Watershed Index Online (WSIO)

An Approach to Comparative Watershed Assessment With Downloadable Nationwide Data and Tools

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The Environmental Protection Agency
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Acknowledgment

The Watershed Index Online (WSIO) would not have been possible without Dr. John Richardson, who retired from EPA Region 4 in 2013. Dr. Richardson developed the concept, designed the geospatial analysis approach, and performed the geospatial analysis that lead to Region 4's WSIO Watershed Indicator Data. His knowledge, skill, and dedication to protecting the environment *everyday* are unmatched.

Disclaimer and User Requirements

- **Software requirements:** The WSIO tool requires Microsoft Excel 2010 (or later) for data download and calculation. Excel 2013, the ESRI Maps for Office Add-in, and access to ArcGIS Online are required to use the tool's interactive mapping feature. Mention of product names does not denote endorsement by the EPA.
- **The WSIO is intended to be used as a decision-support tool** by government, professional, academic, and community users with a basic understanding of how the ecological condition of a watershed and the stressors that act upon it can affect hydrology, biology, and water quality. The WSIO data and tool outputs do not represent, change or substitute for any statute, regulation, policy, EPA decision or position.
- **It is the responsibility of the user to read and evaluate dataset limitations, restrictions, and intended use.** To the best of our knowledge, the data, information, and supporting materials on the WSIO website are accurate; however, no warranty expressed or implied is made regarding the accuracy or utility of the data for general or scientific purposes, nor shall the distribution constitute any such warranty. All modeled geographic data are, by their nature, imperfect. The data provided by this tool shall not be taken as absolute truth, but rather as an approximation made in good faith based on the best available data.
- **For site-specific data, WSIO data will not replace "boots-on-the-ground" measurements or local knowledge.** Better local data may be available from local sources.
- **Neither the EPA, EPA contractors, nor any other organizations cooperating with the EPA assume any responsibility for damages or other liabilities** related to the accuracy, availability, use or misuse of the information provided on this website. The EPA reserves the right to change information at any time without public notice. Any errors or omissions should be reported to WSIO team using "Contact Us" on the WSIO website. We are always happy to hear your feedback and use that feedback for future enhancements.
- **Some features described in this and other documents on the WSIO website may not yet be fully implemented, updates and improvements are planned to achieve full functionality described. In particular, the interactive mapping feature within the WSIO tool is a new product and can be subject to freezing (not responding). An update to the ESRI Maps for Office plug-in is planned and will be utilized by the WSIO in a future version of the tool.**

About the Watershed Index Online (WSIO)

What it is: A free, publically available data library of watershed indicators and a decision-support tool, developed by the EPA to assist resource managers with evaluating, comparing, and prioritizing watersheds.

Goal: To provide government, professional, academic, and community users with data, tool(s) and an approach for ranking large numbers of watersheds, as well as communicating potentially important differences among them.

Data: Ecological, stressor, and social watershed indicators, measured at the HUC12 scale for the contiguous United States.

Tool: An Excel-based workbook that allows users to automatically download watershed indicator data for a defined project area, perform screening calculations and examine the results using tables, maps and bubble plots.

Approach: Following scientific recommendations for assessing and reporting on the health of ecological systems, the WSIO approach calculates relative rankings for user-selected watersheds based on attributes related to their ecological condition and the stressors acting upon them. Social, economic, and/or policy factors are used as the third dimension of the analysis. The approach is repeatable and allows users to document and communicate the results of any screening analysis.

Background

In recent years, the use of geospatial data to evaluate and compare watershed characteristics across large areas such as states, regions or the nation has increased dramatically as a mainstream component of water quality program tracking, evaluation, prioritization and strategic planning. Nineteen states now have Recovery Potential Screening (RPS) projects driven by as many as 100 or more watershed indicators. Other states and watershed programs are beginning to compile Healthy Watersheds Assessments to identify aquatic ecosystems that still have natural structure and function but are under significant threat from pollution and other adverse impacts, such as habitat fragmentation and hydrologic alteration. The Federal government has also recognized the value of watershed assessments in managing aquatic resources. The EPA's new long-term vision for the Total Maximum Daily Load (TMDL) program calls for watershed prioritization as part of states' biennial Integrated Reporting of water body condition, while the Nonpoint Source Program recommends watershed prioritization as a way to determine where funding for agricultural management practices would be most beneficial. One key element of the EPA's recommendations to states, to maximize progress in reducing nutrient pollution, is to prioritize their watersheds on a state-wide basis, taking into account available water quality information as well as existing resources. These and many more activities and programs are routinely aided by the availability of watershed-based indicators and analytical tools to support decision-making and guide effective action.

These types of watershed assessments have been applied at local or state-wide scales for several years, but most projects must first develop an appropriate dataset. Few projects have attempted to compile and make available uniformly measured watershed indicators on a national scale, and most of the national datasets that do exist have not taken the step of interpreting watershed parameters of greatest interest from source data. For example, a national dataset showing the presence of agriculture has some value in recognizing possible watershed condition and stressors. However, translating this data into watershed indicators, such as the percentage of agriculture on steep slopes within a set distance of streams, is more directly useful in a watershed assessment. Such metrics generally do not exist on a national scale. Rather, metrics like this are being calculated again and again on single states or river basins throughout the country as individual projects demand them. The Watershed Index Online (WSIO) was initiated to fulfill the need for readily available, nationally consistent watershed indicators, processed and compiled on a useful watershed scale. Given the limitations of dwindling budgets and resources, the timing has never been better to provide watershed tools rich in data with customizing features that help water quality programs make effective, data-driven strategic planning decisions.

The EPA WSIO project is complementary to the Recovery Potential Screening (RPS) project, which was developed as a state-specific comparative watershed assessment tool, with the goal of helping state TMDL and nonpoint source programs consider where best to use limited restoration resources among large numbers of impaired waters and watersheds. The development focus of RPS is on ranking watersheds based on their relative restorability, given each watershed's ecological capacity to regain function, its exposure to stressors, and the social context affecting efforts to improve its condition (USEPA, 2011). The RPS project has made available various tools and methods, including: recommendations outlining a consistent method for recovery potential screening; advice on indicator selection; access to a restoration and recovery literature database containing information on available data sources and measurement methods; and a scoring workbook to help organize watershed indicator data, automate the process of screening watersheds based on user selected criteria, and to interpret and display results.

The existing RPS workbook and methodology require users to compile the necessary data, and measure or calculate relevant watershed indicators for use in their comparative assessments. Different recovery potential efforts have found themselves re-creating the same measurements used in other efforts, for their specific project area. The compilation and processing of data to develop watershed indicators is a necessary but significant hurdle to performing recovery potential screening.

The Watershed Index Online

Through development of the WSIO, the EPA is furthering its support of watershed prioritization efforts by eliminating or reducing the workload associated with data compilation and processing necessary to perform a watershed screening. The WSIO provides a library of hundreds of the most popular watershed indicators, already processed and compiled for approximately 83,000 HUC12 watersheds throughout the contiguous United States. This watershed attributes library has been integrated with the RPS tool, such that users can easily download uniformly measured watershed indicators directly into the WSIO tool for a defined project area. By providing a free-publically available database of pre-processed watershed indicators related to ecological condition, stressors, and social/policy factors, as well as a scoring tool, the WSIO is able to support a range of water quality objectives, including both restoration of impaired waters and protection of healthy watersheds, among others. The availability of a variety of relevant data and the flexibility of the WSIO's ranking approach allows users to consider a number of objectives that support multiple strategic plan goals of the EPA, and other federal, state, or local natural resource agencies.

The WSIO is the result of collaboration between the EPA Region 4's Water Protection Division, OPM division, the RPS project developed by the Watershed Branch at the EPA Headquarters, and contractors SAIC and Cadmus. The development of the WSIO tool was heavily influenced by the existing RPS tool, the Healthy Watershed Initiative, EnviroAtlas, Waterscape, and published research. The EnviroAtlas was the basis for some of the watershed indicators included in the WSIO and informed their structure and function within the tool. The concept and data organization of the WSIO tool was also guided by recommendations for assessing and reporting on the ecological condition of natural resources from the EPA Science Advisory Board (SAB, 2002). The SAB proposed a conceptual framework, including a list of Essential Ecological Attributes that should be considered when assessing and reporting on the health of natural systems.

The WSIO tool is built upon the RPS tool developed for the EPA's RPS project. Enhancements within the WSIO tool includes the ability to select and automatically download indicator data and the addition of an interactive map. The user can now define a geographic project area from within the workbook, select a subset of watershed attributes from among hundreds of options, and automatically download these indicators into the workbook for the specified watersheds. Users also have the option of incorporating any watershed indicators they have developed for their project area. The rest of the workbook takes advantage of the already existing tool's ability to normalize indicator values, and apply weights to them, to calculate ecological, stressor, and social indicator scores, as well as a combined Watershed Index score. It retains the ability to quickly re-perform calculations with different indicator combinations and/or differently assigned weights and to save each scenario as a separate workbook. The WSIO tool may also be used to compare index scores for the screened waters using bubble plots, rank-ordering, and the newly added thematic map.

The WSIO Tool, an enhanced scoring spreadsheet, is custom-designed by the user and then downloaded to their local computer. Although, the spreadsheet's calculations are performed locally, the computer must have internet access in order for the spreadsheet to display and retrieve indicator and geospatial data from external sources. A macro within the spreadsheet connects to a server to download data for selected HUCs and watershed indicators.

WSIO Contents

- *Watershed Indicator Library*: The library contains specific values for ecological, stressor, and social indicators calculated consistently at the HUC12 scale nationwide. A major source of the library is the EPA Region 4's WSIO datasets compiled for the conterminous U.S., however, other indicator data sources, including RPS and EnviroAtlas data were also used. As tabulated indicator values are georeferenced only to the national HUC12 dataset, the WSIO library maximizes attribute information while minimizing geographic data, thus utilizing a fraction of the storage and response time that would be required to host all of the source GIS datasets from which all these indicators were measured. Users may select individual attributes for differently-sized project areas, such as regions, states or major river basins.

- *Analytical Tool*: The initial user interface is an adaptation of the RPS tool, which has been in use as a custom-coded excel workbook for several years helping states compare and prioritize watersheds for restoration investments. The WSIO tool enables users to define a project area, select indicators and weight them, perform a variety of different WSIO screening runs and save results as rank-ordered priority lists, thematic maps, and bubble plots. The WSIO assessments is conducted with this tool locally (i.e. on a user's computer) after tool and data downloads.

- *Programmatic Links:* Although the WSIO has the potential to attract a broader user audience, its initial design is to support watershed analysis, comparison and prioritization relative to the Clean Water Act programs mentioned above. The WSIO also aims to increase the use of new analytical tools and data through collaboration with and appropriate linkages to other programs that utilize watershed indicators and tools in their missions.

WSIO Indicators

Indicator Overview

Healthy ecosystems support clean water, clean air, pollution prevention, pollutant removal, and ecological processes. A common objective of comparative watershed analysis is to rank watersheds in in the project area along a gradient of least-disturbed to most-disturbed. The ecological and stressor indicators can be used as predictors of the likelihood of a watershed supporting healthy ecological processes. The WSIO ranks selected watersheds, relative to each other, by the likelihood that they can support good quality of air, water, and biology; sustainable human and natural habitats; and benefits to humanity, such as recreation, aesthetics, culture, food, fuel, and materials.

The concept supporting the WSIO is that by measuring ecological condition and stressors we can predict the likelihood that a watershed supports natural disturbance regimes and ecological processes that provide benefits to the environment and humanity. The WSIO approach ranks watersheds relative to each other based on user-selected indicators of ecological condition, stressors (drivers of change), and social, economic, and/or policy factors. The selection of indicators is based primarily on the objective(s) for watershed comparison. The three types of WSIO indicators (i.e. ecological, stressor, and social) have been organized into sub-categories to facilitate selection of indicators from as many

Essential Ecological Attribute’s (EEA) and stressor categories as practical for a given project’s objectives.

WSIO Conceptual Basis

The EPA Science Advisory Board (SAB) recommendations for estimating condition and stressor factors for all Essential Ecological Attribute’s (EEA) are difficult to fully achieve when attempting to populate a database of indicators covering the conterminous United States. The SAB framework is a valid and useful scientific concept, but it does not consider scale of measurement or availability of information in its construct. Although the WSIO attempted to follow the SAB framework as much as possible, the practicality of assembling watershed attributes that can be measured consistently across the country requires use of surrogates for some ecological and stressor indicators which are difficult to directly measure. As an example, stream channel morphology/complexity is an important variable of the SAB’s Hydrology and Geomorphology EEA. While it is possible to measure relevant data for a small-scale project, it is difficult to consistently measure stream channel properties across the nation from existing datasets. As such, the WSIO uses surrogate measures related to condition in the stream corridor and land adjacent to water to estimate channel flow dynamics in a watershed.

The condition and connectivity of the landscape are known to have effects on hydrology, water quality and aquatic biology. These attributes can be measured as a percentage of the entire watershed, or as a percentage of the watershed’s riparian corridor. Indicators measured using either of these spatial zones can be ranked in terms of the amount of natural verses anthropogenic land cover, level of disturbance, severity of impairment, land cover change, and biological indices. The spatial position of the measured attribute relative to the waterbody (i.e. proximity to water) is an important factor in estimating its effect. For example, natural land cover - or disturbed land cover - that is directly adjacent to a waterbody will have a different effect than the same land cover located further from a waterbody. Watershed attributes, like, wetness, stream order, and flow accumulation measured from the topographic setting also contribute to understanding the hydrologic condition of watersheds.

Measured watershed attributes are grouped into ecological condition and stressor metrics. There is a degree of overlap and similarity among ecological indicators, and among stressor indicators, affecting the quality of air, water, biology, and sustainability of human and natural habitats. Therefore, a single measurable watershed indicator may relate to more than one ecological attribute or stressor. Likewise, a particular aspect of ecological condition or stress may be estimated by more than one watershed indicator. Thanks to cooperating data developers, the WSIO is able to make available a variety of indicators of ecological condition; indicators of stressors driving change in condition or quality; and indicators of social, economic, and policy-related factors. These indicators are summarized at a HUC12 watershed scale (typically covering an area of approximately 40 square miles). The organization of WSIO indicator data and the relationship of these indicators to the SAB’s EEAs and stressors are further described below.

Ecological Indicator Components

As defined by the SAB, EEAs include six categories: Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, Hydrology and Geomorphology, Natural Disturbance Regimes and Ecological Processes. In the WSIO, ecological indicator data is grouped into one of six ecological components that are related to the SAB EEAs, as shown in the table below. The goal for the WSIO user, when selecting indicators, is to use indicators from as many different ecological components as their objective will allow. The ability of a watershed to provide clean water and other beneficial resources is its ecological capacity. Watershed ecological capacity is estimated by combining indicators related to the natural habitat/biology, watershed and corridor structure, soil/channel stability, hydrology, and connectivity of the watershed. Ecological indicators are grouped by WSIO components as follows in **Table 1**:

Table 1

WSIO Ecological Component	SAB Essential Ecological Attribute
Biotic Community Condition	Biotic Condition
Watershed Natural Condition	Landscape Condition
Corridor Natural Condition	Landscape Condition; Hydrology/Geomorphology
Hydrology Flow & Channel	Hydrology/Geomorphology
Aquatic Condition/Connectivity	Biotic Condition; Hydrology/Geomorphology
Ecological History	Historic Condition & Trend (improving/declining)

Stressor Indicator Components

Stressors are the drivers of change to landscape features and waterbodies. In its report, shown in **Figure 1**, the SAB illustrated how common anthropogenic stressors relate to one or more of the EEAs by virtue of the multiple ways their effects are mediated in the environment (SAB, 2002). There are 16 unique stressors identified by the SAB, most potentially affecting more than one EEA. Many more individual pollutants, such as pathogens and phosphorous, could be added to the diagram. Hydrologic alteration affects all EEAs but is difficult to directly or consistently measure at a national scale.

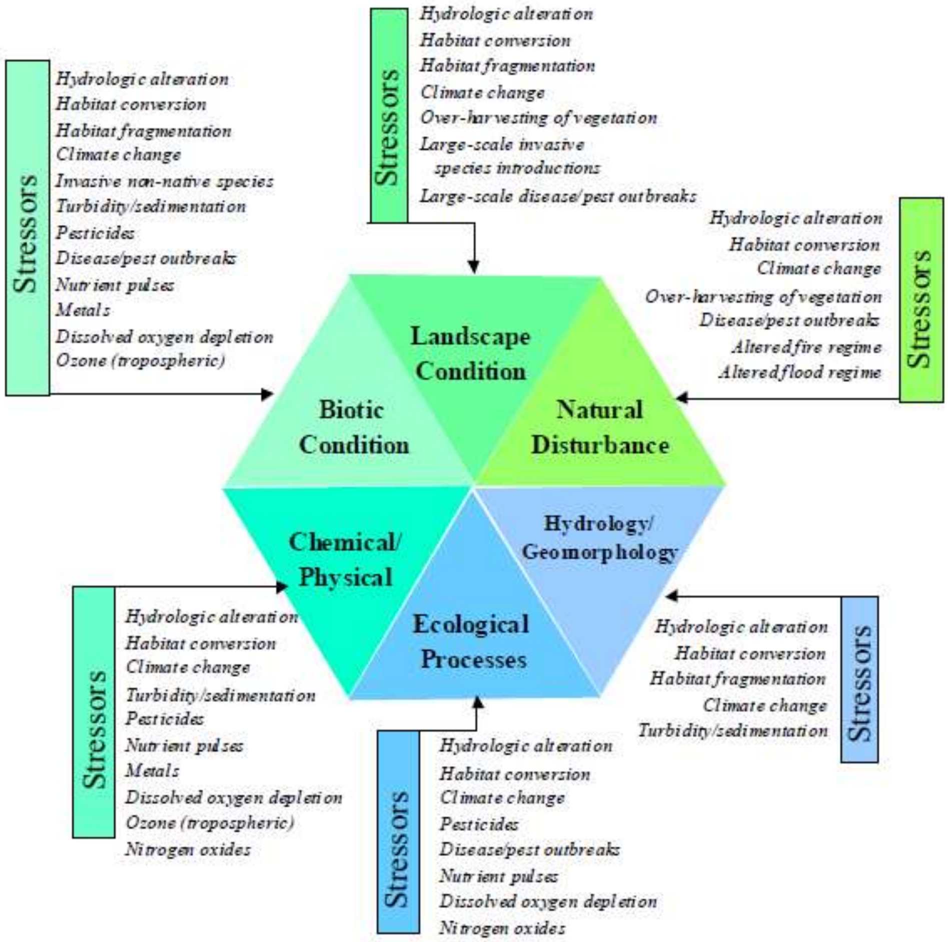

Figure 1 Sample stressors and the Essential Ecological Attributes they affect (SAB 2002).

The SAB stressor indicators from Figure 1, can be grouped into eight broad categories as shown below:

1. Hydrologic Alteration
2. Habitat Change
    a. Conversion
    b. Fragmentation
3. Pollutants
    a. Turbidity/Sedimentation
    b. Nutrient pulses
    c. Nitrogen oxides
    d. Dissolved oxygen depletion
    e. Metals
    f. Pesticides
    g. Ozone (tropospheric)
4. Overharvesting

    a. Vegetation [also include fish, animal]
5. Invasive non-native species
6. Climate Change
7. Disease/pest outbreak
8. Alteration of Natural Regime
    a. Flood
    b. Fire

Measuring most of the stressor indicators - even for some of the broad categories - requires the use of surrogate metrics. The underlying concept of the WSIO, is that by using data to estimate the presence and intensity of known anthropogenic stressors in a watershed, the susceptibility of that watershed to alteration of its natural regime, disease or pest outbreaks, or invasive non-native species, as well as other stressors, can be predicted. In the WSIO, stressor indicator data is grouped into one of six stressor components that are related to the SAB stressors, as shown in **Table 2**. When selecting indicators for screening, it is beneficial to use indicators from as many different stressor components as make sense for the project's objective(s).

Table 2

WSIO Stressor Component	SAB Stressor
Biotic/Climate Risks	Habitat Change; Pollutants; Overharvesting; Invasive Non-Native Species; Climate Change; Disease/Pest Outbreak; Alteration of Natural Regime
Watershed Disturbance	Habitat Change
Corridor Disturbance	Habitat Change
Hydrologic Alteration	Hydrologic Alteration; Habitat Change
Severity of Pollutant Loading/Fragmentation	Pollutants; Invasive Non-Native Species; Alteration of Natural Regime
Stressor History	Habitat Change; Overharvesting;

Separating Condition and Stressor Assessments

The SAB report discusses the advantages of addressing ecological condition indicators and stressor indicators separately, including more clearly differentiating natural variations from human induced variations, and enabling more systematic assessment of the relationships between these stressors and ecosystem impacts (See: Section 4.2 SAB, 2002). The WSIO followed the recommendation to keep ecological condition indicators distinct from anthropogenic stressor indicators when developing its database of watershed indicators. However, since the WSIO was conceived as a database of watershed indicators, the project focused on what has been or could be measured that is relevant to ecological condition and drivers of change (stressors). Organization of available information into conceptual categories and components for the WSIO required modification of the categories and components suggested by the SAB, while maintaining the science basis for why the measured indicator is a valid predictor.

There are significant inter-relationships between condition and stressor indicators. **Table 3** shows the primary affiliation between condition and stressor indicators. Of course, there are many overlaps and cross affiliations in the relationship of stressors to ecological condition. For example, ecological components 3, 4, and 5 are highly inter-related. All the stressors not just primary stressor is affecting ecological condition for these components. Because of overlaps and cross affiliation in condition and stressor attributes the user may be able to select fewer indicators to calculate ecological or stressor index. It is better to use one indicator to represent two components than to include two highly correlated indicators.

Table 3

WSIO Ecological Component	WSIO Stressor Component
Biotic Community Condition	Biotic/Climate Risks
Watershed Natural Condition	Watershed Disturbance
Corridor Natural Condition	Corridor Disturbance
Hydrology Flow & Channel	Hydrologic Alteration
Aquatic Condition/Connectivity	Severity of Pollutant Loading/Fragmentation
Ecological History	Stressor History, Legacy of past, trajectory of future land use

Social, Economic, Policy Indicators

Consistent national social, economic, and policy indicators are the hardest to develop. These factors tend to be more local or at least state driven. For this reason users may find it useful to add social indicators based on more local information. The social indicators included in the WSIO are largely based on the EPA water priorities related to impaired waters and TMDLs.

Indicator Order

The WSIO organizational structure groups indicators by **Type** and further sub-divides the Types into **Components** based on the essential ecological attributes and stressors driving change in those attributes. The database of watershed indicators are stored in order by type and component as shown in Table 3. Indicator type and component are also listed in the indicator metadata file.

EPA Strategic Plan Goals Supported by WSIO Objectives

Example comparative assessments supporting the EPA Strategic Plan goals:

- Comparative assessments to identify areas (HUC12 watershed, approximately 40 sq. miles)
    - Identify and Protect healthy watersheds – HWI
    - Identify Recovery Potential of impaired watersheds – TMDL, NPS, and NPDES
    - Identify condition / likelihood of impairment, in unassessed areas - Monitoring

- Identify, compare and rank areas (HUC12 approximately 40 sq. miles) based on relative conditions to support clean water, clean air, and healthy environments versus stressors affecting quality and condition of water, air, land, and biology. With the ability to include social, policy, and economic indicators relevant to objectives.
    - Supports Clean Water, Clean Air, Climate Stabilization, Natural Hazard Mitigation, Biodiversity / Conservation, and Ecological Processes that provide benefits.

- Identify proximity of and opportunities to connect natural areas to communities for sustainability

More information and related projects

- Recovery Potential Screening Website

  A watershed comparative assessment method using ecological, stressor, and social indicators in each watershed to compare restorability differences among the watersheds and set priorities for action. The Recovery Potential Screening (RPS) tool is a customized Excel workbook that houses all the watershed indicator data and auto-calculates four RPS indices, displaying the watershed comparison results as rank-ordered tables, graphics, and maps. Users can select the watersheds to be screened, indicators and their weights, and customize the graphic and map outputs as well as save the latter as images for later use. As of 2014, the RPS data from the WSIO and statewide RPS tools cover the entire lower 48 states at the HUC12 and HUC8 watershed scales (tools for remaining states and territories are planned), and over 20 states have applied the RPS tool in watershed screenings for a variety of purposes since 2005.

- Healthy Watersheds Website

  The EPA created the Healthy Watersheds Program to proactively protect aquatic ecosystems as dynamic systems across landscapes in order to maintain the natural structure and function of ecosystems as intended by Congress in the 1972 Federal Water Pollution Control Act amendments. This systems approach protects aquatic biota and their habitat as well as watershed characteristics and processes that support them such as vegetative riparian corridors and headwaters, hydrology, geomorphology, and natural disturbance regimes. The holistic protection approach provided by the Healthy Watersheds Program is essential for addressing the pervasive threats to healthy watersheds, including loss and fragmentation of habitat, hydrologic alteration, invasive species, and climate change.

- EnviroAtlas Website

  Ecosystems, such as forests and wetlands, provide many essential benefits, including clean air and water, food, fiber, and recreational opportunities. These and other benefits from nature, referred to as "ecosystem services," are multifaceted, often intertwined, and can be difficult to quantify because of their complexity. Due to this complexity and a lack of information, planning efforts often discount or overlook the impacts of decisions on the full suite of ecosystem services. To help fill this information gap, the EPA and its partners researched effective ways to measure and communicate the type, quality, and extent of services that humans receive from ecosystems so that their true value can be considered in decision-making. These research efforts and data are incorporated into the EnviroAtlas, a web-based tool that combines maps, analysis tools, and interpretive information on ecosystem services. Data are provided for subwatersheds across the contiguous United States and at a higher resolution for selected communities.

- The EPA Science Advisory Board

  EPA Science Advisory Board (SAB), 2002. *A Framework for Assessing and Reporting on Ecological Condition* (EPA-SAB-EPC-02-009)