliance monitoring for verification data collection to assess model prediction error. TMDL model choice is currently hampered by the fact that relatively few models have undergone thorough uncertainty analysis. Postimplementation monitoring at selected sites can yield valuable data sets to assess the ability of models to reliably forecast response. Large or complex models that pose an overwhelming computational burden for Monte Carlo simulation are particularly good candidates for this assessment.

MODELS FOR BIOTIC RESPONSE: A CRITICAL GAP

The development of models that link stressors (such as chemical pollutants, changes in land use, or hydrologic alterations) to biological responses is a significant challenge to the use of biocriteria and for the TMDL program. There are currently no protocols for identifying stressor reductions necessary to achieve certain biocriteria. A December 2000 EPA document (EPA, 2000) on relating stressors to biological condition suggests how to use professional judgment to determine these relationships, but it offers no other approaches. As discussed below, informed judgment can be effectively used in simple TMDL circumstances, but in more complex systems, empirical or mechanistic models may be required.

There have been some developments in modeling biological responses as a function of chemical water quality. One approach attempts to describe the aquatic ecosystem as a mechanistic model that includes the full sequence of processes linking biological conditions to pollutant sources; this typically results in a relatively complex model and depends heavily on scientific knowledge of the processes. The alternative is to build a simpler empirical model of a single biological criterion as a function of biological, chemical, and physical stressors. Both approaches have been pursued in research dating back at least 30 years, and there has been some progress on both fronts. One promising recent approach is to combine elements of each of these methods. For example, Box 4-3 describes a probability network model that has both mechanistic and empirical elements with meaningful biological endpoints.

Advances in mechanistic modeling of aquatic ecosystems have occurred primarily in the form of greater process (especially trophic) detail and complexity, as well as in dynamic simulation of the system (Chapra, 1996). Still, mechanistic ecosystem models have not advanced to the point of being able to predict community structure or biotic integrity. Moreover, the high level of complexity that has been achieved with this approach has made it difficult to use statistically rigorous calibration methods and to conduct comprehensive error analyses (Di Toro and van Straten, 1983; Beck, 1987).

The empirical approach depends on a statistical equation in which the biocriterion is estimated as a function of a stressor variable. Success with this empirical approach has been primarily limited to models of relatively simple biological metrics such as chlorophyll *a* (Peters, 1991; Reckhow et al., 1992). For reasons that are not entirely clear, empirical models of higher-level biological variables, such as indices of biotic integrity, have not been widely used. Regressions of biotic condition on chemical water quality measures are potentially of great value in TMDL development because of their simplicity and transparent error characteristics. Two accuracy issues, however, need to be considered. First is the obvious question of whether the level of statistical correlation between biotic metrics and pollutant concentrations is strong enough that prediction errors will be acceptable to regulators and stakeholders. A second and more difficult issue is that of gaining assurance of a cause–effect relationship between chemical predictors and biotic metrics. The construction of empirical models of biotic condition would benefit greatly from (1) observational data that show the effects of changes in chemical concentrations over a time period when other factors have remained relatively constant and (2) inclusion of as many factors that are relevant to biotic condition as possible. The latter, of course, increases the requirement for observational data. Despite these limitations, in the near term, empirical models may more easily fill the need for biological response models than would mechanistic models.

Conclusions and Recommendations

1. EPA should promote the development of models that can more effectively link environmental stressors (and control actions) to biological responses. Both mechanistic and empirical models should be explored, although empirical models are more likely to fill short-term needs. Such models are needed to promote the wider use of biocriteria at the state level, which is desirable because biocriteria are a better indicator of designated uses than are chemical criteria.

Box 4-3 Neuse Estuary TMDL Modeling

The Neuse Estuary is listed for chlorophyll *a* violations (exceedances of 40 g/l), and nitrogen is the pollutant for which a TMDL is developed. Two distinct estuarine models have been developed to guide the TMDL process; one is a two-dimensional process model (CE-Qual-W2), and the other is a probability (Bayes) network model (Borsuk, 2001) depicted in Figure 4-1.

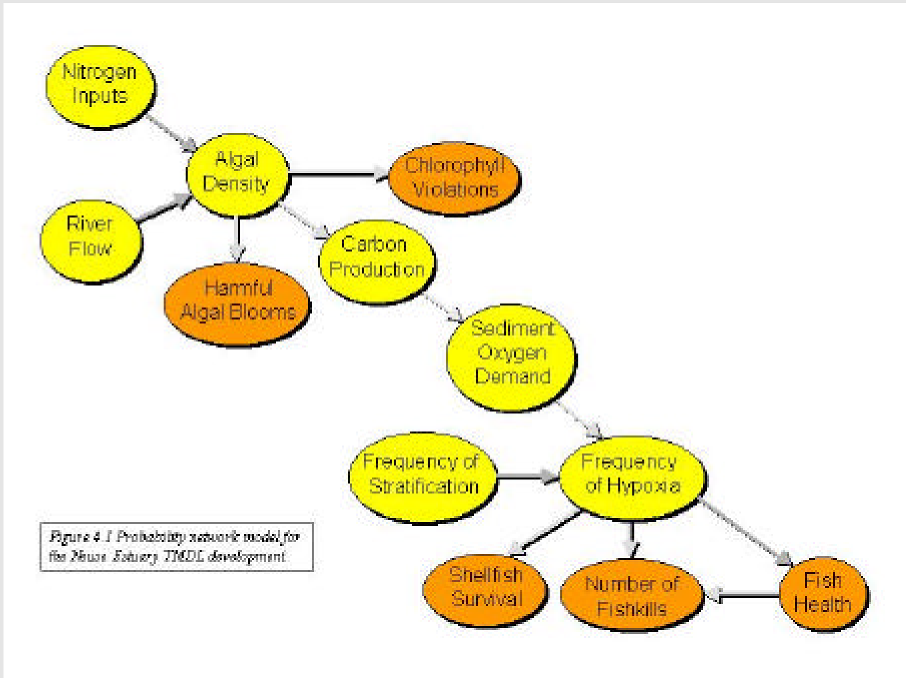

Figure 4.1 Probability network model for the Neuse Estuary TMDL development

This probability network model has several appealing features that are compatible with the modeling framework proposed here:

- The probabilities in the model are an expression of uncertainty.
- The conditional probabilities characterizing the relationships described in Figure 4-1 reflect a combination of simple mechanisms, statistical (regression) fitting, and expert judgment.
- Some of the model endpoints—estimated using judgmental probability elicitation, which is a rigorous, established process for quantifying scientific knowledge (Morgan and Henrion, 1990)—such as “shellfish survival” and “number of fishkills,” characterize biological responses that are more directly meaningful to stakeholders and can easily be related to designated use.

The Neuse Bayes network is a waterbody model; it is being linked to the USGS SPARROW watershed model for allocation of the TMDL.

ADDITIONAL MODEL SELECTION ISSUES

Data Required

The use of complex mechanistic models in the TMDL program is warranted if it helps promote the understanding of complex systems, as long as uncertainties in the results are reported and incorporated into decision-making. However, there may be a tendency to use complex mechanistic models to conduct water quality assessments in situations with little useful water quality data and/or involving major remediation expenditures or legal actions. In these situations, there is usually a common belief that the expected realism in the model can compensate for a lack of data, and the complexity of the model gives the impression of credibility. However, given that uncertainty in models is likely to be exacerbated by a lack of data, the recommended strategy is to begin with a simple modeling study and iteratively expand the analysis as needs and new information dictate.

For example, a simple analysis using models like those described by EPA (Mills et al., 1985) as screening procedures could be run quickly at low cost to begin to understand the issues. This understanding might suggest (perhaps through sensitivity analysis) that data should be collected on current land use, or that a limited monitoring program is warranted. Following acquisition of that information/data, a revised (perhaps more detailed) model could be developed. This might result in the TMDL (to be further evaluated using adaptive implementation as described in Chapter 5), or it might lead to further data collection and refinement of the model. This strategy for data-poor situations makes efficient use of resources and targets the effort toward information and models that will reduce the uncertainty as the analysis proceeds.

The data required for TMDL model development will be a function of the water quality criterion and its location and the analytical procedures used to relate the stressors to the criterion. Data needs may include hydrology (streamflow, precipitation), ambient water quality measures, and land use and elevation in a watershed (see Box 4-4 for more information). TMDL development will also likely require data on point/nonpoint sources and pollutant loads, atmospheric deposition, the effectiveness of current best management practices, and legacy/upstream pollutant sources. Because the amount of available data varies with site, there is no absolute minimum data requirement that can be universally set for TMDL development. Data availability is one source of uncertainty in the development of models for decision support. Although there are other sources of uncertainty as well, models should be selected (simple vs. complex) in part based on the data available to support their use.

Simple vs. Complex Models

The model selection criteria concerning cost, flexibility, adaptability, and ease of understanding (Box 4-2) all tend to favor simple models, although they may fail to adequately satisfy the first criterion. There are many situations, however, when an exceedingly simple model is all that is needed for TMDL development, particularly when combined with adaptive implementation (to be discussed in Chapter 5). For example, it is not uncommon in many states for farm fields to straddle small streams, with cows being allowed to freely graze in and around the stream. If a downstream water quality standard is violated, a simple mental model linking

Box 4-4 Data Requirements for TMDL Modeling of Pollutants

The data and information required for TMDL modeling must reflect the parameters that affect attainability of water quality standards. Many of the models used today have extremely large data requirements, a fact that must be addressed prior to TMDL development so that adequate data collection can occur.

Flow Data. Critical to the process of calibrating and verifying models are flow data, from sources and various locations in the receiving water. Flow data are generally high in quality if gathered as part of unidirectional stream surveys, but become less reliable in areas subject to tidal effects. The USGS is generally considered to be the most reliable source for long-term, high-quality data sets. Tidal records are available, historically and for predictive purposes, for many coastal waters in the United States from the National Oceanic and Atmospheric Administration. Some states have maintained long-term gages in coastal waters, but these are usually few in number.

Ambient Water Quality Data. A number of federal agencies, state agencies, regional organizations, and research groups collect surface water quality data. Many of these data are retrievable over the Internet, particularly data from the USGS and EPA. Although there is no universal repository for all surface water quality data, the STORET database is the most comprehensive. Because methods of collection and analysis may vary, there is a need for QA/QC of these data.

Land Use Data. All states should have access to a series of land use records and projections. For ease of use, the land use data sets should be made available as Geographic Information System (GIS) coverages. EPA has provided default coverages as a component of its BASINS model. For TMDL purposes, land use data are required for the time period over which water quality data are available in order to calibrate and validate models. Projected land use data are needed for predicting future scenarios. The overall quality of these land use data will vary, often as a function of the level of ground-truthing that was done or the accuracy of the predictions for future land use changes.

Point Source Data. Model inputs may include measured values of pollutant loading from point sources (e.g., based on information reported on NPDES Discharge Monitoring Reports submitted by permitted facilities). Other possible data sources include results from periodic compliance inspections and wasteload allocation studies, or data collected as part of field surveys done in support of the TMDL. Such data are generally available and reliable.

Nonpoint Source Data. Data on pollutant loadings from nonpoint sources are much less available and reliable than data from point sources. This is partly because during high-flow, high-rainfall events, monitoring is only infrequently conducted. For nonpoint sources, Event Mean Concentrations (EMCs) are needed to estimate the loadings that are delivered from each significant land use in a basin. EMCs are useful tools in providing estimated nonpoint source loads. Given the wide range of actual loads that may be associated with nonpoint sources, these estimates frequently represent the best science available.

Atmospheric Deposition. Data on pollutant loadings from atmospheric deposition have been compiled by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) using a nationwide network of precipitation-monitoring sites to generate reliable

Box 4-4 Continued

estimates of loads for many parameters. However, unlike watersheds, airsheds vary in size, depending upon the pollutant of concern and its specific forms and chemistry. Assessing the atmospheric contribution to any one basin is complicated by variations attributable to factors such as seasonal shifts in prevailing winds and distance from contributing sources. Thus, it is currently difficult to differentiate impacts from local sources vs. remote sources. For example, although significant work has been done in the northeastern United States to link sources of nitrous oxides with the areas subject to impact, similar studies elsewhere are not routinely available. Data for parameters other than those covered by NADP sites, as well as data on basin-specific wet and dry atmospheric deposition rates, are also scant.

Legacy/Upstream Sources. **For many impaired waters, states will need to identify and estimate loads attributed to legacy sources (e.g., PCBs, DDT, or the phosphorus-laden lake sediments) and upstream sources (those entering a waterbody segment upstream of the watershed currently being studied). The availability and reliability of such data vary widely across the nation.**

Best Management Practices. **TMDL development will in many cases require estimates of the treatment efficiency for a best management practice (BMP). Such data are generally not available, except for a small number of well-studied stormwater BMPs and a limited number of pollutants (see NRC, 2000). To account for these deficiencies, states might use best professional judgment to estimate the percent**

reduction, taking into account treatment provided by similar BMPs and stakeholder input. EPA has recently provided funding for a national database designed to help states track the effectiveness of BMPs as they are developed and evaluated. Databases of BMP effectiveness are currently available at ASCE (1999) and Winer (2000).

the cows to the violation, and subsequent actions in which the first step might be to limit cow access to the riparian corridor, may ultimately be sufficient for addressing the impairment. This example is certainly not intended to suggest that all TMDLs will be simple, but it does suggest the value of simple analyses and iterative implementation. Box 4-5 presents a relatively simple modeling exercise (based on a statistical rather than mechanistic model) that was used successfully to develop a TMDL for clean sediment.

With regard to mechanistic models, there is no intrinsic reason to choose the particular scales that have become the basis for representing processes in the majority of mechanistic water quality models. As an alternative, Borsuk et al. (2001) have shown that it is possible to specify relatively simple mechanistic descriptions of key processes in aquatic ecosystems, which limits the dimension of the parameter space so that parameters may be estimated using least squares or Bayesian methods on the available data. The SPARROW model (Smith et al., 1997) is another more statistically based alternative that includes terms and functions that reflect processes. These efforts suggest that a fruitful research direction for the TMDL program is the development of models that are based on process understanding yet are fitted using statistical methods on the observational data.

Box 4-5 Use of a Simple Empirical Model:
Suspended Sediment Rating Curve for Deep Creek, MT

One relatively simple form of model that has been used successfully in many TMDL applications is a statistical regression of a water quality indicator on one or more predictor variables. The indicator may be either the pollutant named in the TMDL or a related metric used to determine impairment but not directly involved in the TMDL analysis. Such a model was used to develop a TMDL for suspended sediment in Deep Creek, MT (see Endicott, 1996). The designated use of that waterbody was to support a cold water fishery and its associated biota, especially to provide high-quality spawning areas to rainbow and brown trout from a nearby reservoir. The reservoir and the river provide a blue-ribbon trout fishery. Analyzing the effects of suspended sediment on salmonids is complicated by the fact that sediment concentrations in western trout streams increase dramatically with streamflow in healthy as well as sediment-impaired streams, but are lower at any given flow in the healthy streams than in the impaired streams. Suspended sediment concentrations at all stages of the hydrograph are important biologically.

To develop a sediment TMDL at this site, modelers compared the relationship of sediment concentration to streamflow (known as the “sediment rating curve”) at the impaired site to the corresponding sediment rating curve for an unimpaired reference site. Rating curves were developed by regressing sediment concentration on streamflow. In the case of Deep Creek, the sediment–flow relationship is approximately linear with a slope of 0.51 mg l^{-1} per ft^3sec^{-1}. Based on rating curves for reference streams of similar size in the area (Endicott, 1996), an appropriate slope would be 0.26 mg l^{-1} per ft^3sec^{-1}. Thus, the goal of TMDL implementation is to lower the Deep Creek ratio by about half. According to the approved TMDL management plan, certain channel modifications and a combination of riparian and grazing BMPs are expected to reduce the slope of the sediment rating curve and restore the health of the trout fishery. Determination of whether the control measures have reduced the rating curve slope to the target level can be accomplished in the future by a hypothesis test on the slope parameter of the revised regression of concentration on flow. The Type 1 and Type 2 error rates for this decision-making method will relate directly to the statistical confidence limits on the estimated slope parameter, and are controllable through the quantity of monitoring data collected after the control measures are in place.

There are several aspects of this modeling approach that make it well suited to the TMDL problem. The analysis was simple to carry out and relatively easy for stakeholders to understand. Despite its simplicity, the model focuses on a critical aspect of the Deep Creek ecosystem—suspended sediment concentrations over the entire hydrograph. Future decision-making on the success of the management plan can be based on an objective test with known error rates that are controllable through monitoring.

Pilot Watersheds

Another approach to consolidate modeling efforts and develop TMDLs more efficiently is the pilot watershed concept[14]. Many TMDLs involve small- to medium-sized watersheds that have a dominating nonpoint source pollution problem (e.g., the Corn Belt region, watersheds draining forested areas, or suburban watersheds). Watersheds located in the same ecoregion may have similar water quality problems and solutions. Thus, a detailed modeling study of one or two benchmark watersheds can provide problem identification and solutions. These findings could potentially be extrapolated to less investigated but similar watersheds.

Conclusions and Recommendations

If accompanied by uncertainty analysis, many existing models can be used to develop TMDLs in an adaptive implementation framework. Adaptive implementation, discussed in detail in Chapter 5, will allow for both model development over time and the use of currently available data and methods. It provides a level of assurance that the TMDL will ultimately be successful even with high initial forecast uncertainty.

1. EPA should not advocate detailed mechanistic models for TMDL development in data-poor situations. Either simpler, possibly judgmental, models should be used or, preferably, data needs should be anticipated so that these situations are avoided. The strategy of accounting for data-limited TMDLs with increasingly detailed models needs rigorous verification before it should be endorsed and implemented. Starting with simple analyses and iteratively expanding data collection and modeling as the need arises is the best approach.

2. EPA needs to provide guidance for determining the level of detail required in TMDL modeling that is appropriate to the needs of the wide range of TMDLs to be performed. The focus on detailed mechanistic models has resulted in complex, costly, time-consuming modeling exercises for single TMDLs, potentially taking away resources from hundreds of other required TMDLs. Given the variety of existing watershed and water quality models available, and the range of relevant model selection criteria, EPA should expand its focus beyond mechanistic process models to include simpler models. This will support the use of adaptive implementation.

3. EPA should support research in the development of simpler mechanistic models that can be fully parameterized from the available data. This would lead to models that meet several model selection criteria present in Box 4-2, such as consistency with theory, assessing uncertainty, and consistency with available data.

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[14] In various forms, "pilot watersheds" have for years been the basis for understanding land use impacts on water quality. The concept is implicit in the acceptance and use of export coefficients for pollutant load assessment. A prominent example is the series of PLUARG (Pollution from Land Use Activities-Reference Group) studies to determine the total loads of pollutants to the Great Lakes. The group used several pilot watersheds on each side of the border and extrapolated the detailed monitoring and modeling results into the entire Great Lakes basin.

4. To more efficiently use scarce resources, EPA should approve the use of pilot watersheds for TMDL modeling. Rather than detailed models being prepared for every impaired waterbody, pilot TMDLs could be prepared in detail for a benchmark watershed (e.g., a typical suburban or agricultural watershed), and the results could be extrapolated to similar watersheds located in the same ecoregion. The notion of extending modeling results to similar areas, which underlies the present-day use of export coefficients, is reasonable if applied in the framework of adaptive implementation. Such a framework, coupled with the rapid application of specific controls/approaches in a number of watersheds, can reveal where techniques do or do not work and can allow for appropriate modifications.

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5
Adaptive Implementation for Impaired Waters

Water quality assessment is a continuous process. The finding of an impaired waterbody during assessment triggers a sequence of events that may include listing of the water, development of a Total Maximum Daily Load (TMDL), planning of state and federal actions, and implementation events designed to comply with water quality standards—all of which are characterized by uncertainty. This chapter describes the process of adaptive implementation of a water quality plan. Adaptive implementation simultaneously makes progress toward achieving water quality standards while relying on monitoring and experimentation to reduce uncertainty.

SCIENCE AND THE TMDL PROCESS

The planning sequence of moving from data to analysis to information and knowledge is supposed to provide confidence that the sometimes costly actions to address a water quality problem are justified. A desire for this confidence is often behind the call for "sound science" in the TMDL program. However, the ultimate way to improve the scientific foundation of the TMDL program is to incorporate the *scientific method*, not simply the results from analysis of particular data sets or models, into TMDL planning. The scientific method starts with limited data and information from which a tentatively held hypothesis about cause and effect is formed. The hypothesis is tested, and new understanding and new hypotheses can be stated and tested. By definition, science is this process of continuing inquiry. Thus, calls to make policy decisions based on the "the science," or calls to wait until "the science is complete," reflect a misunderstanding of science. Decisions to pursue some actions must be made, based on a preponderance of evidence, but there may be a need to continue to apply science as a process (data collection and tools of analysis) in order to minimize the likelihood of future errors.

Many debates in the TMDL community have centered on the use of "phased" and "iterative" TMDLs. Because these terms have particular meanings, this report uses a more general term—adaptive implementation. Adaptive implementation is, in fact, the application of the scientific method to decision-making. It is a process of taking actions of limited scope commensurate with available data and information to continuously improve our understanding of a problem and its solutions, while at the same time making progress toward attaining a water quality standard. Plans for future regulatory rules and public spending should be tentative commitments subject to revision as we learn how the system responds to actions taken early on.

Like other chapters, this chapter discusses a framework for water quality management (shown in Figure 5-1, which is the same as Figure 3-1). Before turning to adaptive implementation, it discusses an important prior step—review of water quality standards. Before a waterbody is placed on the action (303d) list, it is suggested that states conduct a review of the appropriateness of the water quality standard. The standards review may result in the water not being listed as impaired if the standard used for the assessment was found to be inappropriate. On the other hand, the same process may result in a "stricter" standard than was used in the assessment process, in which case the waterbody would have a TMDL plan developed to achieve that revised standard. A review of the water quality standard will assure that extensive planning and implementation actions are directed toward clearly conceived designated uses and associated criteria to measure use attainment.

REVIEW OF WATER QUALITY STANDARDS

Water quality standards are the benchmark for establishing whether a waterbody is impaired; if the standards are flawed (as many are), all subsequent steps in the TMDL process will be affected. Although there is a need to make designated use and criteria decisions on a waterbody and watershed-specific basis, most states have adopted highly general use designations commensurate with the federal statutory definitions. However, an appropriate water quality standard must be defined *before* a TMDL is developed. Within the framework of the Clean Water Act (CWA), there is an opportunity for such analysis, termed use attainability analysis (UAA).

A UAA determines if impairment is caused by natural contaminants, nonremovable physical conditions, legacy pollutants, or natural conditions (see Box 5-1). More importantly, a UAA can refine the water quality standard. UAA should result in more stratified and detailed narrative statements of the desired use and measurable criterion. For example, a UAA might refine the designated use and criterion from a statement that the water needs to be fishable to a statement calling for a reproducing trout population. Then one or more criteria for measuring attainment of this designated use are described; these might include minimum dissolved oxygen or maximum suspended

sediment requirements. Alternatively, an index to measure biological condition appropriate to the trout fishery designated use, such as an index of biological integrity (IBI), may be defined.

In the 1990s, TMDLs were undertaken for some waterbodies where the designated use was not attainable for reasons that could have been disposed of by a UAA. For example, TMDLs conducted in Louisiana resulted in the conclusion that even implementing zero discharge of a pollutant would not bring attainment of water quality standards (Houck, 1999). A properly conducted UAA would have revealed the true problem—naturally low dissolved oxygen concentrations—before the time and money were spent to develop the TMDL. Unfortunately, UAA has not been widely employed. Novotny et al. (1997) found that 19 states reported no experience with UAA. The majority of states reported a few to less than 100 UAAs, while five states (Indiana, Nebraska, New York, Oklahoma, and Pennsylvania) performed more than 100.

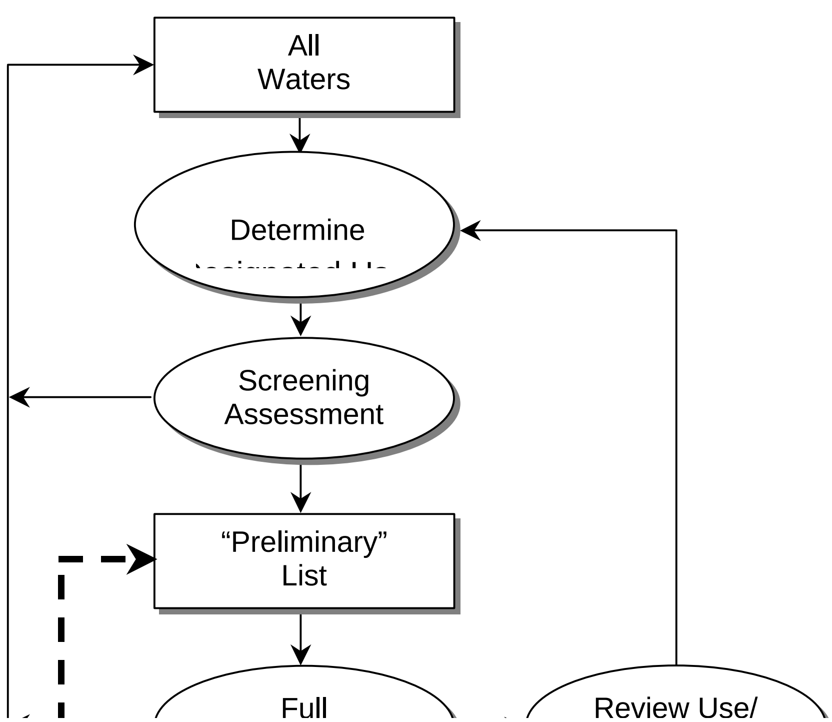

FIGURE 5-1 Framework for water quality management.

Box 5-1 Six Reasons for Changing the Water Quality Standard

The following six situations, which can be revealed by UAA, constitute reasons for changing a designated use or a water quality standard (EPA, 1994). Conducting a UAA does not necessarily preclude the development of a TMDL.

1. Naturally occurring pollutant concentrations prevent attainment of the use.

2. Natural, ephemeral, intermittent, or low flow water levels prevent the attainment of the use unless these conditions may be compensated for by a sufficient volume of effluent discharge without violating state conservation requirements to enable uses to be met.

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place (e.g., as with some legacy pollutants).

4. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use.

5. Physical conditions related to the natural features of the waterbody, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses.

6. Controls more stringent that those required by the CWA mandatory controls (Sections 301b and 306) would result in substantial and widespread adverse social and economic impact. This requires developing a TMDL and conducting a socioeconomic impact analysis of the resulting TMDL (Novotny et al., 1997).

One possible explanation for the failure to widely employ UAA analysis is the absence of useful EPA guidelines. The last technical support manuals were issued in the early 1980s (EPA, 1983) and are limited to physical, chemical and biological analyses. It is presently not clear what technical information constitutes an adequate UAA for making a change to the use designation for a waterbody that will be approved by the EPA.

In addition to being a technical challenge, standards review also has important socioeconomic consequences (see point 6 in Box 5-1). EPA has provided little information on how to conduct socioeconomic analyses or how to incorporate such analyses in the UAA decision. The socioeconomic analysis suggested by EPA is limited to narrowly conceived financial affordability and economy-wide economic impact assessments (e.g., employment effects) (Novotny et al., 1997). However, when setting water quality standards, states may be asked to make decisions in consideration of a broader socioeconomic benefit–cost framework than what is currently expected in a UAA. Finally, EPA has offered no guidance on what constitutes an acceptable UAA in waterbodies of different complexity and on what decision criteria will be accepted as a basis for changing a use designation. This is significant because EPA retains the authority to approve state water quality standards. These uncertainties discourage state use of UAA because there is no assurance that EPA will accept the result of the UAA effort as an alternative to a TMDL, especially if the EPA expectation for a UAA will result in significant analytical costs.

Conclusions and Recommendations

1. EPA should issue new guidance on UAA. This should incorporate the following: (1) levels of detail required for UAAs for waterbodies of different size and complexity, (2) broadened socioeconomic evaluation and decision analysis guidelines for states to use during UAA, and (3) the relative responsibilities and authorities of the states and EPA in making use designations for specific waterbodies following a UAA analysis.

2. UAA should be considered for all waterbodies before a TMDL plan is developed. The UAA will assure that before extensive planning and implementation actions are taken, there is clarity about the uses to be secured and the associated criteria to measure use attainment. UAA is especially warranted if the water quality standards used for the assessment were not well stratified. However, the decision to do a UAA for any waterbody should rest with each state.

ADAPTIVE IMPLEMENTATION DESCRIBED

Once a waterbody is on the 303d list, a plan to secure the designated use is developed and a sequence of actions is implemented. The adaptive implementation process begins with initial actions that have a high degree of certainty associated with their water quality outcome. Future actions must be based on (1) continued monitoring of the waterbody to determine how it responds to the actions taken and (2) carefully designed experiments in the watershed. This concurrent process of action and learning is depicted in Figure 5-2.

The plan includes the following related elements: immediate actions, an array of possible long-term actions, success monitoring, and experimentation for model refinement. In choosing *immediate actions*, watershed stakeholders and the state should expect such actions to be undertaken within a fixed time period specified in the plan. If the impairment problem is attributable to a single cause or if the impairment is not severe, then the immediate actions might be proposed as the final solution to the nonattainment problem. However, in more challenging situations, the immediate actions alone should not be expected to completely eliminate the impairment.

Regardless of what immediate actions are taken, there may not be an immediate response in waterbody or biological condition. For example, there may be significant time lags between when actions are taken to reduce nutrient

loads and resulting changes in nutrient concentrations. This is especially likely if nutrients from past activities are tightly bound to sediments or if nutrient-contaminated groundwater has a long residence time before its release to surface water. For many reasons, lags between actions taken and responses must be expected. As discussed below, the waterbody should be monitored intensively to establish whether the "trajectory" of the measured water quality criterion points toward attainment of the designated use.

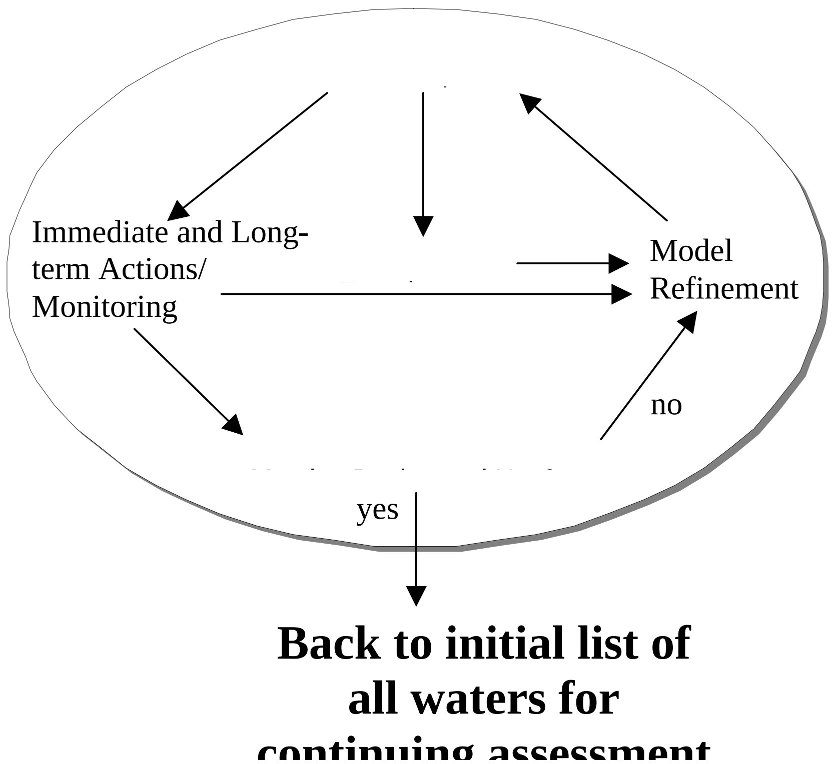

FIGURE 5-2 Adaptive implementation flowchart.

Longer-term actions are those that show promise, but need further evaluation and development. They should be formulated in recognition of emerging and innovative strategies for waterbody restoration. The commitment in the plan is to further evaluate such actions based on the collection of additional data, data analysis, and modeling. An adaptive implementation plan would specify analyses of specific long-term alternatives, a schedule for such analyses to be conducted, and a mechanism for supporting such analyses.

Success monitoring follows after implementation actions. If success monitoring shows that the waterbody is meeting water quality standards including designated uses, then no further implementation actions would be taken. Waterbodies should be returned to the “all waters” list (see Figure 5-1) where they will be monitored as a part of the rotating basin process. A primary purpose of success monitoring is to establish compliance with water quality standards and ultimately make the delisting decision. Because state ambient monitoring programs typically have limited resources, it may be necessary to design and implement success monitoring for the TMDL program outside the rotating basin process. Those stakeholders affected by 303d listing and TMDL development may have an incentive to make a significant contribution to the monitoring effort to assure that the water is truly impaired and that the best possible models are being used for plan development. Stakeholder monitoring would be conducted with input on its design by the state.

One of the most important applications of success monitoring data is to revise and improve the initial TMDL forecast over time. This revision of the TMDL model can be formally accomplished using techniques such as Bayesian analysis, data assimilation, or Kalman filtering.

For example, a TMDL for total phosphorus, based on a model forecast that included uncertainty analysis, might be implemented to address a chlorophyll *a* standard violation. As part of the implementation program, monitoring would be undertaken to assess success and compliance. At the end of the five-year rotating basin cycle, the original chlorophyll *a* forecast could be combined with the monitoring-based chlorophyll *a* time trajectory to yield a revised forecast of ultimate chlorophyll *a* response. This revised forecast could provide the basis for changes to be implemented during the next five-year cycle in order to meet the water quality standard.

Techniques to accomplish model refinement have existed for some time in a Bayesian context (Reckhow, 1985), and under various labels and modifications, they are being applied in other areas. For example, "data assimilation" (Robinson and Lermusiaux, 2000), a derivative of Bayesian inference, is being widely used in the earth sciences to augment uncertain model forecasts with observations. The Bayesian approach holds particular appeal for adaptive TMDLs because it involves "knowledge updating" that is based on pooling precision-weighted information.

The need for *experimentation* to be part of the plan depends on the complexity of the problem and the need to learn more about the system for subsequent model refinement and decision-making. Experiments can, for example, be developed to test the site-specific effectiveness and response time of best management practices (BMPs) (like riparian buffers), to determine the fate and transport of pollutants in runoff, or to answer other questions critical to model refinement. Experiments must be carefully designed and adequately supported (with both funding and staff) to study the effectiveness of actions in the watershed context and to study and learn about watershed processes that are not well understood. TMDL plans for waterbodies with relatively simple problems that can be addressed with high certainty about cause and effect might not include experimentation.

All the actions described above can be used to refine the original TMDL plan so that it better reflects the current state of knowledge about the system and innovative modeling approaches. When revising the TMDL plan, water managers should consider whether the longer-term actions discussed above, or other new alternatives, should be implemented in addition to the immediate actions called for in the original plan. TMDL plans for complicated systems (e.g., a reservoir impacted by multiple nonpoint sources of pollution) can be expected to undergo more revisions before water quality standards (including designated uses) are met than will TMDL plans developed for simple systems.

TMDL IMPLEMENTATION CHALLENGES

Allocation Issues

Plan implementation involves actions taken to reduce all the stressors responsible for the impairment. The allocation of financial and legal responsibility for taking those actions will fall on stakeholders in the watershed, who may not receive public subsidies for taking such actions.

Because of these cost consequences, stakeholders want to be sure that water quality standards are appropriate and that total load limits and the limits proposed on other stressors (e.g., flow modifications) are necessary to secure the designated use.

The committee's charge included a request to evaluate the reliability of "the information required to allocate reductions in pollutant loadings among sources." Allocation is *first and foremost a policy decision* on how to distribute costs among different stakeholders in order to achieve a water quality goal. Consider a hypothetical example where three different actions are possible: reduction of pollutant loads from a treatment plant, reductions in pollutant load in runoff from urban areas and farm fields, and increases in stream flow from reduced consumptive irrigation water use. Also suppose that different combinations of all of these actions can achieve the designated use. Allocation becomes a difficult decision because the different combinations will have a different total cost and different levels of perceived fairness. One suggestion might be to choose the combination of actions that minimizes total cost. However, this may result in a cost distribution that places most of the burden on the customers of the treatment plant (for example). An alternative may be to reduce loads from the plants and from runoff by the same proportion; however, this leaves unanswered whether any cost responsibility should fall on the irrigators. Other combinations of actions would have other cost distribution effects.

Although the allocation process is primarily a policy decision, there is one important role that science can play—determining when actions are "equivalent." Water quality management actions are defined to be "equivalent" when their implementation achieves the designated use, taking uncertainty into consideration. Note that there are two aspects of this definition of equivalency. First, equivalency is established with respect to ambient outcomes for the watershed and not in terms of pollutant loading comparisons, which is the way the allocations are described in the standard TMDL equation. Second, the definition recognizes that equivalency must account for the relative uncertainty of different actions with respect to meeting the applicable water quality standard.

One common scenario might be the need to establish equivalency between nitrogen load reductions from a proposed agricultural BMP vs. a proposed wastewater treatment plant improvement. Estimates of the effectiveness of the BMP and wastewater treatment technology can be made in a controlled setting, perhaps with field studies of the BMP and with experiments at the treatment plant. To achieve equivalency, these load reductions must have the same effect on meeting the water quality standard, which would normally be determined using a modeling approach as described in Chapter 4. It is quite possible that the nitrogen load reductions at the sources (the agricultural BMP and the wastewater treatment plant) are different, but they are equivalent in that they are predicted to have an identical effect on the standard. Further, as noted above, equivalency is a function of both the forecasted mean and forecast uncertainty. Thus, if the BMP and wastewater treatment improvement are both forecast to have the same mean effect on the water quality standard, but the wastewater treatment improvement response has less uncertainty, then the actions are not equivalent.

Determining equivalency across sources requires predicting or measuring the results of control actions, rather than simply noting the presence or absence of a particular control technology (the results of which may vary depending on how it is operated and on many other factors). Careful thought must be given to determining meaningful results, especially in those watersheds where actions like flow augmentation or planting of oysters in an estuary are being used as substitutes for, or necessary complements to, load reduction to meet the designated use.

Finally, because it should be focused on water quality outcomes, allocation is dependent on modeling the effects of different actions on waterbody response. Thus, the issues of model selection and uncertainty that were described in Chapter 4 for TMDL development also apply to TMDL allocation. If there is uncertainty about the effect of certain control actions, those who bear the costs may resist taking such actions without further evidence of their worth. Adaptive implementation would support a cautious approach of taking low-cost actions with a high degree of certainty about the outcome, while taking parallel longer-term actions to improve model capabilities and revise control strategies.

Progressing Toward Adaptive Implementation

The TMDL program is limited by an incomplete conceptual understanding of waterbodies and watersheds, by models that are necessarily abstractions from the reality of natural systems, and by limited data for testing hypotheses and/or simulating systems. As a result, it is possible for a waterbody to be identified as impaired when it is not; in such cases, the costs to plan and implement control actions are wasted. On the other hand, it is also possible that an impaired waterbody will not be identified, resulting in other adverse consequences. Many of the stakeholders who addressed the committee expressed concern about the ramifications of uncertainty in the TMDL process. Some cautioned against listing errors, noting that the listing decision can trigger a linear and inflexible process of potentially expensive controls on land use and pollutant discharges that may ultimately prove unwarranted. Others who are concerned that impaired waterbodies will go unidentified advocated more aggressive and comprehensive actions to address problems quickly. These differences in viewpoint can be traced to the policy context that now governs the TMDL program. The committee views adaptive implementation as accommodating this spectrum of opinions.

If adaptive implementation is to be adopted, three policy issues that stand in the way of acceptance of the approach must be addressed. These issues are described without specific recommendations on their solution, except to note that their resolution is needed in order for the TMDL program to fully embrace the scientific method. Criticism of the TMDL program is too often, and sometimes inappropriately, directed at the quality of the data and information, rather than at these underlying policy issues.

1. The listing of a waterbody and the initiation of the TMDL process appear to call for a constraint on total pollutant loading associated with population growth and land use shifts until the designated use is obtained. Given the often weak water quality standards that underlie a listing, the long lag times between actions taken and measured responses, and the uncertainty in our ability to predict what actions will secure a designated use, it is unrealistic to expect that there will be no changes in economic activity and in land uses in a watershed until the designated use has been achieved. A basis for accommodating growth and change in watersheds needs to be established as adaptive implementation proceeds.

2. Many waterbody stressors currently lie outside the CWA regulatory framework, where the only federal enforcement tool available is point source discharge limits. Recognition of this fact was a motivation for EPA’s endorsement of the watershed approach in 1991 (EPA, 1993). Nonetheless, in some cases point source permitting is used to impose conditions on point sources that essentially require them to finance control practices for unregulated nonpoint sources (NAPA, 2000). Perceptions of the inequity and the ineffectiveness of such a requirement may be manifested as technical critiques of the TMDL analysis itself. Distributing the cost and regulatory burdens for designated use attainment in a way that is deemed equitable by all stakeholders is critical to future TMDL program success.

3. Watersheds can range in size from a few acres to an area that covers several states, and their diversity can be as far reaching as the diverse climate, soils, topography, and physiography of the entire United States. Consequently, the approaches and solutions to water quality problems must be responsive to the unique characteristics of the surrounding watershed. EPA can set broad guidelines for each state’s water quality program and can provide technical assistance in helping states meet the guidelines. There may be a leadership role for EPA on

waterbodies that cross state boundaries, like the Chesapeake Bay. However, EPA cannot write and review all the designated uses that will apply to each of the nation's waterbodies, it cannot conduct all the monitoring and make all the listing decisions, and it cannot conduct the model analyses for all waterbodies. The scientific foundation for adaptive implementation must rely on state initiative and leadership. Today, EPA retains an extensive oversight role for the TMDL program. This raises the possibility that in an effort to ease the administrative burdens of reviewing and approving every TMDL, EPA will establish requirements for uniformity. This may result in standard setting, listing/delisting, and modeling approaches that are nationally consistent but are scientifically inappropriate for the planning and decision-making needs of the diversity of waterbodies. In the National Pollution Discharge Elimination System (NPDES) permitting program, EPA has helped states assume responsibility for point source permitting such that EPA does not review every permit that is issued. Using similar logic, EPA need not review every TMDL. The concern that the states cannot be relied upon to take action (Houck, 1999) needs to be tempered by the reality that continued extensive EPA oversight may not be feasible, it may place a premium on developing plans instead of taking actions, and it may inhibit the nation's progress toward improved water quality. The adaptive implementation approach may require increased state assumption of responsibility for individual TMDLs, with EPA oversight focused at the program level instead of on each individual water segment.

Conclusions and Recommendations

The call for adaptive implementation may not satisfy those who seek more definitive direction from the scientific community. Stakeholders and responsible agencies seek assurance that the actions they take will prove correct; they desire predictions of the costs and consequences of those actions in as precise terms as possible. However, waterbodies exist inside watersheds that are subject to constant change. For this reason and others, even the best predictive capabilities of science cannot assure that an action leading to attainment of designated uses will be initially identified. Adaptive implementation will allow the TMDL program to move forward in the face of these uncertainties.

1. EPA should act (via an administrative rule) to incorporate the elements of adaptive implementation into TMDL guidelines and regulations. To increase the scientific foundation of the TMDL program, the scientific method, which is embodied by the adaptive implementation approach, must be applied to water quality planning.

2. If Congress and EPA want to improve the scientific basis of the TMDL program, then the policy barriers that currently inhibit adoption of an adaptive implementation approach to the TMDL program should be addressed. This includes the issues of future growth, the equitable distribution of cost and responsibility among sources of pollution, and EPA oversight.

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Appendix B

Biographies of the Committee Members and NRC Staff

Kenneth H. Reckhow **(chair) is a professor at Duke University with faculty appointments in the School of the Environment and the Department of Civil and Environmental Engineering. In addition, he is director of The University of North Carolina Water Resources Research Institute and an adjunct professor in the Department of Civil Engineering at North Carolina State University. He currently serves as president of the National Institutes for Water Resources and is chair of the North Carolina Sedimentation Control Commission. He has published two books and over 80 papers, principally on water quality modeling, monitoring, and pollutant loading analysis. In addition, Dr. Reckhow has taught several short courses on water quality modeling and monitoring design, and he has written eight technical guidance manuals on water quality modeling. He is currently serving, or has previously served, on the editorial boards of *Water Resources Research, Water Resources Bulletin, Lake and Reservoir Management, Journal of Environmental Statistics, Urban Ecosystems, and Risk Analysis.* He received a B.S. in engineering physics from Cornell University in 1971 and a Ph.D. from Harvard University in environmental systems analysis in 1977. Dr. Reckhow is currently a member of the NRC's Committee to Improve the USGS National Water Quality Assessment Program.**

Anthony S. Donigian, Jr., is president and principal engineer for AQUA TERRA Consultants. His expertise is in watershed modeling; nonpoint pollution and water quality modeling; chemical fate, transport, and exposure assessment; and model validation and testing. Mr. Donigian has 30 years of a broad range of experience in the development, testing, and application of modern analytical techniques for the assessment of environmental contamination and water resources planning problems. He is an internationally recognized authority on modeling nonpoint pollution and chemical migration in the environment, primarily for water, soil, and groundwater systems. His recent research and applications studies have concentrated on regional and watershed-scale modeling of nutrients and impacts of management practices, movement of contaminants through the vadose zone, groundwater contamination by pesticides and hazardous wastes, model validation issues and procedures, and the evaluation of control alternatives such as best management practices, conservation tillage, and remedial actions at waste sites. Mr. Donigian received an A.B. in engineering sciences and a B.S. in engineering from Dartmouth College and an M.S. in civil engineering from Stanford University.

James R. Karr is a professor of aquatic sciences and zoology and an adjunct professor of environmental engineering, environmental health, and public affairs at the University of Washington, Seattle. He was on the faculties of Purdue University, University of Illinois, and Virginia Polytechnic Institute and State University; he was also deputy director and acting director at the Smithsonian Tropical Research Institute in Panama. He has taught and done research in tropical forest ecology, ornithology, stream ecology, watershed management, landscape ecology, conservation biology, ecological health, and science and environmental policy. He is a fellow in the American Association for the Advancement of Science and the American Ornithologists' Union. Dr. Karr has served on the editorial boards of *BioScience, Conservation Biology*, *Ecological Applications*, *Ecological Monographs*, *Ecology*, *Ecosystem Health, Freshwater Biology*, *Ecological Indicators,* and *Tropical Ecology*. He developed the index of biotic integrity (IBI) to directly evaluate the effects of human actions on the health of living systems. Dr. Karr holds a B.S. in fish and wildlife biology from Iowa State University and an M.S. and Ph.D. in zoology from the University of Illinois, Urbana-Champaign.

Jan Mandrup-Poulsen is an environmental administrator with the Watershed Assessment Section of the Florida Department of Environmental Protection. He is responsible for evaluating surface water quality, surface water/groundwater interactions, and mixing zones, and for determining the Total Maximum Daily Loads (TMDLs) allowable to support designated uses. He has coauthored materials on nonpoint source regulation in Florida and permitting guidance documents for point source discharges in Florida with consideration of the TMDL program. He is a frequent speaker on the topics related to the Florida Department of Environmental Protection watershed management approach, TMDLs, and the Impaired Waters Rule. Mr. Mandrup-Poulsen received his B.S. in atmospheric and oceanic science from the University of Michigan and his M.S. in biological oceanography and M.B.A. from Florida State University.

H. Stephen McDonald is a principal with Carollo Engineers. He has 22 years of experience in the areas of wastewater planning, watershed management, wastewater disinfection, biosolids treatment/reuse/disposal, and chemical and biological wastewater treatment/reuse. He is currently project manager for the development of TMDLs for several watersheds, including the Truckee River from Lake Tahoe to Pyramid Lake and the Calleguas Watershed in California. For the Truckee River, he is developing the Coordinated Monitoring Program and an adaptive management watershed/water quality modeling and stakeholder process to establish TMDLs for nutrients (nitrogen and phosphorus) and total dissolved solids (TDS). Mr. McDonald has developed master plans for water and wastewater treatment facilities in many western regions, including Sacramento County, the city of Fresno, CA; and the cities of Reno, Sparks, and Washoe County, NV. He holds a B.S. in biology from Portland State University and a B.S. in chemical engineering from Oregon State University. He has an MBA from California State University in Hayward and is a registered professional engineer in California.

Vladimir Novotny is a professor of environmental and water resources engineering at Marquette University and director of the Institute for Urban Environmental Risk Management. He is also president of the consulting firm Aqua Nova International, Ltd. His research has included risk-based urban watershed management integrating water quality and flood-control objectives, development of an adaptive methodology for online computerized modeling and real-time control of wastewater treatment facilities, and development of algorithms for control of urban sewer systems. He developed nationwide manuals on attainment of water quality goals (use attainability analysis) and abatement of winter diffuse pollution by road deicing operations. He is a past chair of an international group of specialists dealing with diffuse pollution and watershed management with the International Water Association. Dr. Novotny received a diploma engineer degree in sanitary engineering and a candidate of science degree in sanitary and water resources from the Technical University of Brno, Czechoslovakia and a Ph.D. in environmental engineering from Vanderbilt University.

Richard A. Smith joined the Water Resources Division of the U. S. Geological Survey (USGS) in 1975 and began working with a small research team on statistical methods in water quality and their applications to the extensive and diverse water quality monitoring records maintained by the USGS. Throughout the 1980s, his research dealt with patterns of change in the nation's water quality and with statistical analysis of data collected from the more than 400 stream and river monitoring stations in the Survey's NASQAN program. In the early 1990s he began to investigate the possibility of using the rapidly advancing technology of GIS to enable the use of monitoring data in making statistically based predictions of water quality in unmonitored waters. For more than a decade he has also been very interested in the question of the adequacy of the nation's monitoring programs. He recently served on a panel of scientists charged with making recommendations for a comprehensive monitoring plan for the drinking-water supply watersheds serving New York City. Dr. Smith received his B.S. and M.S. in biology from the University of Richmond and his Ph.D. in environmental engineering from Johns Hopkins University.

Chris O. Yoder is manager of the Ecological Assessment Section of the State of Ohio Environmental Protection Agency. His current responsibilities include ecological evaluation of Ohio's surface water resources including streams, rivers, lakes, and wetlands; development of ambient biological, physical, and chemical assessment methods, indicators, and criteria for rivers, streams, inland lakes, wetlands, Lake Erie, and the Ohio River; reporting on the condition of Ohio surface water resources on a local, regional, and statewide scale; and development of environmental indicators for the surface water program. Previously he was a principal investigator of a cooperative agreement with the U.S. EPA Office of Water for developing approaches to implementing bioassessments and biological criteria within state and federal water quality management programs. Mr. Yoder received a B.S. in agriculture from Ohio State University and his M.A. in zoology from DePauw University.

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Leonard Shabman is a professor in the Department of Agricultural and Applied Economics at the Virginia Polytechnic Institute and State University and director of the Virginia

Water Resources Research Center. He earned his Ph.D. in resource and environmental economics from Cornell University. His research interests include water supply, water quality, and flood hazard management; fishery management; and the role of economists in public policy formulation. Dr. Shabman was a member of the NRC's Committee on Watershed Management, Committee on USGS Water Resources Research, Committee on Flood Control Alternatives in the American River Basin, and the Committee on Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy.

Laura J. Ehlers is a senior staff officer for the Water Science and Technology Board of the National Research Council. Since joining the NRC in 1997, she has served as study director for seven committees, including the Committee to Review the New York City Watershed Management Strategy, the Committee on Riparian Zone Functioning and Strategies for Management, and the Committee on Bioavailability of Contaminants in Soils and Sediment. She received her B.S. from the California Institute of Technology, majoring in biology and engineering and applied science. She earned both an M.S.E. and a Ph.D. in environmental engineering at the Johns Hopkins University. Her dissertation, entitled RP4 Plasmid Transfer Among Strains of *Pseudomonas* in a Biofilm, was awarded the 1998 Parsons Engineering / Association of Environmental Engineering Professors award for best doctoral thesis.

Appendix A

Guest Presentations at the First Meeting of the NRC Committee[15]
January 24–26, 2001

Introduction to the TMDL Program: Current Status and Future Plans
Don Brady, EPA Office of Water

Congressional Request for the study—Senate
John Pemberton and Peter Washburn, Senate Committee on Environment and Public Works

Congressional Request for the study—House
Susan Bodine, House Subcommittee on Water Resources and Environment

March 2000 GAO Report on Status of Water Quality Data
Patricia McClure, General Accounting Office

Environmental perspective on the TMDL program and this study
Nina Bell, Northwest Environmental Advocates

State perspectives on the TMDL program and this study
Robbi Savage, Association of State and Interstate Water Pollution Control Administrators
Shawn McGrath, Western Governors' Association

EPA's Pressing Science Issues for the TMDL Program
Lee Mulkey and Tom Barnwell, EPA Office of Research and Development

TMDL Case Studies
Bruce Zander, EPA Region VIII
Gail Mitchell, Bob Ambrose, and Tim Wool, EPA Region IV

Water Environment Research Foundation Support of TMDL Research
Dean Carpenter, Water Environment Research Foundation
Paul Freedman, Limno-Tech, Inc.
Kent Thornton, FTN & Associates

Stakeholder Presentations
Fred Andes, Federal Water Quality Coalition
Doug Barton, National Council of the Paper Industry for Air and Stream Improvement
Richard Bozek, Edison Electric Institute
Faith Burns, National Cattleman's Association

[15] The NRC committee does not necessarily agree with all the comments or testimony given but all were taken into account.

John Cowan, National Milk Producers Federation
Cynthia Goldberg, Gulf Restoration Network
Jay Jensen, National Association of State Foresters
Norman LeBlanc, Association of Metropolitan Sewerage Agencies
Mike Murray, National Wildlife Federation
Rick Parrish, Southern Environmental Law Center
Rob Reash, American Electric Power and the Utility Water Act Group
Dave Salmonsen, American Farm Bureau Federation

Other Attendance:
Judy Blauchard, Chevron Corp.
Françoise Brasier, EPA Office of Water
Susie Bruninja, BNA
Bruce Cleland, Association of State and Interstate Water Pollution Control Administrators
Steve Elstein, General Accounting Office
Clay Freeberg, Chevron Corp.
Abby Friedman, National Association of Counties
Lee Garrigan, Association of Metropolitan Sewerage Agencies
Susan Gilson, Interstate Council on Water Policy
Ben Grumbles, House Subcommittee on Water Resources and Environment
Keith Hansen, Minnesota Power
Joe Hezir, EOP Group
Mark Hoeke, Association of Metropolitan Sewerage Agencies
Meg Hunt, Edison Electric Institute
Carissa Itle, National Milk Producers Federation
Russ Kinerson, EPA Office of Water
Steven Koorse, Utility Water Act Group
Kenneth Kopocis, House Subcommittee on Water Resources and Environment
Jeff Lynn, International Paper
David Malakoff, Science Magazine
Tracey Maloney, Rohm and Haas
Charles Noss, Water Environment Research Foundation
Walton Poole, America's Clean Water Foundation
Don Pryor, National Oceanic and Atmospheric Administration
Bart Ruiter, DuPont
Jerry Schnoor, University of Iowa
Winnie Schubert, Exxon Mobil Chemical Company
Jerry Schwartz, American Forest and Paper Association
Dick Schwer, DuPont
Kari Simonelic, Federal Water Quality Coalition
Margaret Stewart, Water Environment Research Foundation
Kate Sullivan, American Association for the Advancement of Science
Sharon Thomas, Water Environment Federation
David Travers, EPA Office of Water
Tony Wagner, American Chemistry Council
Harry Zhang, Parsons Engineering

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Yoder C. O. & E. T. Rankin. (1998) The role of biological indicators in a state water quality management process. Environmental Monitoring and Assessment 51: 61-88.

http://link.springer.com/article/10.1023/A:1005937927108