BRITISH COLUMBIA
MINISTRY OF WATER, LAND AND AIR PROTECTION - 2002

Environmental Indicator: Surface Water Quality in British Columbia

Primary Indicator: ***Trends in water quality in British Columbia.***

Selection and Use of Indicator: Trends in water quality for selected waterbodies, over time, is a *state* or *condition* indicator. The quality of water is a major concern because of the impact it has on the suitability of water sources for human and natural uses. This indicator shows the direction of departure (if any) of water quality from an acceptable threshold for each waterbody. The environmental significance of each trend is assessed in relation to water quality objectives for each waterbody or to province-wide water quality guidelines.

Data Sources:

Environment Canada and the Ministry of Water, Land and Air Protection have been collecting technical data on surface water quality for many years through the Canada - BC Water Quality Monitoring Agreement. Data are from a network of water sampling stations throughout the province. (Note: these are not the same monitoring stations used for the Water Quality Index described in the following secondary indicator). The following Tables 1-3 presents the waterbody sampling stations shown on the map on pg. 16 of *Environmental Trends in British Columbia 2002*.

Table 1. Monitoring Stations Showing Improving Water Quality

Location of monitoring station (Years)	Water Quality Indicators	Cause of Trend	Water Use at Risk	Action
Fraser River at Hope (1979-97)	AOX Chloride	Waste abatement at pulp mills.	Aquatic life and human and wildlife consumption of aquatic life.	Monitoring continues.
Salmon River at Salmon Arm (1985-97)	Fecal coliforms	Agricultural non-point source abatement.	Recreation, irrigation and livestock watering.	Continued abatement and monitoring.
Thompson River at Spences Bridge (1985-1997)	Chloride (indicator of chlorinated organics) Dioxins & furans in fish	Pulp mill waste abatement.	Aquatic life and human and wildlife consumption of aquatic life.	Continued abatement and monitoring.
Similkameen River near US Border (1979-97)	Arsenic	Unknown	Aquatic life and drinking water.	Continued monitoring.
Fraser River at Stoner (1990-1997)	AOX	Pulp mill waste abatement.	Aquatic life, wildlife and their human consumers	Monitoring continues.

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Location of monitoring station (Years)	Water Quality Indicators	Cause of Trend	Water Use at Risk	Action
Salmon River near Hyder, Alaska (1990-1997)	Cyanide	uncertain	Aquatic life and wildlife.	None required. Monitoring continues.
Pyrrhotite Creek (Tsolum River) (1985-98)	Copper	Mine reclamation	Aquatic life	Continued reclamation and monitoring.
Stocking Lake (1985-95)	Phosphorus	Unknown	Drinking water	Monitoring continues.
Maxwell Lake (1985-95)	Phosphorus	Unknown	Drinking water	Monitoring continues.
Shawnigan Lake (1976-98)	Phosphorus	Unknown	Drinking water, aquatic life and recreation.	Monitoring continues.
Lizard Lake (1985-95)	Phosphorus	Unknown	Aquatic life and recreation.	Monitoring has resumed.
Old Wolf Lake (1985-95)	Phosphorus	Unknown	Aquatic life and recreation.	Monitoring continues.
Langford Lake (1979-98)	Phosphorus	Lake aeration and unknown	Aquatic life and recreation.	A lake stewardship group has been formed and additional monitoring is being done. Aeration and basic monitoring are continuing.
Kootenay River at Fenwick Station (1991-96)	Zinc	Waste abatement	Aquatic life	Continued waste abatement and monitoring.
Columbia River at Birchbank (1983-97)	Iron, aluminum	Dams/reservoirs	Drinking water, aquatic life	Abatement for total dissolved gases is being planned. Monitoring continues.
Columbia River at Waneta (1983-96)	Cadmium, chromium, iron, lead, zinc, fluoride, sulphate, phosphorus	Waste abatement	Aquatic life, drinking water, irrigation, recreation	Continued waste abatement for cadmium, chromium, copper, zinc, and total dissolved gases. Monitoring continues.
Fraser River at Marguerite (1985-96)	AOX Chloride	Pulp mill waste abatement	Aquatic life, wildlife and their human consumers.	Monitoring continues.
	Fecal coliforms	Improved sewage treatment.	Drinking water, recreation and irrigation	Further monitoring and investigation will be done.

Table 2. Monitoring Stations Showing Deteriorating Trends in Water Quality

Location of monitoring station (Years))	Water Quality Indicators	Cause of Trend	Water Use at Risk	Action
Salmon River at Salmon Arm (1988-2000)	Turbidity	Agricultural and forestry non-point sources	Aquatic life and recreation	Continued abatement and monitoring.
Quinsam River (1986-2000)	Sulphate & other major ions	Coal mining	Aquatic life - potential effects no direct threats at present.	Investigation underway at coal mine. Continued monitoring.
Quamichan Lake (1973-2001)	Fecal coliforms	Waterfowl	Recreation (swimming)	Remediation plan, expanded monitoring and stewardship needed. Basic monitoring continues.
Elk River (1984-2000)	Selenium Nitrogen	Coal mining Coal mining	Aquatic life Recreation	Studies are underway. Monitoring continues.
Kootenay River at Creston (1979-2000)	Phosphorus	Dam/reservoir	Aquatic life (declining Kootenay Lake fish production).	Fertilization of Kootenay Lake since 1992. Monitoring continues.

Table 3. Monitoring Stations Showing No Changes in Water Quality or Showing Other Water Quality Concerns

Location of monitoring station (Years)	Water Quality Indicators	Concern	Water Uses at Risk	Action
South Thompson River at Kamloops (1987-2000)	Suspended solids, turbidity	Agricultural, forestry and residential non-point sources.	Drinking water, aquatic life and recreation	Continued abatement and monitoring. Alternative drinking water sources and treatment options are being evaluated.
Salmon River near Salmon Arm (1988-99)	Phosphorus Water temperature	Elevated loadings to Shuswap Lake High in summer	Recreation Aquatic life	Continued abatement and monitoring.
North Thompson River at North Kamloops (1987-96)	Fecal coliforms	Exceeded objective at times	Drinking water	Monitoring is continuing and objective will be re-evaluated.
Nicola River at Spences Bridge (1992-97)	Phosphorus	Agricultural non-point sources of pollution.	Aquatic life	Remediation of non-point sources is encouraged. Monitoring continues.
Kettle River at Midway (1980-95)		None at present		Monitoring continues.
Kettle River at Carson (1980-95)		None at present		Monitoring continues.
Okanagan River at Oliver (1980-97)	Water temperature	High in Summer	Coldwater aquatic life	Monitoring continues.

Location of monitoring station (Years)	**Water Quality Indicators**	**Concern**	**Water Uses at Risk**	**Action**
Similkameen River at Princeton (1989-97)		None		Monitoring continues.
Liard River at Upper Crossing (1983-94)		None		Monitoring continues.
Liard River at Fort Liard (1984-95)		None		Monitoring continues.
Peace River above Alces River (1984-94)	Turbidity, suspended solids, metals	High levels during spring freshet.	Aquatic life, drinking water, recreation.	Monitoring is continuing to assess the effects.
Fraser River at Red Pass (1985-94)		None		Monitoring continues.
Fraser River at Hansard (1985-94)		None		Monitoring continues.
Nechako River at Prince George (1985-95)		None		Monitoring continues.
Salmon River near Hyder, Alaska (1990-97)	selenium	Often exceeded guidelines. May be natural or due to old mines.	Aquatic life	Survey of selenium sources will be done. Monitoring continues.
Iskut River below Johnson River (1981-94)		None		Monitoring continues.
Skeena River at Usk (1985-94)		None		Monitoring continues.
Tsolum River 500 m downstream from Murex Creek (1989 - 97) Tsolum River at Farnham (1987 - 94) Murex Creek at Duncan Main (1986-97)	Copper	Drainage from mine on Mt. Washington is toxic to fish.	Aquatic life	Tsolum River Task Force is leading remediation. Monitoring continues.
Elk Lake (1983-98)	Phosphorus, dissolved oxygen, algae	Eutrophication	Aquatic life and recreation	Basic monitoring is continuing. Watershed planning, remediation and expanded monitoring are desirable.
Glen Lake (1981-98)	Phosphorus, dissolved oxygen, fecal coliforms	Eutrophication Fecal contamination	Aquatic life and recreation	Basic monitoring is continuing. Watershed planning, remediation and expanded monitoring are desirable. The lake aerator needs to be replaced.
St. Mary Lake (1974-98)	Phosphorus	Eutrophication	Drinking water, aquatic life and recreation	Basic monitoring is continuing. Watershed planning, remediation and expanded monitoring are desirable.

Location of monitoring station (Years)	Water Quality Indicators	Concern	Water Uses at Risk	Action
Cusheon Lake (1974-98)	Phosphorus	Eutrophication	Drinking water, aquatic life and recreation	Basic monitoring continues. Ministry of Water, Land & Air Protection supports the local stewardship group in monitoring and watershed management planning.
Prospect Lake (1980-98)	Phosphorus Fecal coliforms	Eutrophication Fecal contamination	Drinking water, aquatic life and recreation	Watershed planning is underway. Monitoring continues.
Kickinghorse River above field (1987-95)		None		Monitoring continues.
Kootenay River at Kootenay Crossing (1987-95)		None		Monitoring continues.
Beaver River in Glacier National Park (1987-95)		None		Monitoring continues.
Illecillewaet River in Glacier National Park (1987-95)		None		Monitoring continues.
Pend D'Oreille River at Waneta (1980-95) Second station started 1997.	Total dissolved gases	Dams have caused levels that are harmful to fish.	Aquatic life	Means of reducing total dissolved gases are being investigated. Monitoring continues.

Sources: Water Quality Trends in Selected British Columbia Waterbodies. 2000. British Columbia Ministry of Water, Air and Land Protection.
An Update on Deteriorating Trends in Water Quality in British Columbia. 2001. British Columbia Ministry of Water, Air and Land Protection.

Table 4. Monitoring Stations Terminated Since Reporting in 2000

Location of monitoring station (Years)	Water Quality Indicators	Concern	Water Uses at Risk	Action
Spectacle Lake (1985-92)	Phosphorus	Unknown	Aquatic life and recreation.	None needed.
Lower Fraser River Sediments (4 stations) (1985-96)	Lead	Reduction and ban of leaded gasoline.	Aquatic life and wildlife.	Ban on leaded gasoline remains in place.
Marion Jacobs Lake (1984-94)		None		None needed.
Bonaparte River near mouth (1986-95)	Fecal coliforms, turbidity, suspended solids, algae	Agricultural non-point sources of pollution and sewage treatment plant effluents.	Aquatic life, drinking water, recreation, irrigation, livestock watering.	Remediation of non-point sources is continuing and sewage treatment plants have been upgraded.
Boundary Creek at Midway (1980-94)		None		None needed.

Location of monitoring station (Years)	Water Quality Indicators	Concern	Water Uses at Risk	Action
Eagle River at Solsqua Road (1985-95)	Suspended solids, turbidity	Riverbank erosion	Aquatic life	Will be considered for watershed restoration.
Kettle River at Gilpin (1980-95)		None		Monitoring continues at Midway and Carson.
Similkameen River above Hedley (1989-97)		None		Monitoring continues at Princeton and near the US border.
Big Sheep Creek near US Border (1979-95)		None		None needed.
Columbia River at Donald (1984-95)		None		None needed.
Columbia River at Revelstoke (1984-97)	Phosphorus	Dams/reservoir s	Aquatic life (limits fish production).	Studies have been done and fertilization & monitoring of Upper Arrow Reservoir began in 1999.
Kootenay River at Canal Flats (1985-95)		None		None needed.
Moyie River at Kingsgate (1979-95)		None		None needed.
Flathead River at US Border(1979-95)		None		None needed.
Liard River at Lower Crossing (1984-94)		None		Monitoring continues at Upper Crossing and Fort Liard.
Stikine River above Choquette River (1981-94)		None		None needed.
Bear River at Stewart (1987-94)	Selenium	Often exceeded guidelines. May be natural or due to old mines.	Aquatic life	Survey of selenium sources will be done.

Table 5. New Monitoring Stations

Location of monitoring station (Years)	Water Quality Indicators
Cowichan River (1999-)	Too soon to detect trends.
Koksilah River (1999-)	Too soon to detect trends.
Myers Creek (1998-)	Too soon to detect trends.
Pend d'Oreille at US Border (1997-)	Too soon to detect trends.

<u>Methodology and Reliability</u>: Waterbody trend data are based on regular and consistent long-term monitoring. Of the 50 waterbodies included in this analysis, the majority have at least 10 years of data collected between 1985 and 1995 (or later, in some case). The 50 water bodies are represented by 53 sampling stations. Since this indicator was reported on in 2000 (*Environmental Trends in British Columbia: 2000*), 20 water quality monitoring stations have been terminated (see Table 4; most had no water quality concerns or concerns were related to natural conditions) and 4 new stations were added (Table 5).

Selection of Waterbodies
Greater efforts are being made to monitor waterbodies in areas of high human activity, therefore the waterbodies selected tend to represent water quality in developed watersheds around the province. That means that overall trends should not be considered as representative of water quality trends in the province as whole.

Sampling Frequency and Timing
Depending on the type of waterbody, sampling is 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. Bottom sediments are less variable than surface waters and can be sampled annually or even once every few years.

Water Quality Characteristics
For a given waterbody, water quality measures can include some or most 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.

Analysis of Trends
Trends were determined by plotting water quality measurement values on a graph over time along with the relevant water quality objectives or guidelines. Water quality objectives are limits set for water quality characteristics by the Ministry of Water, Land and Air Protection or by Environment Canada to protect all designated uses of a specific waterbody. They take into account the local water quality conditions and uses, and they establish a reference against which the state of water quality in the waterbody can be measured. Guidelines are safe levels of water quality characteristics that apply province-wide or nationally to protect sensitive uses of water such as drinking, aquatic life, agriculture and recreation. They are used when objectives have not been established for a waterbody to provide a general reference against which the state of water quality can be checked.

After plotting, the graph was inspected for environmentally significant trends. Trends that were increasing or decreasing over time and were considered to represent an important change in water quality were evaluated further. This was to determine whether the trend was a result of measurement errors, to test for statistical significance and to identify the cause of the change.

The condition of each waterbody was classified into one of three categories (Improving, Stable, Deteriorating) based on the trend in its water quality as compared to its water quality objectives or guidelines. Note that within each category, there is no ranking to account for the amount by which a waterbody had departed from the objectives or guidelines.

References:

British Columbia. Ministry of Environment, Lands and Parks and Environment Canada. 2000. *Water Quality Trends in Selected British Columbia Waterbodies*. http://wlapwww.gov.bc.ca/wat/wq/trendsWQS/index.html

Secondary Indicator: ***Water Quality Index for British Columbia.***

Selection and Use of Indicator: The Water Quality Index (WQI) for British Columbia is a *state* or *condition* indicator. The WQI has been developed as a tool for expressing, in one statistic, the measurements from a multitude of water quality characteristics made on one waterbody. The index is a valuable communication tool that can be understood by a wide audience.

The WQI was developed in British Columbia in 1995. It has since been adapted for use by other Canadian jurisdictions through the Canadian Council of Ministers of the Environment (CCME). In general, most jurisdictions rely on trends associated with a specific water quality parameter, such as the level of heavy metals (Organization for Economic Cooperation and Development), or the concentration of phosphorus and nitrogen in waters (Environment Canada). This method often proves inadequate, as there is rarely one parameter that is an indicator of the trend in other characteristics that might be monitored. To overcome this problem, some jurisdictions rank waterbodies into broad categories such as "impaired by pollution". The percentage of streams and rivers that are impaired based on various characteristics is the reported statistic. This method most closely approximates the WQI.

Data and Sources:
The status report ratings are derived from the WQI, which measures the impact of pollutants on water quality. The WQI results for this indicator are based on an assessment of 33 water bodies (including fresh surface streams, rivers and lakes and marine areas) for which at least three years of data were collected between 1992 and 1999. Most of the thousands of water bodies in the province are not monitored.

Table 1. Water Quality Index - Provincial Summary

	Excellent	Good	Fair	Borderline	Poor
Number of Water Bodies	10	7	14	2	0

Source: Ministry of Water, Air and Land Protection, 2001.

Table 2. Water Quality Index Geographic Summary of Results by Waterbody, Listed by Ecoprovince

Waterbody by Ecoprovince	Rating in ET 2002[1]	Rating in ET 2000[2]	Rating in ET 1998[3]
Boreal Plains Ecoprovince			
Beatton River	N/A[4]	Fair	Fair
Charlie Lake	N/A	N/A	Borderline
Dawson Creek	N/A	N/A	Borderline
Peace River	N/A	Fair	Fair
Pine River	N/A	N/A	Good
Pouce Coupe River	N/A	N/A	Fair
Central Interior Ecoprovince			
Bonaparte River	N/A	Fair	Fair
Bulkley River	N/A	N/A	Good
Clinton Creek	N/A	Fair	Fair
Fraser River from Hansard to Hope	Good	Fair	N/A
Kathlyn Lake	N/A	Fair	Fair
Loon Creek	N/A	Fair	Good
Loon Lake	N/A	Poor	Borderline
Nechako River	Fair	Fair	Fair
Necoslie River	N/A	Excellent	N/A
Round Lake	N/A	N/A	Fair
San Jose River	N/A	Poor	N/A
Seymour Lake	N/A	N/A	Poor
Tyhee Lake	N/A	Fair	Fair
Williams Lake	Fair	Borderline	Borderline
Coast Mountains Ecoprovince			
Chilliwack River	N/A	N/A	Excellent
Cultus Lake	N/A	N/A	Excellent
Elk Creek	N/A	N/A	Fair
Fraser River from Haney to New Westminster	N/A	N/A	Good
Fraser River from Hope to Haney	N/A	N/A	Good
Kitimat Arm	N/A	N/A	Fair
Kitimat Harbour	N/A	N/A	Fair
Kitimat River	N/A	Fair	Good
Lakelse Lake	N/A	N/A	Good
Or Creek	N/A	N/A	Good
Pitt Lake	N/A	N/A	Good
Lower Mainland			
Alouette Lake	N/A	N/A	Excellent
Alouette River	N/A	N/A	Fair

Waterbody by Ecoprovince			Rating in ET 2002[1]	Rating in ET 2000[2]	Rating in ET 1998[3]
		Anderson Creek	N/A	N/A	Good
		Atchelitz Creek	N/A	N/A	Fair
		Bertrand Creek	N/A	N/A	Good
		Boundary Bay	N/A	N/A	Fair
		Brunette River	N/A	N/A	Good
		Burnaby Lake	N/A	N/A	Fair
		Burrard Inlet – 1st to 2nd Narrows	N/A	Fair	Fair
		Burrard Inlet – 2nd Narrows to Roche Pt	N/A	Fair	Fair
		Burrard Inlet – False Creek	N/A	Fair	Borderline
		Burrard Inlet – Indian Arm	N/A	Fair	Fair
		Burrard Inlet – Outer Burrard	Good	Fair	Fair
		Burrard Inlet – Port Moody Arm	N/A	Fair	Fair
		Capilano River	N/A	Fair	Good
		Chilliwack Creek	N/A	N/A	Good
		Coquitlam River	N/A	N/A	Fair
		Deer Lake	N/A	N/A	Fair
		Fraser River Main Arm	Excellent	Fair	Fair
		Fraser River Main Stem	N/A	Fair	Good
		Fraser River Middle Arm	N/A	Good	Good
		Fraser River North Arm	N/A	Fair	Fair
		Hope Slough	N/A	N/A	Good
		Hoy Creek	N/A	N/A	Fair
		Hyland Creek	N/A	N/A	Fair
		Iona Beach (Sturgeon Bank)	Excellent	Excellent	N/A
		Kanaka Creek	N/A	N/A	Fair
		Latimer Creek	N/A	N/A	Fair
		Little Campbell River	N/A	N/A	Fair
		Luckakuck Creek	N/A	N/A	Good
		Lynn Creek	N/A	Fair	Good
		Mahood (Bear) Creek	Fair	N/A	Fair
		Murray Creek	N/A	N/A	Fair
		Nicomekl River	Fair	N/A	Fair
		North Alouette River	N/A	N/A	Fair
		Pender Harbour – Bargain Bay	N/A	Fair	N/A
		Pender Harbour – Pender Harbour	N/A	Borderline	N/A
		Pitt River	N/A	N/A	Good
		Roberts Bank	N/A	Fair	Good
		Saar Creek	N/A	N/A	Poor
		Salmon River	N/A	N/A	Good

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Waterbody by Ecoprovince			Rating in ET 2002[1]	Rating in ET 2000[2]	Rating in ET 1998[3]
		Schoolhouse Brook	N/A	Fair	Fair
		Scott Creek	N/A	N/A	Fair
		Serpentine River	Fair	N/A	Fair
		Still Creek	N/A	N/A	Good
		Sturgeon Bank	N/A	Borderline	Fair
		Sumas River	N/A	N/A	Good
		Tssawwassen Beach	N/A	Excellent	Excellent
	Vancouver Island				
		Beaver Lake	N/A	Poor	Poor
		Cowichan River	Fair	N/A	Fair
		Elk Lake (Victoria)	N/A	Borderline	Borderline
		Koksilah River	Good	N/A	Fair
		Little Oyster River	N/A	N/A	Good
		Long Lake	Good	Excellent	N/A
		Middle Quinsam Lake	Excellent	N/A	Excellent
		No Name Lake	Good	Excellent	N/A
		Oyster River	Excellent	N/A	Good
		Quinsam River	Fair	Fair	Good
		Tsolum River	Borderline	Poor	N/A
		Woodhus Creek	N/A	N/A	Good
Southern Interior Ecoprovince					
	Bessette Creek		N/A	Fair	Fair
	Lower Vernon Creek		N/A	Fair	N/A
	Kettle River				
		Christina Lake	Borderline	Fair	N/A
	Okanagan Lake				
		Brandt's Creek	N/A	Poor	Fair
		Deep Creek	N/A	Fair	N/A
		Hydraulic Creek	N/A	N/A	Fair
		Kalamalka Lake	Good	Fair	Good
		Kelowna Creek	N/A	Fair	Fair
		Mission Creek	N/A	Fair	Fair
		Okanagan Lake	Fair	Fair	Good
		Okanagan Lake	N/A	N/A	Good
		Osoyoos Lake	Fair	Excellent	Poor
		Peachland Creek	N/A	N/A	Good
		Skaha Lake	Excellent	Excellent	Fair
		Trepanier Creek	N/A	N/A	Good
		Westbank Creek	N/A	N/A	Fair

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Waterbody by Ecoprovince	Rating in ET 2002[1]	Rating in ET 2000[2]	Rating in ET 1998[3]
Wood Lake	Excellent	Good	Fair
Similkameen River			
Allison Creek	N/A	N/A	Fair
Allison Lake	N/A	N/A	Excellent
Cahill Creek	Excellent	Fair	Good
Hedley Creek	Fair	Good	Good
Missezula Lake	N/A	N/A	Poor
Nickel Plate Mine Creek	N/A	Poor	Good
Osprey Lake	N/A	N/A	Good
Red Top Gulch Creek	Fair	Fair	Good
Similkameen River	Fair	Fair	Good
Sunset Creek	N/A	Fair	Good
Wolfe Creek	N/A	N/A	Good
Harris Creek	N/A	Good	Good
Lawson Creek	N/A	Fair	Fair
Spider Creek	N/A	Fair	Fair
Thompson River			
Kamloops Lake	Excellent	Excellent	N/A
Lower Thompson River	Fair	Fair	Fair
North Thompson River	Excellent	Excellent	N/A
South Thompson River	Excellent	Excellent	N/A
Southern Interior Mountains Ecoprovince			
Columbia Lake	N/A	N/A	Good
Columbia River – Birchbank to US border	Fair	N/A	N/A
Columbia River - Toby Creek to Edgewater	N/A	N/A	Fair
Columbia River - Keenleyside to Birchbank	Good	Fair	Fair
Toby Creek	N/A	N/A	Good
Windermere Lake	N/A	N/A	Good
Sub-boreal Interior Ecoprovince			
Bullmoose Creek	N/A	N/A	Fair
Chilako River	N/A	Excellent	Excellent
South Bullmoose Creek	N/A	N/A	Good
Stuart River	N/A	Fair	Excellent
West Bullmoose Creek	N/A	N/A	Fair

[1] *Environmental Trends 2002* ranking is based on two years of data collected in 1999 and 2000.
[2] *Environment Trends 2000* ranking is based on at least 3 years of data collected between 1992 and 1997.
[3] *Environmental Trends 1998* ranking is based on at least 3 years of data collected between 1985 and 1995.
[4] N/A = insufficient data or not monitored.
Source: Ministry of Water, Air and Land Protection, 2001.

Methodology and Reliability: The Water Quality Index (WQI) analysis presented here is based on an assessment of 33 water bodies throughout the province of British Columbia. These include 11 lakes, 21 reaches of streams (such as rivers and creeks), and 1 marine area (Burrard Inlet – Outer Burrard). To be included in this analysis, waterbodies had to have two years of measurements, collected in 1998 and 1999.

Selection of Waterbodies
The waterbodies included in the index were selected for monitoring if they receive industrial, municipal or agricultural discharges and, therefore, were potentially at risk of being polluted. Since monitoring focuses on waterbodies that are likely to become, or already are, polluted, it is important to note that this WQI analysis indicates the state of waterbodies in areas of human activities and concentrations.

Sampling Frequency and Timing
Water quality measures are similar to the measures made for documenting long-term trends, however the frequency, location, and timing of sampling differ. In contrast to long-term monitoring, which requires sampling at a regular intervals, measures for the water quality index 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.

Water Quality Characteristics
Water quality characteristics measured at a given sampling station can 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.

Establishing the WQI for Waterbodies
For each waterbody monitored, acceptable threshold levels or concentrations are set for the water quality characteristics measured. Acceptable levels are dependent on the water uses identified for the waterbody. The WQI for a waterbody is based on the followng three factors:

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

A detailed description of the WQI is available in Appendix A.

The WQI takes a very 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 regardless of the type of characteristic. For example, the amount by which a water quality objective for a highly toxic substance (e.g., cyanide) is exceeded, is treated in the same manner as the amount by which an objective for aesthetic factors (e.g., colour and clarity) is exceeded. Future improvements in the WQI methodology may account for these differences.

The WQI rank for a waterbody is sensitive to the number of water quality objectives. 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. For example, in the Okanagan valley lakes, where there is only one water quality objective (phosphorus levels), the rank of Okanagan Lake went from 'Good' to 'Fair' in two years; Kalamalka Lake went from 'Good' to 'Fair' to 'Good' between 1998 and 2002 (see Table 2).

In cases where there are a greater number of threats to water quality, the greater number of additional objectives result in a more stable rank. For example, in Burrard Inlet, which has water quality objectives for over 40 characteristics, the rank has remained at 'Fair' throughout the reporting period.

The appropriateness of water quality objectives can be a problem in some cases. There may be instances where objectives are set at levels beyond those that are naturally attainable. In such cases, further analysis of the background and historical conditions of the waterbody would be required to reset the objective at different levels. The process of revising old objectives is in progress.

Both a description of the Water Quality Index and a further explanation of the methodology can be found in Appendix A.

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

Secondary Measure: ***Stream crossings density in community watersheds.***

Selection of Indicator: The number of times a road crosses a stream per km of watershed is a *pressure* indicator. Roads are the greatest source of sediment delivery to streams in developed forest watersheds, with sediment being delivered mainly where roads cross streams (Haskins and Mayhood 1997). Since roads are invariably built as part of almost any type of land development, the density of stream crossings serves as a useful indicator of the overall impact of development on water courses in watersheds.

An estimated 76 percent of the population of British Columbia obtains its drinking water supply from surface water. More than two million of these people (approximately half the province's population) are served by the Greater Vancouver or Greater Victoria water systems. While the Vancouver and Victoria watersheds are now closed to the public, most of the water sources for other community and individual water supplies support a variety of land uses, including forestry.

Community watersheds account for 2.3 percent of the provincial timber harvesting land base and are concentrated in the southern half of the province, mainly the Southern Interior, Lower Mainland and Vancouver Island. The Forest Practices Code recognizes drinking water as a priority use for community watersheds. One of the main concerns regarding forestry operations is the potential for erosion and mass wasting to introduce sediment into streams, causing increased turbidity. Turbidity can interfere with water treatment operations and may result in increased illness and liabilities. As well, turbidity is often associated with increased concentrations of heavy metals that can cause adverse health effects.

Other potential impacts of high-suspended sediment load include damage to fish habitat and food supplies, direct injury to fish, bank erosion, channel widening and flooding.

Data and Sources:

Table 3. Density of Stream Crossings in Community Watersheds in British Columbia.

Density (number of crossings per km^2)	Number of community watersheds
0	70
less than 1	57
1-3	54
greater than 3	11
Total community watersheds used in analysis	192

Source: Decision Support Services, Ministry of Sustainable Resource Management, 2002.

Methodology and Reliability: As of 2001, 467 watersheds were classified as community watersheds under the Forest Practices Code of British Columbia Act (BC Ministry of Forests, 1996). A community watershed is defined as a watershed, in which:

- the water is used for human consumption;
- the water source is licensed under the Water Act for a waterworks purpose or a domestic purpose controlled by a water users' community; and
- the drainage area is no larger than 500 square kilometres.

The methodology for this indicator follows the Forest Practices Code Watershed Assessment Procedure (WAP) (BC Ministry of Forests, 1999). The WAP uses nine indicators, including density of active stream crossings, to determine the cumulative effect of harvesting operations on water bodies. Density of stream crossings is calculated by counting the total number of stream crossings in the watershed and dividing by the total watershed area. Streams used were all those visible on Terrain Resource Information Management (TRIM) or forest cover maps. Active stream crossings are defined as those that are presently being used or that will be maintained in a coordinated access management plan.

Maps used for this indicator were from the TRIM Program. This program provides two sets of data: TRIM1 (late 1980's), which covers the entire province, and TRIM2 (late 1990's), which covers approximately 40 percent of the province. Only watersheds with complete TRIM2 coverage were used in this watershed analysis. Of the province's 467 community watersheds (1,485,735 ha), 191 (609,626 ha) were totally covered by TRIM2.

Stream data were obtained from the most accurate data set (TRIM2). Road data were obtained from both TRIM1 and TRIM2 to provide a comparison between the two time periods.

References:

BC Ministry of Forests. 1996. *Forest Practices Code Community Watershed Guidebook*. http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm

BC Ministry of Forests. 1999. *Forest Practices Code Coastal Watershed Assessment Procedure Guidebook and Interior Watershed Assessment Procedure Guidebook*. http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm

Haskins, W., and D. Mayhood. 1997. Stream Crossing Density as a Predictor of Watershed Impacts. http://gis.esri.com/library/userconf/proc97/proc97/abstract/a457.htm

Appendix A - *Description of the Water Quality Index*

Basis of the Index

Few water quality index systems have been developed, and none are in widespread use. Available indices are either highly specialized (e.g., those applicable only to lakes), or are very simple in terms of the number of variables considered. None seem to be geared to the protection of multiple water uses or to encompass the variety of measurements of water quality we now gauge, including physical, chemical, and biological characteristics.

For these reasons, a water quality index was developed that would be based on the attainment of water quality objectives for the water column, sediments, and aquatic life. The main benefits to an objective-based system are as follows:

- objectives have been developed for more than 140 separate bodies of water,
- the objectives focus on the most important characteristics at risk in a body of water,
- the degree to which objectives are attained reflects directly how well the most sensitive water uses will be protected,

- the attainment of the water quality objectives is a measure of water quality impairment caused by human activity, excluding random events such as spills unless these are long-lasting or relatively frequent,
- the index is not bound by any limits on data use because objectives exist for variables from simple water column chemistry to complex biological measurements,
- the use of objectives allows consistent application of the index to fresh water, marine water, or groundwater, and
- the system allows great flexibility since it will accommodate changes due to new scientific information or due to the need to examine new water quality characteristics.

The index is founded on three factors involving the measurement of the attainment of water quality objectives. The factors measure the following:

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

These three factors are combined to form the index, which can fall into one of the following, five rankings: excellent, good, fair, borderline, or poor. These rankings describe the state of the water quality compared to its desirable or natural state.

The Meaning of the Rankings

The following brief descriptions related to water use and natural conditions are helpful in interpreting the meaning of each water quality ranking.

We recognize six uses of water: drinking, recreation, irrigation, livestock watering, use by aquatic life, and use by wildlife. The first four are related to human-use and are only considered in the rankings when they are naturally sustainable. The uses by aquatic life and wildlife are usually always naturally sustainable in BC waters. Note that drinking water in this context always refers to the quality of the raw water source, as it exists in the environment before it is delivered to a consumer's tap. Such raw water, even if ranked as excellent, always needs, at the least, disinfection before drinking.

Natural water quality conditions refer to conditions that exist in the absence of any human interference. Desirable conditions are those which will sustain the most sensitive water uses. Natural and desirable are usually synonymous, although they may differ when human activity has wrought permanent change.

The rankings are described as follows:

Excellent
- all uses protected with the virtual absence of threat or impairment
- no uses ever interrupted
- conditions very close to natural or pristine levels

Good
- all uses protected with only a minor degree of threat or impairment
- no uses ever interrupted
- conditions rarely depart from natural or desirable levels

Fair
- most uses protected but a few threatened or impaired
- more than one use may be temporarily interrupted
- conditions sometimes depart from natural or desirable levels

Borderline
- several uses threatened or impaired
- more than one use may be temporarily interrupted
- conditions often depart from natural or desirable levels

Poor
- most uses threatened or impaired
- more than one use may be temporarily interrupted
- conditions usually depart from natural or desirable levels

Calculation of the Index

Conditions Followed in Calculating the Index

There are six steps followed in calculating the index. The first is to define the body of water to which the index will apply. The second is to choose the period over which the index will apply. The last four steps are to work out the three factors that make up the index and calculate the index itself.

In working out the three factors, we recommend the following conditions regarding the data on water quality objectives attainment:

1. Work only with usable attainment results. Omit indefinite results, such as those from incomplete monitoring (e.g., fewer than the minimum 5 measurements in 30 days needed for a monthly average), or when the available minimum detection limit is too high.
2. When a variable has an objective measured in two or three ways, such as by a maximum and an average or 90th percentile, count the attainment results as two or three separate objectives, as the case may be.
3. When a variable has short-term and long-term objectives, use only the attainment results for the short-term objectives.

4. Calculate the index using all three factors only when attainment results are available for three or more unrelated or independent objectives (a maximum and an average do not count as separate objectives in this case). The index is not an accurate reflection of water quality when there are fewer than three independent objectives tested in a body of water. For example, when only one objective has been set, as in the case for some lakes and groundwater aquifers, the index can only produce a ranking of either excellent or poor which is not realistic.
5. When only one or two objectives have been set, as in the case of some lakes and groundwater aquifers, calculate the index using just two factors. The factor omitted is the number of objectives not met (see the last paragraph of **Step 6: Combining the Factors to Form the Index** below).
6. When microbiological attainment data are reported using more than one indicator (such as fecal coliforms, *E. coli*, or entercocci), incorporate the data according to the results obtained. If results with all indicators are similar, whether all met or all not met, use results for only one indicator - usually fecal coliforms. If the results are mixed, use results from all indicators.
7. Censor data that are outliers due to suspected laboratory or field contamination. Use quality assurance information to help identify such data

Step 1: Defining the Body of Water

The body of water to which the index will apply can be a stream or river in its entirety or in just certain reaches or a groundwater aquifer. Tributaries, lakes, river arms, estuaries, inlets and bays are usually considered separately, or they can be combined, if desired, to calculate an index for the entire watershed. We recommend caution in the watershed approach since extreme results from one reach can unduly influence the index for a much wider area. The more that bodies of water are combined, the more the index or ranking will average variable conditions; the more that bodies of water are separated, the fewer data available to work with, and the higher the likelihood of getting an index or ranking which fluctuates unduly with time.

Step 2: Defining the Period of Time

Decide the period of time for which the index applies. This will be the period from which all objectives attainment data are drawn. A minimum period of one year is usually chosen because attainment data are collected on an annual basis.

Data from several years can be consolidated to obtain an index over a longer time frame. Combining data from several years masks year to year variations, but it has the advantage of filling in data gaps that frequently occur during incomplete monitoring.

Step 3: Calculating the Number of Objectives Not Met (factor F_1)

The first factor, called F_1, measures the number of objectives not met, It is expressed as a percentage of the number of objectives checked. Calculate F_1 for one year by summing the number of objectives not met in that year, dividing by the total number of objectives measured that year, and multiplying by 100.

Example
If 10 objectives were measured in a section of a river and 2 objectives were not met at times, then the F_1 factor is 2 in 10 or 20% for the river in 1990. The factor can range from 0, indicating all objectives are met, to 100% indicating that every objective was not met at one time or other.

To calculate F_1 over several years, sum all of the objectives not met over the period in question and divide by all the objectives checked in that period. For example, if 5 objectives were measured in 1990, 8 in 1991 and 7 in 1992 for a total of 20 and the number of objectives not met were 1, 3, and 2 in each of those years for a total of 6, then F_1 is 6 in 20, or 30%. This approach is used in preference to averaging F_1 from each year because the averaging procedure can be unduly affected by extreme values in years with incomplete data when only a few objectives were checked.

Step 4: Calculating the Frequency with which Objectives Not Met (factor F_2)

The second factor, called F_2, is the number of times objectives were not met, at all sites and dates within a given time period, expressed as a percentage of all instances of objectives being checked. It is calculated for one year by summing all events of objectives not met in that year, dividing by the total number of instances objectives were checked that year, and multiplying by 100. The factor can range from 0, indicating all objectives were met at all sites, to 100% indicating that none of the objectives are met at any sites. Note that for an objective value such as an average, which is based on five values in 30 days, the instance of an objective being checked is counted as 1, not 5.

To calculate F_2 over several years, perform the same summations for the period under consideration as for one year.

Example
If 10 objectives were measured in a river in 1990 at 2 sites and each objective was checked 5 times at each site, then the total number of instances objectives would be checked would be 10 x 2 x 5 = 100. If the total number of times objectives were not met was 20, then F_2 is 20 in 100 or 20%.

Step 5: Calculating the Amount by which Objectives Not Met (factor F_3)

The third factor, called F_3,is a measure of the maximum amount by which objectives are not being met in a given year. For the common case of an objective expressed as a maximum, this deviation is calculated by subtracting the objective value from the maximum measurement exceeding the objective, dividing by this maximum measurement, and multiplying by 100. The highest deviation obtained in a year from all objectives checked is the value of F_3 used in the index.

<u>Example</u>
If the objective for copper in a river is a maximum of 2 µg/L and the maximum measurement of copper in 1990 was 10 µg/L, then the maximum deviation of copper is 10 - 2 = 8 out of 10 or 80%. If this is the highest deviation for all objectives not met in 1990, then F3 = 80. The factor can range from 0, indicating that all objectives are met, to close to 100 indicating that a very significant deviation from an objective has occurred.

This factor is readily influenced by extreme values in the data and can thus affect the index unduly. It is mainly for this reason that it is recommended that outliers be censored due to suspected contamination in the field or laboratory, as indicated by quality assurance.

To calculate F_3 over several years, average the F_3 factors obtained from each year. Using the average instead of the maximum for all the years avoids characterizing the period by an extreme event that occurred in only one year.

For objectives expressed as a minimum instead of the more common maximum (e.g., dissolved oxygen or water clarity), the deviation is calculated slightly differently. Subtract the minimum measurement from the objective, and multiply by 100. These deviations are then treated in the same way as the others with the highest value among all becoming F_3.

Step 6: Combining the Factors to Form the Index

The index is obtained by summing the three factors as if they were vectors. Thus, the square of the index is equal to the sum of the squares of each factor. This approach is used because the index is envisaged as a three-dimensional space defined by each factor along one axis. With this model, the index, or space defined by the factors, changes in direct proportion to the changes in all three factors regardless of the type of waterbody involved.

When we tested the index with historical attainment data, we found that the third factor, F_3, which measures the extent of non-attainment, tended to dominate the index. We brought the effect of this factor into balance by applying a weighing factor and dividing F_3 by three.

The index is therefore given by the following formula:

$(Index)^2 = (F_1)^2 + (F_2)^2 + (F_3/3)^2$
or
$Index = [(F_1)^2 + (F_2)^2 + (F_3/3)^2]^{1/2}$

The relationship between the index value, as derived by the above formula, and the ranking of a body of water is shown in the index table below.

	F_1	F_2	F_3	**Index Value**	**Index Rank**
Excellent	0 -2	0 - 1	0 - 9	0 - 4	**0 - 3**
Good	3 - 14	2 - 14	10 - 45	5 - 25	**4 - 17**
Fair	15 - 35	15 - 40	46 - 96	26 - 62	**18 - 43**
Borderline	36 - 50	41 - 60	97 - 99	63 - 85	**44 - 59**
Poor	51 - 100	61 - 100	99.1 - 100	86 - 145	**60 - 100**

The index values are rounded to the nearest integer to produce an index rank, on a scale from 0 to 100, by dividing each index value by 1.45. This gives an index rank that ranges from 0 for the best water quality, to 100 for the poorest.

The index scale gives values which increase numerically as water quality worsens. This type of scale is in keeping with other environmental indices now in use, such as the air quality index or the index for UV radiation, where values increase as conditions deteriorate.

The model for the index is a mixture of the following: (a) factors that are known to affect water quality, and (b) empirical relationships established by testing with historical data from monitoring. Users will note that the index values do not increase regularly. For example, the range for excellent water quality is narrower than for good water quality, etc. This result is due to empirical factors which were introduced when the model was tested with actual water quality data.

In the case when only one or two objectives have been set in a body of water, calculate the index by summing the two factors F2 and F3 in the same manner as for three factors. Thus the index for the cases of less than three objectives is given by:

$Index = [(F_2)^2 + (F_3/3)^2]^{1/2}$

Calculate an index for one year if sufficient data were collected for a reliable outcome. Otherwise, if the data are sparse, calculate the index consolidated over at least three years.

Source: British Columbia. Ministry of Environment, Lands and Parks, Water Quality Branch. November 1995. *The British Columbia Water Quality Index*. pp. 5-11.