About the
Watershed Index Online (WSIO)

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

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https://www.epa.gov/wsio

Disclaimers

- **WSIO is intended to be used as a general decision-support tool** by government, professional, academic, or 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. Lack of background knowledge or intentional misuse of the WSIO can produce unsatisfactory results.
- **For site-specific data, WSIO data will not replace "on-the-ground" measurements or local knowledge.** WSIO indicators describe HUC12 hydrologic units that average about 36 square miles in area. Finer-scaled local data may be available from other sources.
- **It is the responsibility of the user to read and evaluate dataset limitations, restrictions, and intended use.** The data and supporting materials on the WSIO website have undergone quality control procedures routinely used for geospatial information; 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. Modeled or measured geographic data are, by their nature, generalizations across a given area. 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 available data. The user has full control over their indicator selection, analysis and application of WSIO results, and thus takes full responsibility for their use.
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- **Some tool features described in this and other WSIO documents may cease to function** if affected in unpredictable ways by periodic updates of commercial software or changes in web links. We will try to maintain full functionality of WSIO as skills and resources permit.

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. Geographic Information Systems (GIS) have become commonplace in industry and all levels of government. National geospatial digital frameworks such as the National Hydrography Dataset (NHD) and the Watershed Boundary Dataset (WBD) provide a common structure for measuring and accumulating countless attributes of the nation's waters and the surrounding watersheds that may affect their condition. Further, scientific understanding of how watershed characteristics influence the condition of the nation's waters has grown substantially.

Watershed data and tools are increasingly important to maintaining the health of US waters and the benefits they bring to people and their environment. EPA has contributed to meeting this need by supporting watershed data and tool development in partnership with other federal agencies and the states for decades. The 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 one 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 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.

Watershed assessments have been applied at local or basin-wide scales for many years, but even through the 1990's and 2000's many projects were data-limited. Uniformly measured watershed indicators weren't available in many areas, and most of the national datasets that did exist had not been used to interpret the many watershed parameters known to be of greatest interest. 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. Rather, metrics like this were being calculated again and again on single states or river basins throughout the country as individual projects demanded them. An opportunity clearly existed to fulfill the need for readily available, nationally consistent watershed indicators, processed and compiled on a useful watershed scale at which planning and management often occurs.

Developing Watershed Indexing in EPA

To help counteract dwindling budgets and resources in the mid-2000's, EPA began to provide watershed data and tools rich in features that could help state and federal water quality programs make more cost-efficient, data-driven strategic planning decisions. Pioneers in this effort arose in different parts of the Agency and soon began to collaborate. EPA's southeastern US Region 4 office in

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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, scientists and interested citizens 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 about potentially important differences among them.

Data: Hundreds of ecological, stressor, and social indicators, measured at the HUC12 scale throughout the contiguous United States.

Tool: An enhanced scoring application 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, stressors acting upon them, and social context factors that may influence watershed management efforts. The approach is repeatable and allows users to document and communicate the results of any screening analysis.

Atlanta first began the Watershed Indexing (WSI) project to help compare watershed management options for a wide variety of environmental issues across their eight-state region. Their team developed many useful watershed indicators and multi-metric indices, then processed the data on hundreds of metrics across all the lower 48 states as it represented negligible additional effort to process GIS data beyond their own region alone.

Meanwhile, EPA's Office of Water had initiated the Recovery Potential Screening (RPS) project with the goal of helping state TMDL and nonpoint source programs systematically analyze where best to use limited restoration resources among very large numbers of impaired waters and watersheds. The RPS project had developed a versatile, comparative watershed assessment tool that was being customized for several individual state water programs. These state-specific RPS tools were being populated with numerous watershed indicators from state and national data, and added valuable insight into the most useful indicators and the applications such data and tools could support. However, different recovery potential projects were re-creating many of the same measurements state after state, and this bolstered the case for a national indicators library. The RPS project's analytical tool and state user experiences attracted the interest of the regional WSI team, as their national data offered enormous opportunity to reach more states. Years later, the EPA Office of Research and Development's new EnviroAtlas project would also share their national watershed data on ecological goods and services with the partners of WSIO.

The development of hundreds of key watershed indicators across the country was a valued contribution to the data behind watershed management and protection, but there was still progress to be made with watershed assessment tools. Fueled by the contributions of national data from WSI, RPS, and the EnviroAtlas teams, there was more interest and opportunity to focus on tools. The RPS project moved from state-specific single tools upon request to development of statewide tools for all states, populated with hundreds of indicators from the national datasets. But these tools were being used only in the desktop environment – and an online version drawing on national data could help so many more users, as well as implement new functions through accessing maps online. The WSI and RPS projects agreed to collaborate by adapting and enhancing the RPS Tool's code to create an online interactive and downloadable tool that would draw from the national indicators library, ultimately creating the Watershed Index Online (WSIO) in 2014.

The Watershed Index Online

The current WSIO website represents a centralized source of data, tools and services regarding watershed assessment. As of 2018, WSIO's most recent version of the WSIO tool is a Windows application that draws indicators from the WSIO data library and incorporates additional online maps for any user-defined set of watersheds in the conterminous states. WSIO's national indicator data library has been maintained and updated periodically by the Office of Water as key data become available. Beyond the master dataset accessed by the WSIO Tool, regionalized HUC12 data tables with approximately 460 indicators per HUC are downloadable, as well as a few of the key geospatial datasets. The full set of Recovery Potential Screening (RPS) Tools covering each individual state and territory are also offered for download; these tools are updated yearly and are embedded with a core set of over 250 of the WSIO indicators. WSIO's tools and data have since been applied to many projects, including a national Preliminary Healthy Watersheds Assessment and RPS projects in over half of the states and territories.

The development of the WSIO analytical approach was patterned after the Recovery Potential Screening methodology and utilizes ecological, stressor, or social context indicators measured from a wide variety of readily available landscape datasets, impaired waters attributes reported by states to EPA, and monitoring data sources. Metric selection is specific to each assessment's location and purpose. Ecological capacity, stressor exposure, and social context represent three gradients, or axes, along which watersheds are rated using the selected indicators. The user's objective is to choose indicators that collectively estimate the influence of each of the three classes on a user-specified assessment objective. Much of the indicator development is also aided by EPA Causal Analysis/Diagnosis Decision Information System (CADDIS) conceptual models, which helped relate indicator development and relevant causal pathways.

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) list of Essential Ecological Attributes that should be considered when assessing and reporting on the health of natural systems. Some of these recommendations are difficult to fully address with consistent national data when populating a database of indicators covering the conterminous United States. The use of surrogates was helpful for some ecological and stressor indicators difficult to directly measure over large geographic scales.

Indicator Overview

A common objective of multi-metric, comparative watershed analysis is to array watersheds along a gradient meaningful to an evaluation and management need. The nature of the scoring gradient (and the indicators selected to generate it) can vary substantially depending upon the need; some common gradient examples are from least-disturbed to most-disturbed, or from least to most suitable for pollutant loading reductions. The ecological, stressor and social factors that determine differences in watershed condition provide three fundamental axes for watershed comparison, and are the three primary categories of WSIO indicators used in analysis. A fourth category, base indicators, are value-neutral and used only for reference or grouping of subsets without affecting the comparative scores.

Measuring the same indicators on all watersheds allows for systematic, consistent and information-based comparison. Calculating separate ecological, stressor, and social indices enables the user to consider each of these three classes of factors, individually or in combination. The ecological index score reflects overall current condition and resilience (i.e., the capacity of the watershed to maintain or regain functionality) based on metrics related to natural watershed processes and structure. The stressor index score reflects the pressures on watershed condition from several primary sources of pollutants and water quality impairments. The social index score can include many factors, such as community involvement, incentives, economics, governance, regulation, and planning status, that do not constitute watershed condition or stressors but often strongly influence the level of effort and complexity of achieving improvements.

WSIO's indicators are compiled at the HUC12 scale (typically covering an area of approximately 35 square miles; the lower 48 states contain roughly 83,000 HUC12s). The organization of WSIO indicator data and the relationship of these indicators to the SAB's EEAs and stressors are further described below. WSIO Indicator metadata including indicator definitions, dates and sources are available on the WSIO website. More detailed descriptions of how to use the WSIO Tool can be found in the WSIO Quick Start Guide and WSIO User Manual, and additional reading on methods for comparative analysis of watersheds can be found on the Recovery Potential Screening and Healthy Watersheds websites.

Ecological Indicators

As defined by the SAB, Essential Ecological Attributes (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 further sorted into six ecological components that are related to the SAB EEAs as shown in the table below.

When selecting indicators, a general goal for the WSIO user is to use indicators from as many different ecological components as their objective and available data will allow. The ability of a watershed to provide clean water and other beneficial resources is strongly linked to its ecological condition. Watershed ecological condition 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 shown in Table 1:

Table 1. Comparison of WSIO Ecological Component groupings with SAB Essential Ecological Attributes.

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 Indicators

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. 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.

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

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

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. Comparison of WSIO Stressor Component groupings with SAB Stressors.

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;

Social Indicators

The SAB's EEA descriptions were limited to stressor pressures and ecological responses and did not address a broad class of additional factors that often strongly influence watershed condition and the prospects to maintain or improve it through management action. Nevertheless, water quality programs routinely recognize the importance of such factors as a 'third dimension' influencing the prospects for success in their efforts to restore and maintain the nation's waters under the Clean Water Act. WSIO terms these factors Social Indicators, but the category encompasses a wide variety of parameters that are capable of affecting watershed restoration and protection efforts (see Table 3).

Social indicators, although often highly influential, are among the hardest to develop as nationally consistent data. Many of these factors are not consistently measured across large areas and tend to be more locally- or state-driven. Thus, WSIO's total menu of social indicators is not as extensive as its stressor or ecological indicator lists. For this reason, it is useful to add social indicators relevant to local or state projects based on more local information.

Table 3. WSIO Social Indicator category component groupings..

WSIO Social Indicator Components	
Leadership, organization and engagement	Restoration cost, difficulty, or complexity
Protective ownership or regulation	Socio-economic considerations
Level of information, certainty and planning	Human health, beneficial uses, recognition and incentives

More about related projects

- Recovery Potential Screening Website

  RPS is 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 RPS Tool is a customized Excel spreadsheet 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.

The RPS data from the WSIO and statewide RPS tools cover all states and territories at the HUC12 watershed (and in some cases additional) scales, and over half the states have applied the RPS tool in watershed screenings for a variety of purposes since 2004.

- Healthy Watersheds Website

  EPA created the Healthy Watersheds Program (HWP) 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. Several healthy watersheds assessments at state and/or river basin level, and the national Preliminary Healthy Watersheds Assessment, made substantial use of WSIO indicator data in calculating health and vulnerability indices at various watershed scales.

- 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. Collaboration with WSIO has enabled data consistency and exchange involving many HUC12 indicators used in the Atlas and WSIO.

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Gary Davis (EPA Region 4). Oversaw the development of the first WSIO Tool from recovery potential screening tool code including several functional enhancements for online use.

Glenn Fernandez (EPA Region 4). Developed and coded the most recent version of the WSIO Tool as a Windows application.

Annie Neale (EPA ORD EnviroAtlas Project). Adopted joint consistency standards with WSIO and shared national data on hundreds of watershed indicators and key EnviroAtlas geospatial data sources.

Amy Newbold (EPA Region 4). Coordinated and fostered the partnerships among Region 4, Office of Water and EnviroAtlas in developing WSIO as a joint effort.

Doug Norton (EPA Office of Water). Developed recovery potential screening concept on which WSIO tool analysis is based, led testing and applications assistance throughout the states, and developed the WSIO website and its national indicator library.

John Richardson (EPA Region 4). Developed watershed indexing concept, designed numerous environmental indices and performed the geospatial analysis and national compilation of hundreds of watershed indicators.

Andy Somor (Contractor, Cadmus). Developed the code for the recovery potential screening tool functions from which the WSIO tool was adapted and led compilation of hundreds of indicators.

Vincent Zhuang (Contractor, SAIC). Adapted recovery potential tool code to create the first interactive, online WSIO Tool on EPA's Geoplatform.

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