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# INTRODUCTION

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**The Fraser River Basin is British Columbia's largest river basin, occupying approximately one-quarter of the province's area. The river's headwaters originate in three major mountain ranges (the Rocky, Columbia and Coast mountains) and a large plateau that separates the coastal range from the others. The geological, climatic and landform diversity in this basin is so great that it includes 11 out of the 14 biogeoclimatic zones identified in B.C. After a journey of 1,375 km from its farthest headwaters, the river empties into the Strait of Georgia in the Vancouver metropolitan area, the most densely populated region of the province.**

The river and its basin occupy a special historic, political and socio-economic niche in the province. While salmon fishing and fur trading led to minor settlement and agricultural development around Fort Langley and New Westminster before 1855, the discovery of gold in the upper basin in 1856 provided the impetus to use the river's canyon as a path through the coastal mountain barrier (Hutchison 1950). The development of the interior's immense mineral, forest and agricultural resources followed, continuing through the last 140 years. The basin's present economy is still dominated by resource extraction, but now the highly urbanized population increasingly depends on the river to carry away its liquid wastes and on the basin's rivers, lakes and wetlands for recreation. Because of the Fraser basin's importance to the province, the federal government decided, in 1991, to assist citizens, industries and all levels of government in the development of new ecosystem management practices that would ensure the future sustainability of the basin's ecosystem and economy. All activities were coordinated through the Fraser River Action Plan (FRAP), jointly implemented by Environment Canada and the Department of Fisheries and Oceans between 1991 and 1997. This report describes the results of the Environmental Quality Program, one of the several programs that made up Environment Canada's FRAP initiative (Environment Canada 1998a).

## RATIONALE FOR THE ENVIRONMENTAL QUALITY PROGRAM

Developing ecosystem-based management practices requires quantitative measures of ecosystem health which can be used to identify components under stress and to measure the results of programs aimed at controlling these stresses. To this end, the Environmental Quality Program was designed to assess the basin's present aquatic ecosystem health and the stresses affecting it, and to develop indicators of stress for subsequent management. The program was focused on pollution stress as there were concerns that this stress, already evident in the basin, would lead to a rapid decline in the ecosystem's biological productivity and diversity. There was also a need to establish a baseline of conditions to track the performance of pollution abatement strategies implemented or recommended by the Pollution Abatement Program of FRAP (Environment Canada 1998b).

The signs that pollution problems were serious or warranted investigation included the following observations:

- The levels of dioxins and furans in fish caught downstream of pulp mills near Prince George, Quesnel and Kamloops from 1988 to 1990 exceeded the human consumption guideline (Mah *et al.* 1989; Dwernychuk *et al.* 1991). This observation and the well documented history of dioxin contamination in the eggs of great blue heron living in the estuary (Whitehead 1989; Elliott *et al.* 1989), many hundreds of kilometres downstream, confirmed the basin-wide dimension of this contamination.
- The rapid population growth, especially in Vancouver's eastern suburbs, where 600,000 people now lived, was resulting in dramatic increases in the discharge of primary-treated municipal wastewater treatment plant (WWTP) effluent into the river at Annacis Island. This location is just upstream of one of the most ecologically productive and habitat-rich environments in the basin: the estuary and its intertidal delta foreshore. In addition, areas served with combined storm and sanitary sewers were contributing a mixture of contaminants from street runoff and untreated domestic sewage (Schreier *et al.* 1991). These combined sewer outfalls (CSOs) were discharging to nearshore habitats, which are important for younger and more sensitive life stages of fish and invertebrates. Along with the growth in population was an even greater growth in vehicle traffic, which was resulting in greater loading of polycyclic aromatic hydrocarbons (PAHs), metals (copper, zinc, chromium, manganese) and petroleum hydrocarbons from street runoff (Hall *et al.* 1991).
- The lumber industry was using up to 600,000 kg per year of new antisapstain formulations in the Lower Fraser Valley. Unknown quantities of the active ingredients in these formulations were being lost to the river in stormwater runoff from sawmill yards. While the industry had recently replaced pentachlorophenol and then 2-(thiocyanomethylthio) benzothiazole with less toxic chemicals, such as DDAC (didecyl dimethyl ammonium chloride) and IPBC (3-iodo-2-propynyl butyl carbamate), the effects of these new chemicals on the estuarine environment were unknown.
- Riparian habitats had been substantially altered in many small tributaries by urban and agricultural development. There was evidence that fish, including salmon, were being increasingly stressed by modifications to the normal physical (flow, temperature, turbidity) and chemical (nutrients, organic carbon, dissolved oxygen) characteristics of the streams (Northcote and Burwash 1991). In addition, contaminants running off suburban and agricultural areas were becoming a significant problem (Schreier *et al.* 1991). These stresses were expected to increase with development and to affect populations of fish and benthic invertebrates. Indeed, one endangered fish species (salish sucker—a genetically distinct form of longnose sucker, *Catastomus catostomus*) now only occupied limited lengths of the headwaters of a few streams in the Lower Fraser Valley (McPhail 1987).
- Finally, contamination of fish in remote lakes by persistent organic pollutants had emerged as an issue in the Rocky Mountains of British Columbia (Donald *et al.* 1993) and in southern Yukon (Kidd *et al.*

1993). Surprisingly high concentrations of polychlorinated biphenyls (PCBs) and toxaphene had been measured in top-predator fish from some of the lakes in these areas. The studies suggested that these pollutants could be transported via the atmosphere from industrial and agricultural areas in North America and Asia and then deposited in these drainage basins. It was not known how widespread this phenomenon was or if deposition rates would be even higher closer to potential sources in the basin or North America.

As the preceding observations indicate, the Fraser was showing signs of stress brought on by contamination from many point and non-point sources. While these problems were the result of past development practices which were being improved, the extent and intensity of urban, industrial and agricultural development was expected to increase over the next 25 years. It was imperative then to obtain an accurate assessment of contaminant stress levels in the basin's aquatic environment. Additionally, there was a need to understand the transport and fate processes that would allow the prediction of which ecosystem components were most at risk from any new contaminant releases to the basin. Both the assessment and the predictive capability were needed to ensure the effective prioritization of pollution abatement and prevention programs by environmental planning and management agencies in the basin.

## PAST ASSESSMENTS AND RESEARCH

During the last 25 years, many studies have examined the impacts of specific contaminants in several reaches of the river or the cumulative impacts of many contaminants in a single reach (*e.g.* Federal-Provincial Thompson River Task Force 1976; Fraser River Estuary Study Steering Group 1979; Carey and Murthy 1988; Swain and Walton 1991; Bothwell *et al.* 1992 ). Most of these studies were reviewed and included in a comprehensive assessment of contamination from point and non-point sources by Hall *et al.* (1991) and Schreier *et al.* (1991). These two reviews highlighted several knowledge gaps that needed to be addressed to generate practical science-based environmental management information. They recognized the importance of characterizing and quantifying non-point source pollution, the critical need for effects-based assessment techniques, and the lack of understanding of the cumulative effects of contaminants. These reviews provided the foundation for designing the Environmental Quality Program.

## OBJECTIVES OF THE FRAP ENVIRONMENTAL QUALITY PROGRAM

The Environmental Quality Program set out to answer the following questions about the present and future impacts of contamination in the Fraser basin:

1. What is the relative level of contaminant stress and how is it expressed in media concentrations and biological responses at the species, population and community levels?
2. What contaminant or classes of contaminants are responsible for the stress?
3. Are these contaminants exceeding available guidelines, criteria or objectives for the protection of aquatic life and other uses and are these adequately protective? If a guideline or an objective is not available for a contaminant, should it be developed?
4. Are present pollution abatement programs addressing the contaminants responsible for stress in the system and has the ecosystem responded positively to recently implemented abatement programs?
5. On what sub-basins or ecosystem components should ambient environmental assessment focus in the next decade?

6. Are there new indicator species, biotic communities or media components that would improve the assessment of the level of contamination and its impact on aquatic ecosystem health?

7. Are there better ways to evaluate the impacts of complex effluents in large rivers than the upstream-downstream comparison approach?

Of course, many environmental scientists working in this river basin over the years have asked similar questions. In this instance, FRAP provided the opportunity to apply new techniques and analytical tools on a much larger geographical scale and in a more interdisciplinary manner. Of even more importance, these new studies were undertaken over a relatively short time, making the assessment the first comprehensive "snap-shot" of contamination and its effects that has ever been attempted for the Fraser River and many of its tributaries.

## Organization of the research and assessment projects

In order to generate the data and knowledge on the present status of contamination impacts and processes controlling contaminant fate and effect, the program was organized into three components.

The first component assessed the level of contamination in water and sediments in the Fraser main stem, its estuary and its major tributaries (Thompson and Nechako rivers); assessed its impact on specific species or communities; and developed new knowledge on sediment dynamics and fish movements in the basin. This assessment investigated tissue or whole-body contaminant concentrations, enzyme measures of contaminant exposure, abnormalities, growth and condition factors, and reproductive success in fish and wildlife. In addition, benthic macroinvertebrate community structure was determined at sites selected to represent most river orders and ecozones throughout the basin. The strategy for this component was developed, in part, from the results of a workshop, held in December 1992, involving federal, provincial and municipal environmental management agencies and university scientists (Bernard *et al.* 1993).

The second component assessed the impacts of specific sources of pollutants, particularly those from pulp mills, municipal WWTPs, urban areas, agriculture and the atmosphere.

The contaminant impacts from pulp mill effluents, and how to assess them, were discussed at a workshop held in April 1992. The recommendations from this workshop (Marmorek *et al.* 1992), which were largely implemented, included an examination of (a) the interaction of effluents and natural suspended sediments, (b) the impacts on benthic communities in the field and in mesocosms, (c) contaminant exposure and effects in fish and birds, and (d) the development of a contaminant fate model.

Assessing non-point source contaminants and their impacts in small tributaries in urban and agricultural areas was discussed extensively during the development of the Tri-Council Eco-Research study proposal submitted by the University of British Columbia to assess ecosystem functioning in the Lower Fraser Valley (Healey 1992). Selected research projects undertaken on three watersheds in the lower Fraser were enhanced with additional funding from FRAP. Other studies examined the impacts of agricultural runoff on amphibians and the effects of non-target pesticides on raptors.

The impacts of municipal WWTP effluents were assessed "retroactively" through a research project conducted to evaluate the recovery of the northern delta foreshore ecosystem following the diversion of Vancouver's WWTP effluent from the intertidal area to a deeper area 4 km offshore. Towards the end of the program, other WWTP effluents and downstream waters were analyzed for the potential endocrine disrupting chemical, nonylphenol, and other contaminants.

Finally, a project was undertaken to evaluate the extent and trends of atmospheric deposition of contaminants in headwater lakes through the examination of sediment cores and top predator fish.

The third component developed toxicity information and guidelines for contaminants that were identified as being of potential concern in the early stages of the program. A major effort was mounted to assess the toxicity of the two recently introduced antisapstain chemicals (DDAC and IPBC) on fish and invertebrate species living in the basin. A preliminary toxicity study of selected chlorophenolics and resin acids associated with pulp mill effluents was also undertaken.

The 22 chapters comprising this report are organized in five sections, the first being the introduction. Section 2 reviews contaminant sources. Section 3 contains ten chapters that summarize contaminant exposure and effects in the basin, sediment transport processes, and the development of biological indicator species and communities. Section 4 focuses on specific sources of contaminants, such as pulp mills, antisapstain facilities, agriculture and urban runoff, and their effects on the ecosystem. Guidelines for antisapstain chemicals and selected chemicals associated with pulp mill effluents are discussed, and a contaminant fate model is also included. Section 5 presents an integration of all the results, conclusions and recommendations found in the report.

Environmental scientists with appropriate expertise from Environment Canada, Fisheries and Oceans Canada, several universities and the private sector undertook the research and participated in its synthesis. The Environment Canada - Pacific and Yukon Region scientific resources for assessing aquatic pollution and wildlife contamination were heavily involved throughout the program. Major contributions to the program were provided by the Burlington and Saskatoon laboratories of Environment Canada's National Water Research Institute and by the Institute of Resources and Environment at the University of British Columbia. The coordination and development of the program was facilitated through three program workshops (Landucci 1995; Landucci and Hanawa 1996) and several sub-component workshops held during FRAP.

The Environmental Quality Program faced many scientific and organizational challenges during its planning and implementation stages. In the end, the greatest challenge was scientific, not organizational, as the techniques and approaches available to the scientific team could not fully answer every question listed earlier in this introduction. However, we believe the comprehensive assembly and synthesis of the new knowledge, generated by the program and summarized in this report, constitute a valuable legacy for environmental management in the Fraser Basin as well as other river basins in the region.

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