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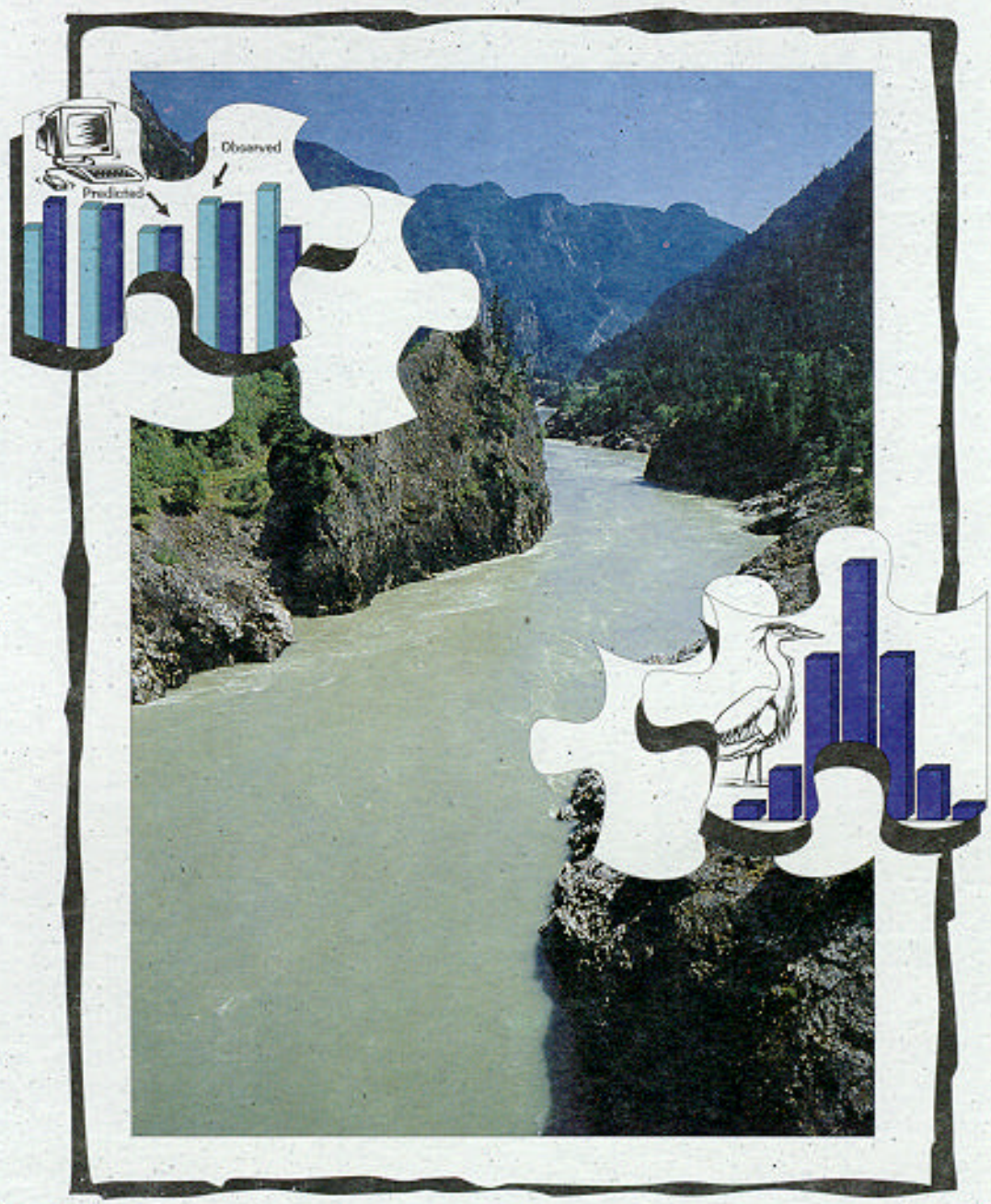
FRASER RIVER ACTION PLAN

MEASURING THE HEALTH OF THE RIVER



ENVIRONMENTAL QUALITY PROGRAM

CLEANING*UP*POLLUTION

1995 STATUS REPORT

Environment Canada Environnement Canada

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photo courtesy of B. Raymond

The Thompson River upstream of Spences Bridge

Introduction

The Fraser River basin is one of B.C.'s most valued ecosystems. Its productive rivers, streams and estuary are home to many species of fish, birds and wildlife. It supports one of the largest salmon populations in the world and is a major part of the Pacific Flyway, an international migratory bird route between South America and Siberia.

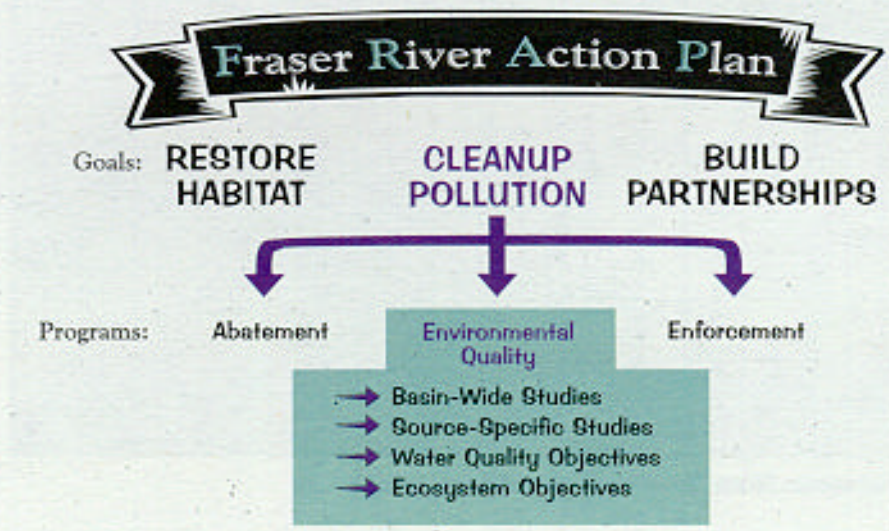
By the time the Fraser River exits the coastal mountains at Hope and enters the Fraser valley lowland, it has drained one quarter of B.C. It has travelled over 1,200 kilometers of varied landscape, starting at its alpine headwaters and running through the arid B.C. interior. The Fraser River empties into the Strait of Georgia forming the largest estuary on the B.C. coast.

The Fraser Basin is home to nearly two million people, over 60 per cent of B.C.'s population, which participate in approximately 80 per cent of the province's economic production.

Recognizing the need to safeguard this ecosystem, the federal ministers of Environment and Fisheries and Oceans established the Fraser River Action Plan (FRAP). Announced in 1991, this seven-year program aims to cleanup pollution, restore the productivity of the natural environment and build partnerships to ensure the sustainability of the Fraser River ecosystem.

The major cleanup goal is to arrest and reverse the existing contamination and degradation of the Fraser River ecosystem by developing targets and strategies to reduce the discharge of pollutants, especially persistent toxic substances. Cleanup needs are identified and actions are implemented under three programs: Environmental Quality, Abatement and Enforcement.

Sustainable ecosystem: one in which ecological systems maintain their long-term diversity, quality, productivity and relative stability



A major goal of the Environmental Quality Program is to determine the health of the Fraser River, thereby providing a baseline against which to measure the success of cleanup efforts and the achievement of sustainability.

Prior to FRAP, environmental studies of pollution problems within the basin were largely restricted to specific development projects on the Fraser River and its major tributaries. FRAP's Environmental Quality Program has expanded this focus to encompass a more comprehensive evaluation of the health of the Fraser River system. The program focuses on detecting the presence of toxic contaminants and determining their effects on biological communities in the mainstem river and its major tributaries.

The objectives of the **Environmental Quality Program** are to:

- develop indicators of ecosystem health;
- measure, assess and report on the health of the Fraser basin aquatic ecosystem;
- determine and assess the effects of major sources of pollution stress, and their abatement, on the ecosystem;
- develop the capability to predict pollution problems;
- develop objectives or targets to protect the most sensitive water uses; and
- develop a process for establishing ecosystem objectives.

Ecosystem objective: a description of a desirable living environment (as defined by stakeholders) that balances social, economic and environmental goals

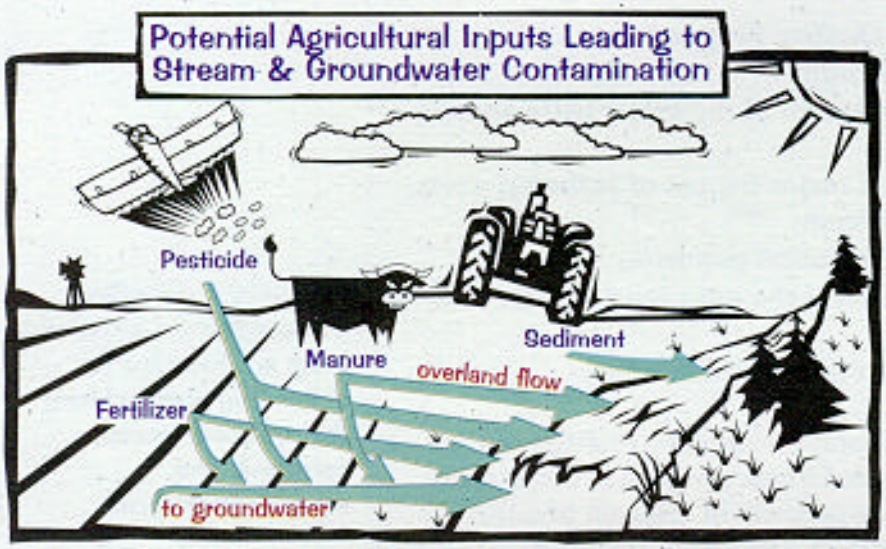
This report describes the current status and preliminary findings of the Environmental Quality Program. This ambitious program is being conducted by Environment Canada and our partners in research institutes, universities, other government agencies and non-profit organizations funded by the FRAP. A final report summarizing the environmental quality of the basin will be available to the public following completion of the FRAP program in 1998.

photo courtesy of FREMP

The Fraser River estuary

How do people use and affect the river basin?

Human activities in the Fraser River basin are affecting environmental quality although the full impact has yet to be determined. Many of the activities, such as fishing or tourism, depend upon a healthy ecosystem. Effective environmental management demands a thorough understanding of how people are using the basin and how this affects the environment. Much of the following information is from a Westwater Research Centre report[1].



Agriculture

Approximately 50 per cent of all farmable land in the province is located in the Fraser basin. Twenty-five per cent of all farmers need to irrigate during parts of the growing season and over 50 per cent of this water is drawn from the Fraser and its tributaries.

Fertilizer, manure and pesticide applications, as well as soil erosion caused by agricultural activities can have a substantial impact on the quality of both streams and groundwater. The situation in the lower Fraser valley is of particular concern since this area has the highest fertilizer application rates in the country and a high density of livestock in some areas.

In 1992, 680 million cubic meters of the basin's water was allocated for irrigation by water license. While this is only 0.8 per cent of the mean annual flow of the mainstem river (measured at Hope) withdrawals have caused problems with reduced flow in some smaller tributaries.

Forestry

The large expanses of forested lands within the basin support logging, lumber production, pulp and paper manufacturing and various other related industries.

Logging and silviculture can alter the functioning of a stream ecosystem, especially in smaller tributaries. For instance, logging can increase summer water temperature, modify stream flow, and add nutrients and sediments. Forest fertilization can elevate stream nutrient levels which may lead to increased algal growth and levels of ammonia that can be toxic to fish.

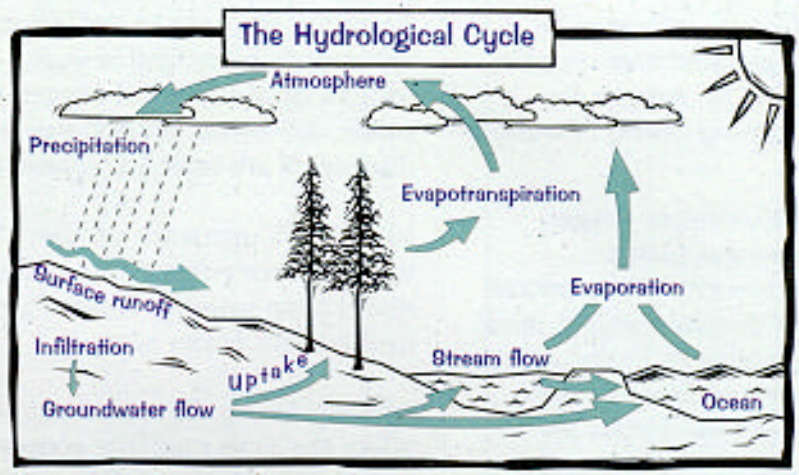
Anti-sapstain chemicals: compounds used to kill fungus that grows on fresh cut lumber; the fungus discolours the wood and reduces its market value

Wood products industries in B.C. use several million kilograms of wood preservative and anti-sapstain chemicals each year. Many of these chemicals, which can enter the river through discharges or runoff, can be toxic to

[1] Dorcey, A.H.J. and J.R. Griggs (eds.). 1991. *Water in Sustainable Development: Exploring our Common Future in the Fraser River Basin. Research Program on Water in Sustainable Development, Volume II.* Westwater Research Centre, University of British Columbia.

aquatic life. Leachate from wood debris generated by these industries is another source causing river pollution.

There are seven pulp mills in the Fraser basin — five located along a 150 km stretch of river in the middle of the basin. Together, they contribute 75 per cent of all effluent released into the river above Hope and 39 per cent in the entire basin. This constitutes more than half of all industrial effluent discharged into the Fraser basin. Pulp, paper and related industries also have the highest gross water intake and net water consumption of all industries (excluding agriculture) in the basin.



Trees and other vegetation are an integral part of the hydrological cycle. Consequently, land clearing activities such as forestry affect water pathways in the environment.

Pulp mills produce a complex wastewater containing a variety of contaminants that may be toxic to aquatic life. Pulp mill effluent may also alter pH, suspended solids, dissolved oxygen and nutrient levels of receiving waters. Several chlorinated contaminants (e.g., dioxins and furans) can accumulate in fish and wildlife and have been identified in water, sediments, fish and wildlife collected downstream of pulp mills in Prince George, Quesnel and Kamloops.

Pulp mills have made a major effort to reduce contaminants, particularly dioxins, in their effluent. As a result of federal regulation, the industry is also implementing an Environmental Effects Monitoring (EEM) program. The main purpose of this program is to determine if current legislation is adequate to protect the environment.

Dioxins and furans: a family of chlorinated organic compounds, some of which are highly toxic. They are formed as by-products of chemical production that involves chlorine and high temperatures or during combustion where a source of chlorine is present (e.g., chlorine bleaching of wood pulp and waste incineration).

Combined sewer overflow (CSO): a discharge containing untreated sewage and stormwater during high rainfall periods

Mining

Three types of mining take place within the Fraser basin: metal mining, placer mining, and gravel extraction.

Metal mines in the basin primarily extract copper, molybdenum, silver and gold, and account for approximately 60 per cent of B.C.'s total metal production. The potential for acid mine drainage from tailings is the main concern with this type of mining.

There are over 200 small and several large placer mining operations extracting gold from the Cariboo and upper Bridge River areas. Placer mining can create local sediment problems in smaller tributaries, and mercury used in historic placer mines can be released when old claims are reworked.

On a volume basis, gravel extraction is the largest mining activity in the basin. Ninety per cent of all B.C.'s sand and gravel production originates in the Fraser basin — most in the lower Fraser area. Major concerns include local groundwater alterations, sedimentation and fish habitat loss.

Urban Development

Approximately 83 per cent of the population within the basin resides in the lower Fraser area. Municipal water withdrawals, combined sewer overflows (CSOs), land use changes, air pollution, sewage treatment plant (STP) discharges and stormwater releases are a few elements of urbanization that can have detrimental effects on the river ecosystem.

Faecal coliforms: a group of bacteria often used to measure the sanitary quality of water

Biochemical oxygen demand (BOD): a measure of the amount of dissolved oxygen used by bacteria to decompose organic waste in water. Thus, the greater the degree of pollution by organic wastes, the greater the BOD.

Levels of Sewage Treatment

Primary treatment removes suspended solids by gravity settling and floating materials by skimming in sedimentation tanks.

Secondary treatment reduces the suspended solids and wastewater BOD by biodegradation using microorganisms.

Tertiary treatment achieves advanced reduction in nutrients, suspended solids, BOD and contaminants. The amount removed is a function of the system.

About 34 per cent of the effluent discharge volume in the Fraser basin arises from municipal sewage. Sewage discharges are the largest point sources of biochemical oxygen demand (BOD), faecal coliforms, suspended solids, ammonia, phosphorus and trace metals in the basin. Some of these discharges are toxic to aquatic organisms.

Most STPs upstream of New Westminster employ secondary sewage treatment. Primary-treated wastewater from the two Greater Vancouver STPs discharging into the Fraser River (Annacis and Lulu) are a major concern in the lower Fraser area.

Atmospheric pollutants from both municipal and industrial sources can affect the Fraser aquatic ecosystem. Automobile exhaust is a significant emission in the lower Fraser region that influences the quality of stormwater. Pulp mills and sawmills are also known to affect air quality in the middle Fraser area.

Hydroelectric Power Generation

Water use and storage for power generation in the Fraser basin is confined to tributaries; there are no hydroelectric developments on the mainstem river. The major hydro facilities are found on the Nechako and Bridge rivers.

Hydroelectric developments have impacts on both water quality and aquatic habitat. Water quality problems include elevated mercury levels in some reservoirs and altered water flows downstream of dams.

Fisheries

The Fraser River system produces more salmon than any other river system in the world and supports a thriving commercial fishery. Recreational fishing is a major activity in the numerous small lakes and tributaries of the Fraser. Rainbow, cutthrout and steelhead trout, and kokanee are the most sought-after recreational fish species.

Wilderness Recreation and Tourism

The Fraser basin is a significant source of B.C.'s tourism and recreation income. Popular water-related activities along the Fraser River (other than recreational fishery) include boating, river rafting, hiking, hunting and waterfowl watching, beach use and camping.

photo courtesy of Tourism B.C.

Fishing for steelhead

How is FRAP assessing the health of the basin?

FRAP is assessing the health of the Fraser River by interpreting historic contaminant data and conducting new studies. These new studies build upon historical information to paint a more complete picture of river quality.

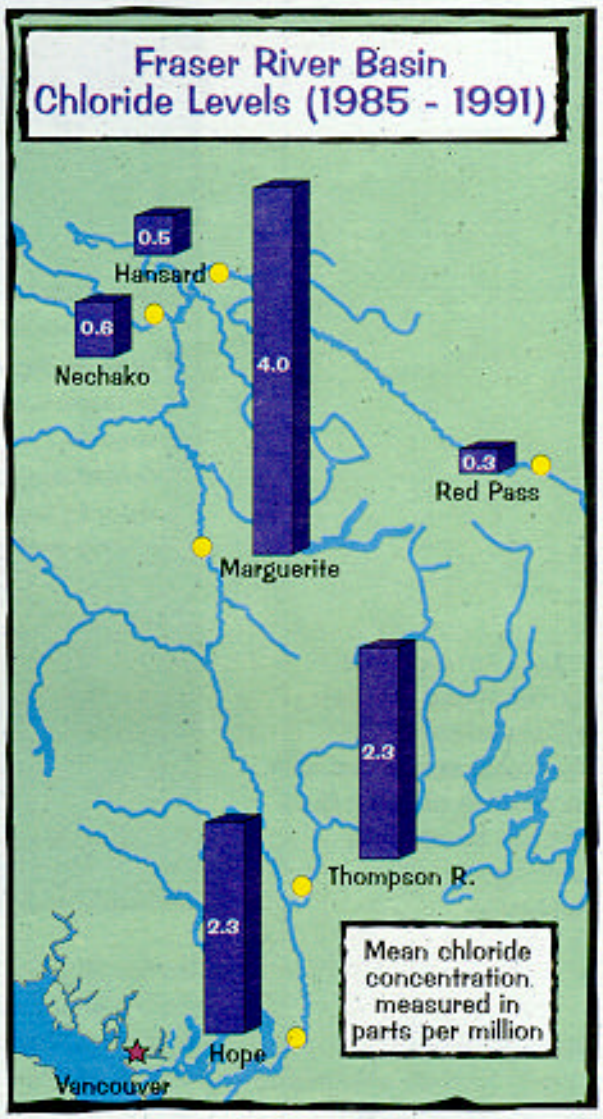
HISTORIC INFORMATION

Water, Sediment and Fish

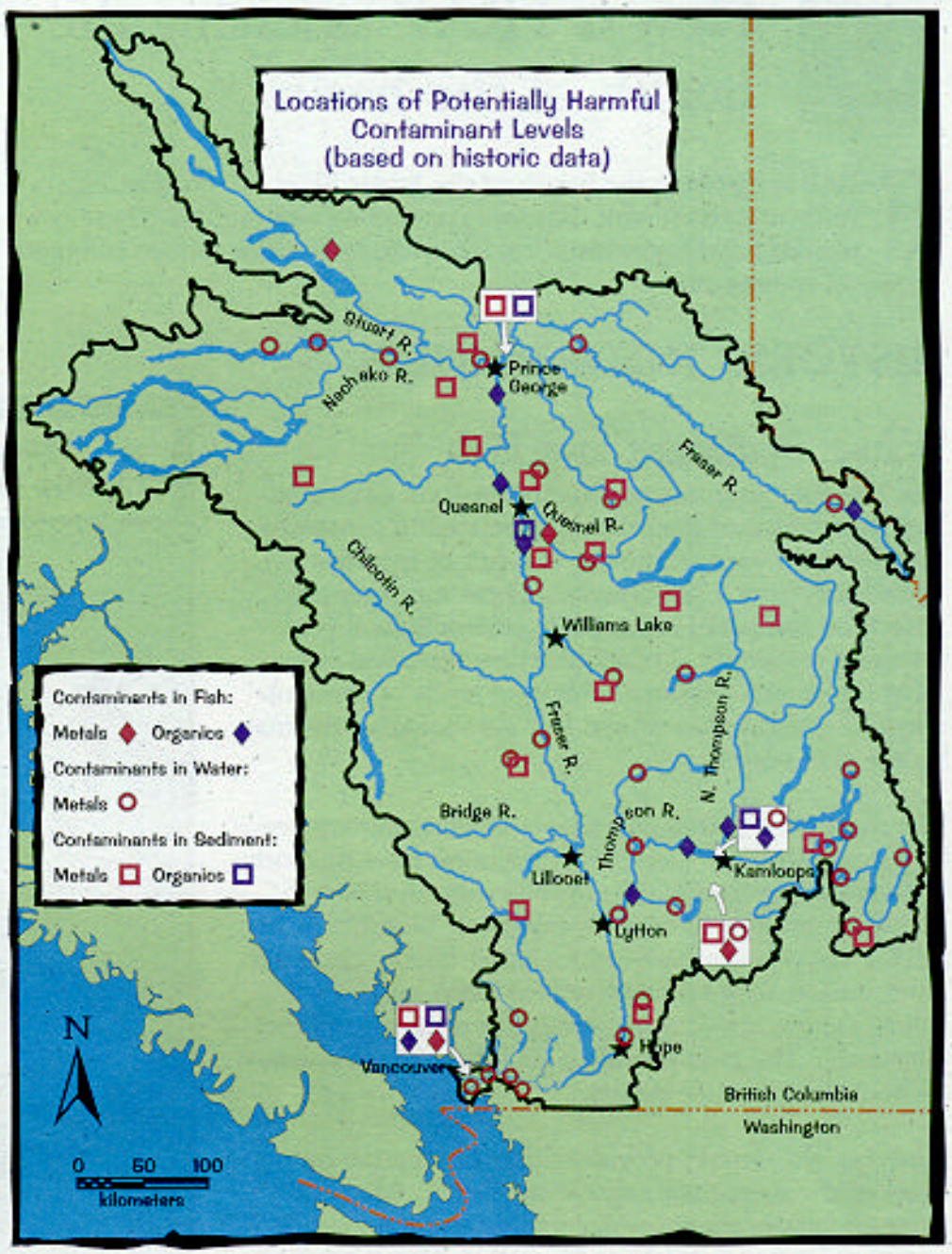
The FRAP Environmental Quality Program has assembled and evaluated historical data related to contaminant levels in water, sediment and fish of the Fraser River basin from 1985 onward. These measurements have been compared to available environmental guidelines and standards. Locations where historical sampling has shown potentially harmful levels of contaminants in water, sediment and fish are shown on the map on the next page.

The most information is available on contaminant levels in water. Since the mid-1980s, scientists have routinely collected water quality data at nine sites on the mainstem Fraser and major tributaries. Monthly or bi-weekly samples are analyzed for water quality characteristics such as major ions (dissolved salts), suspended solids, metals, and less frequently for some organic chemicals. The data provide a good base of information on background water quality.

However, the dataset provides little information on some of the more toxic organic chemicals. Many of these chemicals are not water-soluble and were either not measured or not detected in water. Some constituents can act as tracers for toxic compounds. For example, chloride is a common constituent in pulp mill effluent. Increased chloride levels downstream of pulp mills on the Fraser and Thompson rivers indicate where to investigate toxic compounds associated with mill effluent.



This dataset and other water quality data from the basin show some elevated metal concentrations. High metal levels occur naturally and are associated with sediment or particles suspended in the water. At some locations, such as the Brunette River basin in the Vancouver area, the high levels are due to urban runoff. Upstream of Hope, many of the high metal levels were measured near mining operations. Though mines in the basin do not discharge effluent, runoff from mine sites may elevate metal levels in small streams.



Polycyclic aromatic hydrocarbons (PAHs): organic compounds commonly associated with the burning of fossil fuels that can be strongly carcinogenic and mutagenic

Chlorophenols: a group of toxic chlorinated organic compounds commonly associated with wood preservatives and pulp mill effluent

Historically, sediments and fish have been sampled mainly in the Fraser estuary area and, more recently, downstream of pulp mills. In Fraser estuary sediments, there is evidence of contamination by organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and chlorophenols, as well as some metals. Sediments downstream of the pulp mills that used a chlorine-based bleaching process have been contaminated with furans.

The most significant fish contamination problem in the basin has been the presence of dioxins and furans in fish tissue. This resulted in consumption advisories for resident fish, such as mountain whitefish and largescale sucker in the Fraser, Quesnel, North Thompson, South Thompson and Lower Thompson rivers in 1989 and the early 1990s. The consumption advisories for mountain whitefish have been lifted recently due to de-

creases in dioxin and furan levels, resulting from process changes in the mills. Historic data also show elevated mercury levels in fish from Pinchi Lake near Stuart River (where mercury has been mined), PCB levels in fish from Moose Lake in the Fraser River headwaters and some elevated metal levels in fish from the lower Fraser.

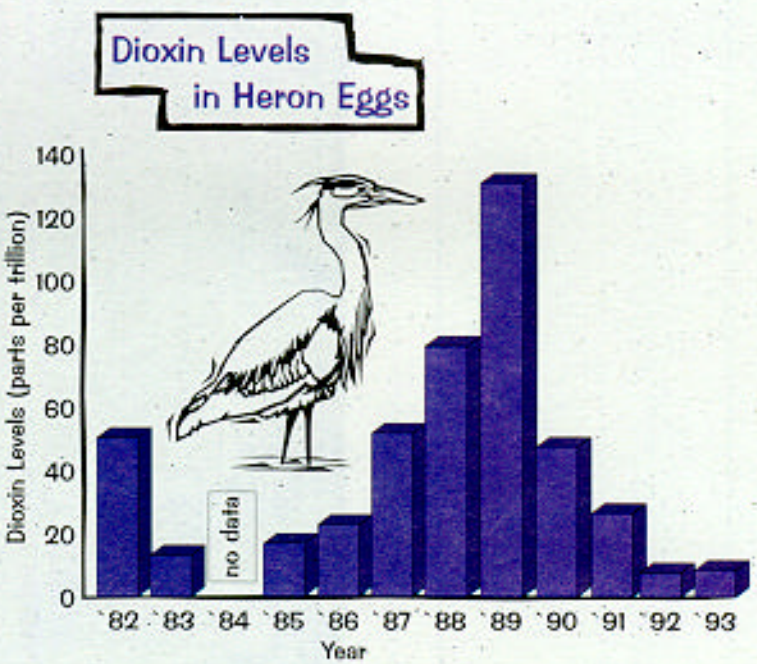
Wildlife

Wildlife have been routinely monitored for contaminants in the lower Fraser River. In addition, there have been short-term studies to investigate the causes of bird kills and to evaluate the exposure of aquatic-based wildlife to metals and toxic organic chemicals such as pesticides, PCBs, dioxins and furans.

Lead poisoning is a problem in the lower Fraser valley. Here waterfowl feed in wetland and estuarine areas where hunters once used lead shot. This problem also affects eagles which feed on the poisoned ducks. In 1992, a federal regulation banned the use of lead shot for hunting waterfowl in the lower Fraser valley. Lead poisoning is expected to decline as a result of this regulation. Pesticide poisoning in ducks occurred only on occasions when they fed on cropland flooded by winter rains.

Traces of toxic organic compounds have turned up in eggs and other tissues of fish-eating birds and mammals in the basin. Low levels of DDE (a breakdown product of DDT) and PCBs have been detected in eggs of the great blue heron, cormorant, bald eagle and osprey, and in livers of mink and otter.

Historically, dioxins and furans were present in the early formulations of the wood anti-sapstain chemical pentachlorophenol, and in effluent from bleached kraft pulp mills. As shown in the bar graph below, dioxin levels in great blue heron eggs from a colony in the lower Fraser River, at the University of British Columbia, have been decreasing since 1989. Dioxins have also been detected in osprey eggs from Kamloops and Quesnel areas, in bald eagle eggs from the lower Fraser valley and in the livers of mink and otter from small tributaries of the Fraser River near Prince George.

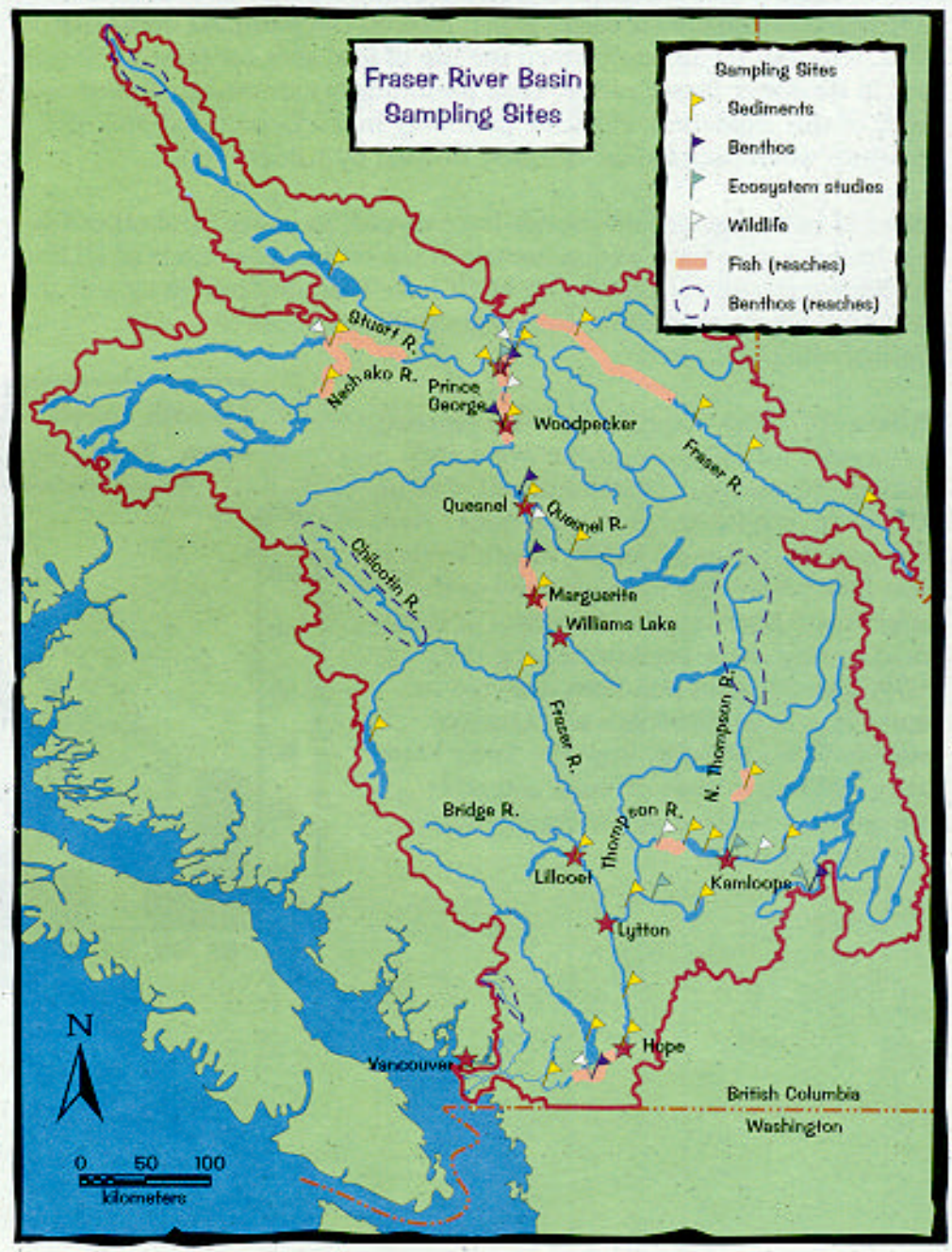


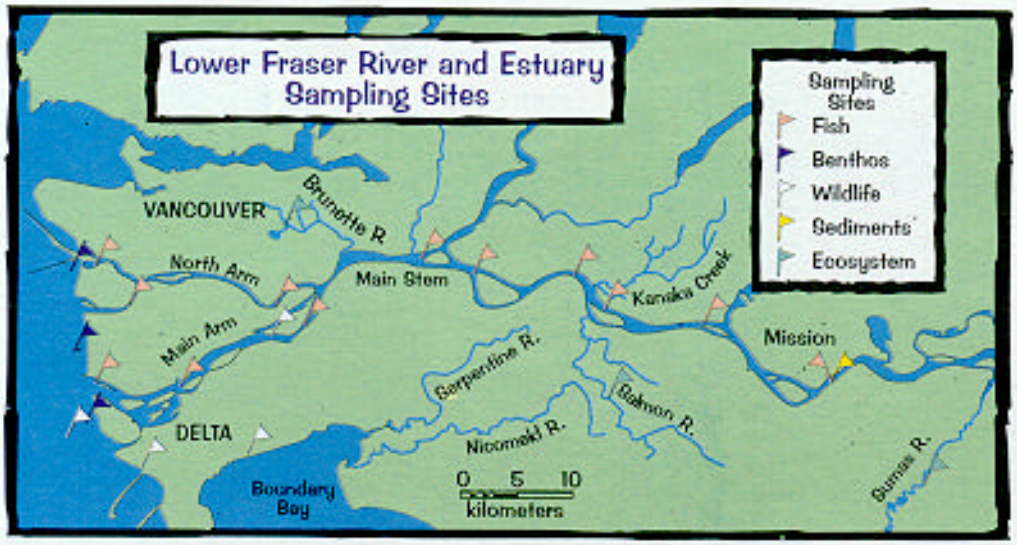
DDT (dichlorodiphenyl-trichloroethane): a chlorinated organic pesticide. DDT does not readily break down in the environment and is commonly detected despite the ban on its use.

PCBs (polychlorinated biphenyls): a group of 209 chlorinated organic compounds, some of which are highly toxic. They were widely used as fire retardants in electrical transformers and capacitors, as plasticizers and waterproofing agents, and in inking processes. PCBs are persistent, accumulate in the food web and are suspected carcinogens.

NEW ENVIRONMENTAL QUALITY PROGRAM STUDIES

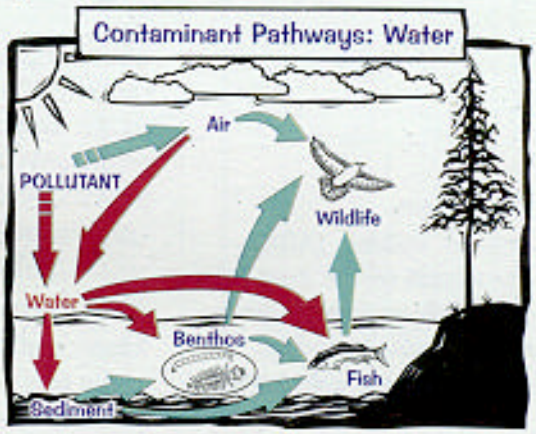
Historically, studies in the basin concentrated on measuring contaminant levels in the water environment. Few studies have taken the next step to investigate the effects of contamination on the animals and plants living in the river and its tributaries. FRAP is focusing its efforts on assessing the "effects" of contamination on the aquatic ecosystem of the basin. FRAP projects include basin-wide studies on environmental quality and studies of specific pollution sources. The following two maps show locations in the basin where the Environmental Quality Program is collecting samples.





BASIN-WIDE STUDIES OF THE FRASER ECOSYSTEM

To assess the state of river quality, the Environmental Quality Program is measuring contaminant levels in air, water, sediment, fish and wildlife. At key locations in the basin, the program is also measuring the effects of contaminants on organisms. These components of the ecosystem represent the pathways by which contaminants travel throughout the environment and can be used to indicate the effects of contaminants on ecosystem health. The interrelationships among these pathways can be seen in the small diagrams accompanying each of the following sections.

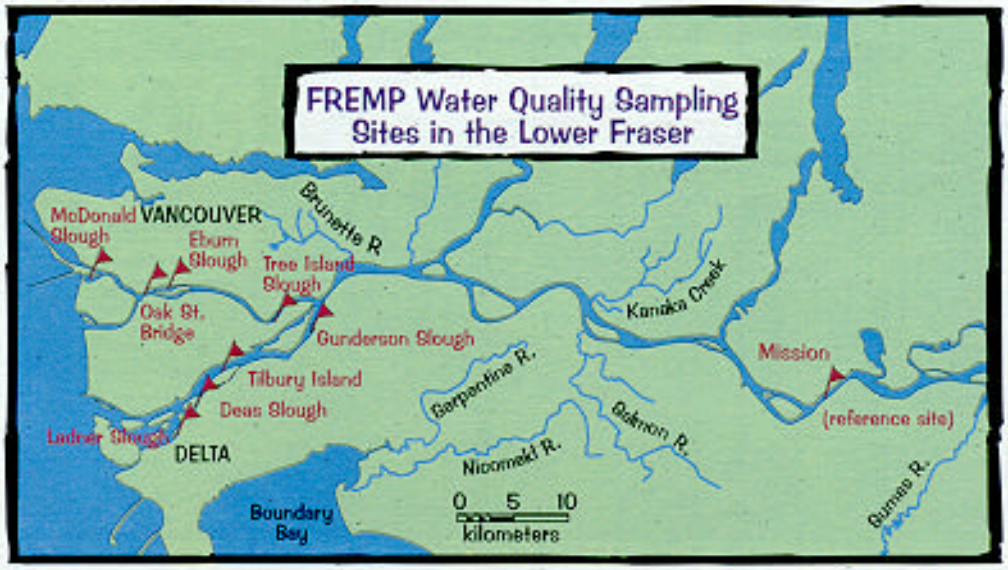


Water Quality

The Environmental Quality Program supported a detailed assessment of water quality in the Fraser River estuary as part of the Fraser River Estuary Management Program (FREMP). FREMP sampled a total of 151 characteristics from three mainstem sites and six sloughs at varying frequencies from January 1993 to March 1994. Forty characteristics (including temperature, dissolved oxygen, salinity, major ions (dissolved salts), nutrients, metals and faecal coliforms) were measured bi-weekly at mainstem sites. Sampling sites are shown on the map on the next page.

Federal Water Quality Guideline or B.C. Water Quality Criterion: a numerical concentration or narrative statement recommended to support and maintain a designated water use, for example, protection of aquatic life

In comparison to the Mission site, levels of faecal coliforms were elevated at estuarine locations. Discharges from sewage treatment plants (STPs), combined sewer overflows (CSOs) and agricultural and urban runoff are the major sources of this contamination. The faecal coliform problem is worse during the winter months when the STPs suspend disinfection of their discharges and heavy precipitation increases both runoff and CSO discharge. Based on B.C. Water Quality Criteria, levels of faecal coliforms throughout the winter and occasionally in August are high enough to present a hazard for contact recreation (e.g., swimming) and irrigation in the lower Fraser River.



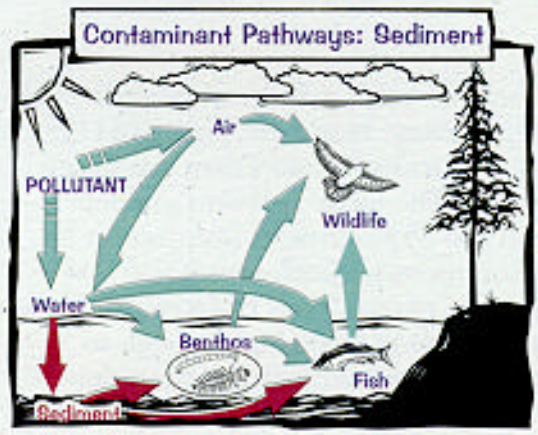
Total chromium, copper, iron and zinc exceeded federal guidelines and provincial criteria for the protection of aquatic life during some parts of the year. These levels are primarily associated with the suspended sediment in the water. Consequently, most of the high metal levels were recorded during freshet (a period of high flow and suspended sediment load associated with snowmelt). Total metal levels were lower in the sloughs than the main river, probably because the lack of current allowed much of the suspended solids to settle out of the water column.

Most organic contaminants were near or below measurable levels throughout the estuary, except for PAHs which often exceeded provincial criteria in the sloughs. Adsorbable organic halides (AOX) levels at all three mainstem sites were similar to levels recorded at Hope by the federal / provincial water quality monitoring programs. This indicates that these compounds are entering the estuary from upstream of the sampling area.

Adsorbable organic halides (AOX): a measure of the sum total of all halogenated organic compounds, including those that are chlorinated

Sediment

Many pollutants attach to sediment particles in the water column and settle out in quiet areas of the river or in lakes and estuaries. These areas become reservoirs where contaminants can remain in the environment long after sources have been removed. The quality of these sediments affects the health and productivity of bottom-dwelling aquatic life and the food web it supports.



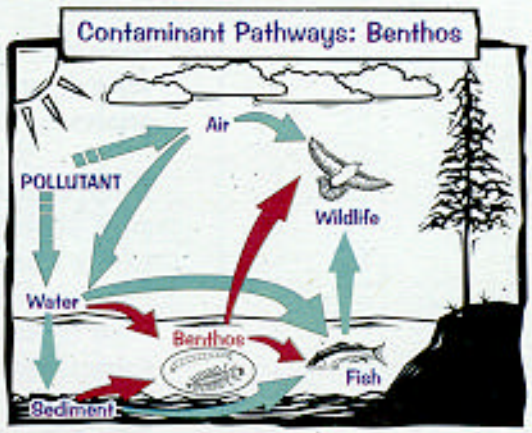
Pollution levels can be measured and traced by analyzing sediments suspended in the water column (suspended sediments) or settled on the river bottom (bed sediments). Scientists from the Environmental Quality Program identified sites in the Fraser River and its main tributaries where bed sediments can be safely and effectively sampled

Bed sediment sampling in the Chilcotin River

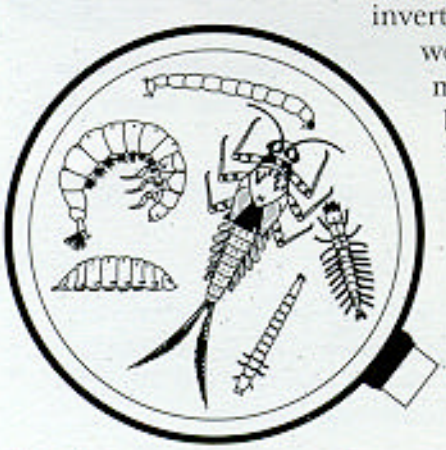
for the presence of toxic chemicals. Samples were collected from these sites in the fall of 1994 and are being tested for trace organic and metal contaminants. The sampling program will be repeated in 1995 and 1996.

Benthic Invertebrates

Benthic invertebrates live in contact with bed sediments and some feed by filtering suspended sediments from water. Their close contact with sediments exposes them to sediment-bound contaminants and provides an avenue for pollutants to enter the food web. These organisms are also fairly stationary and vary in their pollution tolerance. Due to these characteristics, benthic invertebrates can be used to measure sediment quality and act as site-specific indicators of exposure and effects.



A study is underway to classify the benthic invertebrate communities in unpolluted sites within the Fraser River basin. This information will determine whether characteristics of the site, such as rock size, water flow and simple water chemistry, can be associated with particular benthic invertebrate community structures. Fifty sites were sampled in October 1994 and approximately 200 sites throughout the basin will be sampled by the end of the program. These communities will give scientists a baseline against which to rate areas that are affected by human activities.

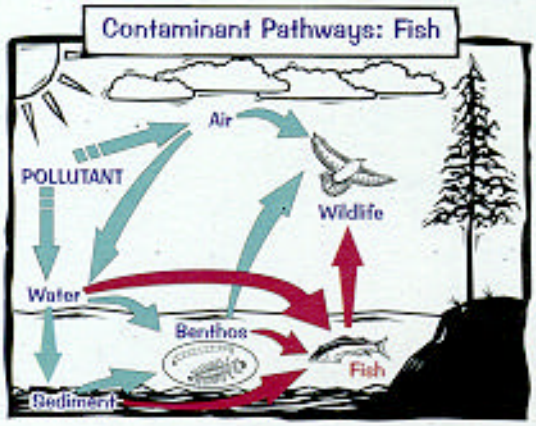


Benthic invertebrates (benthos): animals with no backbones (e.g., insects, worms, mussels and snails) that live on or in the bottom of a body of water

Scientists are also generating a reference database from historical and current sets of benthic invertebrate data. A library of benthic invertebrate specimens from the Fraser basin is being compiled at the Royal British Columbia Museum to verify future species changes.

Fish

The health of resident fish populations is important as an indicator of ecosystem health and as a factor that can affect human health. Resident fish (e.g., mountain whitefish) spend their entire lifespan in the river and reflect the river conditions more closely than migratory fish (e.g., salmon). A three-year study investigating the health of three resident fish species began in the summer of 1994.

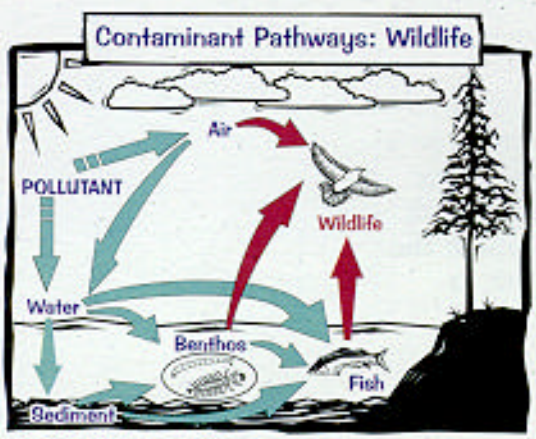


Mountain whitefish and peamouth chub were collected from seven reaches of the Fraser, Nechako, Thompson and North Thompson rivers during the fall of 1994. Peamouth chub and starry flounder were collected from the estuary during the summer of 1994. Sampling will be repeated in 1995 and 1996. A series of visual indicators of health (e.g., number of skin lesions, colour of liver, etc.) were recorded for each fish. The levels of certain pollution-sensitive liver enzymes were also measured. Tissue from each fish was preserved for microscopic examination and contaminant analyses.

Dissecting fish for the fish health study

Interpretation of the whitefish data requires knowledge of their migration patterns. Mountain whitefish in the Prince George area are being radiotagged to reveal their upstream and downstream movements.

The past and present distribution of Fraser River fish is being compiled from historical records in a computerized database. This will lead to the production of an atlas that will provide a baseline against which changes in fish distribution, numbers or community structure can be detected.



Wildlife

Scientists within the Environmental Quality Program are evaluating several aquatic-based wildlife species (eagles, osprey, cormorants, swallows, otters and selected amphibians) for use as indicators of ecosystem health.

Cormorants and great blue herons in the Fraser delta area have been sampled since 1985 for several contaminants, including dioxins and furans. The well-understood feeding patterns of the great blue heron make this bird a useful indicator species. Under FRAP, cormorants were also evaluated as a potential indicator species for the Fraser Estuary. The study showed that cormorants feed beyond the Fraser Estuary and

photo courtesy of Tourism B.C.

The bald eagle: a potential indicator species

may be reflecting contaminant levels in the Strait of Georgia, as well as the estuary.

Bald eagles that nest in the lower Fraser area are also being investigated for possible use as an indicator species. These predatory birds are at the top of the food web and would make an excellent indicator of contaminant biomagnification. Blood and egg samples from eagles collected in the lower Fraser River basin and at Vancouver Island reference sites are undergoing contaminant and biochemical analyses.

Biomagnification: the cumulative increase of persistent substances in successively higher levels of the food web

A project to study contaminant levels in river otters and mink (both of which obtain a large proportion of their food from the aquatic environment) is in the planning stages.

SOURCE - SPECIFIC STUDIES

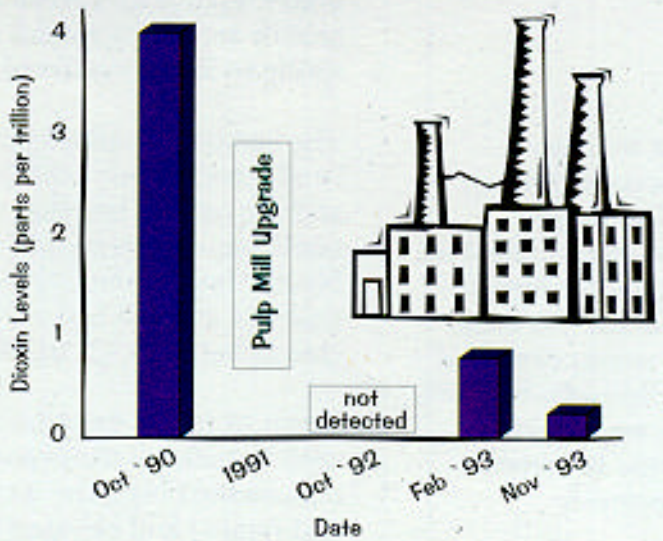
In addition to developing indicators to assess the state of river health, the Environmental Quality Program is also assessing the effects of major pollution sources.

Pulp Mills

Due to their large contribution to the Fraser River's pollutant loading, pulp mills are the focus of several studies.

A study of suspended sediments determined that trace organic contaminants from pulp mill effluent can be found over 225 km downstream from the nearest pulp mill and that levels were highest during low flow in the winter. This study also revealed that levels of specific dioxins and furans dropped between 1990 and 1992 in response to pulp mill upgrades.

Dioxin Trends in Suspended Sediments at Marguerite in the Fraser River: 1990 - 1993



Scientists also discovered that pulp mill effluent enhances the natural process of sediment flocculation. Pulp mill pollutants tend to "stick" to suspended solids of biological origin (biosolids) that are present in the effluent. Once released into the river, these biosolids clump together (or "flocculate") with river sediments. Field studies and laboratory analyses confirm that pulp mill effluent increases the amount of sediment flocculation in the river.

The size of these flocculated particles affects how far they (and their associated contaminants) travel down the river and where they are deposited. In this way, flocculation influences patterns of pollution. The particle size also affects contaminant uptake by benthic invertebrates since many of these animals feed by either filtering suspended particles or grazing on deposited material.

photo courtesy of K. Cash

An artificial stream experiment near Prince George

The effects of pulp mill effluent on algae and benthic invertebrates is being investigated in the Thompson River at Kamloops and with Fraser River water at Prince George. The studies at Kamloops, undertaken in artificial streams, indicate that the effluent stimulates the growth of algae, and mayfly and midge larvae. The stimulation could be the result of nutrients in the effluent that fertilize algal growth and, in turn, provide extra food for the invertebrates. In river experiments 50 km downstream of Kamloops at Walhachin, algal and midge growth stimulation was evident in autumn and winter, but not in spring. However, the benthic community was less stimulated in tests at higher effluent concentrations, suggesting that some component in the effluent can inhibit growth.

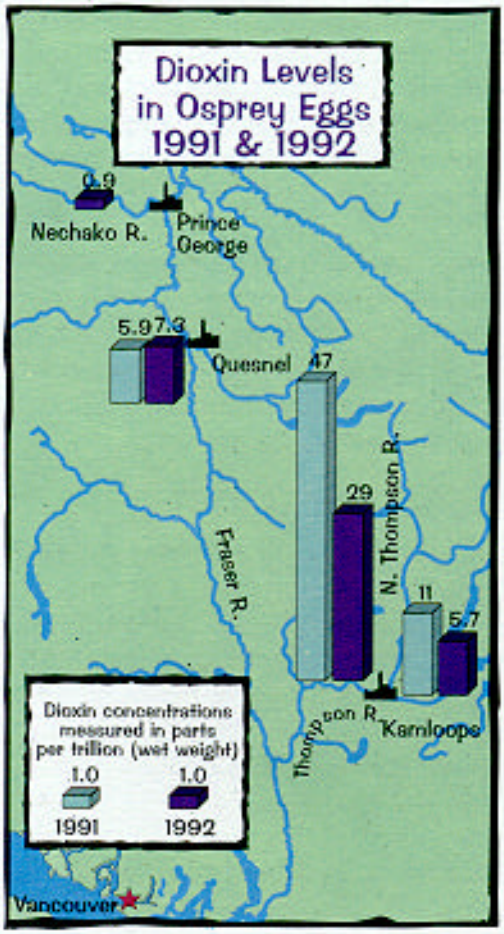
Another part of the study compared the amount of organic carbon in the food web produced by algae in the river with that originating from land-based sources (e.g. plant litter or pulp mill effluent). Studies revealed that more than 60 per cent of the organic carbon consumed by benthic organisms originates from the land-based sources.

In the fall of 1994, an artificial stream was installed at the pulp mill furthest upstream at Prince George. This facility is being used to test the effect of effluent on benthic community growth and the accumulation of contaminants in sediment and invertebrates. Preliminary results confirm that pulp mill effluent stimulates algal growth and alters species composition. These tests are being run again this spring to look at seasonal variability.

Mixed function oxygenases (MFOs): enzymes, largely concentrated in the liver, which change foreign substances into forms more readily eliminated from the body; high MFO levels can indicate exposure to certain contaminants

The benthic community occupying the Fraser River below Hope could also be affected by pulp mill contaminants. In this area, the river slows down and the habitat becomes more suitable for benthic communities. Contaminated sediments may settle to the bottom and increase exposure of benthic invertebrates to pollutants. Benthic invertebrates collected from this area in 1993 had very low furan concentrations and only one chlorophenol (3,4,5 trichloroguaiacol) was consistently detected.

Levels of mixed function oxygenases (MFOs) in fish livers are commonly used to indicate the exposure of an organism to toxic chemicals. Scientists documented both the accumulation of persistent compounds (e.g., dioxins and furans) and elevated liver MFOs in fish downstream of pulp mills in the Fraser River. Current studies aim to determine whether these biochemical measurements can be linked to the long-term condition of resident fish like peamouth chub.



Pulp mills discharge significantly less chlorinated organic compounds than in the past but are still a source of these compounds. Scientists are examining the effects of selected chlorinated contaminants on sturgeon eggs and larvae.

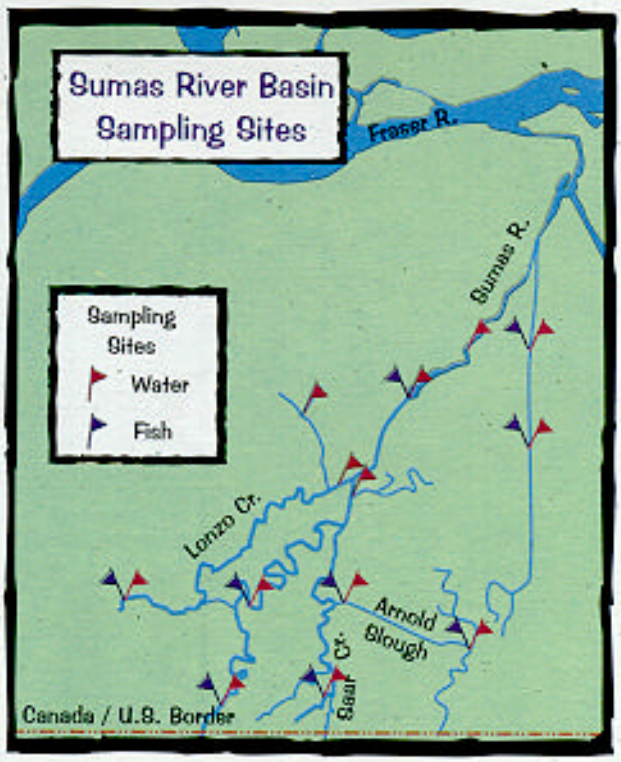
Scientists are also studying the effects of pulp mill effluent on aquatic-based wildlife. Osprey that nest in the vicinity of a pulp mill are particularly vulnerable because they prey exclusively on fish and their foraging range is restricted during the breeding season. Eggs collected from nests near Kamloops and Quesnel show higher levels of chlorinated organics below the pulp mills compared to upstream sites. Studies are being conducted to determine if these higher levels are affecting reproductive success (i.e., the number of osprey fledglings per nest).

Tree swallows eat numerous insects that have larval stages in rivers and lakes. These birds are easily attracted to nest boxes placed near river banks, offering a potential monitoring technique for contaminants in the river. To test this, nestlings collected from nest boxes placed above and below pulp mills near Kamloops and Prince George are being analyzed for chlorinated organics, including chlorophenols.

Agriculture

The Sumas River basin has been chosen for in-depth studies of the impacts of agricultural activities on the aquatic ecosystem. The Sumas River originates in the State of Washington and drains into the lower Fraser River. The lowland is one of the most intensively used agricultural floodplains in Canada. Over the past 20 years, with the rapid increase in animal numbers and intensification of crop production, the use of chemical fertilizers and the generation of manure has also increased.

Studies are examining the fate of manure and fertilizer applications — uptake by plants, losses and returns to and from the atmosphere, and input to the stream and groundwater systems. Water quality will be related to land use type and intensity, animal density, nutrient



application rates, soil texture and stream proximity. Monitoring conducted between March and November 1994 identified low dissolved oxygen and high nitrate and ammonia levels as problems in several tributaries and reaches in the Sumas. In addition, invertebrate communities, amphibians, selected microorganisms and fishes will be examined to determine changes in health conditions over time.

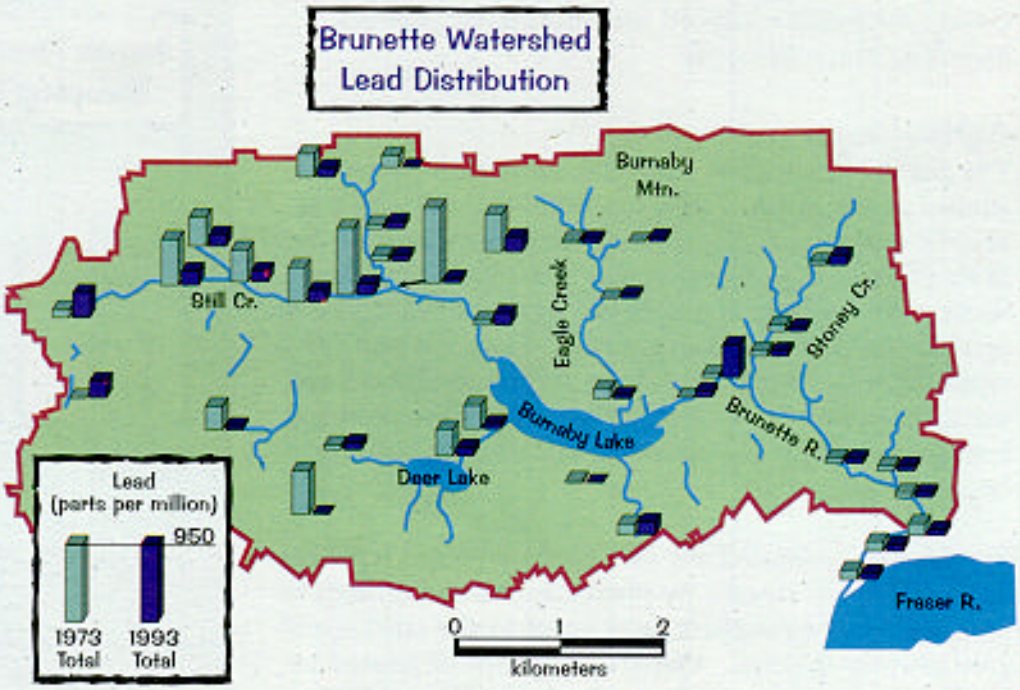
The effects of agriculture and other human activities on ecosystem structure are also being studied in two Thompson River tributaries — the Salmon and the Nicola rivers. During the fall of 1994, six sites on each river were surveyed for the abundance and diversity of fish, invertebrates and birds. The data will be analyzed to determine how the streamside vegetation affects the animals that live in and beside the water.

Urban

The effects of urban activities on the aquatic ecosystem are being studied in the Brunette River. The Brunette River is located in one of the most highly urbanized areas of the lower Fraser. In addition, two major transportation corridors run through the watershed. Pollutants from heavy traffic as well as from residential, commercial and industrial activities are deposited on extensive paved and other impervious surfaces. During rainfall events, the contaminated runoff from these surfaces flows quickly into storm drains then directly into streams in the watershed.

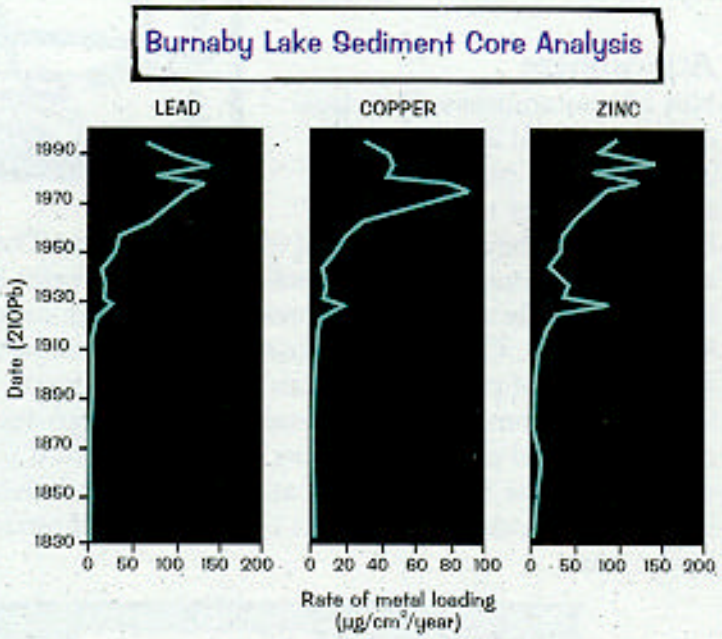
Chemical oxygen demand (COD): a measure of the amount of oxygen required to chemically oxidize the inorganic and organic matter in water

A variety of samples of runoff, stream water and sediment have been collected before and during rainfall events. These samples are being analyzed for trace metals, organic contaminants, suspended sediments, BOD and chemical oxygen demand (COD). Early results have been compared to results from similar samples collected in 1973. This comparison shows that lead levels in sediment have decreased at most sites, largely due to the



elimination of leaded gasoline. A related study is evaluating the relative contribution of contaminants deposited from the air.

Benthic invertebrate community analysis, bioassays and artificial stream studies are being conducted at selected stream sites as additional indicators of the health of the aquatic ecosystem. To date, bioassays with midge larvae, which live in the sediments, showed reduced growth and survival at three out of five sites.



Scientists have also collected sediment cores from Burnaby and Deer Lakes. These meter-long vertical columns of sediment taken from the lake bottom carry an historical record of contaminant deposition. The cores indicate that levels of lead, copper and zinc increased between 1910 and the 1970s, and declined more recently.

Bioassay: a method for determining the level of toxicity of a substance, such as sediment, by its affect on a suitable animal, plant or microorganism under controlled conditions.

Sewage Treatment Plants (STPs)

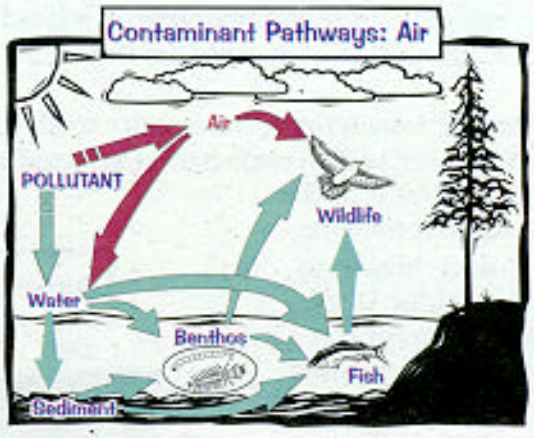
STPs are another major source of contaminants and nutrients to the Fraser River, especially in the lower Fraser and estuary. A study is underway to analyze the long-term response of benthic communities to the 1988 diversion of the Iona Island STP outfall (now discharged to deep water). The study will measure the impact of past and present nutrient loading on biological productivity and will determine whether contaminants are being passed up the food web.

Scientists are also investigating the feeding behaviour of two migratory shorebirds (dunlin and western sandpiper) in the estuary and Boundary Bay. These nationally and internationally significant shorebirds rely on the Fraser delta as an overwintering site or as a migratory stop-over. They feed upon invertebrates found in the intertidal sediments all along the delta — sediments that exhibit elevated contaminant levels in some areas. Scientists are measuring invertebrate contaminant levels and studying the shorebirds' feeding habits to determine their exposure to contaminants from this area.

Wood Products Industry

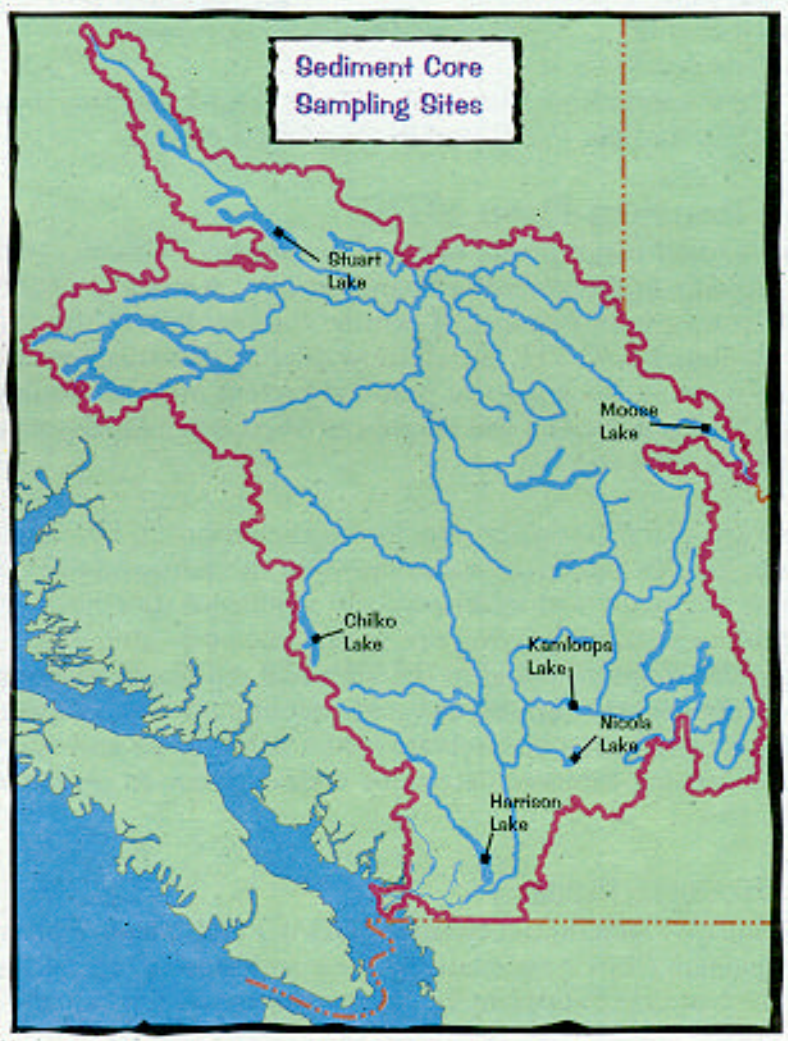
Didecyldimethyl ammonium chloride (DDAC) and 3-iodo-2-propynyl-butyl carbamate (IPBC) are relatively new anti-sapstain chemicals that replace the banned chlorophenols. Scientists are testing fish and inverte-

brates to assess the effect of DDAC and IPBC on survival, behaviour, stress and reproduction. The results will be used to develop Canadian Water Quality Guidelines for protection of aquatic life.



Atmosphere

Not all contaminants have local origins. Global air currents carry airborne pollutants from faraway sources to the Fraser basin, where they are deposited in rain and snow. The contribution of the atmospheric contaminants to pollution of the Fraser basin is being assessed through a study of sediment cores collected from headwater lakes — Moose, Stuart, Chilko and Harrison lakes. These lakes have no known local sources of pesticides, metals or other pollutants. Cores from these lakes will be compared with those from Kamloops and Nicola lakes — two lakes with local pollutant sources. The data derived from these analyses will identify the importance of atmospherically derived pollutants to the basin and provide an indication of when the contaminants were deposited in the lakes.



How will the information be used?

Results of the Environmental Quality Program provide a baseline of ecosystem conditions within the Fraser River basin. This information equips managers with a sound, scientific basis for making wise and effective management decisions regarding the Fraser River ecosystem. In particular, this information can be used to:

- develop tools for measuring and predicting consequences of environmental management efforts and proposed developments;
- develop targets (e.g., water quality objectives) to protect designated water uses;
- promote sustainability by catalyzing a process for developing ecosystem objectives; and
- prioritize and focus pollution cleanup.

photo courtesy of Tourism B.C.

The Fraser River near Steveston

Predictive Modelling

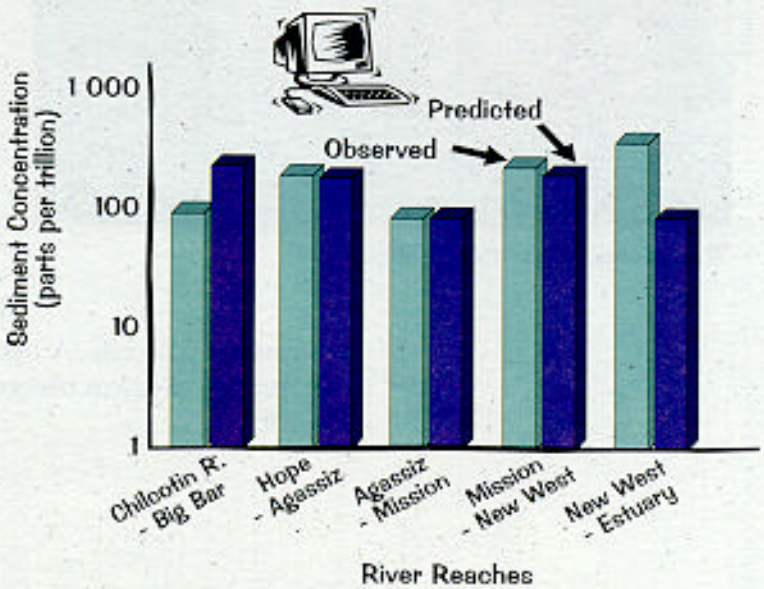
The information collected by the Environmental Quality Program is being used to develop predictive tools to enhance environmental management.

A computer model is being developed to predict contaminant concentrations in water, sediment, air and fish based on contaminant discharges. The model's predicted contaminant concentrations in the different ecosystem compartments match well with field observations. It will be an effective tool for predicting the effects of abatement strategies on chemical contamination in the river.

A new computer application is being tested in Langley's Salmon River basin (a FRAP demonstration watershed) — the development of a knowledge base to facilitate informed decision-making by stakeholder groups. The Salmon River basin was chosen for this project because a geographic information system (GIS) which contains current information on land use, environmentally sensitive areas, water use and quality and contaminant sources is already under development.

Under the Environmental Quality Program, the GIS will be completed and linked with simulation models to allow stakeholder groups to interactively explore the consequences of different development scenarios.

Observed vs. Predicted Furan Levels in Fraser River Sediments



Designated Water Uses:

- ❑ aquatic life
- ❑ wildlife
- ❑ drinking water
- ❑ water for livestock
- ❑ irrigation
- ❑ recreation & aesthetics
- ❑ industry

Water Quality Objectives

Water quality objectives are limits established to support and protect designated uses of a water body. In other words, they are targets for good water quality that are expressed as a numerical concentration or a narrative statement.

In natural areas or those planned for development, objectives are established to preserve water quality. In disturbed or polluted areas, objectives provide goals for cleanup efforts and are one tool for measuring the effectiveness of cleanup activities.

Some provincial lower Thompson River objectives:

Algae: 50 mg/m^2 chlorophyll a to protect use for recreation and aesthetics.

Faecal coliform: 10 per 100mL to protect use for drinking water

Water Quality Objectives are being developed jointly by Environment Canada and B.C. Ministry of Environment, Lands and Parks (BCMELP) for the Salmon River at Salmon Arm and the Fraser River from Moose Lake to Hope. In addition, Environment Canada and BCMELP are jointly revising the provisional Water Quality Objectives for the Fraser River from Hope to the estuary.

Ecosystem Objectives

Ecosystem objectives are a new concept in Canadian environmental management. These objectives will describe a desireable living environment (e.g., clean air, clean water, good jobs and a strong community) as defined by local stakeholders. The process requires that these stakeholders strike a balance among social, economic and environmental goals to achieve sustainability.

photo courtesy of B. Raymond

The Salmon River near Salmon Arm

The environmental information and predictive tools generated by the Environmental Quality Program will permit informed choices that support a sustainable community, economy and environment. The Program will also provide ecosystem indicators that stakeholders can monitor to evaluate abatement or restoration strategies and to estimate the consequences of proposed developments.

The Salmon River near Salmon Arm is a testing ground for this new management concept. Through the Salmon River Watershed Roundtable, stakeholders are working cooperatively to set ecosystem objectives. The involvement of these stakeholders in the decision-making process is crucial to obtain commitment and voluntary implementation of recommendations. A manual describing the step-by-step process for developing ecosystem objectives will be available following the completion of FRAP.

Local stakeholders restore streamside vegetation in the Salmon River basin near Salmon Arm

In the Salmon River near Salmon Arm, information on abatement of agricultural impacts by modifying traditional agricultural practices is disseminated through workshops and literature. Due to this effort, some ranches have voluntarily implemented a few recommendations, such as controlling grazing and restricting cattle access to streams.

In Conclusion...

Through initiatives such as those mentioned in this booklet, the Environmental Quality Program is helping to safeguard the future health of the Fraser River ecosystem. Experts from various scientific disciplines — geology, hydrology, chemistry, biology and toxicology —. are pooling their efforts to create a scientific foundation for evaluating the health of the Fraser River basin and making informed management decisions.

This report reflects the progress achieved at the mid-point of the Environmental Quality Program. A report summarizing the final results will be available following the completion of the program in 1998.

"Our mission is to be a catalyst to achieve and maintain a healthy Salmon River Watershed through coordinated management of all resources, respect for all concerns and cooperative, positive action." - Salmon River Watershed Roundtable.

Glossary

Abatement: the act or process of reducing

Acid mine drainage: the seepage of acid solutions from mines and their removed wastes; the acid is produced by natural reactions between exposed sulphide minerals, air and water

Algae: a large group of mainly aquatic one-celled or multi-celled plants, lacking true stems, roots and leaves

Ecosystem: the system formed by the interaction of all the living things of a particular environment with one another and with their environment

Effluent: liquid waste material (e.g., sewage) discharged to the environment

Estuary: where freshwater meets the sea

Food web: the transfer of food energy from plants (the base of the food web) through a series of organisms, by the process of eating and being eaten, to top consumers

Larva: an animal in some pre-adult stage of development

Leachate: a liquid that has filtered slowly through a solid and dissolved parts of the solid

Loading: a quantity of a particular chemical entering the environment, calculated over time (e.g., tonnes of chlorine per month)

Mayfly: a group of insects, the larvae of which are aquatic and the adult having large membranous, triangular forewings, small hindwings, and a slender body

Midge: a group of small two-winged flies, the larvae of which are aquatic, usually found in swarms around ponds and streams; midges resemble mosquitoes, but do not bite

Nutrients: substances containing phosphorus, nitrogen and potassium that are essential to the health and for the growth of plants

Organic: describing material originating from living organisms, or chemicals based on carbon and hydrogen

Organic carbon: carbon from an organic source

Part per million (ppm): one part in 1,000,000 parts

Part per billion (ppb): one part in 1,000,000,000 parts

Part per trillion (ppt): one part in 1,000,000,000,000 parts

Part per quadrillion (ppq): one part in 1,000,000,000,000,000 parts

Persistent toxic substances: substances that kill, injure or impair organisms, and endure a long time in the environment

Placer mining: the process of washing loose sand or gravel for gold or other minerals

River reach: a relatively uniform section of a river

Sediment: material such as sand, silt and clay that is suspended in moving water but will settle to the bottom in still water

Silviculture: the branch of forestry dealing with the cultivation and care of forests

Slough: a shallow, quiet backwater channel connected to some larger body of water such as a river, estuary, lake or sea

Stakeholder: an interested person or organization who has a share or a part in property or actions

Suspended solids: solids that can be filtered from water (e.g., algae or sediment)

Water chemistry: the science that deals with the behaviour of elements and simple substances in water

Environmental Quality Program Projects

A. BASIN-WIDE ASSESSMENT OF POLLUTION IMPACT ON AQUATIC QUALITY

Integrative

Summary of historical and current information on environmental quality in the basin; LGL Consultants (funding by DOE and DFO)

Bibliography on scientific information on the basin; H. Missler

Meta-data of organic contaminants in the Fraser River Basin; T. Fyles, U. Vic.

Fraser Basin Assessment Program: conceptual monitoring design.; D. Bernard, Environmental and Social Systems Analysts Ltd.

Inventory and review of quality assurance/quality control documents; S. Gormican; AXYS Environmental Consulting Ltd.

Discover Your Estuary book and educational kit; R. Kistritz; G. Moyle, DOE; M. Fearron Communications Incorporated

Wildlife

Estuarine cormorant seasonal movement study; P. Whitehead, DOE

Estuarine cormorant food-web interactions; R. Butler, P. Whitehead, DOE; K. Cheng, UBC

Candidate sentinel species studies: bald eagles; J.E. Elliot, DOE

Food-web interactions of western sandpiper and dunlin; M. Sewell, DOE\SFU

Aquatic riparian ecosystem structure and two southern interior streams of the Thompson River drainage; R. Vadas, DOE\SFU

Water

Analysis of water quality in the Fraser basin from 1985 to 1991; P. Shaw, DOE; A. El-Shaarawi, NWRI

Water quality in the Fraser River estuary, January 1993 to March 1994; FREMP

Benthos

Meta-data of benthos data for the Fraser River basin; T. Fyles, U.Vic.

Development of reference collection of biological samples for the basin; G. Green and J. Cosgrove, Royal British Columbia Museum

Benthic invertebrate community structure and function as indicators of ecosystem health; T. Reynoldson and K.Day, NWRI; D. Rosenberg, DFO; V. Resch, U. California, Berkley; J. Richardson, UBC

Sediment

Sediment transport pathways in the lower Fraser River and identification of deposition areas for contaminant sampling; P. McLaren, GeoSea Consulting Ltd. (funding through DOE, Canadian Coast Guard, Geological Survey of Canada and GVRD)

Determination of sediment deposition zones in the Fraser River basin; Northwest Hydraulic Consultants

Survey of contaminants in sediments from 14 reaches in the basin; M. Sekela, DOE

Field and laboratory studies of transport and sedimentation of contaminants; M. Church, UBC

Suspended sediments and contamination plume interactions; G. Lawrence, UBC

In-river flocculation processes and transport characteristics; B. Krishnappan, NWRI

Fish

Movements of mountain whitefish in the upper Fraser system; J. McPhail, UBC

Database on the distribution of Fraser River fish for sentinel species development; J. McPhail, UBC

Distribution of toxaphene in burbot; C. Gray, DOE

Study on fish condition in selected sites in the basin; B. Raymond, DOE; J. Nener, DFO

Study of fish condition in the lower Fraser River, 1994; FREMP

DOE = Department of the Environment, DFO = Department of Fisheries and Oceans, UBC = University of British Columbia, SFU = Simon Fraser University, NWRI = National Water Research Institute, NHRI = National Hydrology Research Institute, BCMELP = B.C. Ministry of Environment, Lands and Parks, U.Vic. = University of Victoria, GVRD = Greater Vancouver Regional District

B. ASSESSMENT OF ENVIRONMENTAL EFFECTS OF SPECIFIC POLLUTION SOURCES

Integrative

The effects of pulp mill discharges on suspended sediment and water quality in the basin; M. Sekela, DOE

Study on atmospheric deposition of contaminants to a lower Fraser urban environment; W. Belzer, DOE

Non-point source contamination and ecosystem health: A case study of the Brunette River watershed; K. Hall and H. Schreier, UBC

Evaluation of agricultural non-point source pollution in the Sumas River basin; H. Schreier and K. Hall, UBC

Mesocosm technology for agricultural impact assessment; J. Richardson, UBC

Assessment of atmospheric input of heavy metals and persistent organic compounds to the upper drainage basin; R. MacDonald, DFO

Modelling the fate of contaminant discharges to Fraser River; F. Gobas, SFU

Benthos

Effects of pulp mill and STP effluent on benthic communities; J. Culp, K. Cash, F. Wrona, R. Robarts, L. Wassenaar and R. Lowell, NHRI

Long-term response of benthic communities at Iona Island after STP diversion and status of communities currently exposed to Annacis and Lulu STP effluent; P. Harrison, UBC; C. Levings, DFO

Metal bioavailability and accumulation in benthic biota in sediments near Iona Island; L. Bendell-Young, SFU

Fish

Effects of pulp mill effluent on resident fish species in the Fraser and Thompson rivers; W. Taylor, Waterloo; K. Munkittrick, DFO.

Development of a biochemical assay for the induction of cytochrome P450 1A1 as an indicator of exposure to halogenated hydrocarbons; S. Bandiera, UBC; R. Addison, DFO

Particulate MFO induction potential; P. Hodson and B. Krishnappan, NWRI

Wildlife

Effects of pulp mill contaminants on aquatic based wildlife: Swallow biomonitoring and analysis; L. Harding and P. Whitehead, DOE

Effects of pulp mill contaminants on aquatic based wildlife: Osprey reproduction and growth assessment in Quesnel and Kamloops; L. Harding and P. Whitehead, DOE

Effects of pulp mill contaminants on aquatic based wildlife: River otter and mink contaminant studies; L. Harding, DOE

Non-point source contaminant impacts on aquatic based wildlife: Amphibian ecology and toxicology in the Sumas River basin; L. Harding, DOE and S. Orchard, Royal British Columbia Museum

C. CHEMICAL CRITERIA DEVELOPMENT

Anti-sapstain toxicological studies; A. Farrell and C. Kennedy, SFU

Chlorophenol effects on the early development and growth of white sturgeon; A. Farrell, SFU

D. WATER QUALITY OBJECTIVES DEVELOPMENT

Water quality objectives for the Salmon River, Salmon Arm; F.Mah, DOE and G. Butcher, BCMELP

Water quality objectives for the Fraser River from Moose Lake to Hope; F. Mah, DOE; L. Swain, BCMELP

Water quality objectives for the lower Fraser River; F. Mah, DOE; L. Swain, BCMELP; FREMP

E. ECOSYSTEM OBJECTIVES DEVELOPMENT

Ecosystem objectives pilot project: Salmon River, Salmon Arm; F. Mah, DOE; G. Butcher, BCMELP, Salmon River Watershed Roundtable

Combining simulation models with GIS as a decision support system for multi-resource conflict resolution; H. Schreier, UBC

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Environmental Quality Technical Working Group

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Environmental Quality Program Partners

- B.C. Ministry of Agriculture, Fisheries and Food
- B.C. Ministry of Education
- B.C. Ministry of Environment, Lands and Parks
- B.C. Ministry of Forests
- B.C. Ministry of Small Business, Tourism and Culture
- B.C. Ministry of Social Services
- Department of Fisheries and Oceans
- Environmental Protection, DOE
- Fraser River Estuary Management Program
- Greater Vancouver Regional District
- National Hydrology Research Institute
- National Water Research Institute, Burlington
- Natural Resources Canada
- Pacific Wildlife Research Centre
- Royal British Columbia Museum
- Salmon River Watershed Round Table
- Simon Fraser University
- Transport Canada, Canadian Coast Guard
- University of British Columbia
- University of California, Berkley
- University of Victoria
- University of Waterloo