PROCESS FOR SELECTING INDICATORS AND SUPPORTING DATA

Second Edition

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1.0 INTRODUCTION

Offices within the U.S. Environmental Protection Agency (EPA) have been developing processes for selecting environmental indicators and supporting data. In early 1994, the EPA Data Quality Action Team (Data QAT), comprising representatives from many EPA offices, prepared the first edition of this document as a tool for selecting indicators. The earlier edition has now been updated and revised to reflect lessons learned in earlier work.

The purpose of this document is to present a process for selecting indicators and data sets that can be used to measure the current status of the environment and to show patterns or trends in that status. This proposed process, which is endorsed by the Data QAT (which includes members from virtually all of the EPA programs involved in indicator selection), is directed primarily to technical managers within EPA who are responsible for specifying and quantifying indicators.

This document is organized as follows:

- **Section 2.0, Definition of Environmental Indicator**—Provides background on definitions and uses of environmental indicators
- **Section 3.0, Frameworks for Developing Indicators**—Describes a commonly used framework for the organization and presentation of environmental indicators
- **Section 4.0, Process for Selecting Environmental Indicators**—Recommends steps for Indicator Teams and stakeholder groups to select the most appropriate indicators for particular projects
- **Section 5.0, Criteria for Selecting Environmental Indicators**—Describes the process of determining and applying indicator selection criteria as a means to focus the selection process by evaluating candidate indicators
- **Section 6.0, Criteria for Selecting Existing Data Sets to Quantify Indicators**—Identifies proposed criteria for evaluating the usefulness of an existing data set to support environmental indicators.

2.0 DEFINITION OF ENVIRONMENTAL INDICATOR

An indicator is most commonly understood as a sign or signal that relays a complex message in a simplified manner. Environmental indicators describe, analyze, summarize, and present scientifically based information on environmental conditions, trends, and their significance.[1] Both direct measures of environmental attributes of interest (e.g., health and ecological effects) and indirect measures (e.g., emission/discharge quantities) can serve as indicators. Environmental indicators are usually presented statistically or graphically to simplify complex environmental issues by 1) quantifying information to highlight its significance and 2) presenting the information in a useful format for communicating ideas and trends related to the issue.[2]

The definition of indicators is dynamic and flexible and is influenced by project-specific factors, including purpose, scope, and target audience. Many definitions of environmental and environmentally related indicators appear in the literature. Table 2-1 presents selected definitions **[table to be added]**.

Indicators are developed to quantify and simplify large amounts of information, thereby making it more useful for the audience. An indicator can be used individually (e.g., ambient pollution concentrations), but is more commonly used with other indicators to tell a more complete story. In some instances, several individual indicators are grouped under a common theme (e.g., the theme Toxics in the Chesapeake Bay may contain several indicators: Toxic Release Inventory summaries on loadings and releases, trends of contaminants in bottom sediment and ambient surface water, pesticide use by county). Indicators can be presented individually in a slide or fact sheet or compiled in an environmental bulletin, multimedia presentation, or other more comprehensive presentation. Sometimes two or more indicators are presented together on a single indicator graph to illustrate possible associations among several related pieces of

[1]State Environmental Goals and Indicators Project. 1995. *Prospective Indicators for State Use in Performance Agreements*. Florida Center for Public Management, Florida State University.

[2]Hammond, A., A. Adriaanse, E. Rodenburg, D. Bryant, R. Woodward. 1995. *Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development*. Washington, D.C.: World Resources Institute.

information (e.g., municipal wastewater treatment plant loadings and population change). Data can also be aggregated into an index, which is then presented as an indicator. For example, the Pollutant Standard Index aggregates individual measures of air quality into a single indicator that rates daily air quality as good, unhealthful, or hazardous. The scope of the message communicated by an indicator can be at any of several different levels—community, sectoral, national, or international.

Typically, environmental indicators are used either in a decision-making context or as a tool for public education/outreach to achieve the following purposes:

- Show patterns or trends (changes) in the state of the environment (such indicators are the focus of this report)
- Show patterns or trends in the human activities that affect or are affected by the state of the environment
- Show relationships among environmental variables
- Show relationships between human activities and the state of the environment
- Provide a benchmark against which to measure progress toward a particular goal
- Communicate a message, theme, or story clearly, succinctly, and accurately
- Motivate the readers to change behavior
- Correct misperceptions.

Because indicators are user-driven and are characterized by the quantification and simplification of important information, a specific relationship exists among indicators, the audience, and the level of data. The information pyramid, shown in **Figure 2-1**, contains three levels of data for three different target audiences.[3] The base of the pyramid is primary data derived from monitoring and data analysis. Primary data are most useful for scientists or for an audience with a more technical background. The next layer is analyzed data, which decision makers frequently use to quickly assess and evaluate trends, such as progress toward achieving

[3]State Environmental Goals and Indicators Project, op. cit.

policy goals. Proceeding upward, the next layer represents indicators, which are the most aggregated forms of data. Very condensed amounts of highly aggregated data are useful for larger audiences with a less technical background, such as the general public.

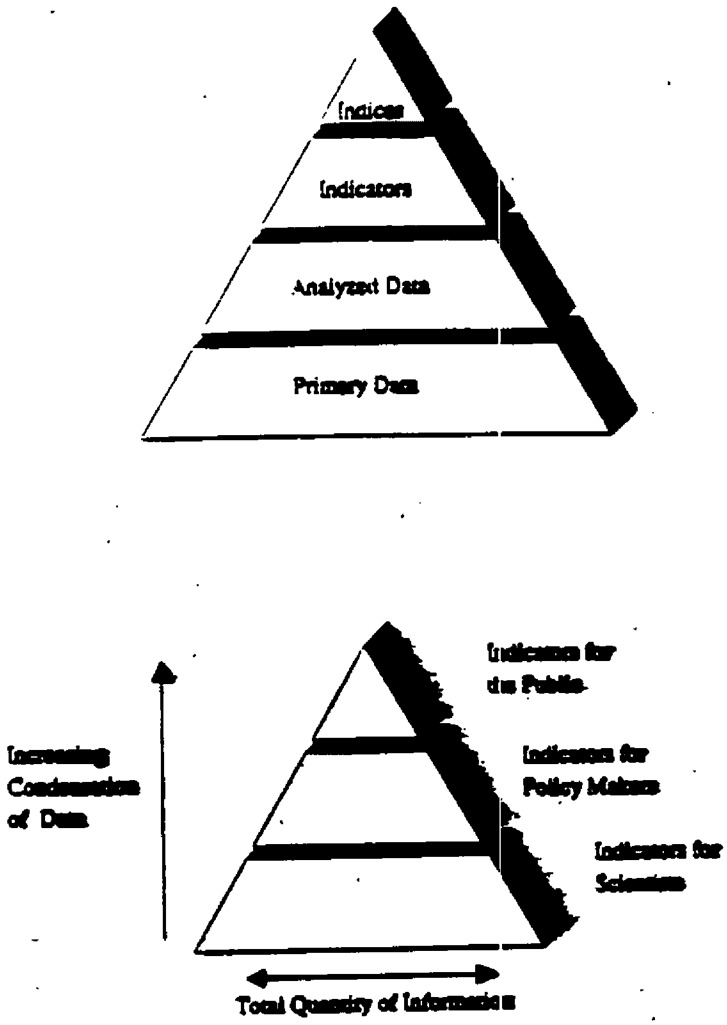

Figure 2-1. The Information Pyramid
(adapted from State Environmental Goals and Indicators Project, 1995 and Hammond, Adriaanse, et al., 1995)

3.0 FRAMEWORKS FOR DEVELOPING INDICATORS

This section will present a framework commonly used for the development of environmental indicators, known as the Pressure-State-Response (PSR) framework. Used by various environmental organizations for environmental indicator projects, this framework serves to convey environmental information in a coherent way. A detailed description of the PSR framework and typical characteristics of indicators developed under each component is provided below. Readers familiar with the PSR framework may continue on to Section 4.0 for information on the process of indicator selection.

Environmental indicators synthesize complex, scientific information in a simplified and understandable manner. Although the content and presentation style of indicators may vary depending on such factors as the intended use, target audience, and message (or theme) of the indicators, most indicators are derived from an extensive information base. Effective frameworks are needed to provide context for the indicator and to structure the diverse environmental information so that it is relevant, interpretable, accessible, and intelligible to the target audience (e.g., decision makers, general public).[4] Developing indicators within a specific framework promotes effective information collection, integration, and interpretation (e.g., linking environment-related data to policy and management actions or needs), while also revealing potential data gaps and providing the impetus for future data collection efforts.[5]

A variety of conceptual frameworks or models of human-environment interactions can serve as the basis for selecting, organizing, and using indicators in different policy contexts. Because the relationships between human activities and the environment are extremely complex, no one framework may meet the needs of every indicator project. The PSR framework, adopted by the Organization for Economic Co-operation and Development (OECD) as the basis for organizing its State of the Environment reports and environmental performance reviews (OECD,

[4]Hammond, op. cit.

[5]United States Environmental Protection Agency. 1995. *A Conceptual Framework To Support Development And Use Of Environmental Information In Decision-Making*. EPA 239-R-95-012.

1993), is widely used, however, for organizing environmental indicators and supporting information.

The PSR framework[6] provides a valuable means for relating and integrating environmental information necessary for developing effective indicators that are capable of telling a story or conveying a discrete message. The basic PSR framework, given in **Figure 3-1**, establishes a causal relationship among human activities, the state of the environment, and society's response. Human activities exert pressures on the environment (e.g., pollution loadings and land use changes) and induce changes in the state of the environment (e.g., ambient levels of pollutants and habitat diversity). Society responds to these changes by addressing the pressures through environmental and economic policies (e.g., programs to reduce impacts to the environment).

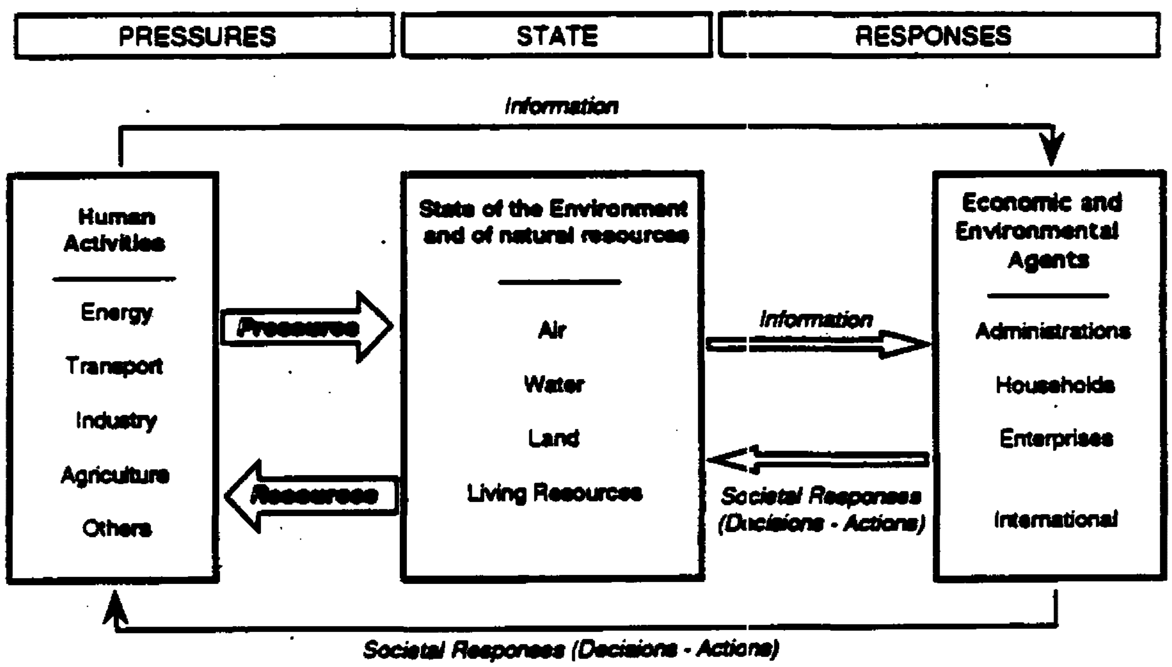

Figure 3-1. OECD Pressure-State-Response Framework (Adapted from "OECD Core Set of Indicators for Environmental Performance Review," Environmental Monograph No. 83 (1993).

[6] "Causal" frameworks seek to organize or classify environmental information in terms of the aggregate causal flow or "cycle" or human-environment interactions (USEPA, 1995).

Within the PSR framework, three broad types of indicators, and potential subcategories, can be distinguished:

- **Indicators of Environmental Pressure** describe the pressure that human activities exert on the environment, including the quality and quantity of natural resources. The subcategories of this indicator type are indicators of direct pressures (pressures exerted directly on the environment that are normally expressed in terms of emissions or consumption of natural resources), indirect pressures (background indicators reflecting human activities that lead to direct environmental pressures), and underlying societal pressures (social and technological forces that drive human activities).

- **Indicators of the State of the Environment** relate to the quality of the environment and the quality and quantity of natural resources. As such, they reflect the ultimate objective of environmental policy making. Indicators of environmental conditions should measure the state of the environment and changes in that state over time, rather than the pressures on the environment. In practice, however, the direct measurement of environmental conditions can be difficult or very costly. Therefore, the measurement of environmental pressures is often used as a substitute for the measurement of environmental conditions. Indicators of the state of the environment can be subcategorized by nested spatial scales (local, regional, and global ecosystems; human health and environment-related welfare) and by biological, chemical, physical, and ecological functions and variables.[7]

- **Indicators of Societal Responses** relate to individual and collective actions to mitigate, adapt to, or prevent human-induced damage to the environment and to halt or reverse environmental damage that has already occurred. Societal responses also include actions for the preservation and the conservation of the environment and natural resources. Indicators of societal response can be subdivided by the type of responding entity (e.g., governments, private sector, individuals, or partnerships).[8]

Each type of indicator has advantages, provided that it is appropriate for the target audience and effectively meets the goals and objectives of the project, and disadvantages.

Pressure indicators are particularly useful in formulating short-term (i.e., annual) objectives and in evaluating short-term (i.e., annual) performance, because they explore potential cause and effect relationships between human activities and the environment (e.g., whether increasing or decreasing emissions are associated with changes in ambient conditions). They can

[7] USEPA, op. cit.

[8] Ibid. 5, 8, 9, and 10.

in many cases be relatively easy to assemble, maintain and update, and are easy to interpret. A fairly extensive data base is available to construct pressure indicators because of the widespread environmental monitoring and regulatory compliance framework established in the United States (e.g., many emissions are regularly monitored). Because pressure indicators are often developed from direct measurements or model-based estimates, they can provide direct feedback on whether policies are meeting project goals (e.g., reduce total nitrogen discharges by 40% from all direct dischargers).[9,10,11] One disadvantage of pressure indicators is that it is sometimes difficult to establish a causal link between the pressures exerted and the state of the environment without additional information.

State of the environment indicators are crucial for a long-term evaluation of the environment and environmental programs.[12,13,14] Preparing these indicators, however, can be difficult. Data on ambient environmental conditions (e.g., amount of old growth forest, concentration of mercury in water) are often limited in temporal or geographic scope, difficult to locate, or confusing to interpret. Techniques to measure actual environmental conditions (i.e., state) can be difficult and costly and must occur over an extended period (i.e., there is often a lag time after a control action is taken before measurable changes to the state of the environment occur). Nevertheless, continued efforts to develop such indicators are being made and are needed. Without them, no firm conclusion can be reached about the effectiveness of current policies in protecting and improving the state of the environment.

Societal response indicators are useful because they provide a measure of the scope of and level of participation in environmental protection programs (e.g., number of dischargers affected by and level of compliance with government regulations). Response indicators are limited,

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[9]Hammond, op. cit.

[10]State Environmental Goals and Indicators Project, op. cit.

[11]USEPA, op. cit.

[12]Hammond, op. cit.

[13]Ibid.

[14]Ibid.

however, because they do not directly measure what is happening to the environment. Ideally, response indicators should be developed after and be closely integrated with pressure and state indicators to provide a complete picture of the issue being studied.[15,16,17]

The PSR framework can be modified to suit a particular environmental indicator development project. For example, an expansion of the PSR framework has been suggested for developing a system of environmental statistics and indicators. The new version includes "Effects" as a category to describe relationships between two or more pressure, state, and/or response variables. **Appendix A** contains additional information on the PSR/E framework. Because frameworks provide the context for organizing indicators and associated data, flexibility is necessary to ensure that the framework adopted best meets the goals and objectives of the specific project or use for which it is being employed.

[15]Ibid.

[16]Ibid.

[17]USEPA, op. cit.

4.0 PROCESS FOR SELECTING ENVIRONMENTAL INDICATORS

Presented in this section is a step-wise approach for selecting indicators, based on standard decision-making practices. Three primary steps are described; they include:

- Identifying and recommending indicators
- Identifying and recommending data to support indicators
- Selecting final indicators.

Examples appear throughout this section to demonstrate the application of the selection process. A description is provided for developing an Indicator Team to best perform the recommended process.

Different approaches can be used to select environmental indicators. One approach is to select indicators for a particular application on an ad hoc basis from existing indicators and/or readily available data. Although this approach can yield meaningful and informative indicators, indicators developed from existing indicators and/or available data can have limitations:

- The range of possible indicators is limited to indicators or data developed previously for other purposes.
- Available indicators or data may not be directly related to or appropriate for the intended message, goals, or objectives of the new indicator project. Yet, there may be a bias to try to "force fit" available information.
- Available indicators or data may not be suitable for the target audience.
- Using previously developed indicators or data may result in confusing or mixed messages, as well as indicators that are neither relevant, nor representative.

Another approach uses a systematic process in which indicator selection is based on postulated cause-effect linkages between valued environmental attributes and the societal and natural factors that potentially affect these attributes.[18] This approach suggests that it is important to define, at the beginning of the effort, the overall goals and objectives of the indicator project, the intended message for the indicator, the framework (i.e., pressure, state, response) for presenting indicators, and the target audience before selecting indicators and evaluating data availability. Although this approach may expose gaps in existing data, it allows society's environmental values and current scientific understanding of environmental linkages to drive indicator selection. The identification of such data gaps can drive further research and data collection. The remainder of this section provides more detail on the latter approach.

PROCESS DESCRIPTION

The indicator and data selection process presented in this document is meant to be flexible and should be modified to best meet the needs of the particular indicator development activity. The likelihood of a successful outcome will be increased, however, if the following fundamental principles of decision making are followed:[19,20]

- Initiate the process by clearly identifying goals and objectives (including defining the theme and target audience for the indicator)
- Identify candidate indicators that support the identified goals and objectives
- Develop and apply a decision making process for selecting the best indicators.

In addition, developing successful environmental indicators requires leadership and a feedback mechanism. The project will need a lead group (i.e., Indicator Team) that is responsible for initiating and coordinating the project, as well as providing leadership throughout the process. The Indicator Team should involve a representative and balanced stakeholder group of interested and affected parties throughout the process. Stakeholders can be involved in many ways,

[18]For discussions of this type of approach, see, for example, *Managing Troubled Waters: The Role of Regional Marine Environmental Monitoring* (National Academy Press, 1990) and the *Indicator Development Strategy for the Environmental Monitoring and Assessment Program* (USEPA, 1994).

[19]Chang, R.Y. and P.K. Kelly. 1993. *Step-By-Step Problem Solving.* Irvine, CA: Richard Chang Associates, Inc.

[20]Chechile, R.A. and S. Carlisle. 1991. *Environmental Decision Making: A Multidisciplinary Perspective.* New York: Van Nostrand Reinhold.

including participation in team meetings, workshops, or other facilitated sessions; and inclusion in product review and comment cycles. Stakeholders will vary by indicator project, but may include the following types of individuals:

- Subject matter experts
- Information and data providers
- Outside professionals (e.g., consultants and representatives from industry, public interest groups, nongovernmental organizations, academe, and individuals with financial and economic backgrounds)
- Decision makers (e.g., government policy makers)
- Customers (e.g., educators, media representatives, general public).

Involving stakeholders in the indicator development process is crucial for achieving buy-in, ensuring that the indicator is on target with the desired goals and objectives and message or theme and that the indicator is understandable and effectively promoted. Indicators developed in the absence of stakeholders may be stalled, derailed, or refuted.

The remainder of this section discusses the three steps in selecting environmental indicators: identifying indicators, identifying data for supporting indicators, and selecting final indicators. **Figure 4-1** is a flow chart illustrating the indicator selection process.

STEP 1: IDENTIFY AND RECOMMEND INDICATORS

This step results in a list of candidate indicators that serve the goals and objectives of the indicator project, support the framework for communicating the theme or message of the project, and meet the evaluation criteria developed to aid in indicator selection. The first task of the Indicator Team is to define the goals and objectives of the indicator project and develop a theme and framework that will be used to communicate to the target audience. Next, the Indicator Team develops a draft list of potential indicators. Then, the team selects candidate indicators using specific evaluation criteria.

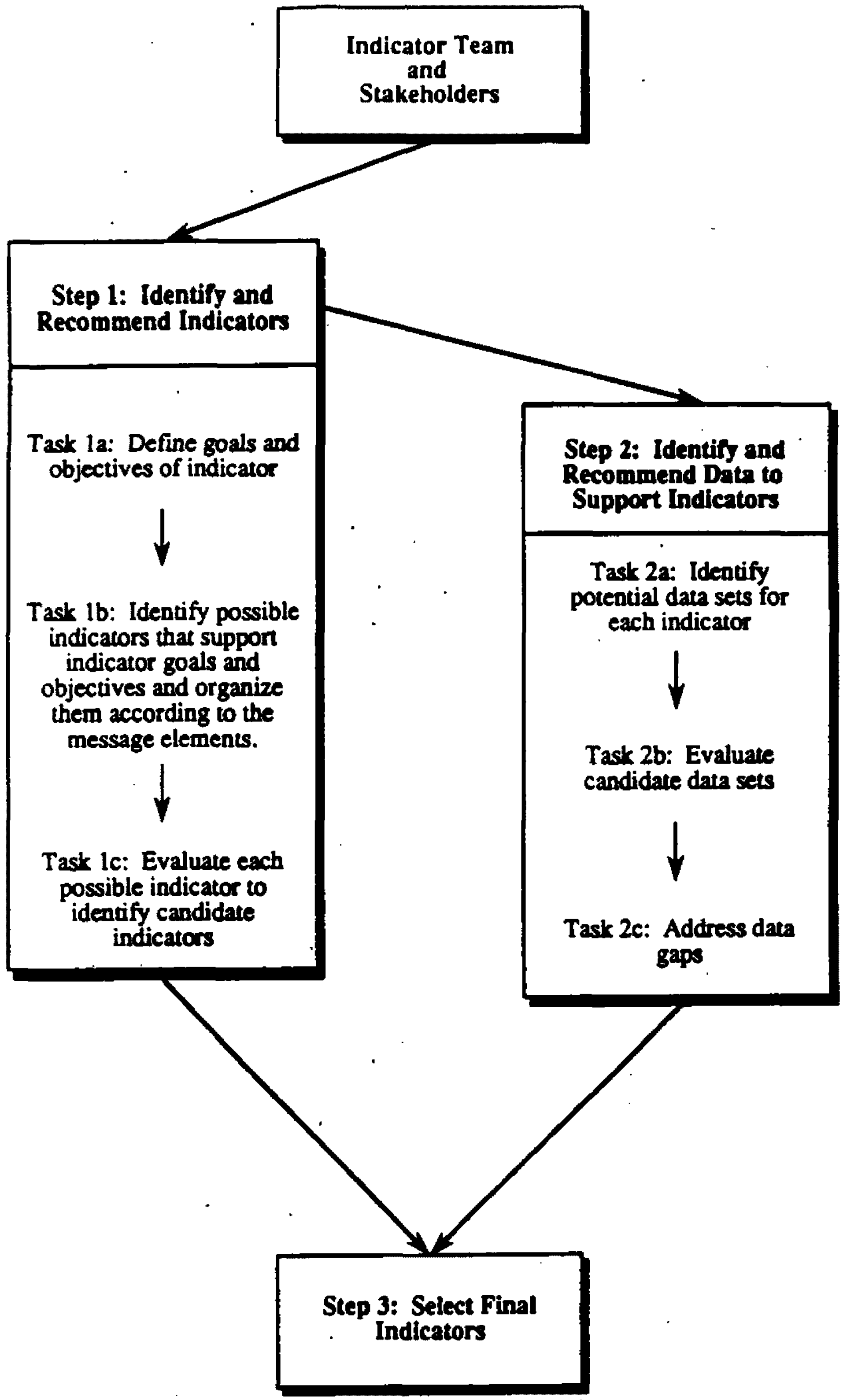

Figure 4-1. Process for Selecting Indicators

Task 1a: Define goals, objectives, and framework of the indicator

The following questions guide the development of indicator goals, objectives, and theme or message:

- Why is the indicator being developed?
- What is its intended use (e.g., track progress toward meeting program goals, develop an objective description of the state of the environment, educate the general public)?
- Who will use the indicator (e.g., program manager, scientists, educators)?
- Who is the intended audience for the indicator (e.g., program managers, legislators, the general public)?
- What are society's goals, values, and concerns? Are they addressed by the indicator?
- Is the indicator related to a program mission or goal statement(s)?
- Does the indicator objectively communicate information to the target audience?

The answers to these questions provide the essential foundation for effective indicator development. These questions should be considered at project initiation and referred to throughout the entire process. They are critical at the outset to establish the scope and approach of the indicator project. They are also central to the development of individual indicators. An effective indicator, whether used individually or in a group, must have a clear message relevant to the target audience and intended use of the indicator. By carefully answering the goal and objective questions, the Indicator Team will be better able to implement an efficient and effective process. Stakeholders can contribute during these early stages to help define goals and objectives, especially when identifying key messages and audiences.

Although defining the goals and objectives is critical to effective, targeted indicator development, defining a framework is central to the indicator selection process. The framework serves as the organizational structure for the indicator project. The most common framework used to date has been the Pressure-State-Response framework. described briefly in Section 3.0.

An indicator topic may be narrow and require few indicators or be broad and need many indicators to tell the entire story. If the topic is broad or complex and requires many indicators, it may be necessary to develop an outline or a list of all information needed to convey each element of the framework. This step is similar to preparing an outline for a story. Each individual indicator should relate closely to the overall goals and objectives. **Exhibit 4-1** provides an example of developing the goal, objective, and elements of the PSR framework for an air pollution topic.

Exhibit 4-1. Example Application of Task 1(a)

Define the goals, objectives, and framework of the indicator project.	
Goal:	Raise public awareness about air pollution.
Objective:	Communicate to the public the role of individuals in air pollution.
Framework:	
1. Pressure	• Mobile sources affect air quality • Mobile source emissions are significant compared to other sources
2. State	• Ambient concentrations of pollutants associated with mobile sources
3. Response	• Behavioral changes • Technological changes

Task 1b: Identify possible indicators that support indicator goals and objectives.

After identifying the overall goal and objectives, the next step is identifying potential indicators. The potential indicators are developed based on their effectiveness in conveying the elements of the framework, while ensuring that they are suitable for the intended use of the indicator and target audience. Through one or more meetings, workshops, or other events, supplemented with review and comment cycles of written materials, the Indicator Team and stakeholders should develop a comprehensive list of specific indicators. Next, the Indicator Team may want to examine currently used indicators for additional ideas. The potential indicators can then be grouped according to the elements of the framework, as illustrated in **Exhibit 4-2**.

Exhibit 4-2. Example Application of Task 1(b)

Identify possible indicators and organize them according to the framework.

- Pressure—Mobile sources affect air quality
  - Number and type of vehicles on roads
  - Number of vehicle miles driven per year
  - Emissions of selected pollutants from mobile sources
- Pressure—Mobile sources are a significant source of air pollution compared to other sources
  - Emissions of selected parameters from mobile sources compared to stationary sources
- State—Concentration of vehicle emissions in the environment
  - Atmospheric concentration of selected pollutants
  - Concentration of selected pollutants in soil near roads and highways
  - Concentration of selected pollutants in water
- Response—Extent of behavioral and technological changes
  - Number of individuals participating in car pools
  - Extent of mass transit opportunities
  - Emissions comparison between regular and fuel-efficient vehicles
  - Availability of fuel-efficient vehicles

Task 1c: Evaluate each potential indicator to identify candidate indicators.

The comprehensive list of potential indicators developed in Task 1b should be narrowed to the indicators best suited for the project. The Indicator Team, with the stakeholder group, should now develop the evaluation criteria appropriate to the specific indicator development project so that the criteria can be applied to select candidate indicators from the list of potential indicators. The process of selecting candidate indicators should be well-documented so that it is understandable to participants and outside reviewers and can be reproduced. Section 5.0 describes an approach for identifying appropriate selection criteria.

Before applying the evaluation criteria, the Indicator Team should ensure that each member has the same understanding of each criterion. The Indicator Team may want to use specific questions or examples for each criterion to facilitate evaluation of the candidate indicators. For example, if the criterion is "understandability," the following questions might be helpful:

- Is the information of the right technical level for the target audience?

- Is the proposed display and presentation effective and appealing?
- Is the methodology used to create the indicator well-documented and understandable so that it can be easily communicated and reproduced?

Table 5-1 in Section 5 provides additional examples of evaluation criteria.

The Indicator Team should also decide on the approach to be used for applying the evaluation criteria. The evaluation criterion, for example, can be weighted equally so that possible indicators are simply ranked (quantitatively or qualitatively) according to how well they meet each criterion. Alternatively, each criterion can be weighted to emphasize its relative importance compared to the others. In addition, the evaluation criteria can be grouped into essential criteria (i.e., criteria an indicator **must** meet) and preferable criteria (i.e., criteria an indicator should meet if possible).[21] This idea is discussed in more detail in Section 5.

The result of Task 1c is a list of candidate indicators: the best indicators among those identified for conveying the message.

STEP 2. IDENTIFY AND RECOMMEND DATA TO SUPPORT INDICATORS

Once the candidate indicators are selected, the next step is to identify the data that will be used to quantify the indicators. This requires examining existing data collection and analysis programs to determine whether appropriate data are or will be available. The process can be accomplished using the following two steps.

Task 2a: Identify potential data sets for each indicator.

The Indicator Team should conduct a focused search to identify candidate data sets that will support the candidate indicators. The Indicator Team may work with the stakeholder group and other subject matter and/or data experts to identify potential data sets held by EPA, other Federal agencies, and other entities. A literature review may also be helpful.

[21] State Environmental Goals and Indicators Project, op. cit.

Data sets should be identified and grouped by the candidate indicator they could be used to generate.

Task 2b: Evaluate candidate data sets.

After potential data sets are identified, they can be evaluated to select the most suitable data sets. The Indicator Team and stakeholder group may want to score data sets using pre-determined evaluation criteria. Section 6.0 discusses criteria for selecting appropriate data sets. The Indicator Team may choose one or more of a variety of ways to apply the data criteria, including weighted scoring, completion of a checklist based on the criteria, and best professional judgment. The approach should be well-documented so that it is understandable to participants and outside reviewers and can be reproduced. It may be desirable to complete summary forms for candidate data sets to facilitate decision making. **Appendix B** presents an example summary form.

Several data sets might be appropriate for use in generating a particular indicator. If any of several data sets could be used, all would be considered unless one or more were clearly inferior to the others (i.e., being similar on most criteria but clearly worse on some). It may be necessary, therefore, to develop preliminary screening criteria, in addition to the detailed data evaluation criteria, to quickly eliminate the less suitable candidate data sets prior to a thorough evaluation. Such preliminary screening may be necessary if resources are limited.

After applying the evaluation criteria, if several data sets are found to be appropriate for use in generating a particular indicator, the best one would generally be chosen. In some cases, it might not be possible to identify any appropriate data. A data gap exists if no data are available or if the available data are inadequate and cannot be improved.

Task 2c: Address data gap.

For indicators that lack adequate data, the Indicator Team may take the following actions:

(1) Document the data gaps.

(2) Review other existing indicators and data to determine whether one or more can be used as interim substitute indicators to at least provide some information on the factors to be addressed by the candidate indicators for which no adequate data are available.

(3) Develop strategies for filling the identified data gaps, including improvements to existing programs of data collection, data analyses, and information management. Developing strategies includes determining whether data can be made available by modifying existing data management and analysis procedures. For example, this could include the reanalysis of existing data or the integration of two or more separate data sets.

a. If the needed data can be made available by changes in existing data management or data analysis procedures, develop a strategy for making the needed changes.

b. If the needed data cannot be made available by changes to existing data management or data analysis procedures, determine whether there are validated test methods, statistical methods, etc. at the levels of accuracy and levels of reliability required:

- For each indicator for which validated methods are available, identify what data is required and design a data collection program (of appropriate statistical design) and a data analysis program. If feasible, implement the program.

- For each indicator for which validated methods are not available, set up a process to develop such methods. If needed, set priorities for developing these methods. Once appropriate methods are developed, identify what data are required and design a data collection program (of appropriate statistical design) and a data analysis program. If feasible, implement the program.

STEP 3: SELECT FINAL INDICATORS

After identifying the candidate indicators and the data sets available to support each indicator, the Indicator Team will need to select the final indicators. At this stage, the indicator team has full knowledge of which indicators best serve the goals and objectives of the project. The team has also evaluated the quality of available data and identified data gaps. Now the Indicator Team must work with this information to select final indicators for the project.

The procedure for selecting final indicators will likely be an iterative process using stakeholder involvement, peer review, and expert knowledge. The approach for selecting final indicators used by the State Environmental Goals and Indicators Project (SEGIP) involved the application of decision criteria called qualification standards. These are listed in **Exhibit 4-3**. After applying the standards and identifying final indicators, the participants realized that the qualification standards did not yield a sufficient number of indicators to meet the needs of the project. In response, they developed a three-tiered classification. The first tier, Type A indicators, meet the qualification standards. The next tiers, Type B and Type C, classify the remaining indicators according to the availability of data or the level of effort required to develop the data needed to support the indicators. The definitions of Type A, B, and C indicators are provided in **Exhibit 4-4**.

The process of making a preliminary choice, gathering more information, and making a more refined choice of indicators is iterative. Additional iterations may be necessary to refine the selection of indicators and to incorporate new information as it is gathered.

Exhibit 4-3. State Environmental Goals and Indicators Project Qualification Standards[22]

1. The indicator was national in scope and could be consistently displayed at the state level.
2. The indicator met SEGIP Essential Indicator Selection Criteria.
3. The indicator currently existed and was available to the states.
4. The indicator reflected a direct environmental value and not an administrative or program result. Administrative measures that summarized counts of definable environmental degradation (e.g., exceedances, spills) were acceptable.
5. The indicator supported an environmental result relevant to the U.S. EPA-State relationship as envisioned in the proposed *Performance Agreements*.

[22] State Environmental Goals and Indicators Project, op. cit.

Exhibit 4-4. State Environmental Goals and Indicators Project Classification Scheme[23]

Type A: **Indicators for which adequate data are available now and can be used to support the indicator without significant additional cost considerations.** To be classified as Type A, an indicator:

- Meets all essential selection criteria and most preferred criteria,
- Is presently available for use in its present condition, and
- Can be acquired easily at little or no cost.

Type B: **Indicators which are presently feasible, but cannot be provided due to inordinate cost, analytical complexity, or time constraints.** Type B indicators are those that could be made available now if some operational barrier can be overcome. The data needed to produce the indicator exist but because of cost concerns, analytical difficulties, time constraints, manpower issues, or some other impediment, the indicator cannot be provided.

Type C: **Prospective indicators for which there is no reasonable prospect of development without some extraordinary expenditure of resources.** Type C indicators are purely prospective. The data do not exist and there is no clear intent to collect them. Type C indicators exist as designs only.

[23]State Environmental Goals and Indicators Project, op. cit.

5.0 CRITERIA FOR SELECTING ENVIRONMENTAL INDICATORS

This section presents a list of evaluation criteria that was adapted from a review of other environmental indicator projects (e.g., Intergovernmental Task Force on Water Quality Monitoring, State Environmental Goals and Indicator Project, Environmental Monitoring and Assessment Program, and the International Joint Commission for the Great Lakes) and refined to provide a comprehensive list of criteria that could be used for a variety of indicator selection projects. **Table 5-1** provides these criteria and defines each criterion with one or more specific questions. It is often useful to define the criteria as a series of questions, because questions can be easier to apply when selecting indicators than narrative definitions. **Appendix C** presents examples of selection criteria used by various organizations.

Choosing clear evaluation criteria and determining an effective means of applying them are two critical aspects of the overall process of selecting environmental indicators. The evaluation of possible indicators against criteria enables the Indicator Team and stakeholders to narrow a potentially broad list of indicators to those that are optimally suited for achieving the project goals and objectives. Applying well-defined evaluation criteria will help focus the selection process and reduce potential bias by providing a clearly articulated and relatively objective means to evaluate, or score, possible indicators. This process should ideally be cooperatively developed by the Indicator Team with support from a representative and balanced stakeholder group. The value of developing criteria that are clearly defined and understandable cannot be overstated. Everyone applying them will then be employing the same working definition.

Evaluation criteria should be determined relatively early in the process, not long after defining possible indicators. The Indicator Team and stakeholder group should identify evaluation criteria that will effectively reflect the goals and objectives of the indicator project. Brainstorming techniques can be used to develop a broad list of potential evaluation criteria that can be refined to present a workable list of final criteria. This section describes the process of determining and applying indicator evaluation criteria.

Table 5-1. Suggested Evaluation Criteria for Selecting Indicators

Criterion	Definition
Validity	
Social and Environmental Relevance	Does the indicator express society's environmental values, goals, and concerns by presenting information relevant to a desired policy goal, issue, legal mandate, or agency mission? Does the indicator reflect the project message? Can this information be understood by and easily related to the general public and decision makers? Is the indicator seen by the target audience as being important or relevant to their lives?
Appropriate Scale	Does the indicator respond to changes on an appropriate geographic (e.g., global, national, regional, or local) and temporal (e.g., daily, monthly, yearly) scale?
Integration of Multiple Impacts	Does the indicator represent the cumulative impacts of multiple stressors (e.g., water quality affected by nonpoint source discharges, point source discharges, acid rain, erosion)? Is it broadly applicable to many stressors and sites?
Representative	Are changes in the indicator highly correlated with changing trends in the information it is selected to represent (e.g., is an indicator of industrial loadings to surface water highly correlated to declining surface water quality)? Does the indicator present an accurate picture for the message it is intended to convey?
Sensitivity	Can the indicator distinguish small changes in environmental conditions with an acceptable degree of resolution (e.g., will the indicator respond to modest changes such as occasional permit violations, new plants coming online, or gradual improvements in quality over time)?
Interpretability	
Interpretable	Is there a reference condition or benchmark for the indicator against which to measure changes and trends (e.g., standards, limitations, criteria, goals)?
Trend Evaluation	Has the data for the indicator been collected over a sufficient period of time to allow analysis of trends or provide a baseline for estimating future trends?
Timeliness	
Timely/Anticipatory	Does the indicator provide early warning of changes?
Understandability	
Understandable	Is the indicator appropriate for the target audience? Is the indicator presented in a format tailored to the needs of the target audience? Is it simple and direct?
Documented	Is the methodology used to create the indicator well-documented and understandable so that it can be easily communicated and reproduced?
Consistency	Is the information presented by the indicator consistent over time (e.g., are definitions, measurement techniques, and analytical methodologies consistent and comparable)?
Provision of Decision Support	Is the level of information by the indicator appropriate for the target audience to use in decision making?

Table 5-1. Suggested Evaluation Criteria for Selecting Indicators (continued)

Criterion	Definition
Cost Considerations	
Cost Effectiveness	Is data to support the indicator readily available? Can it be obtained with reasonable cost and effort? Can it be reproduced, maintained, or updated?
Minimal Environmental Impact	Do sampling procedures produce minimal environmental impact?
Measurable	Does the indicator measure a feature of the environment that can be quantified simply, using standard methodologies with a known degree of accuracy and precision?
Data Availability	Are adequate data available for immediate indicator use? Do constraints exist on data collection that require postponement of indicator development?

DETERMINING APPROPRIATE EVALUATION CRITERIA

The process of identifying evaluation criteria is flexible and will vary to best meet the needs of the particular indicator project. The choice of criteria is often driven by the intended use for the indicators. For example, indicators that will be used to evaluate the effectiveness of management measures for improving fish species diversity and population size may require criteria that emphasize assessing scientific validity and accuracy. Indicators intended for communication to the general public may need criteria that stress assessing presentation effectiveness (e.g., clarity and simplicity). In all situations, however, several key features are critical to developing effective criteria, including the following:

- Criteria reflect project goals and objectives
- Criteria are clearly defined and understandable to all involved parties (it is very important that all participants apply the same definition)
- Criteria are sufficiently well-defined to avoid ambiguity (e.g., sometimes it is helpful to provide examples, and/or parameters, ranges, or other measures to define criteria and the extent to which they are met)
- Criteria are practical, valid, and legitimate.
- Criteria are nonbiased.

The evaluation criteria presented in Table 5-1 are grouped according to validity, interpretability, timeliness, understandability, and cost considerations:

- **Validity**—Indicators should be valid measures of the valued attribute. Validity is defined here as a close qualitative or quantitative link between the attribute actually of interest (e.g., biological integrity) and the measurable quantity represented by the indicator. Several factors listed in Table 5-1 contribute to a close logical link between the indicator and the attributes of societal concern or value:

  - Indicators that respond at the appropriate spatial and temporal scales are more likely to be valid measures of an attribute of concern.

  - If the purpose of an indicator is to assess environmental status and trends, indicators that respond to cumulative effects of multiple stressors will be more representative of the overall ecosystem condition than those that are responsive to only a few stressors.

  - Indicators that are highly correlated with other measures (of a specified attribute) will tend to be representative of the environmental attribute or system being measured.

  - Indicators must be sensitive enough to measure changes over a reasonable time but not so sensitive that they fluctuate substantially between time periods. The signal-to-noise ratio for an indicator is determined in part by the data used to generate the indicator. Expert knowledge and peer review can be used to assess the sensitivity of different indicators.

- **Interpretability**—Indicators should be interpretable in terms of the end point in the assessment process. They should be able to distinguish unacceptable from acceptable environmental conditions. Ideally, each indicator will have a benchmark against which to measure change.

- **Timeliness**—Timely indicators that anticipate future changes in the environment are preferred over those that are not anticipatory. To the extent that an indicator does not anticipate future conditions, the indicator with the least time lag would be preferred. The time lag depends on both characteristics of the indicator and the time lag between the data collection and when the data are available to calculate the indicator.

- **Understandability**—Indicators should be geared toward the target audience. Since so many indicators are used for public outreach, indicators should be understandable by the public and perceived as relevant. Understandability is in part a characteristic of the indicator and in part a function of how the indicator is presented. EPA may need to educate the public on the importance of some indicators. If possible, indicators should be "attention grabbers" in that they reflect the values of the audience (e.g., information on the number of fish in a water body is generally more interesting to the public than data on macroinvertebrates lower in the food chain). Keeping data presentations simple, graphic, and consistent enhances indicator understandability. The use of focus groups may help EPA to understand how the public perceives the indicators and may provide insights on ways to improve the indicator. Involving a representative and balanced stakeholder group throughout the indicator selection process should improve indicator presentation and understandability.

- **Cost Considerations**—Indicators should be cost effective relative to alternatives and to the effort and expertise required to collect the data, if required, and report the indicator over time.

The key to effective evaluation criteria is that they are appropriate for the particular indicator project. Whenever possible, criteria should be refined to best meet the needs of the specific project. Evaluation criteria that are targeted to the project goals and objectives, intended use, and target audience, are easier to apply than more generic criteria. For example, **Table 5-2** demonstrates one way that the "validity and interpretability" criteria presented in Table 5-1 might be refined to better meet the needs of a particular indicator project related to surface water quality.

APPLYING THE CRITERIA

Evaluation criteria can be applied using a variety of techniques to rank the possible indicators. The Indicator Team should select or designate an approach best-suited for that particular indicator project. Whatever approach is selected, it should be documented so that it is understandable to outside parties and can be reproduced easily.

One of the most common techniques is to weight the relative importance of various evaluation criteria and to score possible indicators according to how well they fulfill the weighted evaluation criteria. This approach, referred to as a weighted numeric index, is based on the following steps:

- Identifying and assigning weights to criteria
- Applying the criteria to the indicators
- Choosing the indicator(s) with the highest weighted score.

Table 5-2. Example Development and Application of Suggested Evaluation Criteria

This case study demonstrates the development of project-specific evaluation criteria based on the target audience, purpose, and indicator goals. This example is created using the "validity and interpretability" evaluation criteria described in Table 5-1.

Background
Project: *Environmental Indicator Bulletins--Surface Water Quality*
Audience: *General Public and Decision Makers*
Purpose: *Provide audience with a yearly assessment of national surface water quality.*
Format: *Presented in a four-page color bulletin with limited space for graphics.*

Procedure
Following the process outlined in Chapter 4.0 of this document, the Indicator Team, with the close support of the stakeholder group, developed goals and objectives for the indicator project. They also identified possible indicators using brainstorming techniques. In addition, brainstorming was used to determine selection criteria, which were then refined and tailored, using consensus-building techniques, to best meet the needs of the project.

Goal: Assess human and natural impacts, current conditions, and actions to improve water quality at a national level.

Criteria	Definition	*Example of Project-Specific Criteria*
Validity		
Social and Environmental Relevance	Does the indicator express society's environmental values, goals, and concerns by presenting information relevant to a desired policy goal, issue, legal mandate, or agency mission? Is the indicator seen by the target audience as being important or relevant to their lives?	*Does the indicator reflect the goals of the Clean Water Act?*
Appropriate Scale	Does the indicator respond to changes on an appropriate geographic (e.g., national or regional) and temporal (e.g., yearly or biennially) scale?	*Does the indicator provide national representation of surface waters? Are data supporting the indicator appropriate to report on a national scale?*
Integration of Multiple Impacts	Does the indicator represent the cumulative impacts of multiple stressors (e.g., water quality affected by nonpoint source discharges, point source discharges, acid rain, erosion)? Is it broadly applicable to many stressors and sites?	*Does the indicator integrate impacts from agricultural runoff, silviculture, construction activities, point source discharges, and runoff from nonpoint sources? Does the indicator capture all types of land uses?*

Table 5-2. Example Development and Application of Suggested Evaluation Criteria (continued)

Criteria	Definition	*Example of Project-Specific Criteria*
Validity		
Representative	Are changes in the indicator highly correlated to changing trends in the information it is selected to represent (e.g., is an indicator of industrial loadings to surface water highly correlated to declining surface water quality)? Does the indicator present an accurate model of the message it is intended to convey?	*Will the indicator respond to changes in other factors affecting water quality?* *Does the indicator accurately reflect national surface waters?* *Does the indicator separate surface water from ground water? Is the information presented in the indicator indicative of surface water only?*
Sensitivity	Can the indicator distinguish small changes in environmental conditions with an acceptable degree of resolution (e.g., will the indicator respond to modest changes such as occasional permit violations, or new plants coming online)?	*Will the indicator respond to modest changes to environmental conditions (e.g., a 10% increase in national nitrogen loadings from atmospheric deposition)?*
Interpretability		
Interpretable	Is there a reference condition or benchmark for the indicator against which to measure changes and trends (e.g., standards, limitations, criteria, goals)?	*Are there standards or other benchmarks for the indicator?* *Are there water quality criteria for all of the parameters reported in the indicator?*
Trend Evaluation	Has the data for the indicator been collected over a sufficient period of time to allow analysis of trends or provide a baseline for future trends?	*Has ambient surface water quality monitoring data been collected for over 10 years?* *Are there sufficient, accessible, reliable historical surface water monitoring data that can be used to establish a baseline?*

Identifying and Assigning Weights to Evaluation Criteria

The Indicator Team and stakeholders should identify criteria and rank them in terms of their importance in relation to each other. After ranking, the Indicator Team should apply a numeric weight to each of the ranked criterion. This can be done by assigning a percentage to each criterion so that all the criteria together total 100 percent. Although criteria sometimes may be weighted equally, it is often more effective to assign different weights so that the criteria accurately reflect the needs of the particular indicator project. If the Indicator Team has difficulty assigning numeric weights, it can group the criteria into essential (i.e., criteria an indicator must meet) and preferable (i.e., criteria an indicator should meet if possible) categories,[24] or use some other type of qualitative ranking approach. Brainstorming and consensus-building techniques should be used throughout this process. **Table 5-3** provides an example of this approach.

Table 5-3. Example Approach for Using Weighted Criteria for Evaluating Possible Indicators

Criteria	Weight	Rating Scale: 1 to 10		
		Possible Indicators		
		Indicator 1	Indicator 2	Indicator 3
Validity	40%	2 (0.8)	4 (1.6)	8 (3.2)
Interpretability	20%	3 (0.6)	6 (1.2)	6 (1.2)
Timeliness	10%	8 (0.8)	7 (0.7)	4 (0.4)
Understandability	20%	7 (1.4)	3 (0.6)	6 (1.2)
Cost Effectiveness	10%	5 (0.5)	1 (0.1)	7 (0.7)
Total	100%	4.1	4.2	6.7

Applying the Criteria

The Indicator Team should rate each possible indicator against each criterion on a scale (e.g., 1 to 10, with 10 being the highest). Then the scores can be determined using the weighting factors. A typical numeric index approach uses such formulas as the following:

- Additive Model

  $$Score = (S_1 \times W_1) + (S_2 \times W_2) + \ldots (S_n \times W_n)$$

  Where:

  S = Score assigned to each indicator for a particular evaluation criterion
  W = Weight assigned to the criterion.

[24] State Environmental Goals and Indicators Project, op. cit.

- Multiplicative Model

  $$\text{Score} = (S_1 \times W_1) \times (S_2 \times W_2) \times \ldots (S_n \times W_n)$$

  Where:

  S = Score assigned to each indicator for a particular evaluation criterion
  W = Weight assigned to each criterion.

Additive models tend to equalize the influence of all factors, whereas multiplicative models tend to emphasize the differences among factors. As a result, an additive model tends to produce scores within a narrow range; a corresponding multiplicative approach generates a much wider range of scores. Weighting the scores using either the additive or multiplication model produces a numeric index for each possible indicator. Additional information on applying numeric indices is presented in Chechile and Carlisle (1991) and Chang and Kelly (1993). The following list briefly summarizes selected advantages and disadvantages of this approach:

- Advantages
  - A numeric index can be based on quantifiable criteria important to the indicator selection process.
  - The index can be developed with input from different sources and easily modified so that the information can be tailored to serve a variety of indicator projects.
  - The approach is straight-forward, with results that are standardized and reproducible.
- Disadvantages
  - The more complex the index, the more difficult it is to apply, reproduce, and explain to the public.
  - Care must be taken in constructing the index to ensure that the correct criteria are chosen and weighted appropriately; the wrong choice of criteria and/or weighting factors may result in a poor index.
  - The range of scores may end up too small to allow for choosing between indicators.

To minimize the potential disadvantages of this approach, the Indicator Team may want to compare weighted results to unweighted scores. Also, if any of the resulting rankings seem inappropriate (e.g., an indicator that was believed to be good does not make the list or questionable indicators are ranked high), the Indicator Team may need to reexamine the evaluation criteria. It is always helpful to fully test the criteria before using them to select indicators.

6.0 CRITERIA FOR SELECTING EXISTING DATA SETS TO SUPPORT INDICATORS

The basis for all environmental indicators is data. Sections 4.0 and 5.0 presented an approach for selecting environmental indicators based on defining, at the outset, the overall goals and objectives of the indicator project, the intended message for the indicator, and the target audience before considering data availability. After identifying environmental indicators using this approach, however, it is necessary to fully consider the availability and quality of data to support the candidate indicators.

This section describes an approach for evaluating data to support environmental indicators. The evaluation approach will vary depending on the goals and objectives of the indicator project and the stringency of data requirements needed to achieve those goals. Therefore, the Indicator Team, in consultation with its stakeholder group and data experts that could provide technical insights, should determine project-specific data requirements. The Indicator Team may want to identify and weight specific criteria to use in reviewing data sets.

Table 6-1, given at the end of this section, identifies criteria for evaluating the usefulness of existing data in supporting the development of the final environmental indicators. The criteria presented should be modified to best meet the needs of a particular indicator project.

In general, critical criteria for selecting data sets include the following:

- Availability of data on the selected parameters
- Appropriate temporal and spatial coverage
- Documented quality
- Accessibility.

Another critical criterion is that minimal standards of technical credibility, estimation precision, and cost can be achieved by either the present data collection procedures or reasonable modifications of them, because changes in data collection procedures might affect the technical credibility, magnitude of the estimation error and associated sample size, and overall cost.

It is possible that either the sampling procedures or laboratory analysis procedures will change over the time that a data source is used to quantify an indicator and monitor progress. These changes may result from many factors, including advances in technology and changes in budgets and uses of the data sets over time. The effect of these changes can be minimized by using (1) measurements for which changes in technology are likely to improve the precision but not affect the measurement bias and (2) procedures for which the measurement bias is relatively insensitive to the magnitude of the collection effort. To the extent that this cannot be achieved, a comparability study can be used to compare the indicator before and after the change. The value of both the original and revised indicator can be used for some time to provide information on how the two indicators compare. This same procedure can also be used if a entirely new data set is used for the revised indictor.

Application of evaluation criteria to determine which data sets best support candidate indicators is described in Step 2b of the selection process. After evaluation of potential data sets, the selection of final indicators takes place. This is Step 3, the final step, of the indicator selection process.

Environmental indicators provide an accurate measure and an objective description of current environmental trends and patterns. The process for selecting environmental indicators described in this document facilitates the development of unbiased indicators supported by existing data sets. The Indicator Team and stakeholder group should tailor the selection methodology and criteria described within each section to fit the needs of specific indicator projects. Causal frameworks, such as the PSR framework described in this document, provide context and organization structure for environmental indicators. Project-specific factors such as the intended audience, message, and use influence the presentation style of selected environmental indicators. Environmental indicator development promotes effective information collection, quantification, and communication, and illustrates the need for continued research in this area.

Table 6-1. Criteria for Selecting Existing Data Sets to Quantify Indicators

Criteria	Definition	Additional Considerations
*Data Availability	Does the data set provide measurements of the parameter(s) or variable(s) specified in the indicator.	Does the data set measure supporting parameters, such as those needed for data interpretation (e.g., pH for metals, temperature for dissolved oxygen)? Does the data set provide all necessary information to support the data (e.g., location, date, weather, tide level)?
*Appropriate Temporal Coverage	Are appropriate historical data available so that a baseline and/or trends can be established?	Are data available for time periods crucial for data interpretation (e.g., dissolved oxygen data in the summer)? Does temporal coverage within reporting cycles (usually annually) have gaps? If gaps exist, they should not exclude data that will significantly affect the indicator.
*Appropriate Spatial Coverage	Do the data cover the area of interest? Information should be available on a national basis for a national program. If the information is compiled from local or regional data, can the information be aggregated using scientifically and statistically valid procedures?	Are the data representative (i.e., not focused on "hot spots")? Do the data provide sufficient coverage to determine sources, cause, and effect (e.g., can they separate pollution/contamination from natural background)? Do the data use accepted geographic conventions? Are the data of appropriate scale and detail?
Data Quality	Are the data of known quality (i.e., are there (1) documented QA/QC procedures for the collection, analysis, and presentation of data, (2) documentation of any deviations from the procedures, and (3) quantitative information on both sampling and non-sampling errors)?	Is information on field and laboratory methods provided? Are detection limits provided, where applicable? Were results of accuracy checks provided (e.g., duplicates, replicates, split samples, spike recoveries, instrument calibration)? Were lab audits performed and reported? Were there statistical checks on the data, including data entry procedures? Were problems identified in the data? If so, how (e.g., using flags, leaving data points missing, reporting zeros)? Were assumptions and limitations of the data discussed? Was a point of contact provided?

*Critical criterion

Table 6-1. Criteria for Selecting Existing Data Sets to Quantify Indicators (continued)

Criteria	Definition	Additional Considerations
Data Accessibility	Are the data able to be analyzed using existing data retrieval and analysis procedures?	Are data able to be used, or do confidentiality concerns limit data access? Are the data available in electronic format? Are the appropriate computer software and hardware technologies available to access the data? Are the data in an acceptable format? Is there a point of contact available to resolve issues?
Technical Credibility	Did the procedures used to manage and analyze the data follow accepted professional practices. Are the sample and data collection procedures consistent with the use of the data as a measure of the indicator, as judged by technical experts in the field who are familiar with the data? The calculated bias in the indicator should be insensitive to the magnitude of the data collection effort and to political pressures. In general, this criterion will eliminate self-reported data from consideration.	Are the data consistent with that of similar st udies and information? Are the data results consistently interpreted?
Acceptable Estimation Error	Is the precision and bias of the indicator acceptable given the desired precision specified by the program?	Are the data sufficiently accurate to meet the goals and objectives of the indicator project?
Acceptable Cost	Is the cost of data collection, management, and analysis within programmatic guidelines?	Can the indicator and supporting data be reproduced, updated, and/or modified at an acceptable cost?

*Critical criterion

APPENDIX A

PRESSURE-STATE-RESPONSE/EFFECTS FRAMEWORK

EPA is considering an expanded version of the OECD PSR framework.[25] This enhanced conceptual framework adds "Effects" as a category to describe impacts of environmental change on human health and welfare. The updated version, PSR/E, shown in **Figure A-1**, also divides each category into subcategories (e.g., a distinction is made between direct pressures and underlying pressures). In addition, it seeks to link the PSR framework explicitly to society's environmental values, goals, and priorities. Moreover, the framework aims for the incorporation of spatially referenced (geographic) information, organized on the basis of ecologically defined geographic scales; the adoption of sustainability targets; and the multiscaled use of information. **Table A-1** provides a case study illustrating the proposed framework.

Indicators of effects under the PSR/E framework describe relationships between two or more pressure, state, and/or response variables. They are based on models and analyses that provide plausible evidence of a linkage between a problem, potential causes, and/or solutions. The most important types of effects include effects of underlying pressures on human activities; effects of human activities (indirect pressures) on levels of biophysical stressors (direct pressures); and effects of pressures or responses on ecological state, human health, and human welfare.[26] Effect indicators are perhaps the most comprehensive environmental indicators because they describe relationships among two or more variables within the other categories. Theoretically, effect indicators should provide a greater degree of certainty in describing cause and effect relationships than just pressure, state, or response indicators alone; however, the time involved in data collection to develop effect indicators may detract from their usefulness as an evaluation criterion of policy performance.[27]

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[25]United States Environmental Protection Agency, Conceptual Framework to support Development and Use of Environmental Information In Decision-Making, April, 1995.

[26]USEPA, op. cit.

[27]Ibid.

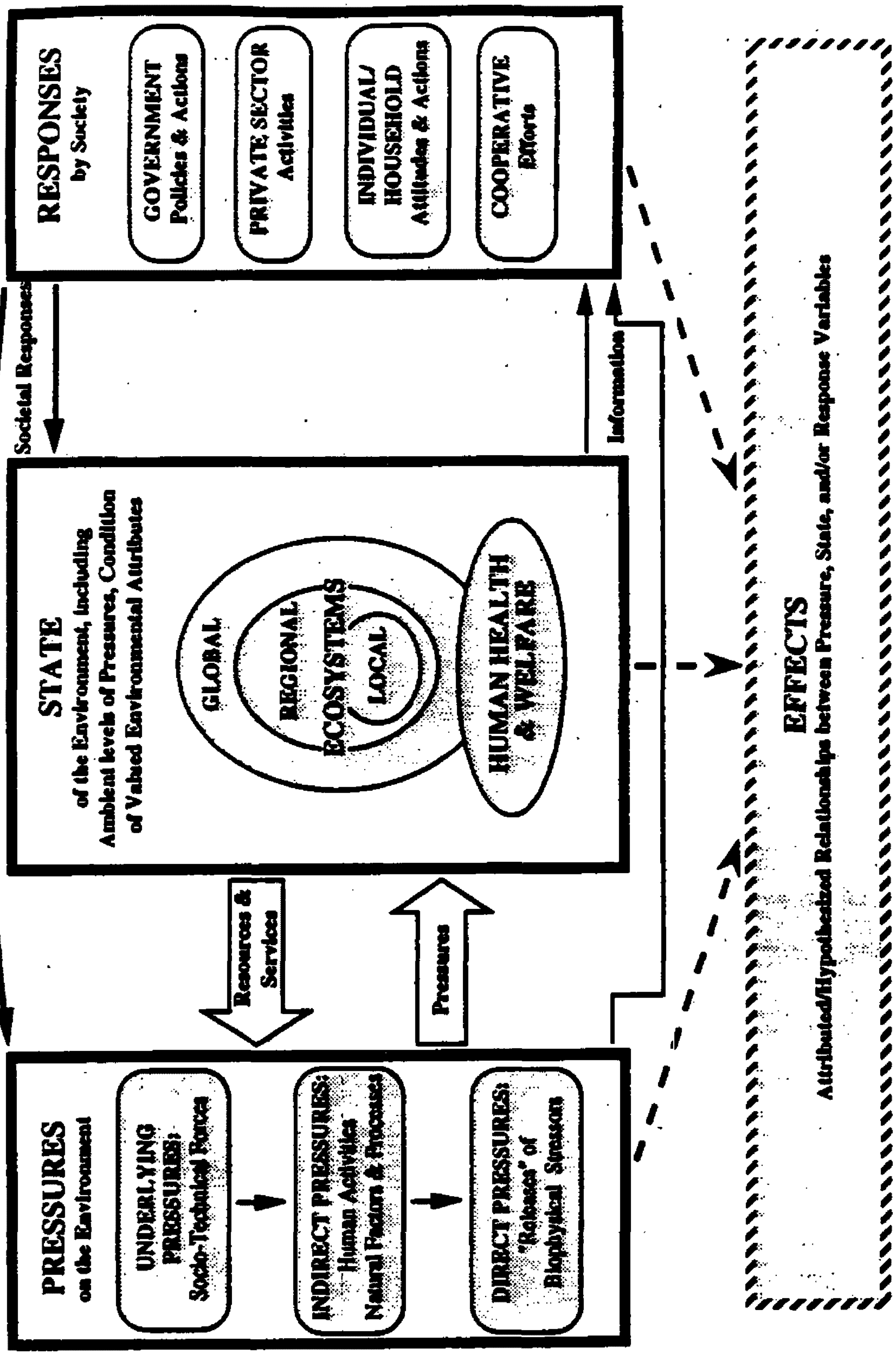

Figure A-1. Pressure-State-Response/Effects (PSR/E) Framework (adapted from USEPA, 1995)

Table A-1. Case Study of Pressure, State, Response/Effects Framework and Subcategories (adapted from USEPA, 1995)

Example Environmental Value, Goal and Priority: *Citizens desire a healthy and vibrant recreational fishery in the nation's estuaries (value). The goal is to reduce nutrient and toxic loadings from the adjacent watershed to increase current fish populations. Reducing nutrient and toxic pollutant loadings from agricultural and urban areas are the top priority.*

Pressures (P)	**State of the Environment (S)**	**Societal Responses (R)**	**Effects (E) (Relationships between P, S and/or R)**
Underlying Pressures Sociotechnical Forces: population, technology, social structure, attitudes & practices, policies ***(e.g., burgeoning populations and increasing density of development)***	**Global Ecosystem** Ambient conditions and trends (chemical, physical, bio/ecological); Status of "valued environmental attributes" (VEAs) ***(e.g., large scale eutrophication, fish kills, declines in species diversity or abundance, loss of habitat)***	**Government Actions:** Legislation, regulations, policies, monitoring, enforcement actions, investments, international agreements, etc. ***(e.g., implementation of Clean Water Act)***	**Linkages** between levels of **Pressures** (Underlying, Indirect, & Direct), or between **Pressures** and **Responses** ***(e.g., effects of population growth on agricultural and industrial output)***
Indirect Pressures Human Activities: agriculture, mining, manufacturing, transport, energy consumption ***(e.g., runoff from agriculture and urban areas, direct discharges)*** and **Natural Processes/Events** (volcanic eruptions, wildfires) ***(e.g., natural erosion)***	**Regional Scale Ecosystems** conditions and trends (chemical, physical, bio/ecological); Status of "valued environmental attributes" (VEAs) ***(e.g., regional eutrophication, fish kills, declines in species diversity or abundance, loss of habitat)***	**Private Sector Activities** Compliance, waste treatment, mitigation, cleanups, process redesign, etc. ***(e.g., pollution prevention planning and implementation, animal waste management, conservation tillage integrated pest management)***	**Ecological Effects** Relationships between Direct Pressures or Societal Responses and State of the Environment ***(e.g., increased density and areal extent of submerged aquatic vegetation, reduced incidences of hypoxia)***
Direct Pressures Biophysical Stressors: pollutants, resource extraction, land use change, exotic species ***(e.g., animal wastes discharges, urban/suburban fertilizer runoff, failing septic systems, increasing levels of impervious area)***	**Local Scale Ecosystems** conditions and trends (chemical, physical, bio/ecological); Status of "valued environmental attributes" (VEAs). ***(e.g., local eutrophication, fish kills, declines in species diversity or abundance, fish tissue concentration of toxins)***	**Individual/ Household Attitudes & Actions** Recycling, conservation, contribution to NGOs, etc. ***(e.g., household hazardous waste collection programs, toxics use reduction, use of integrated pest management, reduced fertilizer use)***	**Human Health Effects** of Direct Pressures, Ecological Changes (in State), or Societal Responses ***(e.g., increased number of fishing bans and human consumption advisories increased disease)***
	Human Health & Welfare conditions and trends (chemical, physical, bio/ecological); Status of "valued environmental attributes" (VEAs) ***(e.g., concentrations of toxins in humans, fishing bans or consumption advisories, incidence of disease)***	**Cooperative Efforts** Research, NGOs, public-private partnerships, etc. ***(e.g., development of watershed management plans, integrated water quality and living resources monitoring programs)***	**Human Welfare Effects** of Ecological Changes (in State), or Societal Responses ***(e.g, incidence of disease attributed to fish or shellfish consumption, reduced economic value of fishery)***

APPENDIX B

DRAFT SHORT FORM FOR SCREENING CANDIDATE DATA SETS

Data Set Screening ("Short") Form

Data Set Acronym/Short Name: **Date Completed:** ___ / ___ / ___

1. Background and Summary Information

1.1 Full Name of Data Set:

1.2 Sponsoring Agency:

1.3 Contact person: Name:

Address:

Telephone:

1.4 Brief summary of data set and the reasons for collecting this data:

.5 References for additional information

2. Target Population [illegible] Sampling [illegible]

2.1 Describe the target population / sampling frame:

2.2 Describe the sampling units:

2.3 How were the sampling units covered by the data base selected? (check one)

[ ] Probability Based Sampling: Briefly describe the sample design:

[ ] Census

[ ] Other: Specify:

2.4 Overall response rate: __ %

2.5 What is the geographic coverage of the data in the data set? (check one)

[ ] National

[ ] Regional: Specify:

[ ] State: Specify:

[ ] Other: Specify:

2.6 What time period (years) does the data set cover? From 19 __ to 19 __.

2.7 Is the data collection on-going? Yes [ ] No [ ]

2.8 Frequency with which the survey or data collection effort is repeated:

3. Information Recorded In The Data Files

3.1 For which of the following types of samples (including questionnaires) are measurements/data recorded in the data set? (Check all that apply) Describe the samples collected and the measurements obtained.

	Sample type	Sample description:	Measurements obtained:
[ ]	Water		
[ ]	Soil		
[ ]	Air		
[ ]	Food		
[ ]	Bulk chemical		
[ ]	Human tissue or fluid		
[ ]	Questionnaire (diary, observation form)		

4. Documentation of Data Collection Procedures

4.1 Did the following data collection activities have written procedures (including the use of accepted standard methods) and were the procedures documented through a QA/QC program review?

Sample/data collection activities	Written procedures	QA/QC review	Not applicable
Environmental sampling:	[ ]	[ ]	[ ]
Biological sampling:	[ ]	[ ]	[ ]
Field measurements:	[ ]	[ ]	[ ]
Laboratory preparation and analysis:	[ ]	[ ]	[ ]
Interview/questionnaire/field notes:	[ ]	[ ]	[ ]
Data Entry, editing, and verification:	[ ]	[ ]	[ ]

5. Summary Assessment of Data Quality

5.1 For key summary statistics derived from the data, describe the statistic and the associated confidence interval or measure of precision:

5.2 Give a general assessment of the data quality. Include comments, issues, or usage guidance relevant to using this data, including any potential biases or limitations in the data:

6. Description of the Available Data File

6.1 Availability of data:

Non-aggregated data

[ ] Public use. Give cost:

[ ] Restricted use: Specify:

[ ] Confidential (not available for public use)

Summary Statistics

[ ] Public use. Give cost:

[ ] Restricted use: Specify:

[ ] Confidential (not available for public use)

6.2 In what form are data available? Mark all that apply.

Non-aggregated data

[ ] Hard copy (for example, Computer printouts, Files or log books, Reports, Microfilm)

[ ] Machine readable form (for example: Tape, Diskette, On-line, CD-ROM)

Summary Statistics

[ ] Hard copy (for example, Computer printouts, Files or log books, Reports, Microfilm)

[ ] Machine readable form (for example: Tape, Diskette, On-line, CD-ROM)

6.3 Describe available summary statistics:

6.4 On average, how long is the time from field measurement, sample collection, and interviewing until data is available to the public?

APPENDIX C

SELECTION CRITERIA USED IN OTHER ENVIRONMENTAL INDICATOR PROJECTS

Chesapeake Bay Program. 1995. Summary of Environmental Indicator Workshops (draft document):

Does the indicator reflect the message we want to communicate? Can the public relate? Who is the intended audience?

Is the indicator tailored to the intended audience?

Do we have the data? Defensible and valid? Consensus on interpretation? If we do not have the data, should we recommend its collection?

Is there a benchmark against which we can measure our progress?

Is it simple and direct?

Will it help to answer the question, "How is the Bay?"

Does it reflect established Chesapeake Bay Program goals?

Can we combine this indicator with others to form indices/multi-species "community" indicators?

The State Environmental Goals and Indicators Project. 1995. *Prospective Indicators for State Use in Performance Agreements*, Florida State University:

Essential Criteria

Measurable—The indicator measures a feature of the environment that can be quantified simply using standard methodologies with known degree of accuracy and precision.

Data Quality—The data supporting the indicators are adequately supported by sound collection methodologies, data management systems and quality assurance procedures to ensure that the indicator is accurately represented. The data should be clearly defined, verifiable, scientifically acceptable and easy to reproduce.

Importance—The indicator must measure some aspect of environmental quality that reflects an issue of major national importance to states and to the federal government in demonstrating the current and future conditions of the environment.

Relevance—The indicator should be relevant to desired significant policy goal, legal mandate, or agency mission (e.g., contaminated fish fillets for consumption advisories; species of recreational or commercial value) that provides information of obvious value that can be easily related to the public and decision makers.

Representative—Changes in the indicator are highly correlated to trends in the other parameters or systems they are selected to represent.

Appropriate Scale—The indicator responds to changes on an appropriate geographic (e.g., national or regional) and/or temporal (e.g., yearly) scale.

Trends—The data for the indicator should have been collected over a sufficient period of time to allow some analysis of trends or should provide a baseline for future trends. The indicator should show reliability over time, bringing to light a representative trend, preferably annual.

Decision Support—The indicator should provide information to a level appropriate for making policy decisions. Highly specific and special parameters , useful to technical staff, will not be of much significance to policy staff or management decision makers.

Preferable Criteria

Results—The indicator should measure a direct environmental result (e.g., an impact on human health or ecological conditions). Indicators expressing changes in ambient conditions or changes in measures reflecting discharges or releases are acceptable, but not preferred. Process measures (e.g., permits, compliance and enforcement activities, etc.) are not acceptable.

Understandable—The indicator should be simple and clear, and sufficiently nontechnical to be comprehensible to the general public with brief explanation. The indicator should lend itself to effective and appealing display and presentation.

Sensitivity—The indicator is able to distinguish meaningful difference in environmental conditions with an acceptable degree of resolution. Small changes in the indicator show measurable results.

Integrates effects/exposures—The indicator integrates effects or exposures over time and space and responds to the cumulative impacts of multiple stressors. It is broadly applicable to many stressors and sites.

Data comparability—The data supporting an indicator can be compared to existing and past measures of conditions to develop trends and define variation.

Cost effective/availability—The information for an indicator is available or can be obtained with reasonable cost and effort and provides maximum information per unit effort.

Anticipatory—The indicator is capable of providing an early warning of environmental change.

Adriaanse, A. 1993. ***Environmental Policy Performance Indicators: A Study on the Development of Indicators for Environmental Policy in the Netherlands.***[28]

Indicators should be as aggregative as possible.

They must have a definite appeal, partly by being aptly presented.

They must reflect a trend, with a time scale that is tailored to the problems.

They must relate to cause and effect, or in other words, to the causal chain.

The course of actual developments in time must be seen in relation to existing policy objectives and necessary measures.

They must be verifiable and reproducible.

Further refinement of the above resulted in the following criteria:

Acceptable Quality for Data and Methodology (e.g., clearly defined, accurately described, socially and scientifically acceptable, easy to reproduce)

Sensitivity in time

Policy relevance

Recognizability and clarity

[28]Adriaanse, A. 1993. *Environmental Policy Performance Indicators.*

The Organization for Economic Cooperation and Development. 1994. *Environmental Indicators.*

Policy Relevance and Utility for Users

Provide a representative picture of environmental conditions, pressures on the environment, or society's responses.

Be simple, easy to interpret, and able to show trends over time.

Be responsive to changes in the environment and related human activities.
Provide a basis for international comparisons.

Be either national in scope or applicable to regional environmental issues of national significance.

Have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it.

Analytical Soundness

Be theoretically well founded in technical and scientific terms.

Be based on international standards and the international consensus about the validity.

Lend itself to being linked to economic models, forecasting information systems.

Measurability

Readily available or made available at a reasonable cost/benefit ratio.

Adequately documented and of known quality.

Updated at regular intervals in accordance with reliable procedures.

Interagency Working Group for Sustainable Development Indicators. 1995. Criteria and Plan for Selection of Indicators of Sustainable Development and Sustainability (draft document):

Understandable—Should not be obscure or statistically difficult to understand. Clear, understandable, sufficiently universal to be easily communicated.
Relatable to sustainable development and sustainability

Have a constant definition over time. Definition, measurement technique, and analytical methodology is constant over time. Must avoid discontinuities.

Sufficient historical data available. Preferable to have a record for a 20- to 50-year time period. Available in electronic form.

Indicators should be national in scope, including summary data and information that scales and is available at the state, regional, and local levels.

Quality known—Metadata should be included for all indicators that shows the quality. This data should include such information as sensitivity, uncertainty, variability, precision, accuracy, error and similar analyses.

If combining information, should include economic, environmental, and social information.

If building toward an index, indicators should be able to be combined.

Relevance to policy and issues of concern.

QLF/Atlantic Center for the Environment. 1995. Criteria and Ranking Scheme for Indicators of Sustainability:

A true measure of sustainability.

Understandable to the community at large.

Focused on a long-term view of the community (20 to 50+ years)

A link between different aspects of the community (social, economic, environmental)

A yard stick against which to measure potential places

A measure of community level sustainability that was not at the expense of global sustainability

Based on reliable, easily available information

Available on a regular (hopefully yearly or biennially) basis