

**Puget Sound Georgia Basin Ecosystem Indicators Report**  
**Technical Background Document**  
<http://www.epa.gov/region10/psgb/indicators/>

**Freshwater Quality Indicator**

**Indicator Name:** Freshwater quality in the Georgia Basin-Puget Sound

**Data Set Name:** (1) Water quality index for sites in the Puget Sound Georgia Basin (2003) and (2) Index of Biological Integrity (IBI) for sites in the Puget Sound Georgia Basin

**Data Type:** Indicator data

**I. WATER QUALITY INDICES**

**SCOPE**

The methods used by British Columbia and Washington State to calculate water quality indices are not exactly equivalent between the jurisdictions. However, the indices provide a similar result: water bodies are classified as good, fair, or poor relative to the pristine conditions for those water bodies.

For the purpose making the results from both jurisdictions comparable, the following rating scale was used: above 80 = Good; 40-80 = Fair; below 40 = Poor.

**1. British Columbia Water Quality Index**

**1. Geographic Coverage:** The British Columbia Water Quality Index (BCWQI) results are from an assessment of 16 water bodies for the Georgia Basin (4 lakes, 12 reaches of streams) (listed in Table 1.)

Table 1. BC Water quality index results (2003) for the Georgia Basin.

<b>Basin</b>	<b>SubBasin</b>	<b>WQI Value</b>	<b>Ranking</b>
Fraser R. (Kanaka Cr. - Mouth)	Main Arm	90.95	Good
	Main Stem	100.00	Good
	Middle Arm	70.66	Fair
	North Arm	90.73	Good
	Sturgeon Banks	100.00	Good
Middle Quinsam Lake	Long Lake	100.00	Good
	Middle Quinsam Lake	100.00	Good
	Upper Quinsam River	100.00	Good

Tsolum River	Tsolum River	41.12	Poor
Oyster River	Oyster River	88.36	Good
	Little Oyster River	84.95	Good
	Woodhus Lake	92.92	Good
Cowichan - Koksilah Rivers	Cowichan River	69.13	Fair
	Koksilah River	67.14	Fair
Stocking Lake	Holland Creek	58.47	Fair
	Stocking Lake	53.16	Fair

**2. Length of Data Series** N/A

**3. Smallest Geographic Units: Water bodies (lakes and streams)**

**RELIABILITY**

**1. Assumptions and Caveats**

**BC Water Quality Index (WQI):**

1. Water bodies are selected for monitoring if they receive industrial, municipal or agricultural discharges and, therefore, are potentially at risk of being polluted. Since monitoring focuses on water bodies at risk of pollution, most are in populated areas and those with the most human activity. Monitoring periods also focus on the time of year that WQI objectives are most likely to be exceeded.
2. The BCWQI takes a broad approach to the attainment of water quality objectives. The amount by which values for a water quality characteristic exceeds the threshold water quality objective is treated the same way in the algorithm used in the analysis regardless of the type of characteristic.
3. The WQI rank for a water body is sensitive to the number of water quality objectives for that water body. Where there are three or fewer water quality objectives because there are few threats to water quality, the resulting index rank can vary widely over time depending on the monitored results. Where there are a greater number of threats to water quality, thus a greater number of objectives, there is less fluctuation in rankings.
4. The appropriateness of water quality objectives can be an issue. There may be instances where objectives are set at levels beyond those that are naturally attainable for that water body. In such cases, further analysis of the background and historical conditions of the water body is required to define appropriate objectives.

## **2. Quality Assurance Procedures**

Quality assurance procedures for data collection and analysis include:

- Samples are collected using documented sampling procedures (see Resources Inventory Committee. 1994. Ambient Freshwater and Effluent Sampling Manual. <http://srmwww.gov.bc.ca/risc/pubs/aquatic/ambient/index.htm>).
- Each sampler is audited in the field on an annual basis.
- Water samples are analyzed at CAEAL (Canadian Association of Environmental Analytical Laboratories)-certified laboratories with documented procedures.
- An adequate number of replicate and blank samples are collected in addition to the regular sample.
- Data are reviewed in a data approval process to identify obvious errors, possible and probable errors, or certified data.

## **3. Data Confidence Limits: Not Applicable**

### **COLLECTION INFORMATION**

#### **1. Data Methodology**

##### ***Characteristics Measured for the BCWQI:***

Water quality characteristics measured at a given sampling station may include any of the following: levels of nitrate, fecal coliforms, cyanide, total dissolved gases, dissolved oxygen, suspended solids or sediments, nutrients, zooplankton, algae, trace metals, major ions, pH, and temperature.

##### ***Calculating the BCWQI:***

For each water body monitored, acceptable threshold levels or concentrations are set for the water quality characteristics measured. Acceptable levels for each characteristic depend on the water uses identified for that water body. The WQI for a water body is based on the:

- number of water quality objectives that are not met,
- frequency with which they are not met, and
- amount by which they are not met.

#### **2. Collection Frequency**

Measures for the BCWQI are collected only at those times in the year when the water quality threshold is most likely to be exceeded. The WQI rating is based on the attainment of water quality objectives during these critical months.

## ***Sampling Frequency and Timing***

Depending on the type of water body, sampling may be carried out weekly, biweekly, monthly, or annually. Most rivers are monitored biweekly. Lakes and streams are usually monitored at least once per month, although some lakes may be monitored once per year, in the spring, when the water is well mixed.

## **NOTICE OF PROPRIETARY DATA**

### **1. Acknowledgement:**

**2. Data Sources:** BC Ministry of Environment water quality monitoring network.

**3. Contact Names:** Les Swain, Water Quality Network Specialist, BC Ministry of Environment: Phone: (250) 387-4227 and Les.Swain@gov.bc.ca

## **References**

British Columbia. Ministry of Environment, Lands and Parks, Water Quality Branch, April 1999. *British Columbia Water Quality Status Report*. Victoria BC: Ministry of Environment, Lands and Parks.  
<http://wlapwww.gov.bc.ca/wat/wq/public/bcwqsr/bcwqsr1.html>

Canadian Council of Ministers of the Environment. 2001. Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0 User's Manual. Excerpt from Publication No. 1299.

## **2. Washington Water Quality Index (WQI)**

In Washington, Water Quality standards are based on protecting beneficial uses. These uses are defined and adopted in the Washington Administrative Code (WAC 173-201A). Washington's ambient water quality monitoring network is implemented according to a Quality Assurance Project Plan, available at:  
<http://www.ecy.wa.gov/biblio/0303200.html>

## **SCOPE**

### **1. Geographic Coverage**

Washington's WQI covers the entire state of Washington but for purposes of this indicator, data was disaggregated for sampling locations in the 12 Puget Sound counties: Clallam, Jefferson, King, Kitsap, Island, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston and Whatcom.

**2. Length of Data Series:** Long-term stations have been sampled monthly for variable periods of record (most sites have been sampled between 20 and 50 years). WQI *trends* are based on a 10-year assessment of data (<http://www.ecy.wa.gov/biblio/0503036.html>).

**3. Smallest Geographic Units:** Water Resource Inventory Area: <http://www.ecy.wa.gov/services/gis/maps/wria.wria.htm>.

## **RELIABILITY**

### **1. Assumptions and Caveats**

Indices by design contain less information than the raw data they summarize. The WQI is therefore best suited for comparing overall water quality at a station relative to the conditions expected for a typical waterbody of that type in the same ecoregion. The index is therefore best suited to answering general questions like “how is the water quality in my stream?” with the benefit that the results can be clearly displayed in a simple map graphic. In short, the index is a useful tool for “communicating water quality information to the lay public and to legislative decision makers;” it is not “a complex predictive model for technical and scientific application” (McClelland, 1974).

Indices are not well suited to answering specific technical questions. Site-specific decisions should be based on an analysis of the original water quality data. This is particularly important because an index does not by itself reveal which specific parameters or stressors may have contributed to a low score. In addition, a particular station could potentially receive a good WQI score, and yet have water quality impaired by constituents not included in the index, or by constituents acting over a short time duration not emphasized in the index.

Besides being general in nature (and therefore imprecise), there are several reasons why an index may fail to accurately communicate water quality information. First, most indices are based on a pre-identified set of water quality constituents. A particular station may receive a good WQI score, and yet have water quality impaired by constituents not included in the index. Second, a satisfactory score at a particular station does not necessarily mean that water quality was always satisfactory there. Aggregating data over time can mask short-term water quality problems (this is less of a problem with British Columbia’s approach). A good score should, however, indicate that poor water quality (for evaluated constituents, at least) was not chronic. Third, by design, the WQI indicates how well water quality at a station meets expectations, not how good the absolute quality is. Comparing index scores for different stations does not indicate which station has the better absolute water quality unless expectations for both stations were the same.

## **2. Quality Assurance Procedures**

Ecology's Manchester Environmental Laboratory (MEL) Quality Assurance (QA) Program includes the use of quality control charts, check standards, in-house matrix spikes, and laboratory blanks, along with performance evaluation samples. For a more complete discussion of laboratory quality assurance, see MEL's *Quality Assurance Manual* (Ecology, 2005).

The QA program for field sampling consisted of three parts: (1) adherence to a procedures manual for sample/data collection and periodic evaluation of sampling personnel; (2) instrument calibration methods and schedules; and (3) the collection of a field quality control (QC) sample twice during each sampling run. Our QA program is described in detail in Hallock and Ehinger (2003. <http://www.ecy.wa.gov/biblio/0303200.html>).

Three types of field Quality Control (QC) samples were collected.

1. *Duplicate (Sequential) Field Samples*
2. *Duplicate (Split) Field Samples*
3. *Field Blank Samples*

QC samples were submitted semi-blind to the laboratory; they were identified as QC samples, but sample type (duplicate, split or blank) and station were not identified.

## **3. Data Confidence Limits**

The Quality Assurance Monitoring Plan for Ecology's Stream Ambient Water Quality Monitoring Program addresses:

- Measurement quality objectives
- Data quality objectives (including precision, bias and reporting limits)
- Sampling Design Representativeness and Comparability
- Field and Laboratory quality control procedures and data quality assessment procedures

(see Hallock and Ehinger, 2003. <http://www.ecy.wa.gov/biblio/0303200.html>).

## **COLLECTION INFORMATION**

**1. Data Methodology:** Washington's Water Quality Index (WQI) is intended as a tool to summarize and report the Washington State Department of Ecology's (Ecology) routine stream monitoring data. It is based on a unit-less number ranging from 1 to 100; a higher number is indicative of better water quality relative to expectations. For temperature, pH, fecal coliform bacteria and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses (based on criteria in Washington's Water Quality Standards, Washington Administrative Code/WAC 173-201A). For nutrient and sediment measures, where standards are not specific, results are expressed relative to expected conditions in a given region.

Multiple constituents are combined and results aggregated over time to produce a single score for each sample station. In general, stations scoring 80 and above met expectations for water quality and are of "lowest concern" (= good condition), scores of 40 to 80 indicate "marginal concern," (= fair condition), and water quality at stations with scores below 40 did not meet expectations and are of "highest concern" (= poor condition). A technical description of Washington's Water Quality Index and the analytical approach used can be found in Hallock (2002) at <http://www.ecy.wa.gov/biblio/0203052.html>. Data collection and quality control are discussed in our annual reports (e.g., Hallock, 2004) <http://www.ecy.wa.gov/biblio/0403033.html>

**2. Collection Frequency:** The Washington WQI results are based on assessment of water quality data collected from 24 long-term "core" stations (sampled monthly every year) and 22 "basin" stations (sampled monthly for only 1 year) in the Puget Sound Basin.

## **NOTICE OF PROPRIETARY DATA**

**1. Acknowledgment:** No restrictions.

**2. Data Sources:** Washington State Department of Ecology, Freshwater Ambient Monitoring Data:  
[http://www.ecy.wa.gov/programs/eap/fw\\_riv/rv\\_main.html#4](http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html#4)

**3. Contact Name:** Dave Hallock, Washington State Department of Ecology.  
Telephone: (360) 407-6681 and [daha461@ecy.wa.gov](mailto:daha461@ecy.wa.gov)

## **II. Indicators of Biological Condition**

### **1. British Columbia**

**1. Indicator Name:** BEAST Assessment.

**2. Data Set Name:** CABIN.

### **3. Data Type:** Benthic invertebrate community data

## **SCOPE**

The Canadian Aquatic Biomonitoring Network (CABIN) was established to promote national consistency in using biota for water quality monitoring. Currently, CABIN is focused on benthic invertebrates. Benthic (bottom-dwelling) invertebrates include insects, such as mayflies, stoneflies, and caddisflies, as well as freshwater shrimps, worms and other organisms. Organisms living on stream bottoms are used as indicators of contamination because they are easy to collect and relatively inexpensive to identify compared to water chemistry sample analysis. The types and proportion of benthic invertebrates present in a stream can indicate the degree to which water quality is degraded. This information can be summarized in a Benthic Index of Biotic Integrity (B-IBI) to indicate the impacts of changes in water quality on living organisms.

**1. Geographic Coverage:** Georgia Basin (Vancouver Island, British Columbia Lower Mainland, Fraser River Basin)

**2. Length of Data Series: Approximately four years.** In BC, data are only available for a few years. As for the Georgia Basin, this is a recently developed indicator; there are not enough data for a trend analysis.

**3. Smallest Geographic Units:** Sampling sites

## **RELIABILITY**

### **1. Assumptions and Caveats:**

Reference sites represent as many different geographic regions and stream sizes as possible. The habitat data from reference sites are used to develop predictive bioassessment models that establish the type of community of organisms expected to occur in the range of natural habitat types present in the reference network. Once the reference condition has been established, sites suspected of being affected by human activities are sampled. Differences between the organisms found at the reference sites and the test-site show the extent, if any, of impairment at the site. The greater the departure in composition of the benthic community from what is predicted based on the expected community for that habitat, the more the stressed the community is likely to be from impacts of human activity.

Benthic invertebrates reflect site-specific conditions in a stream channel. They are ideal for use in bioassessment because:

- they are sedentary and are constantly exposed to effects from pollution passing a given point in a stream,

- can identify stressor groups (categories of human induced stressors) that influence changes to the benthic community,
- can be long-lived (one to three years in northern temperate waters) so are affected by exposure to environmental stressors over time, and
- exhibit community diversity which is useful when evaluating impacts originating from a broad range of human activities.

Even though benthic invertebrates are ideal for use in bioassessment, there are some limitations:

- analytical expressions are limited for use in wadeable streams,
- evaluations do not necessarily reflect changes in the whole drainage area upstream, and
- changes reflect cumulative impacts to the biological community and cannot necessarily be used to identify single factors causing degradation.

## **2. Quality Assurance Procedures**

A critical part of CABIN is the establishment of a standard set of protocols and methods for all phases of data collection and processing. Over the past ten years, Environment Canada has developed a document which describes those protocols, a set of standard field sheets and laboratory forms all of which are available on the internet at <http://cabin.cciw.ca/>

## **3. Data Confidence Limits: N/A**

### **COLLECTION INFORMATION**

**1. Data Methodology:** The Canadian Aquatic Biomonitoring Network (CABIN) is a collaborative program developed and maintained by Environment Canada to establish a network of reference sites available to all users interested in assessing the biological health of fresh water in Canada. CABIN currently stores and maintains datasets from across the country in the Benthic Information System for Reference Conditions (BIRC) database which is accessible to CABIN users through the internet: <http://cabin.cciw.ca/> .

**Benthic invertebrate sampling:** Benthic invertebrates are collected from flowing reaches of streams using a travelling kick-net method. The person doing the sampling stands in the stream, places a kick-net (a 400 µm size mesh bag fitted on a triangular metal frame with a handle) downstream on the bottom of the stream and kicks the substrate to disturb it. The dislodged benthic invertebrates are carried into the net by flowing water. The sampler moves from bank to bank in an upstream, zig-zag pattern to collect invertebrates from a wide variety of microhabitats within the stream riffle (e.g., small eddies, small runs, leaf packs, etc.) for a standardized period of time (3 minutes).

**Data Analysis:** Each test sample is assessed by matching the site to an appropriate group of reference sites. The reference group is selected based on a

discriminant model that uses habitat information. Extensive background information has been collected at reference sites on benthic organisms. The relationships between environmental characteristics and the benthic community have been established in a predictive discriminant model. Each test site is scored as 'stressed' or 'unstressed' using the model. The multivariate assessment method used is called the BEAST (Benthic Assessment of Sediment).

**Interpretation:** If a site is scored as stressed, it means the site fell outside of the 90% confidence ellipse surrounding the matched group of reference sites in ordination space. The stressed/unstressed scoring used in BC was converted to IMPAIRED/UNIMPAIRED scoring for consistency in presenting this indicator with Washington data.

## **2. Collection Frequency:**

### **NOTICE OF PROPRIETARY DATA**

**1. Acknowledgement:** The underlying data for the benthic assessments can be accessed from <http://www.waterquality.ec.gc.ca>.

**2. Data Sources:** Environment Canada

**3. Contact Name:** Stephanie Sylvestre, Environmental Studies Scientist, Environment Canada: (604) 664-4099 and [Stephanie.Sylvestre@ec.gc.ca](mailto:Stephanie.Sylvestre@ec.gc.ca)

### **References**

Reynoldson, T.B. and D.M. Rosenberg. 1999. Benthic invertebrate community structure. In: Gray and Tuominen (Eds.) Health of the Fraser River Aquatic Ecosystem Vol 1: A Synthesis of research conducted under the Fraser River Action Plan. Environment Canada, Vancouver, BC p. 109-122.

Reynoldson, T.B., R.C. Bailey, K.E. Day and R.H. Norris. 1995. Biological guidelines for freshwater sediment based on Benthic Assessment of Sediment (the BEAST) using a multivariate approach for predicting biological state. Australian Journal of Ecology 20:198-219

Reynoldson, T.B., D.M. Rosenberg and V.H. Resh. 2001. Comparison of models predicting invertebrate assemblages for biomonitoring in the Fraser River catchment, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 58:1395-1410.

Reynoldson, T. B, C. Logan, T. Pascoe and S. C. Thompson. [ND] CABIN Invertebrate Biomonitoring Field and Laboratory Manual. National Water Research Institute. Environment Canada

Stream and Lake Quality Indicator  
Puget Sound Georgia Basin Ecosystem Indicator  
April 2006

Rosenberg, D.M., T.B. Reynoldson and V.H. Resh. 1999. Establishing reference conditions for benthic invertebrate monitoring in the Fraser River catchment, British Columbia, Canada. Fraser River Action Plan, Environment Canada, Vancouver BC DOE FRAP 1998-32.

Rosenberg, D. M., I.J. Davies, D.G. Cobb, and A.P. Wiens. [ND] Protocols for Measuring Biodiversity: Benthic Macroinvertebrates in Fresh Waters. Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba. <http://www.eman-rese.ca/eman/ecotools/protocols/freshwater/benthics/intro.html>

Sylvestre S., T. Tuominen and M. Fluegel (2005) Benthic Invertebrate Assessment of Streams in the Georgia Basin using the Reference Condition Approach: Expansion of the Fraser River Invertebrate Monitoring Program 1998-2002. Environment Canada, Vancouver, BC. EC/GB/04/81 194 pp. [http://www.pyr.ec.gc.ca/GeorgiaBasin/resources/publications/SciTechReports/EC-GB-04-81\\_e.pdf](http://www.pyr.ec.gc.ca/GeorgiaBasin/resources/publications/SciTechReports/EC-GB-04-81_e.pdf).

## **2. Washington Index of Biological Integrity**

### **SCOPE**

**1. Geographic Coverage:** 79 Washington State Department of Ecology stations are distributed throughout the Puget Sound Basin. Station locations can be found at [http://www.ecy.wa.gov/programs/eap/fw\\_benth/index.html](http://www.ecy.wa.gov/programs/eap/fw_benth/index.html).

**2. Length of Data Series:** Nine years (1994-2001). Reference and test sites both have been sampled within this time frame.

### **3. Smallest Geographic Unit**

The sites are located in Water Resource Inventory Areas (WRIAs) 1-19. See <http://www.ecy.wa.gov/services/gis/maps/wria/wria.htm>

### **RELIABILITY**

#### **1. Assumptions and Caveats**

The use of benthic macroinvertebrates in biodiversity studies of lakes and streams is supported by the extensive background information available on these organisms. Analysis methods assume that there is a relationship between environmental conditions in the stream and the benthic community. The model assumes this relationship is constant, and does not consider changes that could occur over time. It is assumed that sampling collection methods capture benthic invertebrates in the proportion in which they occur in the stream.

## **2. Quality Assurance Procedures**

Invertebrate samples are collected in duplicate every ten sites. If less than a multiple of ten sites are sampled, then at least one site is identified for re-sampling in order to evaluate field sampling variability. Commercial Laboratories used for taxonomic identification of Washington benthic samples have a series of quality assurance procedures used to measure processing error. These include, but are not limited to: re-sampling sub-samples, verification of correctness for taxonomic identification, and description of "large-and-rare" taxa not captured in the sub-sampling routine.

## **3 .Data Confidence Limits**

RIVPACS model performance defines membership to the reference condition within one standard deviation (0.14) of the mean for all reference site scores. This measure for variation of model performance incorporates error derived from: field sampling, time of year sampling takes place, field-crew differences, laboratory processing, and taxonomic resolution.

## **COLLECTION INFORMATION**

### **1. Data Methodology**

Washington sampling methods are described in:

Plotnikoff, R.W. and C.Wiseman. 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams: 2001 Revision. Washington State Department of Ecology, Olympia, Washington. Ecology Publication No. 01-03-028 (access at <http://www.ecy.wa.gov>. Search publications)  
34 p. + Appendices .

Plotnikoff, R.W. and S.I. Ehinger. 1997. Using Invertebrates to Assess Quality of Washington Streams and to Describe Community Expectations. Ecology Publication No. 97-332. Washington State Department of Ecology, Ambient Monitoring Section. Olympia, WA. 56p.

Plotnikoff, R.W. and J.S. White. 1996. Taxonomic Laboratory Protocol for Stream Macroinvertebrates Collected by the Washington State Department of Ecology. Ecology Publication No. 96-323. Washington State Department of Ecology, Olympia, WA. 32 p.

### **2. Collection Frequency**

Data are collected annually within an Index Period from July 1 through October 15.

## **NOTICE OF PROPRIETARY DATA**

**1. Acknowledgement:** No restrictions.

**2. Data Sources:** Washington Department of Ecology, Stream Biological Monitoring Unit

[http://www.ecy.wa.gov/programs/eap/fw\\_benth/index.html](http://www.ecy.wa.gov/programs/eap/fw_benth/index.html)

RIVPACS Models. Utah State University, The Western Center for Monitoring and Assessment of Freshwater Ecosystems.

<http://129.123.57.65/WMCPortal/DesktopDefault.aspx?tabindex=2&tabid=1>

Home Page

<http://129.123.57.65/WMCPortal/DesktopDefault.aspx?tabindex=2&tabid=27>

Predictive Models

Plotnikoff, R.W. and C. Wiseman. 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams: 2001 Revision. Washington State Department of Ecology, Olympia, Washington. Ecology Publication No. 01-03-028.

34 p. + Appendices.

Plotnikoff, R.W. and S.I. Ehinger. 1997. Using Invertebrates to Assess Quality of Washington Streams and to Describe Community Expectations. Ecology Publication No. 97-332. Washington State Department of Ecology, Ambient Monitoring Section. Olympia, WA. 56p.

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Reynoldson, T.B., R.H.Norris, V.H. Resh, K.E. Day and D.M. Rosenberg. 1997. The reference condition approach: a comparison of multimetric and multivariate approaches to assess water-quality impairment using benthic macroinvertebrates. *Journal of the North American Benthological Society* 16(4):833-852.

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