CITY OF PORTLAND | BUREAU OF ENVIRONMENTAL SERVICES

Portland Watershed Health Index

SUMMARY

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Nick Fish, Commissioner

Michael Jordan, Director

UPDATED OCTOBER 2019

Portland has about 300 miles of urban rivers and streams that bring nature into the city, provide us with places to work and play and are important to our community's culture and history. The City of Portland and many partners are working to improve the health of our rivers, streams, and watersheds. From building rain gardens, ecoroofs and green streets, to maintaining Salmon Safe parks and protecting natural areas, Portland has a clear commitment to improving our environment. The ***Portland Watershed Management Plan,*** the ***Comprehensive Plan*** and the ***Climate Action Plan*** all demonstrate this commitment.

By monitoring and tracking the health of our watersheds, we can see what is improving and determine where more effort is needed. The Portland Watershed Health Index (WSHI) is a scientifically based tool the Bureau of Environmental Services developed to communicate complex data about the state of watershed health in the city in a simple way.

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Summary

Portland is part of the Willamette River and Columbia River basins. Within the City of Portland, land is divided into these smaller local watersheds, or areas of land where all rainfall drains into the same waterway:

- Columbia Slough
- Fanno Creek
- Johnson Creek
- Tryon Creek
- Willamette River Mainstem
- Willamette River Tributaries (the small tributaries in the west hills are separated from the Willamette River mainstem for this index. For other planning purposes, the tributaries are grouped together with the mainstem and referred to as "Portland's Willamette Watershed.")

City of Portland staff regularly collects data about a series of indicators to monitor watershed health. An indicator is a measurable feature that represents some aspect of ecological function. For example, one water quality indicator is the level of *E. coli* bacteria. The data are analyzed and used for a variety of purposes, including the Portland Watershed Health Index (WSHI). The index is a tool that compiles several pieces of information to summarize current environmental conditions, and provides an easily understandable way to compare conditions over time.

For the WSHI, the data for each indicator in a watershed is converted into a score on a scale of 0 to 10. Environmental Services then uses these index scores, along with interpretation and additional information, to create report cards that illustrate key issues and trends in Portland's watersheds. Together, these scores give a simple snapshot of conditions within each of the six watersheds. Staff can also use WSHI scores for other purposes such as performance measures, framing budget decisions, and informing policy efforts.

This document summarizes the creation of the WSHI, provides more information about how the index scores are calculated, and discusses how the index is best used.

Portland's Watersheds

Background

The Portland City Council adopted the ***2005 Portland Watershed Management Plan*** (PWMP) which outlines the city's comprehensive approach for improving watershed health as a strategy to help meet multiple regulatory requirements and other environmental goals. For example, rather than address individual environmental regulations with separate pipe, treatment or restoration projects, Portland uses a watershed approach to address the source of environmental problems and implement integrated solutions that achieve multiple objectives.

The PWMP is based on the science presented in the city's ***Framework for Integrated Management of Watershed Health***. The city updated the PWMP with a ***5-Year Implementation Strategy*** in 2012. Environmental Services is the lead city bureau for implementing and reporting on the PWMP. For more information about the PWMP and related documents, see ***www.portlandoregon.gov/bes/pwmp***.

The PWMP identifies four primary goals to improve watershed health *(see box at right)*.

The PWMP recommends projects and programs to address these goals. Implementation included developing a citywide monitoring strategy that integrates the PWMP with ongoing regulatory reporting requirements, and tracking progress toward improving watershed health. This led to the development of both the WSHI and the Portland Area Watershed Monitoring Program (PAWMAP), which the next section describes in more detail.

Environmental Services explored how other organizations developed watershed health indexes. Portland's WSHI draws heavily from some concepts in the Clean Water Services (Washington County, Oregon) index development process. The city also found useful information in other examples of indexes, including those for the Chesapeake Bay and Puget Sound.

Four Primary Goals to Improve Watershed Health

HYDROLOGY

Move toward normative stream flow conditions to protect and improve watershed and stream health, channel functions, and public health and safety.

WATER QUALITY

Protect and improve surface water and groundwater quality to protect public health and support native fish and wildlife populations and biological communities.

BIOLOGICAL COMMUNITIES (Fish and Wildlife)

Protect, enhance, manage and restore native aquatic and terrestrial species and biological communities to improve and maintain biodiversity in Portland's watersheds.

PHYSICAL HABITAT

Protect, enhance, and restore aquatic and terrestrial habitat conditions and support key ecological functions and improved productivity, diversity, capacity, and distribution of native fish and wildlife populations and biological communities.

Data Supporting the WSHI

Environmental Services monitors watershed health in a variety of ways. Data for the WSHI come from the Portland Area Watershed Monitoring and Assessment Program (PAWMAP) as well as City of Portland and Metro geographic information systems (GIS).

PAWMAP is a citywide monitoring program based on Environmental Protection Agency (EPA) protocols. PAWMAP combines monitoring for stream hydrology, water quality, aquatic habitat, riparian habitat, and aquatic and terrestrial organisms into a single, efficient monitoring program. Figure 1 shows the 128 in-stream sampling sites located across the city. Each year, city staff collects data at one quarter of the sites. After a four-year rotation, a complete data set is collected and compared against the previous four-year panel of data. Monitoring under the PAWMAP protocol began in 2010. Collection of the first complete set of data was completed in 2014, creating the baseline against which future data can be compared (see Figure 2). This first four years of data also form the baseline scores for the WSHI. Trend information will be available in the future.

Figure 1. PAWMAP Panels 1-4 Sampling Stations

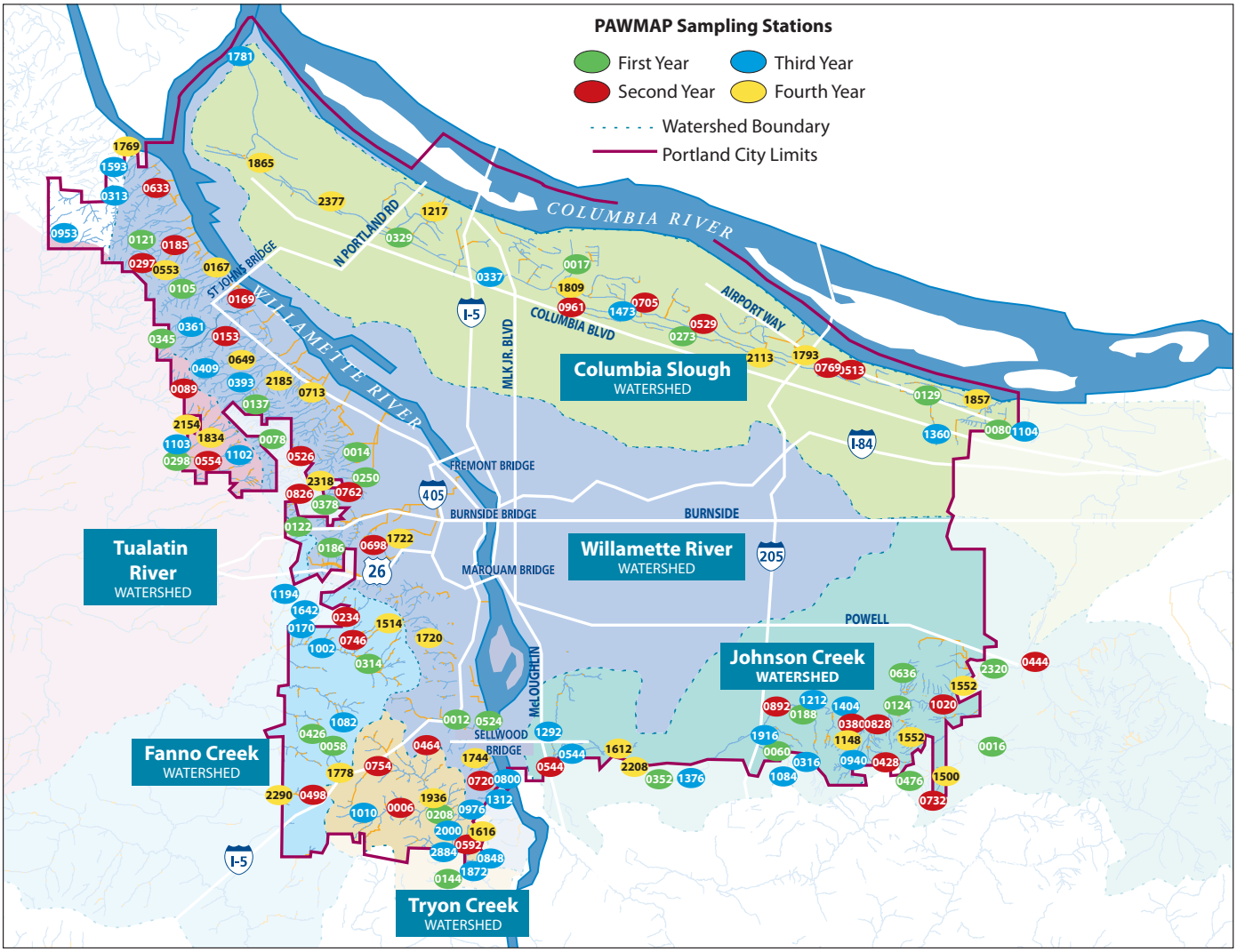


Figure 2. Sampling Schedule

The 128 sampling sites are divided into four panels. Each year, Environmental Services samples the sites in one panel. It takes four years to gather a full set of data.

YEAR	STATION SAMPLES				
Year 1	panel 1				Complete set of data. Establish baseline.
Year 2		panel 2			
Year 3			panel 3		
Year 4				panel 4	
Year 5	panel 1				Complete set of data
Year 6		panel 2			
Year 7			panel 3		
Year 8				panel 4	

PAWMAP includes rigorous statistical design and data analysis. This design for measuring watershed health, combined with compliance and best management practice monitoring, supports the WSHI by providing reliable and consistent data. PAWMAP data are also used for a variety of other purposes, and comprehensive data and analysis are presented in yearly program reports independent of the WSHI. Go to ***www.portlandoregon.gov/bes/monitoring*** for more information about PAWMAP.

Another source of information used to calculate the WSHI is GIS data from the City of Portland and Metro. The bureaus of Environmental Services and Planning and Sustainability maintain city GIS data relevant to the WSHI, including mapped impervious area and citywide tree canopy.

The city can reliably measure and track WSHI indicators over time to allow periodic calculation of the index value and comparison to past indexes.

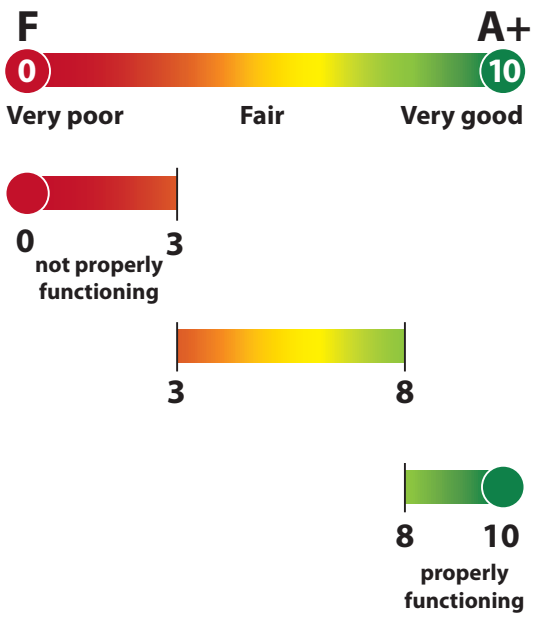
The table below lists the 21 indicators currently used in the WSHI by watershed goal area. Full definitions of the indicators and description of their connection to watershed health can be found at the end of this document. Some indicators may not apply to all watersheds due to the distinct characteristics of different watersheds and waterbodies. For example, shallow water refugia is a relevant indicator only in a large river like the Willamette mainstem.

Table 1. The 21 WSHI Indicators by Watershed Goal Area

Hydrology	Water Quality	Physical Habitat	Biological Communities (Fish and Wildlife)
Effective Impervious Area	Total Suspended Solids	Tree Canopy	Aquatic Communities – Fish
Stream Connectivity (% of streams piped)	Total Phosphorus	Floodplain Condition	Aquatic Communities – Benthic Macroinvertebrates
	Temperature	Bank Condition (Hardening)	Terrestrial Communities – Avian (Birds)
	Total Mercury	Shallow Water Refugia (Habitat)	
	Dissolved Oxygen	Stream Accessibility	
	E. coli	Riparian Integrity	
	Ammonia- Nitrogen	Large Wood	
	Dissolved Copper	Substrate Composition	

Developing Scores and Calculating the WSHI

Figure 3. WSHI Score and Grade Scale



After collecting and analyzing data for the indicators, Environmental Services converts data for each indicator into a score on a scale of 0 to 10, which can also be equated to a letter grade scale.

A score of three or lower means the indicator is **not properly functioning,** or providing little to no function to support a healthy watershed. A score of eight or higher means the indicator is **properly functioning**, or functioning at a level that supports a healthy urban watershed. The range for most indicators is scaled for urban watersheds, not necessarily pristine wilderness conditions.

Properly functioning urban watersheds support human health and a diversity of native fish and wildlife species. They are more resilient to changes in climate and can self-sustain into the future, so generations to come can benefit from Portland's nature.

The range of values and definition of properly functioning condition and not properly functioning condition is specific to each indicator based on scientific literature or best professional judgment. The raw data for each indicator are normalized and assigned a score in the 0-10 range based on a rating curve created to correspond with the properly functioning and not properly functioning conditions.

Example Indicator Scoring

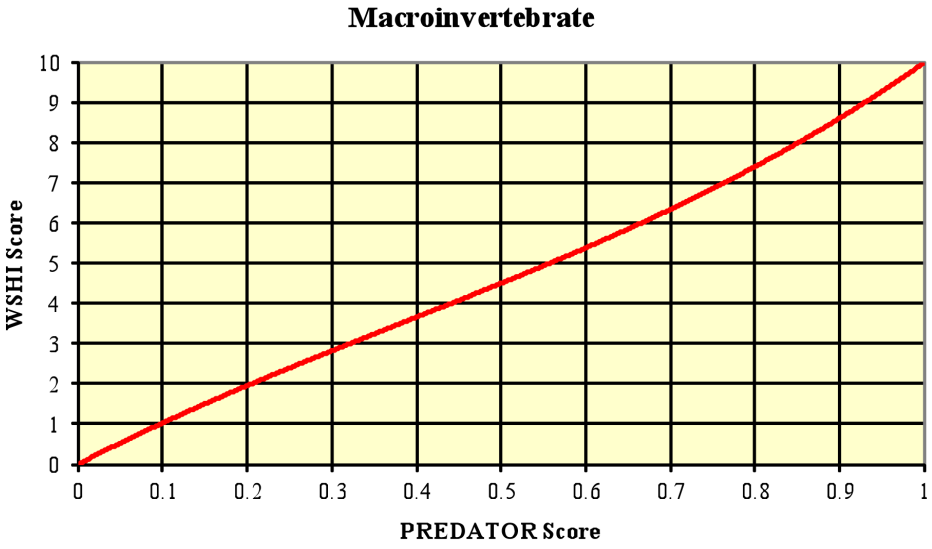
Photo courtesy of Roger Tabor, U.S. Fish and Wildlife Service

The stonefly is an aquatic insect counted in the WSHI macroinvertebrate indicator.

For example, one indicator for biological communities (fish and wildlife) is benthic macroinvertebrates. A macroinvertebrate is an organism that has no backbone and is visible to the human eye. They live on the bottoms of rivers, lakes and streams. The properly functioning condition for macroinvertebrates is a DEQ PREDATOR[1] score of 0.85 or greater, which would receive a WSHI indicator score of 8-10. Significantly impaired populations of benthic macroinvertebrates would result in a PREDATOR score of 0.32 or less which would receive a WSHI score of 0-3 (Figures 4–6).

1 Oregon Department of Environmental Quality's PREDictive Assessment Tool for Oregon (PREDATOR), which measures aquatic macroinvertebrates

Figure 4. WSHI rating curve for benthic macroinvertebrates



The graph assigns a WSHI score between 0 and 10 based on the calculated DEQ PREDATOR score.

Figure 5. Observed/Expected ratio from the DEQ PREDATOR model for the first year of PAWMAP sampling

The bold line is DEQ's benchmark for least impacted macroinvertebrate communities (0.85). This graph compares the number of species found at the sample site (observed) to the number of species typically found in regional reference areas (expected).

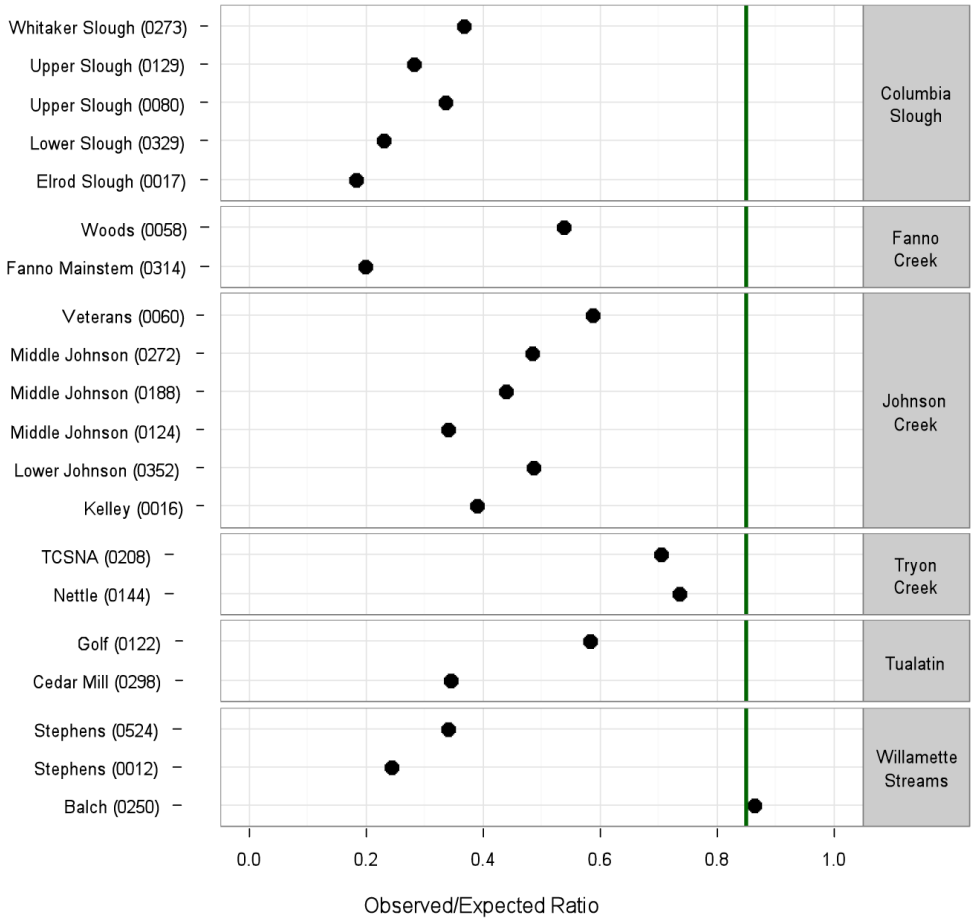
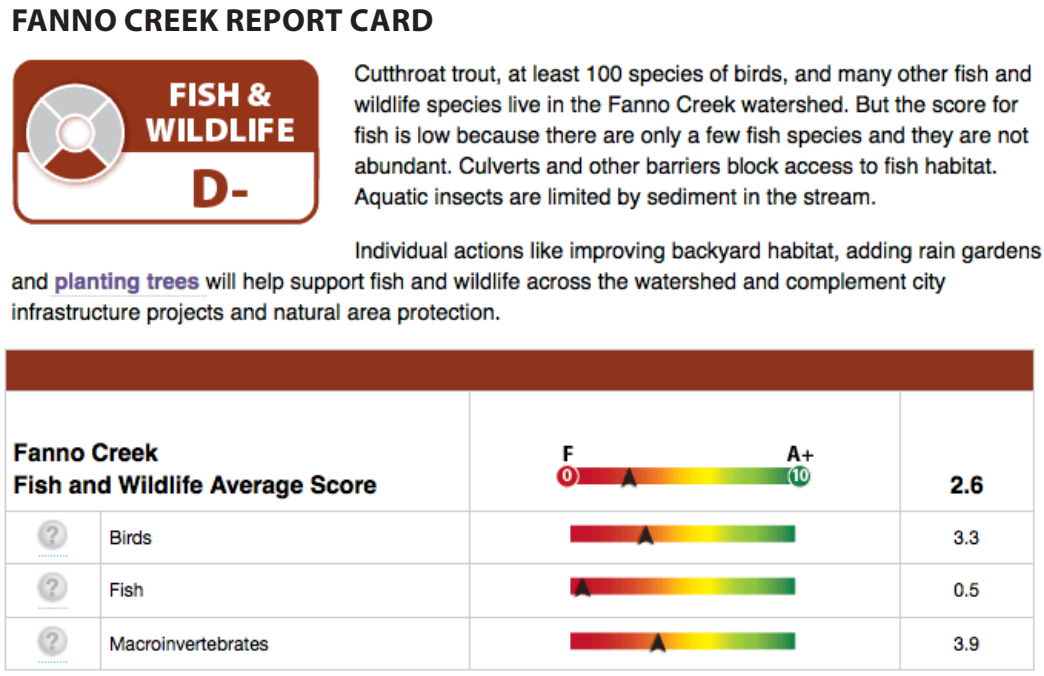


Figure 6. Benthic macroinvertebrate score for an individual watershed.

Scores for groups of indicators can then be rolled up into categories for each watershed health goal area. For example, for the goal area of biological communities (fish and wildlife), indicator scores for macroinvertebrates, fish and birds are averaged to create an overall biological communities score for an individual watershed (Figure 7). The methods used to calculate scores for indicators may change or be refined in future updates. The WSHI is designed to be adabptable to new research and changing assumptions or standards, which may modify the scoring methods.

Currently, all indicators are weighted equally. In the future, the city may weight individual indicators differently based on the relative influence of the indicator on watershed health goals or local policy priorities.

Figure 7. Indicators averaging to an overall biological communities (fish and wildlife) score for a watershed.



More detailed technical documentation of the 0-10 scale, data used and calculation method for each indicator in the WSHI is available upon request.

Use of the WSHI and Its Limitations

The WSHI is a science-based tool developed to communicate the state of watershed health in Portland. The tool:

- Provides a simple way to communicate current watershed health;
- Highlights geographies or goal areas where more work or a shift in focus may be needed;
- Helps inform monitoring, management and policy decisions; and
- Allows for tracking changes in watershed health over time.

Identifying and measuring fish in Portland streams to help determine the fish and wildlife scores

A range of low and high scores in the WSHI is not a surprise. 150 years of urban development, pollution, and other impacts on our rivers and streams have degraded the condition of Portland's watersheds. However, many decades of environmental protections, watershed health investments and individual efforts by Portlanders have helped improve or maintain watershed health even as the city continues to grow.

The long-term goal in Portland is to move towards properly functioning conditions in the city's watersheds, and to avoid further decline in watershed conditions. Scores of 8-10 may not be achievable for all indicators in all watersheds, so success will not be measured by perfect scores across the board. Short-term or intermediate-term targets may be set for specific indicators where the city and community wish to focus efforts for improvements.

Analyzing water samples at Portland's Water Pollution Control Laboratory for water quality indicators

While the WSHI is a useful tool for conveying watershed health information, it has some limitations. These include:

- The WSHI score calculated for an individual watershed only reflects the health of that watershed. The WSHI value of one watershed should not be compared to that of another watershed. Each watershed has distinct physical characteristics that provide a wide variety of benefits or challenges that contribute to differing scores.
- The WSHI scores are designed to represent average conditions across an entire watershed. Within an individual watershed, conditions for any indicator may vary greatly at the local scale. For example, a watershed may receive a high overall score

for tree canopy, but some areas within the watershed may be far below the average and considered substandard or underserved. Similarly, a water quality score may look relatively good on average, but there may be hot spots of high pollutant readings at particular sampling sites. In addition, there are not enough PAWMAP sample points in each watershed for a robust analysis at a smaller, subwatershed scale.

- Scores should not be taken at face value in considering investment and policy decisions. High scores do not necessarily mean "do nothing," and low scores may not necessarily be the highest priority for investment. In some cases, high scores may illustrate the highest priority resources that need further protection or enhancement to prevent further decline in other indicators' scores.
- Monitoring is a long-term effort. It will take time to establish baseline values and to communicate trends with confidence:
    - Some indicators are expected to change more slowly than others. For this reason, the city regularly measures many indicators used in the WSHI, while others are measured less frequently. For example, tree canopy is an indicator that changes very little from year to year due to the time needed for a tree to mature, so data are collected and updated approximately every five years. As a result, the WSHI score for canopy may not change frequently, even though many new trees are planted each year.
    - On the other hand, many indicators (especially water quality) respond strongly to climatic conditions within a given year, and it can take a while to separate this natural variability from true trends that indicate how conditions are changing over the long term. Because of this, it will take more time to determine trends for some indicators.
- Changes in some indicators and the WSHI score are not entirely within Portland's control because portions of Portland's watersheds cross into other jurisdictions. Most of the Willamette River Mainstem and Johnson Creek watersheds are located outside the city, as are parts of the Columbia Slough, Fanno Creek and Tryon Creek watersheds. Pollution from upstream, dams, or downstream fish passage barriers impact conditions in Portland. However, there are still many opportunities for local improvement in most indicators.
- Changes in the WSHI scores relate to many entities within Portland. Multiple city bureaus, other agencies, community partners, businesses and individual Portlanders all have an impact on watershed health.
- Frequency of updates to the WSHI have not yet been determined. While an annual technical report will summarize the PAWMAP data, the city may not update WSHI each year. This is because significant changes to watershed health are unlikely in just one year's time, and because some of the data that will be used in the WSHI are not updated annually (such as the tree canopy example mentioned above).
- The Bureau of Environmental Services is committed to long-term, comprehensive monitoring of watershed health. Knowledge about watershed and ecological processes and trends in the urban context is critical to understand what actions are necessary to improve watershed health, efficiently address regulatory requirements and city goals, and inform adaptive management approaches.

WSHI Indicators

Below are the 21 indicators currently used to calculate the Portland Watershed Health Index (WSHI) and a brief description of their connections to watershed health.

Hydrology Indicators

EFFECTIVE IMPERVIOUS AREA

Effective impervious area (EIA) is a hard land surface (like a street or roof) that sheds stormwater directly into a water body or a storm drain without detention or infiltration into the ground.

EIA creates higher runoff volume and speed that can cause erosion and flooding, destroy habitat, flush biological communities out of the system, and wash pollutants into rivers and streams.

City stormwater projects and the Stormwater Management Manual reduce EIA to help the city meet Oregon Department of Environmental Quality (DEQ) requirements.

STREAM CONNECTIVITY (% of streams piped)

Stream connectivity is a measure of how much of a stream flows freely and how much of it flows through a pipe, culvert or other physical structure.

Pipes confine and concentrate stream flows, which causes flooding and sedimentation upstream. Downstream, increased flow velocities can cause erosion, destroy habitat, and flush aquatic insects out of the system.

This indicator is not used along the main stem Willamette River since there are no dams, culverts or other physical structures that confine or concentrate flows in the city.

Water Quality Indicators

AMMONIA–NITROGEN

Ammonia-nitrogen is the amount of inorganic, dissolved ammonia in water measured in milligrams per liter (mg/L).

Sources include sewage, fertilizers, animal waste, and some industrial uses. Ammonia-nitrogen dissolved in water can stunt aquatic species growth and damage gills. It's even more harmful when pH and water temperatures increase.

DISSOLVED COPPER

Dissolved copper is the fraction of copper remaining in a water sample after filtration and is measured in micrograms per liter (µg/L).

Sources include household plumbing, hull paint on boats, and automotive brakes.

Dissolved copper is toxic to aquatic species and can cause decreased growth, changes in olfactory response, and cell or organ damage.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is the amount of oxygen dissolved in water measured in milligrams per liter (mg/L).

All aquatic species need dissolved oxygen during all life stages. Nutrients and organic matter in water, especially when water temperatures are high, can reduce dissolved oxygen levels.

E. coli

E. coli bacteria in water is measured by the number of organisms in 100 milliliters of water.

E. coli indicates the presence of fecal matter from humans and animals. Some kinds of *E. coli* can cause serious illness in humans.

TEMPERATURE

Temperature is measured in degrees Celsius. Low summer stream flow and impoundments, such as ponds, can increase stream temperatures.

Temperature influences dissolved oxygen and ammonia-nitrogen concentrations in streams. That impacts the spawning, rearing, feeding, and migration behavior of salmon and other aquatic species.

TOTAL MERCURY

Total mercury is inorganic and organic mercury in water measured as micrograms per liter (µg/L).

Most of the mercury in water comes from atmospheric pollutants that settle on the ground and are washed into rivers and streams by stormwater runoff or erosion. Mercury sources include incinerators, crematoriums, metal smelting and refining, cement kilns, coal-fired power plants, and forest fires.

Mercury accumulates in fish tissues and can impact human health through consumption, so is primarily a concern in waterways where people fish for food. It can also impact wildlife. More research is underway in Portland to understand the contribution of global and local sources and what we can do to reduce the input to our streams.

TOTAL PHOSPHORUS

Total phosphorus (TP) is the mass of phosphorus in water measured in milligrams per liter (mg/L). Phosphorous occurs naturally in streams at low concentrations. Streams in urban or agricultural areas often have higher concentrations that primarily come from fertilizers and other chemicals.

Phosphorus can cause excessive algal growth, which increases pH and decreases dissolved oxygen in streams and adversely impacts the health of aquatic species.

TOTAL SUSPENDED SOLIDS

Total suspended solids are particles suspended in water measured in milligrams per liter (mg/L). Materials like silt, decaying plants, industrial waste, and sewage contribute to TSS. Metals, pesticides and other nutrients and contaminants adhere to sediment particles.

Suspended solids can cover gravels and smother fry in salmon spawning grounds, affect feeding behavior and clog gills. TSS also blocks sunlight and may decrease food sources for aquatic species.

Sources of TSS include untreated runoff from impervious surfaces (primarily roadways) and erosion of stream bed and banks.

Physical Habitat Indicators

BANK CONDITION

Bank condition is a measure of the percentage of stream bank that has been artificially hardened by riprap, seawalls, or other structures.

Rivers and streams are dynamic and change form in response to changes in flow. Structures that confine a stream prevent it from adapting to variable flows, hinder interaction of a river with its floodplain, reduce in-stream habitat complexity, increase water velocity, and degrade stream structure.

Hardened banks prevent streams from adapting to changes in flow.

FLOODPLAIN CONDITION

Floodplain condition is the percentage of a floodplain covered with vegetation.

Floodplains provide fish and wildlife refuge, store flood waters, and reduce downstream flooding. This measure applies primarily to the Willamette main stem, Columbia Slough and Johnson Creek because these watersheds have topography and hydrology that support significant floodplain development.

LARGE WOOD

Large wood is a measure of the number of large wood pieces within a stream.

In-stream large wood creates pools, stores sediment and organic matter, and maintains stream complexity, and provides refuge and food for salmon.

On the main stem Willamette River, the supply of large wood today is a small fraction of what it once was. There was a recent inventory of large wood on the main stem Willamette but it is not systematically measured. Monitoring protocol and benchmarks have not yet been established.

In-stream large wood provides places for fish to rest and find food.

RIPARIAN INTEGRITY

Riparian integrity is a measure of vegetation cover, including trees, within 300 feet of a stream.

Riparian areas shade and cool streams, provide overhead cover, filter sediments and runoff, and provide food for aquatic species. Riparian areas are also a source of large wood in channels, control stream bank erosion and reduce sediment production.

SHALLOW WATER REFUGIA *(Willamette River mainstem only)*

Shallow water refugia is a measure of any length of stream that is less than 20 feet deep.

Shallow water in large rivers provides rearing habitat and refuge from predators for juvenile salmon. A lack of shallow water habitat in large rivers limits salmon productivity. River dredging and channelization have reduced the amount of shallow water habitat.

This indicator applies only in the Willamette River mainstem. The amount of cool, deep habitat is important in Willamette tributaries.

STREAM ACCESSIBILITY

Stream accessibility is a measure of stream miles accessible by juvenile and adult salmon and steelhead.

Culverts, dams, weirs and other in-stream structures create barriers for salmon migrating to the different habitats they use throughout their life cycle.

SUBSTRATE COMPOSITION

Substrate composition is a measure of the fine sediment and gravel in a stream.

Salmon need gravels and small cobbles for spawning and incubation. The aquatic insects that form the base of stream food webs live in gravel. Fine sediment harms aquatic insects, incubating salmon eggs and fry, and juvenile salmon. In the mainstem of the Willamette River, shallow water refugia is a better measure for salmon productivity.

TREE CANOPY

Tree canopy is a measure of tree foliage covering an area.

Trees provide wildlife habitat, reduce stormwater runoff, cool air and water, and are a food source for fish and wildlife. The City of Portland has adopted local goals to increase tree canopy coverage in the Portland Plan, Portland Urban Forestry Plan, Climate Action Plan, and other plans and policies.

Tree canopy can provide a multitude of benefits for people and wildlife.

Fish and Wildlife Indicators

TERRESTRIAL COMMUNITIES – BIRDS

Birds are indicators of the health of biological communities and overall watershed conditions. The Bird Integrity Index (BII) measures avian community health to determine the health of larger riparian areas. This index, designed specifically for use in Portland, takes into account the presence of native or non-native species, migratory patterns, foraging and nesting, and other factors.

The score for this indicator is still under development for the main stem Willamette River, since the data scale and models for a large river system are different from what we use for smaller streams.

AQUATIC COMMUNITIES – FISH

Coho salmon in Crystal Springs Creek

The health of Portland's streams is related to the abundance, productivity, distribution, and diversity of fish populations, especially salmon.

For the Watershed Health Index, Environmental Services assesses fish population health using the Index of biotic Integrity (IBI). The IBI measures fish species richness and composition, number and abundance of indicator species, reproductive behavior, and condition of individual fish.

The score for this indicator is still under development for the main stem Willamette River, since the data scale and models for a large river system are different from what we use for smaller streams.

AQUATIC COMMUNITIES – MACROINVERTEBRATES

Photo courtesy of Roger Tabor, U.S. Fish and Wildlife Service

The stonefly is a macroinvertebrate.

Aquatic macroinvertebrates live in water all or part of their lives, have no backbone, and are visible to the naked eye. Examples include freshwater mussels, mayflies, stoneflies, and other bottom-dwelling critters. They process organic matter and are an important food source for fish, birds and other wildlife. Macroinvertebrates are good indicators of watershed health because they are sensitive to biological conditions of a stream.

The Oregon Department of Environmental Quality developed the PREDictive Assessment Tool for Oregon (PREDATOR) to measure aquatic insects, specifically macroinvertebrates.

The scores for this indicator are not applicable for the main stem Willamette River and Columbia Slough, since the data and models for macroinvertebrates are not effective measures of watershed health for larger, slower-moving, water bodies.

View the current Portland watershed report cards at www.portlandoregon.gov/bes/ReportCards



Acknowledgements

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