Fraser River Basin
Strategic Water Quality Plan

Middle & North Fraser Region

Middle Fraser, Nechako, Stuart-Takla, Upper Fraser, and Quesnel Habitat Management Areas

Fisheries and Oceans Canada
Pêches et Océans Canada
Fraser River Action Plan
Plan d'action du Fraser
Canada

Fraser River Basin Strategic Water Quality Plan

Middle and North Fraser Sub-basin:

Middle Fraser, Nechako, Stuart-Takla, Upper Fraser, and Quesnel Habitat Management Areas

by

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Executive Summary

The Middle and North Fraser Habitat Management Areas encompass a very large area and some extremely productive fish habitats, including the spawning grounds of the famous Stuart River and Horsefly River sockeye salmon. The Middle Fraser HMA provides a migratory corridor for numerous runs of all five anadromous salmon species, both as juveniles heading towards the sea, and as adults returning to spawning grounds. It also has numerous small tributaries that collectively support all five species of anadromous salmon. The Nechako, Stuart-Takla, and Upper Fraser HMAs support two species of anadromous salmon, sockeye and chinook. The Quesnel HMA supports sockeye, chinook, pink, and coho populations.

The Middle and northern Fraser HMAs contain three large urban/industrial centers, which are Prince George, Williams Lake and Quesnel. Prince George and Quesnel are both located adjacent to the Fraser River at the confluence of major tributaries (the Nechako and Quesnel Rivers respectively). There are numerous small towns along the Fraser Mainstem and tributaries, and apart from these settlements the HMAs are sparsely populated.

A large number of data were available for several sites in the Fraser River mainstem in the Middle and Upper Fraser HMAs. However, there has been relatively little water quality sampling of salmon-bearing watersheds in the other HMAs addressed here, with the exception of a few of the larger tributaries. Because water quality data were not available for many of the salmon-bearing tributaries, assessments of potential impacts to these systems were largely based on land use information.

The largest urban/industrial centers generate both point sources and non-point sources of impacts to water quality, and negatively affect fish habitat. The largest permitted discharges from the HMAs include effluents from five pulp mills (three near Prince George in the Upper Fraser HMA and two at Quesnel in the Middle Fraser HMA), and treated sewage from Prince George. All of these effluents are discharged to the Fraser River mainstem. The pulp mill effluents were formerly of concern due to the persistent organic contaminants that they contained. Primary production is limited by the high suspended sediment levels that are characteristic of the river, hence nutrients present in these effluents are not considered problematic. Temperature may be one of the main outstanding water quality issues associated with the pulp mill effluents today. Very large volumes of effluent are discharged continuously, at up to 38°C. During some summers water temperatures in the Fraser mainstem reach levels that cause significant pre-spawning mortality in salmon. Any warming influences on the river should be treated with concern when river temperatures are resulting in pre-spawning mortality.

The 23 salmon-bearing watersheds of the Middle Fraser HMA have experienced relatively little human development. Consequently, the water quality of few of these Fraser River tributaries were considered to be significantly affected. Of these streams, four are considered to be significantly impacted by urban development, in addition to the Fraser mainstem, and three are significantly impacted by logging. Narcosli Creek is the only salmon-bearing stream in the HMA with significant impacts from agriculture. Ten of the 23 streams had very low natural summer low flows. Fortunately, with the relatively low level of human development there are not excessive demands for water within the HMA, which would exacerbate natural low flow problems.

Water quality sampling in the Middle Fraser HMA has largely been focussed on the Fraser River mainstem and the San Jose River watershed. Numerous other sites have been sampled a relatively small number of times, usually in the vicinity of a permitted waste discharge to surface waters. For many of the salmon-bearing tributaries to the Middle Fraser HMA water quality data were not available at all, and assessments were based on information available about land use.

In the Middle Fraser HMA efforts should be directed at maintaining the integrity of salmon-bearing watersheds, as well as protecting existing flows in streams that experience natural low flow problems by limiting water withdrawals and protecting the natural hydrology of these systems.

Within the Nechako HMA there are twelve salmon-bearing streams in addition to the Nechako River mainstem. Water quality sampling of the Nechako River has been relatively extensive downstream from Fort Fraser, both geographically and in terms of the number of samples collected at several of the sampling sites. Some data were also available for the Endako watershed, but little or no data were available for other salmon-bearing watershed in the HMA.

Both the hydrology and water quality of the Nechako River have been significantly affected by the damming of the headwaters. Impoundment of the headwaters results in relatively low suspended sediment levels in released water. In addition, water released from the Skins Lake Spillway tends to be relatively warm during summer months. Warm water releases combined with reduced flows result in Nechako River water temperatures that are dangerously warm for salmonids during summer months. The apparent accumulation of mercury in some fish species in the Nechako Reservoir is also of concern.

Urban and industrial development affect water quality and fish habitat of the Nechako River at Vanderhoof and Prince George. Agriculture significantly impacts water quality and fish habitat in some areas of the Nechako and Chilako systems. Natural summer low flows are considered problematic for fish in three tributaries to the Nechako, and two of these three also experience further pressure on flows from water withdrawals.

Timber harvesting is the most significant land use issue in the HMA, and impacts water quality and fish habitat in six of the 12 salmon-bearing Nechako River tributaries. There may be a need for increased enforcement action pertaining to forestry activities in the area.

The Stuart-Takla HMA supports some of the largest sockeye populations in B.C, as well as chinook salmon. Sockeye spawn in the numerous relatively small tributaries of the system, and rear in Takla, Trembleur, and Stuart Lakes. Much of the Stuart-Takla HMA is presently undeveloped, hence the water quality of few of the 44 salmon-bearing systems in the HMA are believed to be affected. Water quality data is very limited within this HMA. Some water quality sampling has been done in the area of Fort St. James. As little or no data were available for most of the salmon-bearing streams in the HMA, assessments of impacts to water quality were based almost entirely on land use information.

Urban and agricultural development, and water withdrawals do not significantly affect water quality in any of the salmon-bearing systems of the Stuart-Takla area. Very low summer flows in 33 of the 44 salmon-bearing systems give rise to the biggest water quality concern in the HMA, which is high summer water temperatures. DFO must work with other agencies and proponents to ensure that water withdrawals do not further aggravate summer low flow problems, and that the natural hydrology of these systems is not disrupted by land development.

The 38 salmon-bearing streams in the Upper Fraser HMA support mainly chinook salmon, however, the Bowron River also supports sockeye. The only large population center in the HMA is a portion of the City of Prince George. Several small towns are located adjacent to the Fraser River, however, there is very little human settlement in tributary watersheds.

Relatively few water quality data were available for the Upper Fraser HMA, except for the Hansard and Red Pass stations, which have been extensively sampled. Based on available land use information, none of the salmon-bearing tributary watersheds were considered to be affected by urban development, and only three tributaries were assessed as being significantly impacted by agriculture. Water withdrawals are not problematic in any of the salmon-bearing systems and in general, natural summer low flows are adequate to meet fish needs – except three which do experience very low summer flows. Compared with other land uses, timber harvesting exerts by far the greatest pressure on salmon streams in the HMA, with 15 of 38 streams significantly impacted by logging.

The Quesnel HMA contains 28 salmon-bearing streams, which collectively support chinook , pink, and coho salmon, in addition to large sockeye populations. Summer low flows are mostly adequate to support fish requirements, with only 3 of 28 systems experiencing summer low flow problems. Water withdrawals result in significant pressures on fish in two of the 28 streams.

The Quesnel HMA is sparsely populated. Apart from the City of Quesnel, there are only a few small towns within the HMA. The lower Quesnel River is the only salmon-bearing system with significant impacts from urban development on water quality and fish habitat, and these impacts are localized around the urban/industrial center of Quesnel. Agricultural development, primarily ranching, covers a significant portion of the land base within the HMA, but only three salmon-bearing systems are significantly affected by this land use.

Placer mining also affects fish habitat and water quality in the Quesnel HMA, mainly in Hixon and Naver Creeks. DFO is now working to promote education and awareness with proponents to reduce impacts of placer mining on fish habitat and water quality.

Timber harvesting is the predominant land use in the Quesnel HMA, and was determined to cause significant impacts to water quality and fish habitat in 9 of the 28 salmon streams. Logging activity was very intensive from 1990-1996, when the area harvested amounted to one-third of all the logging in the previous 30 years. Continuation of this rate of cutting may lead to harmful alterations of the hydrology in salmon streams, as well as an increase in the other types of impacts associated with logging.

Overall, the North Fraser HMAs have experienced relatively little human development compared to the Lower Fraser and Thompson HMAs. Furthermore, it is evident from water quality data and Stream Summaries for salmon-bearing systems in the more developed HMAs that current approaches to resource management are not adequately protecting water quality in a manner that ensures sustainable fish populations and healthy aquatic ecosystems.

In the Middle and North Fraser HMAs, there remains an opportunity to protect many salmon-bearing systems through watershed management approaches that proactively address cumulative impacts on water quality and fish habitat. Recommendations provided in Chapter 9 identify options for addressing existing water quality problems, and preventing development of further impacts. Effectiveness will fall short of the benefits of comprehensive watershed management without jurisdictional barriers.

Successfully protecting ecosystem integrity so that healthy fish populations are sustained will likely require a shift from resource-based management that typically seeks to maximize short-term economic benefits, to ecosystem-based watershed management approaches.

Degradation of water quality results from a complex interaction of human activities and land uses. Unfortunately, the control of these uses and activities is broken into many jurisdictions. Agencies make decisions daily about matters that can have a direct influence on water quality and aquatic habitats without consideration being given to ecosystem sensitivity. To properly manage water quality, a long term and integrated approach is required. The structures necessary to implement such an approach are inadequate or non-existent.

Protecting and/or restoring the ecological integrity of watersheds to sustain healthy fish populations requires multi-agency cooperation and political will. It also requires strong public support to pressure all levels of government for change, for example a shift towards ecosystem management, and improved practices from all of the stakeholders. While the negative effects resulting from the actions and choices of individuals may be small, collectively the impacts of human activities on water quality and fish habitat can become large. Significant efforts to educate the public about how to minimize their impacts on water quality and aquatic habitats will be key to protecting existing water quality and fish habitat values in the Middle and North Fraser HMAs.

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List of Acronyms

ACA	ammoniacal copper arsenate
AEPC	Agriculture Environmental Protection Council
ALR	Agricultural Land Reserve
AOX	adsorbable organic halide
ARDA	Agriculture and Rural Development Agreement
BACT	Best Achievable Control Technology
BCCA	B.C. Cattlemen's Association
BCFA	B.C. Federation of Agriculture
BIEAP	Burrard Inlet Environmental Action Program
BMP	best management plan
BOD	biological oxygen demand
CCA	chromated copper arsenate
CEAA	*Canadian Environmental Assessment Act*
CEPA	*Canadian Environmental Protection Act*
COD	chemical oxygen demand
CORE	Committee on Resources and the Environment
CSO	combined sewer overflow
DFO	Department of Fisheries and Oceans
DOE	Environment Canada
ECA	effective clearcut area
EEM	Environmental Effects Monitoring
EIA	Effective Impervious Area
EMS	Environmental Monitoring System
FPAO	Fraser Pollution Abatement Office (DOE)
FRAP	Fraser River Action Plan
FREMP	Fraser River Estuary Management Program
FRPSI	Fraser River Point Source Inventory database
GCM	global climate model
GIS	Geographic Information System
GVRD	Greater Vancouver Regional District
GVWD	Greater Vancouver Water District
HMA	Habitat Management Area
IC_{25}	Inhibition Concentrations causing a 25% reduction in the number of young produced relative to controls
IDZ	initial dilution zone
IPM	Integrated Pest Management
LC_{50}	Lethal Concentration causing 50% mortality
LRMP	Land Resource Management Plan
LRUP	Local Resource Use Plan
LWMP	Liquid Waste Management Plan
MAF	B.C. Ministry of Agriculture, Foods and Fisheries
MDAA	*Mine Development Assessment Act*
MDRC	Mine Development Review Committee
MELP	B.C. Ministry of Environment, Lands and Parks
MEMPR	B.C. Ministry of Energy, Mines and Petroleum Resources
MMLER	Metal Mining Liquid Effluent Regulations
MOF	B.C. Ministry of Forests
MOH	B.C. Ministry of Health
MOTH	B.C. Ministry of Transportation and Highways
NFR	nonfilterable residues (total suspended solids)
NOEC	No Observed Effect Concentrations
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
PEAA	*Provincial Environmental Assessment Act*
PMCC	Placer Mining Coordinating Committees
PMRA	Pest Management Regulatory Agency
PFZ	pesticide free zone
SISS	Stream Information Summary System
STP	sewage treatment plant
TSS	total suspended solids (nonfilterable residues)
WMB	Water Management Branch, B.C. MELP

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Appendix 1 General Background Information About Water Quality

Both physical and chemical parameters affect water quality. Most of these parameters interact with one another in determining the ability of water to support aquatic life. These parameters and the mechanisms by which they affect aquatic life are discussed briefly in this appendix.

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1 Suspended Sediment

All streams naturally carry loads of sediments, and levels fluctuate with stream flow. Disruption of natural sediment levels in aquatic systems is a common consequence of land-based activities that damage the integrity of riparian zones or alter runoff characteristics and hydrological patterns. Examples of such activities include urban development, agriculture, logging, placer mining, gravel removal, and many others.

Altering sediment inputs often has impacts on both habitat and water quality. Smothering of the natural substrate is the major impact on habitat and occurs when suspended sediments settle. Alterations to substrate materials can negatively affect populations of fish food organisms. Settling of fine sediments degrades fish spawning habitat, and impairs survival of fish eggs by reducing the amount of oxygen which reaches eggs during the incubation period.

Suspended solids reduce the penetration of light through the water column, thereby impacting primary production and reducing production of fish foods. Any changes in seasonal levels of suspended sediments in a system can impact the entire food chain. CCME Guidelines for the Protection of Aquatic Life are based on this potential impact, and state that suspended sediment should not be added to a system in amounts exceeding 10% of natural background levels which are greater than 100 $mg \cdot L^{-1}$, or 10 $mg \cdot L^{-1}$ where natural levels are less than 100 $mg \cdot L^{-1}$.

Very high suspended sediment levels may cause physical damage to fish gills. Fish species which rely heavily on vision for feeding may experience reduced efficiency of food capture if suspended sediment levels increase. Fish may avoid waters with high suspended sediment levels, resulting in effective reduction of available habitat.[1]

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2 Hardness

Hardness is a term used to describe the level of dissolved calcium and magnesium salts present in water. When hardness is in the range of 0 $mg \cdot L^{-1}$ to 60 $mg \cdot L^{-1}$ (expressed as $CaCO_3$) water is generally considered to be "soft". When hardness is in the range of 60 - 120 $mg \cdot L^{-1}$ it is considered moderate, and in the range of 120 - 180 $mg \cdot L^{-1}$ it is considered to be hard. Greater than 180 $mg \cdot L^{-1}$ is very hard. The global mean hardness of river waters is about 50 $mg \cdot L^{-1}$. When hardness is very low (20 $mg \cdot L^{-1}$) aquatic productivity is usually also low, due to a lack of nutrient minerals which are required for primary production. Such low levels of dissolved ions may also cause fish to experience osmotic stress. In addition to supporting higher levels of primary production, water with moderate to high hardness provides opportunities for contaminants to bind with ions and precipitate out of solution, thereby reducing bioavailability of non-desirable substances.

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3 Temperature

A thorough review of water temperature issues pertaining to fish was recently prepared by Levy, and forms the basis of the following discussion.[2] Water temperature is an extremely important component of water quality as it affects aquatic life through a variety of mechanisms. Water temperature is critical to survival of eggs, rearing juvenile fish, and adult salmon returning to spawning grounds. It also controls developmental times for fish eggs and benthic invertebrates. The two are usually synchronized in streams such that timing of alevin emergence is linked with food availability. In lakes, temperature conditions can affect thermal stratification and turn-over, which in turn can have a large effect on productivity. The assemblages of fish in the Fraser River are generally adapted to cold water conditions and are therefore very sensitive to warm waters.

Land-use activities that involve land clearing such as agriculture, forestry, and urban development have significant impacts on temperatures of surface waters.[3-5] Loss of riparian vegetation can increase both daily water temperature fluctuations, and average water temperature. An average increase in stream temperature of 6.7°C is reported for a stream section without riparian vegetation compared with an upstream shaded section.[6] Brownlee, *et al.* report daily temperature fluctuations of up to 8°C compared with 2°C at the upstream reference site.[7] The discharge of effluents from industrial processing, and industrial cooling waters can also have measurable localized effects on water temperature.

Theories about global warming lead to additional concerns regarding the warming of surface waters. Many tributaries of the Fraser River experience critically high temperatures during hot summer months, sometimes resulting in fish mortalities. The temperature of the Fraser mainstem has also reached very high levels in recent years (> 20°C in the summers of 1992 and 1994), causing concern with regard to pre-spawning mortality of all returning salmon species.

Virtually all fish, except a few marine species, are ectothermic animals and their body temperature is determined by the temperature of the surrounding water. Behavioural mechanisms provide the major means of body temperature regulation available to fish and other ectotherms (i.e. swimming to warmer or cooler water).[15] Altered temperature regimes are believed to have two types of impacts of fish, those being direct effects on metabolism and behaviour,[8] and exacerbation of impacts resulting from other stresses such as contaminants and disease.[4] Temperature effects upon acute toxicity of chemicals appear to depend both on the fish species and pollutant involved.[2]

Juvenile salmonids generally prefer and tolerate slightly higher water temperatures in comparison with adults of the same species. Mortality of juvenile pacific salmon species occurs when temperatures reach 20 - 25 °C. Preferred temperatures are in the range of 8 - 15 °C. A number of variables can influence thermal tolerance, including thermal history, seasonal and photoperiodic effects, geographical distribution, and ontogeny.[4] Studies have demonstrated that the preferred temperatures of fish often coincide with temperatures which optimize physiological function.[8]

Other ecological factors may potentially override the importance of temperature in determining fish distribution in the environment. For example, predation pressure may strongly influence salmon behaviour in freshwater, overriding physiological selection pressures, and causing salmon to occupy waters where the temperature is higher or lower than optimal.

Predation by freshwater piscivores is believed to exert an important structuring influence on fish communities in both lakes [9, 10] and streams.[11] With higher aquatic temperatures, prey fish have more opportunities to encounter "hungry" predators (rather than satiated ones) because, other things being equal, all ectotherms need to consume more food in warmer water in order to satisfy their metabolic requirements.[12] Thus, piscivore-induced mortality rates could conceivably increase under higher temperature conditions. Empirical studies on northern squawfish *(Ptychocheilus oregonensis)*, an abundant predator of juvenile salmon in the Fraser River watershed, suggest that stomach evacuation rates are directly related to environmental temperature.[13] Thus higher aquatic temperatures might serve to increase salmon mortality rates through increased piscivore predation.

It is evident that warming of aquatic systems could potentially affect salmon populations in the Fraser River watershed in several ways. First, extreme high temperatures can cause mortality directly where salmon encounter high temperatures at or above their limits of thermal tolerance. Secondly, shifts could occur in the thermal structure of aquatic habitats such that physiological performance of fish is compromised (e.g., growth rate). Thirdly, there are a number of indirect ecological changes with increased temperature (e.g., increased predation, increased susceptibility to parasites and pathogens, increased food abundance) that could profoundly affect salmon populations. Such ecological responses are difficult to predict, and might be positive or negative from a fish production standpoint.

It is crucial to protect the thermal integrity of the many small streams and larger tributaries of the Fraser as these provide much of the habitat used by salmonids for spawning and rearing, and also ultimately contribute to regulating the temperature of the Fraser mainstem. Small streams are very vulnerable to altered temperature regimes as a result of land clearing and loss of riparian vegetation.

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4 pH

The hydrogen ion concentration of water is typically presented as a pH measurement (-log 10 $[H^+]$). The pH range of 6.5 - 9.0 is considered adequate to protect aquatic life.[14] The pH range which is not acutely lethal to fish is 5.0 - 9.0, and different species have different optimum pHs within this range.

A gradual deterioration of water quality occurs as pH strays from the normal range for an aquatic system. In addition to direct effects on aquatic organisms such as affecting osmoregulation, changing pH can exert indirect effects by altering the bioavailability of toxic substances. Many metals, for example, are toxic at fairly low concentrations, and most metals become more soluble as pH declines. Altering pH will also affect speciation of ions, and some ionic species are much more toxic than others. Ammonia toxicity is strongly pH dependent for this reason, toxicity increasing with pH. The sensitivity of aquatic systems to changes in pH is determined by their buffering capacity. Acidic inputs from industrial effluents, non-point source runoff, and acidic rainfall can all affect pH of receiving waters.

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5 Contaminants

The fate and effect of different chemicals in the environment is largely determined by their physical and chemical properties, and the physical, chemical, and biological properties of the receiving environment.

The two general categories of contaminants are organic contaminants consisting primarily of carbon, hydrogen and oxygen, such as dioxins, furans, resin acids, PCBs, and PAHs, and inorganic contaminants such as metals, and nutrients like various forms of nitrogen and phosphorous. Some substances such as trace metals are required in low concentrations by aquatic organisms for normal growth and development, as they are components of particular enzymes, but have negative impacts at higher concentrations. Nutrients are essential for all levels of every food chain, but high levels in aquatic systems cause eutrophication. For the purpose of this report, the term contaminant is defined as a substance occurring in the environment at levels which exceed natural background concentrations for the aquatic system.

Factors to consider in assessing the potential of a substance to harm aquatic biota include:

5.1 *Acute toxicity*

Acute toxicity is measured with standard laboratory assays (bioassays) known generically as LC_{50}s, which measure the concentration of a substance that kills 50% of test organisms in a specific time period.

5.2 *Non-genetic sublethal effects*

This category includes changes in growth, development, reproduction, pharmacokinetic responses, pathology, biochemistry, physiology, and behaviour. Any of these sublethal effects can cause lethality indirectly through increased susceptibility to predation and disease.

5.3 *Genotoxicity*

Genotoxicity is a measure of the ability of a chemical to produce any of the three following effects, which all reflect damage to DNA:

a. **Carcinogenicity:** the ability of a substance to cause cancer as ascertained with experimental tests or human exposure data;

b. **Mutagenicity:** the ability to cause hereditary changes in cells, determined by tests on bacteria, cell lines, or whole organisms;

c. **Teratogenicity:** the ability to cause abnormal development of a fetus, determined with experimental tests or exposure data.

5.4 *Persistence in the environment*

This is measured by half-life, or the time required for 50% of the initial concentration to be eliminated. Substances are removed by a combination of mechanisms including biodegradation, volatilization, and photo-degradation. Persistent substances can accumulate in biota to toxic levels, even with relatively low loading to the environment. Dioxins and furans are well known examples of chemicals which bioaccumulate to harmful levels in aquatic biota.

5.5 *Bioaccumulation*

Substances which bioaccumulate can be present at very low concentrations in water and sediments, but reach harmful levels within biota. The potential for a substance to bioaccumulate can be measured directly in the laboratory, estimated from field measurements, or inferred from the octanol/water partitioning coefficient. The half-life of a substance in aquatic biota provides a measure of the potential for tissue contamination to persist after organisms are no longer exposed to the substance of concern.

The fate of chemicals in aquatic systems determines to some extent their bioavailability. Highly soluble substances will dissolve and remain in the water column until removed or degraded by biota, or other processes such as precipitation, photolysis, hydrolysis, or oxidation. Many dissolved chemicals are freely available to organisms in the water column, as they will pass readily across gills and other permeable body surfaces.

Strongly hydrophobic substances may float in a layer on the surface of the water, or bind to particulates (suspended sediments) and hence be not directly available to biota. Particulates with their bound contaminants may eventually settle out in sediment depositional zones, and be taken up by biota either through incidental ingestion of sediment particles, or through direct uptake from interstitial water, where contaminant concentrations can be high (contaminants will reach a dynamic equilibrium between bound and dissolved state, depending upon their chemical properties and environmental conditions).

The fates and mechanisms of action of contaminants on organisms varies widely among contaminants, and species exposed to substances of concern. Contaminants which are not chemically reactive and not lipid soluble may be simply be excreted. Non-polar substances which are persistent such as dioxins, furans, and PCBs, may accumulate in various tissues or organs, usually fat or liver. Some chemicals such as PAHs will be metabolized into other compounds that can be more or less toxic than the parent compound. Contaminants may have more than one mechanism of toxic action, depending upon the concentrations organisms are exposed to. The same substance may exert lethal effects through one mechanism at high concentrations, and long-term sublethal effects at lower concentrations. In addition, consequences of exposure to contaminants may depend upon other environmental conditions such as dissolved oxygen levels, water temperature, pH, and the presence of other contaminants leading to synergistic effects. Detailed explanations regarding the mechanisms of action of specific contaminants are beyond the scope of this report, however, appropriate references will be provided.

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Parameter	SEAM code	Guideline	For the Protection of:	Guideline Source
Sediments				
PAHs				
Acenaphthelene	PA01	0.01 μg·g^{-1}	Aquatic life	Environment Canada
Acenaphthylene	PA02	0.01 μg·g^{-1}	Aquatic life	BC MELP
Anthracene	PA03	0.02 μg·g^{-1}	Aquatic life	Environment Canada/St. Lawrence Action Plan
Benzo(a)anthracene	PA04	0.05 μg·g^{-1}	Aquatic life	Environment Canada
Benzo(a)pyrene	PA05	1.0 μg·g^{-1}	Aquatic life	BC MELP
Benzo(ghi)perylene	PA07	0.1 μg·g^{-1}	Aquatic life	BC MELP
Benzo(k)fluoranthene	PA08	0.24 μg·g^{-1}	Aquatic life	BC MELP
Crysene	PA09	0.1 μg·g^{-1}	Aquatic life	BC MELP
Fluoranthene	PA11	0.02 μg·g^{-1}	Aquatic life	Environment Canada
Fluorene	PA12	0.01 μg·g^{-1}	Aquatic life	Environment Canada
Indeno(1,2,3-cd)pyrene	PA13	0.07 μg·g^{-1}	Aquatic life	BC MELP
Naphthalene	PA14	0.02 μg·g^{-1}	Aquatic life	Environment Canada
Phenanthrene	PA15	0.03 μg·g^{-1}	Aquatic life	Environment Canada
Pyrene	PA16	0.49 μg·g^{-1}	Aquatic life	BC MELP
Organochlorine pesticides				
Aldrin	A002	2 ng·g^{-1}	Aquatic life	Environment Canada/St. Lawrence Action Plan
alpha-Chlordane	C011	na		no guideline/80th %ile not calc.
gamma-Chlordane	C012	na		no guideline/80th %ile not calc.
DDD	D025	8 ng·g^{-1}	Aquatic life	BC MELP
DDE	D023	5 ng·g^{-1}	Aquatic life	BC MELP
DDT	D026	8 ng·g^{-1}	Aquatic life	BC MELP
Endosulfan I	E040	na		no guideline/80th %ile not calc.
Endosulfan II	E041	<0.001 ng·g^{-1}		80th percentile
Endosulfan Sulphate	E042	na		no guideline/80th %ile not calc.
Endrin	E007	1 ng·g^{-1}	Aquatic life	Environment Canada
Methoxychlor	M016	na		no guideline/80th %ile not calc.
Toxaphene	T014	na		no guideline/80th %ile not calc.
Fish Tissue				
PCBs				
Total PCB		2 μg·g^{-1}	Aquatic life	BC MELP
Dioxins, Furans				
Total T4CDD	T060	na		no guideline/80th %ile not calc.
Total O8CDD	O101	na		no guideline/80th %ile not calc.
Total T4CDF	T062	na		no guideline/80th %ile not calc.
Total O4CDF	O102	na		no guideline/80th %ile not calc.
Pesticides				
p,p'-DDE (246)		5 μg·g^{-1}	Humans	Environment Canada
Total Toxaphene		0.1 μg·g^{-1}	Humans	Environment Canada
Coplanar PCBs				
PCB #77		na		no guideline/80th %ile not calc.
PCB # 126		na		no guideline/80th %ile not calc.
PCB #169		na		no guideline/80th %ile not calc.

Chapter 1 Introduction to the Fraser Basin Strategic Water Quality Plan

1.1 Background

The Fraser River is a major source of Canada's salmon production and produces more salmon than any other single river system in the world.[1] Historically, salmon production in the Fraser River watershed was approximately double present levels. Salmon habitat, including water quality, has been substantially degraded in parts of the basin over the past 100 years, contributing to the decline of salmon populations.

Concerns regarding declining salmon populations and other environmental issues led to the establishment of the Fraser River Action Plan (FRAP) in 1991, under the federal Green Plan program. FRAP was jointly administered by the Department of Fisheries and Oceans (DFO) and Environment Canada (DOE). The overall objectives of DFO's FRAP program were to:

1. Develop new partnerships with other agencies and the public to assist with achieving the goals of sustainable development;
2. Clean up pollution; and
3. Restore and protect the natural environment. DFO efforts focused on protecting existing fish habitat, and restoring and enhancing habitat in some areas of the Fraser Basin.

In order to identify and address pollution issues in the Fraser Basin, DFO undertook the development of a Strategic Water Quality Plan. The Plan was intended to:

1. Document and assess water quality conditions throughout the basin;
2. Identify areas where degradation of water quality may impact aquatic life, with a focus on salmon-bearing streams; and
3. Identify specific actions necessary to address the identified impacts to water quality, and where possible, implement programs to address these impacts.

The Water Quality Plan complements other DFO and FRAP initiatives which focus on physical fish habitat issues. In many cases the activities leading to impairment of water quality also result in impacts to fish habitat, and the solutions required to address both types of problems are the same.

To be compatible with these habitat management efforts and to make the task of developing this Plan more manageable, the Fraser Basin was addressed as fifteen Habitat Management Areas (HMAs) which largely reflect the watershed boundaries of significant Fraser River tributaries (Figure 1.1.1).

The Water Quality Plan is divided into four reports which contain the same introductory and background information and explanation of methodologies used to collect and interpret information, but address different groups of HMAs in detail and provide corresponding recommendations. Where recommendations address broad-based issues rather than problems specific to a watershed they are similar among the four reports.

The HMAs are grouped as follows:

Report 1: Lower Fraser River: Fraser Delta, Pitt-Stave, Chilliwack and Harrison-Lillooet HMAs;

Report 2: Thompson River Sub-basin: North Thompson, South Thompson, and Thompson-Nicola HMAs;

Report 3: Chilcotin Region: Seton-Bridge, Chilcotin, and West Road HMAs; and

Report 4: Middle and North Fraser: Middle Fraser, Nechako, Stuart-Takla, and Upper Fraser, and Quesnel HMAs.

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1.2 Developing the Plan

The Water Quality Plan is based on two types of information:

1. Actual water quality, as well as sediment and fish tissue contaminants data; and
2. Information about factors that may affect water quality including waste discharges, land uses, and stream flow information.

Water quality, sediment contaminant, and fish tissue contaminant data were obtained from the provincial SEAM database and Environment Canada's ENVIRODAT database as well as other limited data sources. All data were combined into one common geo-referenced database as part of a joint DFO-DOE FRAP project.[2]

Data were summarized and assessed on a stream-by-stream basis. Efforts focused on parameters commonly measured, often influenced by anthropogenic activities, and which have implications for aquatic life. The objectives of data assessments were to:

1. Identify the occurrence of water quality conditions which may be harmful to aquatic life;
2. Identify the disruption of natural levels of parameters in watercourses (e.g. pH, metals); and
3. Identify the presence of contaminants in watercourses which indicate pollution resulting from anthropogenic activities.

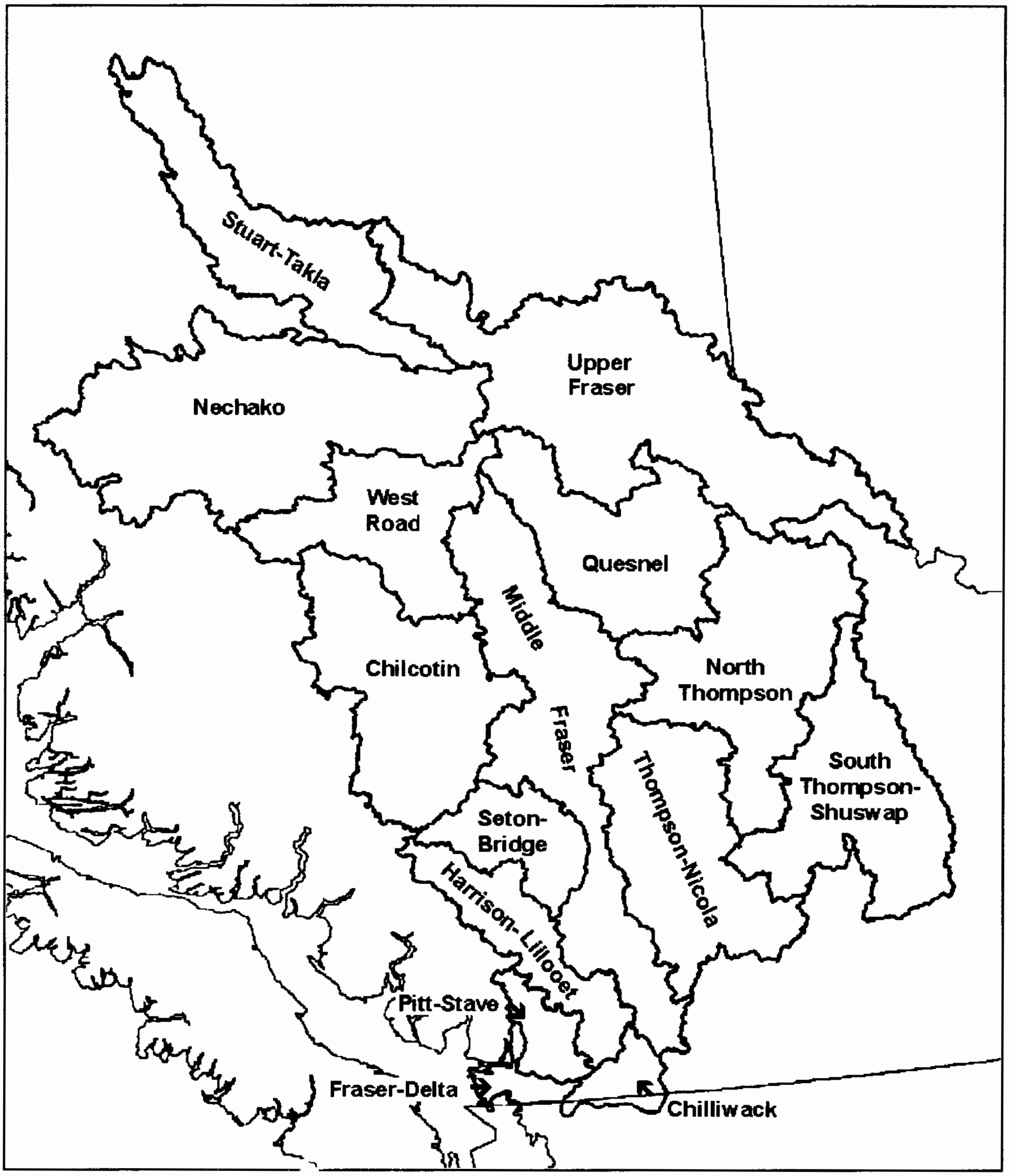
Contaminants may be substances that occur naturally, such as metals, and which may naturally exceed guideline levels considered to protect aquatic life. Some of these substances, such as zinc, copper and other trace metals, are actually required in small amounts by aquatic organisms for normal metabolism and development but are toxic at higher concentrations. These naturally occurring substances are only considered to be pollutants if anthropogenic sources cause levels in an aquatic system to exceed natural background levels, resulting in the potential for impacts to aquatic biota.

Other contaminants are chemicals which have only anthropogenic sources such as some of the complex chlorinated organic compounds.

Because many contaminants can become concentrated in different components of the environment, all available data pertaining to contaminant concentrations in sediments and fish tissues were addressed in addition to data characterizing conditions in the water column.

Water quality data are not available for many salmon-bearing streams in the Fraser Basin. Information about effluent discharges, land uses and stream flows was therefore used to assess the level of concern for water quality resulting from industrial, urban development, agricultural, and/or forestry activities in each salmon-bearing watershed. Information describing natural summer low flows and water withdrawals was included in stream assessments because stream flows can have a large influence on water quality and the sensitivity of streams to

Figure 1.1.1 Fraser River Habitat Management Areas



impacts. This approach facilitated assessment of the level of concern associated with both point and non-point sources of pollution, and also provided an explanation of the sources of some of the conditions measured in surface waters.

All of the information gathered was used to develop a summary of water quality issues in each salmon-bearing watershed in the Fraser Basin. The use of geo-referenced databases and a Geographic Information System (GIS) allowed for all of the water quality, effluent discharge, and land use information to be mapped for the entire Fraser Basin. The use of GIS techniques provided a basin-wide perspective on water quality issues, and greatly facilitated identification of priority problems both within the Fraser Basin as a whole, and within individual HMAs.

Building on the information collected, interpreted, and mapped, the Plan identifies recommendations for actions needed to address existing problems. Recommendations fall into two general categories:

1. What government agencies need to do differently to address short-comings of present approaches to protecting water quality; and
2. On-the-ground actions which are required to address particular problems.

Recommendations are intended to serve as a starting point for addressing water quality problems from a strategic level. Developing a detailed implementation plan goes beyond the scope of this report.

Numerous programs have been developed to address water quality and fish habitat issues at the "hands on" level as part of the FRAP program, and are at varying stages of implementation. An example is the Stewardship series (e.g. *Watershed Stewardship: A Guide for Agriculture*,[3] and *Stream Stewardship: A Guide for Planners and Developers*[4]). While tools, partnerships, and site-specific projects have been developed and/or implemented as a starting point to addressing many problems, the time-frame of the FRAP program was not sufficient to fully address all of the issues identified. Therefore, while many efforts have been made and much has been achieved, we still need to make much more progress to ensure that water quality and fish habitat are adequately protected to support thriving salmon populations in the Fraser Basin.

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1.3 The Audience

This Strategic Water Quality Plan is primarily intended to address a technical audience of resource managers, including individuals who do not have a strong background in aquatic biology or water chemistry. It should serve as an important planning tool for a broad spectrum of agencies and industries in the Fraser River Basin by identifying the larger documented salmon-bearing streams in the basin and their current status with regard to water quality impacts and pressures from human activities. It should also inform the reader about the types of impacts which DFO strives to avoid with any new or established development.

The Strategic Water Quality Plan should also serve as a useful tool for DFO staff by identifying the existing impacts and pressures on each known salmon-bearing watershed in the Basin, and the scope of these impacts at the sub-basin and watershed-wide level.

In addition to the water quality assessments and summary data this Plan provides brief overviews of six general sources of anthropogenic impacts on water quality in the Fraser Basin:

- urban development;
- forestry;
- agriculture;
- mining;
- industry/manufacturing in general; and
- impacts resulting from global human influences on the atmosphere.

These overviews are included to provide some context for the water quality summaries and recommended actions that follow.

With regard to planning specific developments, users of this report should assume that all streams are important fish habitat, even if they are not identified in the present report, until further inventory and clarification is obtained from DFO and MELP. Streams often have significant ecological value even if salmonids are not present. Also, as more sampling is done we continue to learn more about fish distribution in the Fraser Basin and the biological needs of those fish stocks.

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1.4 References

1 Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. 1889. 96 p.

2 Wainwright, P., B. Humphrey, W. Drinnan and M. Foy. 1995. Review of information on the environmental occurrence of chemical contaminants and conditions of environmental degradation in the aquatic environment of the Fraser River Basin, Volume 1, Final Report. Prepared for Environment Canada and the Department of Fisheries and Oceans - Fraser River Action Plan. DOE-FRAP 95-25.

3 Nener, J.C. 1997. Watershed Stewardship - A guide for agriculture. Department of Fisheries and Oceans and B.C. Ministry of Environment, Lands and Parks. 61 p.

4 Lanarc Consultants Ltd. 1994. Stream stewardship: A guide for planners and developers. Stream Stewardship Series. Department of Fisheries and Oceans, B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Municipal Affairs. 48 p.

Chapter 2 Point and Non-point Sources of Pollution in the Fraser Basin

2.1 Introduction

This general introduction to how different types of activities can affect water quality provides some context for how the land use information is assessed in the stream summaries provided within each of the HMA chapters, and also for the recommendations which follow in Chapter 7. It addresses five main types of land uses or activities which can affect water quality: manufacturing and processing industries; urban development; agriculture; forestry; and mining. A brief overview of two main atmospheric issues which are of relevance to the Fraser Basin, global warming and acid precipitation, and how they can influence water quality, is also provided.

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2.2 Manufacturing and Processing Industries

2.2.1 Introduction

The water quality concerns associated with manufacturing and processing industries generally relate to the discharge of processing effluents or cooling water to the environment. There are a wide variety of industries located in the Fraser Basin that discharge wastes into either the Fraser mainstem or tributary rivers and streams. Industries such as pulp and paper manufacturing, cement manufacturing, dry cleaning, petroleum and natural gas industries, breweries, fish processing, and food processing, are located in various parts of the basin, usually near a major urban center. The greatest number of discharges and diversity of industries is located in the Fraser Delta HMA, while there are only one or two industrial discharges to surface waters in some of the more rural and remote HMAs of the northern and western Fraser Basin.

2.2.2. Management of Discharges to Surface Waters

2.2.2.1 Federal Legislation

The general provisions of the *Canadian Environmental Protection Act* (CEPA) that address the "cradle-to-grave" management of persistent toxic substances, and the general provisions of the *Fisheries Act* (in particular Section 36), which prohibit the deposition of deleterious substances, apply to all discharges.

The *Fisheries Act* provides a broad prohibition from polluting waters with substances which are detrimental to fish, their habitat, their consumability, and the quality of the water in which fish reside. This *Act* remains one of Canada's foremost pieces of environmental legislation.

A relatively small number of industries, including pulp and paper manufacturing, mining, and petroleum refineries, must comply with specific liquid effluent regulations under the *Fisheries Act*. These regulations establish industry-specific national effluent quality standards and regulate maximum concentrations of specific parameters which may be present in effluents discharged to surface waters, as well as effluent monitoring and reporting requirements which the proponent must meet. The Pulp and Paper Effluent Regulations are unique in that they require dischargers to undertake Environmental Effects Monitoring (EEM) of the receiving environment in addition to effluent monitoring. The Environmental Effects Monitoring program was designed to test whether or not the effluent regulations are adequately protecting the receiving environment and aquatic biota downstream from mill discharges.

Environment Canada (DOE) has the lead administrative authority for the pollution prevention provisions of the *Fisheries Act* (Section 36), and addresses discharges largely from the perspective of pollution prevention and in-plant waste treatment technology. DFO maintains a strong support role in implementing Section 36 of the *Fisheries Act* because water quality is inextricably linked to the protection of biophysical fish habitat. In this role DFO provides expertise in biology, ecology, and toxicology to discharge issues.

Failure to comply with the *Fisheries Act* can result in fines of up to $300,000 for a first offence and $1 million for a second indictable offence. In extreme cases jail terms are a possibility.

2.2.2.2 Provincial Legislation

The discharge of wastes to the environment is managed primarily via the provincial *Waste Management Act*. Dischargers are required to obtain and abide by a Waste Management Permit, which specifies conditions under which wastes may be discharged to the environment. This permitting process is administered by the B.C. Ministry of Environment, Lands, and Parks (MELP).

2.2.2.2.1 Provincial Waste Management Permits

Provincial Waste Management permits in British Columbia are managed by MELP through a referral system which involves consultation with other regulatory agencies and provides proponents with "one window" access to the relevant agencies. MELP circulates applications for new Waste Management Permits and for significant amendments to existing permits to DOE for review. DOE involves DFO in the referral process if they believe a proposed discharge could potentially harm fish or fish habitat. DFO seeks to obtain compliance with the *Fisheries Act* by participating in this referral process. This "one-window" approach is intended to provide co-ordination among agencies, however, proponents are free to approach any agency directly for information.

The Fraser River Point Source Inventory (FRPSI) database details the conditions specified in every Waste Management Permit for every permitted waste discharge in the Fraser Basin.[1] Although DOE continuously updates the database, the version used here was updated to May 1995 only. According to this database, there are a total of 474 Waste Management Permits covering 239 discharges to surface waters (lakes, rivers, streams, or the Fraser Estuary) and 374 discharges to ground in the Fraser Basin. Permitted discharge volumes of various effluent types to surface waters are summarized in Table 2.2.1

For discharges to surface waters, Waste Management Permits typically limit the volume of effluent which can be discharged over a given time frame, as well as the maximum concentrations of selected parameters in each effluent.

MELP policy states that environmental protection managers must use Best Achievable Control Technology (BACT) as a starting point when establishing permit limits.[137] BACT-based discharge criteria are developed using: 1) scientific review of technical information on control technologies; and 2) stakeholder consultation involving industry, the public, government agencies, and others. This assessment and consultation process leads to discharge criteria for specific types of effluents (e.g. sewage treatment plant effluents). Actual discharge limits which are incorporated into individual waste permits may be more lenient or more strict than limits established under BACT policy, depending upon site-specific factors.[137]

Dischargers are usually required to submit effluent quality and quantity data at defined time intervals to the Pollution Prevention and Environmental Remediation Management Branch in regional MELP offices. Most effluent monitoring by the permit holder will be conducted at times suitable to the permit holder and may result in sampling under optimal rather than typical conditions. Monitoring frequencies as required in permits are usually widely spaced in time and would not be likely to capture transient pollution events such as might occur during plant wash down and other short-term events. The net biological effect of such transient events on fish populations may therefore be underestimated.

Monitoring requirements can apply only to the effluent and not the receiving environment, although major permittees are usually required to monitor both. Permittees may be required to monitor parameters in addition to those with discharge criteria specified in Waste Management Permits. Until recently effluent monitoring data were retained in staff offices, however, they are now incorporated into the MELP Environmental Monitoring System (EMS) database.

Table 2.2.1 Total volumes of permitted discharges of various effluent types to surface waters in the Fraser Basin.

Effluent type	Volume ($m^3 \cdot d^{-1}$)
Processing	1,028,694
Cooling water	124,466
Stormwater*	4,112
Sewage treatment plant	972,015
Leachate	12,542

* Only includes permitted stormwater discharges from industrial sites, not municipal stormwater discharges.

While there is a discharge auditing process, inspectors sometimes phone ahead before visiting a facility. This practice may result in an overly positive compliance record. Failure to comply with permit specifications for a discharge can result in a range of enforcement actions under the *Waste Management Act*, and placement on the provincial Non-Compliance Report.

There has been some discussion of MELP replacing Waste Management Permits for certain industrial dischargers with industry-wide regulations to control effluent quality. While this could be viewed as a more efficient way of managing industries and would reduce work loads for staff, it would also result in a lack of consideration for the site-specific conditions existing at each discharge location. Furthermore, the direction taken with the recently introduced B.C. Petroleum Storage and Distribution Facilities Wastewater Regulation (1994), raises concerns. This regulation replaced Waste Management Permit requirements addressing contaminant levels in stormwater runoff and other discharges from petroleum storage and distribution facilities, and in many cases resulted in a significant relaxation of the conditions dischargers are required to meet. Similarly, MELP is currently developing a Municipal Sewage Regulation which will ultimately replace permits for STPs, and which may not address DFO's concerns with regard to ammonia toxicity in sewage effluent.

2.2.2.3 Guidelines and Best Management Practices

The DOE Fraser Pollution Abatement Office (FPAO) was established under FRAP to develop and implement a pollution abatement strategy for the Fraser Basin. This group studied a number of industries considered to be likely pollution sources, to determine how they operate and to characterize their discharges and effects on the environment. Guidelines for improved management practices were then developed in partnership with the industries of concern, the objective being to reduce loading of pollutants to the Fraser River. As of May 1996, guidelines or Codes of Practice were developed to address the following: fish processors; the ready mix concrete industry; marinas and small boat yards; ship and boat building and repair industry; bulk terminals (through the Burrard Inlet Environmental Action Program [BIEAP]); woodwaste management; wood preservation facilities; antisapstain facilities; auto recycling; and commercial car and truck washes. In addition, a guide to industrial stormwater Best Management Practices (BMPs) was developed.

As Codes of Practice and BMPs were completed, DOE implemented inspection programs to assess the level of compliance, and worked with industries to improve compliance where necessary. While compliance is voluntary, the desire to avoid a regulatory presence, to strive towards demonstrating due diligence, and to attain a favourable reputation with the public encourages many operators to follow existing codes and guidelines. It should also be emphasized that adherence to such BMPs, codes, and/or guidelines may prevent the acquisition of substantive environmental and economic liabilities through the creation of environmental problems such as contaminated sites.

The DOE inspection program addresses compliance with federal regulations such as the *Fisheries Act* and *CEPA*, in addition to BMPs and guidelines. Results of DOE inspections conducted in each fiscal year are published by Environment Canada as part of their FRAP series.[2, 3] To date, their inspections program has addressed antisapstain facilities, wood preservation facilities, woodwaste management, pesticide use, mining, petroleum refineries, pulp and paper mills, and municipal sewage treatment plants. Some enforcement efforts have resulted from these inspections, as discussed in the two DOE-FRAP reports.

2.2.3 Effluent Discharge Quality - Case Studies

2.2.3.1 Effluent Characterization - A Study of Ten Industrial Facilities

An effluent characterization study was completed by DOE-FRAP[4] to investigate the chemical character and toxicity of effluents relative to terms specified under the associated Waste Management Permits, to estimate contaminant loadings to receiving waters, and to assess the acute and chronic toxicity of effluents.

Seventeen discharges from ten industrial facilities located in the Fraser Estuary were analyzed to document their chemical composition. Ten of these effluents were also tested for acute lethal toxicity using the water flea, *Daphnia magna* (48 hour) and rainbow trout (*Oncorhynchus mykiss*) (96 hour), and for chronic lethal and sublethal toxicity by measuring effects on survival and reproduction of the daphnid *Ceriodaphnia dubia* in 7-day tests. Results must be considered as a "snap shot" as only two samples of each effluent were collected.

Results of the wastewater characterization work showed that of the seventeen discharges sampled, one effluent was not covered by a permit and four effluents exceeded permit limits (Table 2.2.2) for one of the following: discharge volume, pH, or TSS levels. Two additional discharges slightly exceeded permit limits specified for oil and grease, however, the measured levels were not considered to be statistically different from permitted levels.

Results of *D. magna* bioassays revealed that three of the ten effluents tested were acutely lethal at concentrations ranging from 35 to 71% in each of the two or three replicate tests, although one sample was contaminated with seawater. Only four of the ten discharges passed all replicated bioassay tests (passing requires that more than 50% of the test population survive in 100% effluent concentration for the prescribed time period). The remaining three discharges yielded inconsistent results, with some replicates passing and others not. For eight of the ten effluents, more than 50% of the test fish populations survived LC_{50} rainbow trout bioassays in replicate tests, while two effluents showed inconsistent results between replicates. Of the seventeen permitted effluents only Scott Paper was required to routinely test for acute toxicity as a condition of its waste management permit. Toxicity testing is a requirement of the Pulp and Paper Effluent Regulations under the *Fisheries Act*.

Chronic toxicity tests with *Ceriodaphnia dubia* showed that each of the ten primary effluents caused significant impairment of reproductive success at concentrations ranging from 1% to 80% effluent. Results are difficult to fully interpret because in some cases less than half of the *Ceriodaphnia dubia* died, yet No Observed Effect Concentrations (NOEC), and Inhibition Concentrations causing a 25% reduction in the number of young produced relative to controls (IC_{25}) were extremely low (1%). Regardless, the overall result is clear; a significant proportion of discharges had some level of toxicity.

Examination of permit requirements shows that the substances considered to possibly contribute to observed toxicity based on wastewater characterization results, such as copper, zinc, viscosity, and others,[4] were usually not restricted under conditions specified in Waste Management Permits.

2.2.3.2 Fish Processing Plant Effluent

Existing effluent chemistry data from four fish processing plants was assessed and effluent from an additional four fish processing plants in the Fraser Estuary was collected for chemical analyses and toxicity testing using rainbow trout and *Photobacterium phosphoreum* (used in the Microtox® test) as the test organisms.[5] Considerable variation was found among and within processing plants in terms of effluent characteristics. While the annual contaminant loading from fish processing plants which discharge directly to the Fraser estuary is relatively small, study results suggest that environmental impacts may occur in the vicinity of outfalls due to high levels of BOD, COD, and ammonia in the effluent. Effluent toxicity was demonstrated at all plants, with the degree of toxicity observed varying on different processing days. Only four of nine effluent samples passed the 96 hour rainbow trout LC_{50} bioassay.

Study findings resulted in development of Codes of Practice for the fish processing industry, through a co-operative effort between the industry and the Pollution Prevention and Assessment Division of DOE. The resulting Code describes ways for fish processors to greatly reduce water use and improve the quality of effluent discharged. If all processors followed the guide, pollutants discharged by this industry could be reduced by up to an estimated 50%.

Table 2.2.2 DOE-FRAP assessment of waste Management permit compliance and effluent toxicity: A case study of ten industries.

Industry	Discharge Sampled	WMP Compliance	Exceedance**	Acute Toxicity (LC_{50})		Chronic Toxicity - *C. dubia*		
				Daphnia magna	Rainbow Trout	LC_{50} (%)	NOEC[1] (%)	IC_{25}[2] (%)
Lafarge Cement (1)	Non-contact cooling water & stormwater	No	Flow 3,106 $m^3 \cdot d^{-1}$ (2,950 $m^3 \cdot d^{-1}$)	NA	NA	NA	NA	NA
Lafarge Cement (2)	Non-contact cooling water & surface runoff	Yes		2/3 passed	2/2 passed	>100	25	51
Scott Paper Ltd.	Paper mill effluent	Yes		3/3 passed	2/2 passed	81	13	18
IFP Fraser Mills Ltd.	Non-contact cooling water & stormwater	Yes		0/2 passed	1/2 passed	55	25	38
MacMillan Bloedel (1)	Cooling water, boiler blowdown & runoff	*No	Oil & grease 6 $mg \cdot L^{-1}$ (<5 $mg \cdot L^{-1}$)	NA	NA	NA	NA	NA
MacMillan Bloedel (2)	Stormwater & kiln condensate	*No	Oil & grease 5 $mg \cdot L^{-1}$ (<5 $mg \cdot L^{-1}$)	2/3 passed	2/2 passed	>100	50	80
IFP Ltd. Hammond Cedar	Non-contact cooling water	Yes		NA	NA	NA	NA	NA
IFP Ltd. Hammond Cedar	Kiln condensate	Yes		NA	NA	NA	NA	NA
IFP Ltd. Hammond Cedar	Boiler blowdown	No	pH 9.06 - 9.49 (pH 6.5-8.5)	3/3 passed	2/2 passed	>100	1	2
Tree Island Industries	Process effluent	Yes		NA	NA	NA	NA	NA
Tree Island Industries	Non-contact cooling water	Yes		3/3 passed	2/2 passed	71	25	42
Domtar Inc.	Steam condensate	Yes		3/3 passed	2/2 passed	100	1	2
Tilbury Cement Ltd.	Non-contact cooling water	Yes		0/3 passed	2/2 passed	35	3	15
Tilbury Cement Ltd.	Ditch discharge (non-permitted)	No	Not permitted	NA	NA	NA	NA	NA
Hilinex Packaging Inc.	Effluent	Yes		0/2 passed	1/2 passed	59	13	16
Westshore Terminals	Runoff	Yes		1/3 passed	2/2 passed	71	<1	1
Westshore Terminals	Septic	No	TSS 194 $mg \cdot L^{-1}$ (TSS < 130 $mg \cdot L^{-1}$)	NA	NA	NA	NA	NA

Notes:

NA = not assessed.

* measured levels not considered to be statistically different from permit value.

** bracketed values indicate permit limits

1 NOEC = No Observed Effects Concentration

2 IC_{25} = the effluent concentration estimated to cause a 25% reduction on the mean number of young *C. dubia* produced, relative to the number produced by control animals.

Source: McDevitt, *et al.* 1993. (See reference 4)

2.2.3.3 Wood Protection

2.2.3.3.1 Heavy Duty Wood Preservatives

Heavy duty wood preservatives are toxic substances applied to wood to protect it from a range of organisms (i.e. fungi, insects, marine borers). There are 19 wood preservation facilities in B.C. using approximately 4,500 metric tonnes of wood preservation chemicals annually,[2] including: chromated copper arsenate (CCA); ammoniacal copper arsenate (ACA); pentachlorophenol (PCP); and creosote - a distillate of coal-tar consisting of some 160 chemicals including many polycyclic aromatic hydrocarbons (PAHs).[9] Results of a pesticide use survey conducted in 1991[143] indicate that chemicals used for wood preservation amounted to 61% of the total pesticides used province-wide.

PCP is chemically and biologically persistent and even low concentrations of PCP interfere with the basic metabolism of fish, leading to both short-term and chronic effects.[6] Acute toxicity to fish has been demonstrated at higher concentrations (30-150 ppb).[7] CCA and ACA are "fixed" to the wood through factory treatment to reduce the leaching of toxic ammonia and metal salts to the aquatic environment, but improperly treated wood will leach significant amounts of chemical.[8]

In B.C. creosote is commonly used to treat wood exposed to the marine environment. Approximately 5,000 to 7,000 m^3 of creosoted structures are used annually in marine construction in this province.[9] The persistence of compounds leached from structures treated with creosote, and the subsequent effects on aquatic organisms, are of concern. Studies have shown strong associations between exposure to creosote-contaminated sediment and the presence of lesions in the livers of fish.[10,11]

Guidelines have been developed for the design and operation of facilities which apply ACA, CCA, creosote, PCP, and thermal PCP to wood.[6, 12-14] Inspection of five B.C. treatment facilities by DOE in 1992/93 showed good implementation of most of the recommendations, however, there were deficiencies in fire and spill contingency plans, and in covered storage areas for freshly treated lumber. In other cases, legal actions were pursued under the *Fisheries Act.*[2]

2.2.3.3.2 Antisapstain Agents

Softwood lumber (except cedar) is subject to attack by micro-organisms, resulting in stains and blemishes which reduce the value of lumber. Antisapstain chemicals are often applied to freshly cut lumber at sawmills and lumber export terminals to prevent damage. A Code of Good Practice was developed in 1983, with the objective of protecting both the environment and the health of workers. A study of province-wide pesticide use in 1991 shows that antisapstain chemicals accounted for 17% of the total provincial pesticide use.[143] Inspections conducted by DOE showed three main areas of non-compliance with the Code: 1) fire and spill contingencies; 2) lack of proper covered areas to store freshly treated wood; and 3) poor sludge and waste handling practices.[2]

2.2.3.4 Pulp & paper industry

Potential physical and chemical impacts of pulpmill effluent on the aquatic environment include:

- localized low dissolved oxygen levels due to the addition of material with a high BOD;
- increased water temperatures which may attract fish to effluent plumes where effluent concentrations are high, especially during the winter;
- eutrophication from the addition of nutrients;
- decreased light penetration due to the dark colour of the effluent and floating foam; and
- sublethal effects, such as increased susceptibility of fish to disease.[144]

There are ten pulp and/or paper mills in the Fraser River basin: three at Prince George, two at Quesnel, one at Kamloops and four in the Vancouver area. One of the Vancouver mills (Newstech) discharges via the Annacis sewage treatment plant. Pulp and paper mills collectively account for 35% of the total permitted volume of liquids (including industrial and STP effluents, cooling water, stormwater and leachate) discharged to the Fraser Basin each day and 72% of the total permitted discharge volume of processing effluent daily, based on calculations using the FRPSI database.

Provincial Waste Management Permits set allowable discharge levels for temperature, pH, total suspended solids (TSS) content, dissolved oxygen level, BOD, and colour of mill effluents. Under the Pulp and Paper Effluent Regulations (1992) of the *Fisheries Act*, the federal government regulates TSS and BOD and also requires that effluents be non-acutely lethal at the point of discharge, as defined by rainbow trout and *Daphnia magna* LC_{50} bioassays. The acute lethality of pulp mill effluents is attributable mostly to resin acids and, to a lesser extent, fatty acids.[16] Secondary treatment significantly reduces the acute toxicity of pulp mill effluent by removing resin and fatty acids[16] and is required for all mills with direct discharges to surface waters in Canada.[3]

In the 1980's it was discovered that chlorinated dioxins and furans discharged with pulp mill effluents were accumulating in the tissues of fish, and the birds and wildlife which rely on fish as a major food source. Chronic exposure to dioxins, furans, and other chlorinated organic compounds may impair reproductive success of aquatic organisms, disrupt metabolism, cause developmental abnormalities, or affect behavioural patterns.[17] Dioxins and furans were also accumulating in tissues of some fish species to levels which were of concern from a human health perspective. Consumption advisories were therefore established for several fish species in different areas of the Fraser Basin. Consequently, under CEPA in 1992, new regulations were introduced to limit the discharge of chlorinated dioxins and furans from pulp and paper mills (Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations [1992] and the Pulp and Paper Mill Defoamer and Woodchips Regulations [1992]). Primarily in response to regulatory pressure, industry spent millions of dollars to make process changes. Mills reduced or eliminated chlorine bleaching, and stopped using contaminated feedstock and defoamers. Levels of chlorinated dioxins and furans in effluent have declined sharply since the late 1980s and early 1990s, and levels in fish tissues mirrored these changes. All consumption advisories which were in place on fish species in the Fraser River due to dioxins and furans have been lifted, as of January 1994.

2.2.4 Evaluation of Processes and Tools for Managing Discharges to the Environment

2.2.4.1 Waste Management Permit System

As part of the assessment of water quality issues in each Fraser Basin Habitat Management Area, the discharge criteria specified for each permitted discharge to surface waters in the Fraser Basin (obtained from the FRPSI database) were evaluated relative to the sensitivity of the receiving environment. Three types of issues emerged:

1. As observed in effluent characterization studies (Section 2.2.3), the loadings and concentrations of potentially harmful parameters likely to be present in specific effluents were not always restricted by permits and were not necessarily correlated with levels of other parameters that did have permit specifications. For example, several of the waste management permits for sewage discharges required chlorination and dechlorination, but did not specify a maximum concentration of total residual chlorine in effluent. Chlorine is highly toxic to fish, and the levels which may remain in improperly dechlorinated effluent can vary considerably. Also, the chlorine found in non-dechlorinated sewage effluent can be in the form of chloramines.[139] While these substances do not differ substantially in toxicity from free chlorine they are much more persistent. Other examples are provided in HMA overviews.
2. It appeared that the criteria specified for certain parameters in some waste management permits might not be restrictive enough to protect aquatic life in receiving waters. Summary tables are provided in HMA chapters indicating permits for which this type of concern exists. MELP is currently initiating amendments to some permits in order to better protect aquatic environments, however, limited staff resources mean that these changes will not happen immediately.
3. Provincial permits usually do not incorporate requirements that permit holders monitor their effluents to ensure that the effluents are non-acutely toxic. Of all authorized discharges to surface waters in the Fraser Basin only 42 (17.6%) are required to pass an acute toxicity test, according to the FRPSI database. Numerous effluents in the Fraser Basin may be in compliance with their Waste Management Permits but potentially in violation of the *Fisheries Act.*

These three types of issues reflect differences between the engineering perspective of MELP's Pollution Prevention and Environmental Remediation Branch, which has focused on pollution prevention from the perspective of best available technology, and DFO's approach as a resource management agency which seeks to prevent the degradation of water quality for the purpose of protecting aquatic biota.

Water Quality Objectives are normally established by MELP for surface waters of concern, as a means of protecting existing and future water uses, including use by aquatic life, in surface waters of concern. Where Objectives are being established for transboundary waters, Objectives are established jointly by MELP and DOE. For areas of the Fraser Basin for which Objectives were established between 1991 and 1997, DOE and DFO participated in this process as part of the FRAP program.

Agency policies on implementation of Water Quality Objectives demonstrate further differences in the approaches taken to protecting water quality by federal and provincial agencies. MELP's policy states that Water Quality Objectives do not have to be met in the Initial Dilution Zone (IDZ) of an effluent discharge, usually considered to be 100 m downstream from a discharge pipe and not exceeding 25% to 50% of the width of the water body.[18] Conversely, DFO and DOE do not accept reliance on the mixing capacity of receiving waters to dilute wastes to an "acceptable" level. DFO and DOE policy states that effluents should not be acutely toxic at the point of discharge, whereas MELP IDZ policy states only that acutely lethal conditions should not occur in the IDZ of a discharge. DFO and DOE have concerns about, and may oppose, any potential degradation of water quality which can harm fish or impair fish habitat. It is contrary to the *Fisheries Act* to deposit a deleterious substance into waters frequented by fish. Fish may not avoid degraded habitats and can actually be attracted into zones of effluent mixing, where they may be negatively affected.

An additional consideration for DFO in relation to "mixing zones" is that they often occur in the nearshore areas, which are preferentially utilized by juvenile salmon as nursery grounds. Accordingly, the actual exposure of fish to toxicants found in effluent discharges may be far greater than predicted by the use of anthropogenically defined "mixing zones".

2.2.4.2 Guidelines as Effective Tools for Protecting Water Quality

There has been increasing effort among federal agencies to work in partnership with industry to address environmental protection issues. Many of these efforts have resulted in development of non-enforceable "Best Management Practices" (BMPs) or guidelines. Results of DOE's Inspections Program show that good compliance often results from this type of approach.[2,3] Benefits include:

- industry gaining a better understanding of agency objectives; and
- agencies gaining a better understanding of industry constraints.

Increased communication has resulted in development of guidelines which are workable for industry and, if followed, reduce or eliminate impacts on the aquatic environment.

Results of follow-up inspections by DOE show generally good compliance with BMP-type guidelines. While a high level of voluntary compliance with BMPs is something to strive for, an enforcement role for regulatory agencies must be maintained.

Where follow-up work shows that industries are not complying with existing Codes, DOE and DFO generally initiate legal investigations leading to direct enforcement actions where warranted. DOE also works with MELP to ensure that performance objectives established in relevant Codes are incorporated into Waste Management Permits, so that they become legally enforceable.

2.2.5 Summary

Federal regulatory control over effluent discharges exists for a limited number of industries under the *Fisheries Act* and CEPA. In many cases, however, DFO and DOE rely on the general provisions of the *Fisheries Act* as a deterrence from polluting. This deterrence, and therefore the value of the *Fisheries Act* as a management tool, require that violations of the *Act* be diligently prosecuted.

Waste Management Permits are one of MELP's main tools for controlling effluent quality for the purpose of preventing pollution, however, in many cases they do not fully address the protection of aquatic biota. While staff from DFO, DOE, and MELP work together on permitting issues and have made considerable progress, there is still room to improve co-operation, and the level of protection achieved for the environment.

Cutbacks have resulted in agencies seeking to scale back their involvement in permit referral reviews. Work loads have increased in this area, but resources to address the demands have declined. While the *Fisheries Act* is largely "after-the-fact" legislation, the referral process affords DFO (and MELP) an opportunity to achieve pro-active control of pollution discharges.

The replacement of Waste Management Permits with industry-wide regulations should be considered with caution. Any new regulations should include provisions for addressing site-specific circumstances of discharge locations, and should not reduce the level of protection afforded to the environment by existing Waste Management Permits.

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2.3 Urbanization

2.3.1 Introduction

Water quality is affected by urbanization through the impacts of land clearing, the presence of numerous diffuse pollution sources, and the disposal of solid and liquid wastes. In addition, natural stream hydrology is disrupted by the replacement of natural areas with permeable soils with roads, buildings, parking lots, and other impermeable surfaces. The flow of surface and groundwaters is disrupted, and the potential for erosion, sedimentation and flooding is increased.

Less than 15% of the total area of the Fraser Basin is incorporated, with 48 municipalities. The population of the Fraser Basin was estimated to be 2.4 million in 1994, about 2 million of which lived in the Lower Fraser Valley. Approximately 76% of this population resides within the Greater Vancouver Regional District (GVRD). Of the 24 municipalities with populations of over 5,000 in 1991, 18 drain entirely into the Fraser Basin.[19] Four drain partly into the Fraser Basin and partly into Burrard Inlet (Burnaby, Coquitlam, Port Moody and Vancouver), and 2 (the City of Armstrong and the Resort Municipality of Whistler) discharge their sewage outside of the Basin while at least some of their stormwater runoff stays within the Fraser Basin.[20]

The population of B.C. is expected to increase dramatically during the next several decades, and in the Lower Fraser Valley is predicted to double by the year 2031. This anticipated population growth and urban development will be a significant source of impacts on water quality and aquatic habitat, particularly in the Lower Fraser Valley.

2.3.2 Impacts Resulting from Physical Alteration of the Land Base

Inadequate planning and precautions during land clearing and excavation associated with urban development can result in high sediment loads in surface runoff. Suspended sediment levels above background levels in streams will negatively affect all fish life stages, and can also have indirect effects on fish by reducing their food supply. Smothering of aquatic organisms and/or loss of aquatic habitat by sedimentation can occur where sediments settle out. Erosion of streambanks by increased volumes of runoff may not only add silt but can also alter channel morphology and destroy valuable habitat.

The clearing of streamside vegetation can result in increased summer water temperatures, which decreases the oxygen carrying capacity of water and increases the metabolic rate of aquatic organisms. An increased metabolic rate coupled with decreased oxygen concentrations in water can cause physical and physiological stress, possibly leading to death of aquatic organisms. Loss of riparian vegetation also affects physical fish habitat, and eliminates an important source of fish food - insects which drop from overhanging vegetation, and leaf litter, an important food source for many insects which in turn are consumed by fish.

The scale of these potential impacts is determined by the extent of land clearing, biophysical features of the land and the development practices used. Management practices recommended in the Federal/Provincial *Land Development Guidelines*[21] include a number of measures which are intended to benefit water quality such as detaining stormwater, minimizing exposure of disrupted soils to precipitation and runoff, retaining streamside vegetation, and the removal of sediment from runoff water prior to offsite discharge to the receiving waters.

2.3.3 Water Quality Issues Associated with Land Development

2.3.3.1 Hydrological Impacts

Urbanization has been described as the land use with the greatest impact per unit area on the hydrological regime of a watershed.[22] The replacement of the natural environment with impermeable surfaces such as roads, parking lots and buildings decreases water absorption by soils, the interception of precipitation by foliage, and evapo-transpiration from plants. This results in greatly accelerated surface runoff and increased peak flows during and following precipitation events. These changes in stream hydrology often lead to scouring of stream banks, bedload movement, and the destruction of fish eggs. Lower groundwater tables and stream levels in dry seasons also result and contribute to higher summer water temperatures.[23]

2.3.3.2 Contaminants in Urban Stormwater Runoff

The type and extent of runoff contamination is highly variable according to storm-specific conditions (i.e., rainfall duration, time between rainfall events, storm intensity).[23] Longer duration storms transport contaminants from more remote areas of the watershed, and higher storm intensities mobilize greater quantities of contaminants associated with particulates.

The intensity and type of land uses in a watershed (i.e., residential, commercial, industrial, open space) greatly influence the quality of runoff water. Runoff from residential, commercial and industrial areas usually has a high biochemical oxygen demand. Urban runoff typically contains nutrients and pesticides from lawn treatments, chemicals associated with petroleum products (components of car exhaust, oil), other fluids which leak from vehicles such as radiator fluid and windshield washer fluid, soaps and detergents from washing cars, and bacteria from animal feces (Table 2.3.1). During winter months runoff may also contain high concentrations of the salt applied to road surfaces to reduce slippery conditions.[138] Runoff from highways contains higher levels of lead and zinc than runoff from other urban areas.

Typically the runoff generated early on in a storm event and preceding the peak discharge will contain the highest concentration of contaminants, as accumulated contaminants are washed from land surfaces into stormwater.[22] Land development practices have traditionally included installation of stormwater infrastructure to quickly conduct stormwater to the nearest stream. Hence, this "first flush" phenomenon can result in extremely high contaminant concentrations in streams during the early part of a storm event.

Minimizing the impermeable surface area is key to addressing urban stormwater runoff problems, and should be the first step in managing stormwater. MELP has developed Urban Runoff Quality Control Guidelines to assist municipalities and regional districts in preparing management plans for stormwater.[23] The guidelines emphasize Best Management Practices for source control (i.e. modification of the polluting activity to eliminate production of the contaminants) and treatment of urban runoff (in cases where source control is unable to address environmental concerns). Stormwater treatment technologies include oil-water separators, extended detention dry basins, wet ponds, constructed wetlands, vegetated swale or filter strips, infiltration basins and trenches, porous pavement, porous storm drain lines, first-flush separators, and revegetation.[23]

In addition to stormwater runoff, storm sewers also carry short pulses of toxic substances which have been deposited illegally into storm lines, to sensitive aquatic environments. These substances can include chlorinated water from swimming pools and hot tubs, washwater from uncured concrete used to make exposed aggregate surfaces and improper wash-down of concrete delivery trucks, used motor oil, household pesticides, and many other substances. These transient events are rarely detected in routine surface water monitoring programs, however, they can have devastating effects on aquatic communities.

2.3.4 Water Quality Issues Associated with the Discharge of Sewage Effluent

2.3.4.1 Sewage Disposal in Urban Areas

Areas which have moderately or highly intensive urban development usually conduct sewage effluents to a central treatment facility, and subsequently discharge treated wastes into the environment.

2.3.4.2 Sewage Effluents

Polluting substances in urban wastewater include suspended solids, oxygen-consuming materials, metals and trace elements, organics, nutrients, ammonia, detergents and soaps, and micro-organisms. In industrialized centers, many operations discharge their process

Table 2.3.1 Pollutants typically found in urban stormwater and potential sources of contamination.

Pollutant	Potential sources	
Bacteria	•Animal feces, faulty septic fields, sewage overflows	
Suspended solids	•Exposed soils	
	•Organic & inorganic debris left on urban surfaces	
Nutrients - general	•Fertilization (golf courses, cemeteries, lawns)	
ammonia	•Landfill leachate	
Oxygen-demanding substances	•Decaying vegetation	•Landfill and woodwaste leachate
	•Animal wastes	•Sewage seepage
	•Chemical wastes	
Metals (dissolved & particulate)	•Motor vehicle operation	•Road salt
	•Copper water pipes	•Industrial discharges
	•Galvanized culverts	•Atmospheric deposition
	•Landfill leachate	•Illicit dumping
	•Pigments in paints	•Poor waste disposal practices
Oil & grease	•Motor vehicle operation	
	•Spills of oil and fuel	
PAH & other hydrocarbons	•Motor vehicle operation	•Creosoted structures
	•Burning of fossil fuels, and fuel spills	•Asphalt particles
	•Leaking underground fuel tanks	•Natural sources, combustion
Phthalate esters	•Leaching of plastic products	
Polychlorinated biphenyls (PCB)	•Stockpiled waste PCB	
	•Transformer leakage	
Pesticides	•Pest control (golf courses, cemeteries, lawns)	
	•Illicit dumping	
Anti-sapstain chemicals & heavy-duty wood preservatives	•Wood preservation and protection	
	•Railway ties	
Chloroform & napthalene	•Interaction between road salt, gasoline & asphalt	

Source: BC Research Corp. 1992. (See reference 23)

effluent to sanitary sewer systems. This can alter the chemical composition of sewage effluent to something quite different from that anticipated from domestic sewage alone. The use of chlorine to disinfect sewage effluent is relatively common, and chlorinated organic contaminants may be produced.

The potential effects of these contaminants in sewage effluent are described below:

1. **Suspended solids** can reduce light penetration through the water column, and when they settle, may smother benthic food-producing habitat, spawning habitat, and fish eggs.
2. **Oxygen-consuming** materials can reduce dissolved oxygen concentrations in the water column, which stresses or kills aquatic organisms. Organic solids consume oxygen from deposition zones where they settle and decompose.
3. Some **metal** and **organic contaminants** may be acutely lethal, depending upon their bioavailable concentrations. **Detergents** and **ammonia** may be present in toxic concentrations in effluent.
4. The addition of **nutrients** to aquatic habitats may result in excessive algal growth, which can smother benthic habitat and use up oxygen. Nutrients can also promote the growth of fungus in benthic environments.
5. **Bacteria** can be concentrated by filter-feeding shellfish, rendering them unfit for human consumption. Fish may be affected by efforts to kill bacteria via chlorination of the effluent, if adequate dechlorination is not achieved prior to effluent discharge.
6. **Residual chlorine** in chlorinated effluent can cause toxicity. Studies at two wastewater plants showed that dechlorination removes 87-98% of chlorine but the remainder is slowly reduced. Kinetic evidence suggests it may be present in the form of chlorinated organic amines and peptides. The hydrophobic nature of the remaining fraction suggests it may be harmful to aquatic biota.[139]

There are 33 municipal sewage treatment plants (STPs) which discharge into surface waters in the Fraser Basin serving approximately 83% of the Basin population (Table 2.3.2). The treatment technologies used are classified as primary, secondary, or tertiary based on the degree of removal of contaminants. Primary treatment facilities remove debris and floatables from wastewater. About 25-40% of 5-day Biochemical

Oxygen Demand (BOD_5) is removed, and approximately 35-65% of suspended solids (sludge) settle in sedimentation tanks[24] resulting in the removal of some persistent contaminants which are associated with the solids.

The distinction between primary and secondary lies mainly in the degree of removal of biochemical oxygen demand (BOD) and total suspended solids (TSS). Secondary treatment facilities utilize micro-organisms to remove additional amounts of these parameters.

Tertiary treatment targets the removal of a specific contaminant of concern, for example the removal of phosphorus from an effluent to protect a nutrient-sensitive receiving water body. Additional TSS may also be removed during the extended treatment, although it is not usually the focus of tertiary treatment.

The volume of sewage sludge produced increases with each level of treatment. Advances have been made in developing beneficial uses for sewage sludge, for example as a soil fertilizer and conditioner in reforestation efforts, and as a top soil in mine reclamation projects. If sludge contains high levels of potentially harmful substances such as heavy metals, sludge disposal can be problematic.

Wastewater treatment plants may treat effluents with chlorine to kill pathogens that may affect human use of the water receiving water course. Subsequent dechlorination is becoming a standard requirement to reduce effluent toxicity prior to discharge, however, some chlorine may persist as discussed above. The use of ultraviolet light to disinfect sewage effluent is gaining favour for STPs which have secondary treatment (the optical clarity of secondary effluent allows adequate light penetration). This approach eliminates concerns over malfunctioning dechlorination systems.

2.3.4.3 Industrial Discharges to Sewage Systems

Municipalities can accept or reject the discharge of industrial wastes to their sewage treatment facilities. Many municipalities in the Fraser Basin do receive industrial wastes and have implemented sewer use bylaws to define the quality of effluent which their sewage treatment system receives. These by-laws are considered generally ineffective due to inadequate enforcement.[26] Also, many of the industrial wastes discharged to sewage systems remain uncontrolled due to lack of regulation of specific industries or of the specific chemicals discharged.[26] The Annacis STP, operated by the GVRD, receives large volumes of liquid wastes from industry, however, it does have a relatively effective program to monitor the effluents received.

2.3.4.4 Combined Sewer Overflows

Combined sewer systems collect both urban stormwater runoff and sewage, and in some cases industrial effluent, and deliver this combination of liquid effluents to sewage treatment facilities. When there are large volumes of runoff the capacity of collection and/or treatment systems is exceeded and the combination of effluents overflow into the aquatic environment untreated. All fifty-three of the CSOs in the Fraser Basin are located in the GVRD.[26]

Contaminants from CSOs can affect the receiving environment in the vicinity of the outfall and can persist in the environment. Levels of bacteria and other pathogens are higher in the vicinity of these outfalls, especially during and shortly after precipitation events. Similarly, CSO discharges may add substantial quantities of solid material with high BOD levels, and persistent plastics.

2.3.4.5 Septic Tanks

Approximately 17% of the Basin population is not serviced by a municipal sewage treatment plant. Households and businesses in these unserviced areas discharge human wastes to on-site septic tanks and tile fields. Several types of conditions can result in septic systems impacting nearby streams. Problems are most likely to result when formerly rural areas experience significant population growth without establishing sewage treatment facilities. This is particularly true if soils are highly permeable, and facilitate the lateral movement of water and contaminants from tile fields to nearby streams. Similarly, septic discharges can result in contamination of unconfined aquifers in the long term. Many streams are fed by unconfined aquifers particularly during dry months, and contaminants from septic tanks are then released to streams via groundwater. Some areas serviced only by septic tanks have very high groundwater levels, which again facilitates the lateral transport of contaminants to nearby

Table 2.3.2 Sewage treatment statistics for the Lower Fraser region vs. the Fraser Interior, 1989. The data are derived from the 1989 Municipal Water Use Database.

	% population served		% volume treated	
Level of treatment	Lower Fraser	Fraser interior	Lower Fraser	Fraser interior
Discharge to septic system (ground)	10	27	-	-
Primary treatment	81	1	93.8	3.28
Stabilization ponds	5	10	6.2*	14.70
Secondary treatment	4	39	*	49.53
Tertiary treatment	0	23	*	32.49
Total population	1,500,574	211,712	-	-
Total volume ($m^3 \cdot d^{-1}$)	-	-	930,286	70,689

*6.2% of the volume treated receives a higher treatment level than primary.
Source: Environment Canada. 1989. (See reference 25)

streams.

Septic systems receiving greater than 22.7 $m^3 \cdot d^{-1}$ (5,000 gallons) require a Waste Management Permit while installation of systems receiving a lesser amount of effluent only requires a permit from the Ministry of Health (MOH). To obtain a MOH permit the applicant must show that certain criteria are met. These criteria are intended to prevent septic tank effluents from becoming a threat to human health but do not adequately address potential environmental impacts. One criteria addresses the minimum percolation rate of soils, with the objective of avoiding soil saturation. There are no criteria to address the extremely high percolation rates linked with impacts to groundwater and subsequently surface waters.

For systems permitted under the *Health Act*, there are no requirements to ensure the proper maintenance of septic systems, and in many cases people do not maintain their systems at all. Premature failure of the system often results. There are many reports of untreated sewage effluent from failed septic systems reaching streams in the Fraser Basin.[27]

Several brochures and a video on septic tank maintenance have recently been developed by DOE and volunteer organizations.

2.3.5 Water Quality Issues Associated With Disposal of Municipal Solid Wastes

Municipal solid wastes include residential, industrial, commercial and institutional garbage, and demolition, land clearing and construction debris. The Regional Districts have planning responsibility to address disposal of these materials under the *Waste Management Amendment Act* of 1989. In 1991, approximately 3.4 million tonnes of municipal solid wastes were generated in B.C. (Table 2.3.3). There are approximately 180 municipal waste landfill sites in the Fraser Basin according to a recently completed inventory.[28]

Landfills produce leachates containing contaminants that reflect the wide spectrum of wastes received. Leachate production can be controlled at landfills by diverting drainage waters around the site and by periodically covering wastes with impermeable materials.[29] Leachates may be collected and treated on-site before discharge to receiving waters or they may be discharged to a sewage treatment plant. There are some old landfills which still generate leachate that reaches surface waters untreated. DOE is currently developing a geo-referenced database of all closed and operating landfills in the Fraser Basin.

The B.C. *Waste Management Amendment Act* (1989) establishes regulatory authority to implement a range of policy tools at both the provincial and Regional District level. The *Act* requires Regional Districts (or municipalities outside of Regional Districts) to submit solid waste management plans to MELP for approval.

2.3.6 Other Sources of Water Quality Impacts

All water distribution systems experience some leakage and pipe breakage. Approximately 640 leaks and/or breaks occur in the Greater Vancouver Water District (GVWD) drinking water distribution system per year.[30] This results in the release of drinking water to numerous small streams near the supply lines for potable water. This is a concern if there are levels of disinfectants in drinking water that are toxic to aquatic life.

Chloramine, a drinking water disinfectant, is comparatively persistent and is toxic to fish. Water main breaks in Surrey resulted in fish kills when chloramine was used on a trial basis by the GVWD.[140] The GVWD has since discontinued the use of chloramine, and is establishing rechlorination systems which will have a reduced potential to negatively affect fish, while protecting public health. Chlorinated swimming pool or hot tub waters discharged into storm drains can be toxic to fish.[31]

Melt water from snow collected from highways and urban areas contains road salt, sand, metals, oils and assorted garbage. Snow is often dumped directly into the Fraser River or its tributaries and these contaminants can have adverse impacts upon aquatic organisms.

2.3.7 Regulation and Guidance of Land Development

Municipal governments have jurisdiction over land development within their boundaries. The *Municipal Act* also allows local governments to regulate stormwater disposal, cutting of trees, removal of soil and the placing of fill.[21] MELP developed the Urban Runoff Quality Control Guidelines[23] to assist municipal and Regional Districts in preparing stormwater management plans which would provide both effective drainage and protection of aquatic habitats.

At the same time, any projects that affect watercourses, whether fish bearing or not, require authorization from MELP, and activities which result in harmful alteration, disruption, or destruction of fish habitat can result in charges under the *Fisheries Act*, unless authorization has been granted by DFO.

Clearly there is considerable room for inter-jurisdictional conflicts with the present system as decisions pertaining to development of the land base often have impacts on streams in the watershed, yet agencies with responsibilities for managing the aquatic resources may not be provided the opportunity for input into land use decisions. While the *Municipal Act* enables municipal governments to pass bylaws addressing a broad range of environmental protection measures, most municipal governments have not developed bylaws which would

Table 2.3.3 Municipal wastes generated, recycled and residuals disposed of in British Columbia in 1991, by regional district.

Regional District	Population	Households	Waste disposed of			Waste recycled			Residual wastes		
			Total waste (tonne)	Per capita ($kg \cdot yr^{-1}$)	Per household ($kg \cdot yr^{-1}$)	Total waste (tonne)	Per capita ($kg \cdot yr^{-1}$)	Per household ($kg \cdot yr^{-1}$)	Total waste (tonne)	Per capita ($kg \cdot yr^{-1}$)	Per household ($kg \cdot yr^{-1}$)
Bulkley-Nechako	40,248	13,053	27,809	691	2,130	2,318	58	178	25,491	633	1,953
Cariboo	64,158	22,142	27,445	428	1,240	2,645	41	119	24,800	387	1,120
Central Fraser Valley	96,964	32,979	78,475	809	2,380	19,131	244	580	59,344	756	1,799
Columbia Shuswap	45,252	17,132	32,442	717	1,894	1,041	23	61	31,401	694	1,833
Dewdney-Alouette	99,307	33,692	49,151	495	1,459	13,420	135	398	35,729	360	1,060
Fraser-Fort George	95,171	32,803	73,439	772	2,239	4,629	49	141	68,810	723	2,098
Fraser Cheam	76,399	27,676	43,354	567	1,566	9,543	125	345	33,801	442	1,221
Greater Vancouver [1]	1,647,806	631,369	1,444,041	876	2,287	343,354	208	544	914,241	555	1,448
Squamish-Lillooet	26,922	9,685	39,327	1,461	4,061	978	36	101	38,349	1,424	3,960
Thompson-Nicola	112,131	41,127	106,782	952	2,596	12,030	107	293	94,752	845	2,304

Notes
[1] GVRD also reports - 1,016,250 DLC tonnes generated, 492,650 DLC tonnes recycled, 523,600 DLC residual tonnes. (DLC = demolition, land clearing and construction)
Adapted from: Resource Integration Systems. 1993 (See reference 32.) Population statistics from BC Stats, 1993 Municipal and regional district population estimates.

afford a significant level of protection to riparian zones, instream habitats, and water quality.

The DFO/MELP *Land Development Guidelines*[21] are designed to aid in the conservation of fish populations and fish habitat at pre-development levels by preventing impacts from occurring before, during, and after development.[21] The guidelines are not enforceable unless incorporated into municipal bylaws. Abiding by the guidelines greatly facilitates approval processes for developments near streams, which provides some incentive for compliance. A guide entitled *Stream Stewardship: A Guide For Planners and Developers,*[33] was jointly developed by DFO and MELP, and is complimentary to the *Land Development Guidelines.*[21] It promotes the protection of fish and fish habitat dur..g urban development through the use of local government bylaws to protect environmentally sensitive areas, and by promoting stewardship values.

2.3.8 Summary

Urban development is a significant source of water quality degradation in developed areas, and unless preventative measures are taken, new developments will contribute further to existing impacts. There are opportunities to address existing water quality and quantity problems associated with urban stormwater via public education programs which focus on source control and minimizing or reducing impermeable surfaces on private property. There may also be limited opportunities to address impacts associated with existing infrastructure (e.g. separation of sewage and stormwater collection systems or the construction of overflow containment tanks) on an opportunistic basis with redevelopment activities.

Preventing impacts to water quality with new developments presents a major challenge to DFO because of the number of agencies with divergent views involved with land use and resource management decisions. Prevention of further water quality impacts with urban development is a key issue particularly in the Lower Fraser Valley where population growth is booming, resulting in increasing pressures on the watersheds which collectively support 65% and 85% of Fraser River coho and chum populations, respectively.

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2.4 Agriculture

2.4.1 Introduction

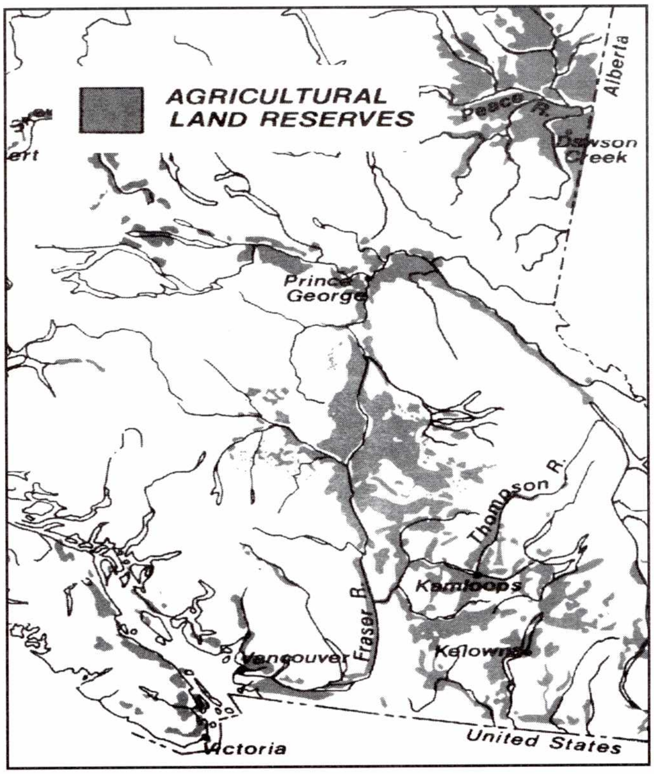
Agricultural activities are usually concentrated in valley bottoms where fertile soils are present and water is available for crop irrigation and livestock watering. The Agricultural Land Reserve (ALR) surrounds a substantial proportion of the Fraser River and tributary streams. This physical association between agriculture and surface waters (Figure 2.4.1) results in widespread potential for water pollution problems throughout farmed areas of the Fraser Basin unless precautions are taken to prevent impacts. Approximately 42% of the best arable lands and 69% of the best pasture lands in B.C. are located in the Fraser Basin, and about 50% of this land is fully utilized.[34] Despite the unfulfilled potential, agricultural development in the Basin is extensive, and has significant implications for water quality and quantity.

Most of the arable land is located in the Chilcotin and Middle Fraser areas, the Thompson sub-basin, and the Lower Fraser Valley. Cattle ranching is the predominant agricultural land use in the interior. Approximately 75% of B.C.'s 330,000 cattle are raised within the Kamloops and Cariboo Forest Regions.[133] Agricultural areas of the interior Fraser Basin also support production of a wide range of other products including ginseng, fruits, some vegetables, dairy, poultry, and ostriches.

Dairy, beef, hog, and poultry production are all significant industries in the Lower Fraser Valley. Fruit and vegetable crops are also produced in this area, including cranberries, raspberries, strawberries, cole crops, corn, potatoes, mushrooms, and turf. In general, agricultural practices in the Lower Fraser Valley are intensive in nature. Both pesticides and chemical fertilizers are used extensively in crop production.

Impacts to water quality from individual operations depend upon a range of factors including the type of crop, intensity of activity, physical features of the landscape, soil type, precipitation patterns, and precautions undertaken by the producer. Pollution generally results from non-point sources, which are difficult to monitor and quantify accurately because they vary widely with weather conditions

Figure 2.4.1 Location of Agricultural Land Reserves in the Fraser Basin.



and land-based activities such as spreading of fertilizer and manure. Impacts to aquatic systems are associated with erosion, excessive inputs of manure and/or fertilizer, and oxygen-consuming substances which result in low dissolved oxygen concentrations, and in some cases direct toxicity from substances such as ammonia from manure, and pesticides.

2.4.2 Impacts of Agriculture on Water Quality

The types of water quality problems commonly observed with different types of activities are described briefly below.

2.4.2.1 Ranching - northern and central areas of the Fraser Basin

Large areas of land are devoted to ranching in the central Fraser Basin, particularly in the Williams Lake and Thompson Basin areas. These areas are typically hot and dry during the summer, and cold with snow accumulation on frozen ground in the winter. There are a variety of impacts associated with ranching and the seasonal movement of cattle in these areas.

The most visible impacts on the aquatic environment are those associated with overwintering, when cattle are held in feedlots or seasonal feeding areas at fairly high densities, usually in valley bottoms in close proximity to streams. Significant amounts of animal waste accumulate on the frozen ground in these areas. During spring thaws, the wastes wash into nearby water courses, introducing large quantities of nutrients, fecal coliforms, biological oxygen demand (BOD), and toxic substances such as ammonia.

Spring runoff events which carry manure into streams can result in degraded water quality conditions that are harmful or lethal to fish. Although these severe conditions may be relatively short-lived (several hours or longer) or localized, they could potentially kill any fish present at the start of the runoff event. Runoff may stay in a relatively concentrated plume along the stream bank or shoreline, the areas most heavily utilized by juvenile fish. Dead salmon fry would not be easily seen in the fast-moving and murky waters; resulting fish kills would therefore likely go unreported.

The current Code of Agricultural Practice (1992) contains a number of specifications for confined livestock holding areas which aim to protect surface water quality from pollution. The Code addresses the location and management of these facilities, and prohibits livestock in confined holding areas from having direct access to a watercourse, with the exception of rangeland holding areas. Confined livestock areas are defined as outdoor, non-grazing areas where livestock, poultry, or farmed game are confined by topography, fences, or other structures (e.g. feedlots, paddocks, corrals, etc., but not including seasonal feeding areas).

Pollution problems can occur even when 30 m setbacks required under the Code for confined feeding areas are established, if runoff can reach a stream or lake. In a joint DFO-MELP study conducted in 1993,[35] runoff was found to contain 73.5 $mg \cdot L^{-1}$ ammonia near the point of entry to a creek, after flowing approximately 300 m over the ground. This concentration of ammonia is highly toxic to fish under the pH and temperature conditions measured in the receiving waters.

Under the Code, livestock in seasonal feeding areas are allowed access to a watercourse, provided that pollution does not occur. As defined by the Code, seasonal feeding areas are used for forage or other crop production during part of the year, and are used seasonally to feed livestock, poultry, or farmed game that is primarily sustained by supplemental feed. The Code states that the actual feeding site within a seasonal feeding area must be 30 m or more away from any watercourse. The amount or degree of livestock access to a stream which is acceptable is not defined (e.g. there are no requirements to limit the scope of access or livestock numbers) which has lead to problems with application of the Code.

Where seasonal feeding areas are located next to an unfenced watercourse, livestock tend to congregate along the shoreline where they trample stream banks and devegetate the riparian area. Degradation of the riparian zone results in increased summer stream temperatures due to loss of shading, increased suspended sediment loads, and sedimentation of stream bottoms. Animal wastes accumulate on the ground and can create spring runoff problems similar to those described for confined feeding areas.

The potential for problems associated with runoff events from both seasonal feeding areas and confined livestock areas has been documented in the Thompson sub-basin where cattle ranching is widespread. Helicopter surveys conducted in the spring of 1994 in the Thompson sub-basin revealed approximately 103 sites with potential environmental impacts from cattle overwintering areas, and approximately 50 of the sites required a follow-up inspection by MELP staff.[35]

During the late spring cattle are driven to outlying range lands where they graze through the summer at theoretically low densities. Calculated summer densities are misleading, as cattle tend to congregate in particular areas such as along streams or lake shores, where they can cause significant impacts.[36] Although the types of environmental damage caused by grazing have been extensively documented in the western U.S.[37] the actual extent of impacts in B.C. is poorly documented.

The Ministry of Forests (MOF) is responsible for managing Crown Lands which are used for grazing. MOF is developing a series of field guides to address grazing issues as they relate to riparian areas, community watersheds, and requirements for obtaining or renewing grazing tenures.

The B.C. Cattlemen's Association is currently revising their *Range Management Practices* manual which was first produced in 1978. The new manual will address the broad scope of range management issues within the context of ecosystem sustainability.

2.4.2.2 Fruit and Vegetable Production in Central Areas of the Fraser Basin

The relatively lengthy and warm summers of central areas of the Fraser Basin, in particular the Thompson River sub-basin, support production of some fruit and vegetable crops. Impacts to water quality from production of vegetable crops may arise from the use of fertilizers (including manure) and pesticides, in addition to suspended sediment problems associated with soil erosion. Removal of riparian vegetation can also cause significant increases in summer water temperatures. Potential impacts arising from the production of tree fruits are likely restricted to those associated with pesticide and possibly fertilizer use. Because soils are not tilled in fruit orchards erosion and suspended sediment problems are unlikely to be common. If precautions are taken and vegetated riparian buffer strips are undamaged, the chances of pesticides or excess nutrients reaching watercourses are greatly reduced.

2.4.2.3 Ginseng production in the Interior Fraser Basin

The ginseng industry is growing rapidly in the interior Fraser Basin, particularly in the Thompson sub-basin where this crop is grown in large plots, which are often located adjacent to watercourses. Typically, 4 to 5 years are required to produce one harvestable crop, therefore it is important for producers to ensure that pests do not damage their investment. As of 1995, four pesticides (all fungicides) were approved by the Pest Management Regulatory Agency (PMRA) of Health Canada (formerly Agriculture and Agri-food Canada) for use on ginseng crops: Dithane M45, Rovral, Dytene, and Quintozene. PMRA approval specifies that buffer zones be left around water courses. The risks associated with application of pesticides to this crop may be reduced compared with other crops because ginseng is usually covered with a canopy, which limits application methods to those least likely to cause drift. Also, because of the dry climate required by ginseng, pesticide runoff is less likely to be a concern than it would be in coastal areas. Both the PMRA and MELP are involved with field studies in the Okanagan area of B.C. to assess the movement of pesticides into aquatic habitats.

2.4.2.4 Animal and Vegetable Crop Production in the Lower Fraser

Agricultural production in the lower Fraser Basin by far exceeds production from all other areas of the Basin combined, in terms of product value per hectare of agricultural land. This is due to the relatively mild climate of the area, the proximity to markets, and the intensity of farming. In 1985, 25% of the B.C. gross income from agriculture was derived from the lower Fraser Basin and the average production value per hectare was more than 15 times the national average[38] for farm land. In 1995, Lower Fraser Valley agriculture generated gross farm receipts of $859 million.[134]

Practices are intensive and resulting impacts to water quality can be severe.[39-41] Common problems include: eutrophication from excessive or inappropriate use of chemical fertilizers and/or manure; potential toxicity from ammonia originating from manure; and low dissolved oxygen concentrations through the summer and into the fall months, resulting from eutrophication and BOD input. As well, damage to or elimination of riparian habitat causes sedimentation of stream beds, high suspended sediment levels, and elevated water temperatures. Salts and metals can also be introduced into aquatic systems by agricultural activities.[42] Low dissolved oxygen concentrations associated with runoff from farm lands resulted in pre-spawning mortality of over half of the Serpentine River coho run in October 1980, and October 1984.[43] Extremely low levels of dissolved oxygen have also been reported for the lowland Matsqui[39] and Sumas[40] systems, where intensive farming practices have developed.

2.4.2.4.1 Manure and Other Animal Wastes

There is a significant excess of nutrients applied to land on an annual basis in the Lower Fraser Valley. Each year feed is imported to support high densities of livestock, resulting in release of nutrients to the environment via manure, which is then spread locally. Nutrient applications from manure plus inorganic fertilizers spread on land in the Lower Fraser Valley greatly exceeds annual removal by crops, hence large imbalances have developed.[44] A nutrient balance modelling study of all agricultural areas in the Lower Fraser Valley showed that 17 of 20 management zones had a surplus of nutrients applied relative to what crops could take up, and 57% of the Lower Fraser Valley cropped area had an excess of more than 100 $kg\text{-}N\cdot ha^{-1}$ each year.[44]

The introduction of excessive amounts of phosphorus to aquatic environments is also of concern, as phosphorus is usually the nutrient which limits primary production in healthy B.C. streams. The same nutrient balance modelling study showed that the net application of phosphorus was at least twice the potential crop removal amount in 18 of 20 agricultural management zones. Phosphorus is normally readily bound by soils, however, the frequent and heavy rainfalls which are characteristic of the Lower Fraser Valley can result in the generation of nutrient-contaminated runoff which reaches streams.

2.4.2.4.2 Chemical Fertilizers

The use of chemical fertilizers in the Lower Fraser further compounds the nutrient excess problem. Chemical fertilizers are considered desirable by growers because the timing of nutrient release is very predictable. When properly applied, nutrients meet immediate crop requirements, resulting in maximum plant growth and nutrient uptake. In the Lower Fraser, however, more nutrients are available through manure alone than are required for crop production, without applying any chemical fertilizers.[44]

Experts in B.C. Ministry of Agriculture and Food (MAF) suggest that use of chemical fertilizers could be reduced as much as 75% without any reduction in crop production if manure was properly applied to the land as a fertilizer.[46] Similar reductions have been attained in European countries. Brisbin estimates that producers in the Lower Fraser Valley could save about $12 million per year collectively by relying more on manure as a nutrient source and reducing chemical fertilizer use.[44]

2.4.2.4.3 Pesticide Use

Pesticides are toxic substances designed to kill, repel, or control unwanted organisms including weeds, insects, rodents, fungi, nematodes, and others. They are also potentially toxic to non-target organisms, including aquatic biota if they enter streams. A study of pesticide use in 1991 covering all of B.C. showed that agriculture accounted for 13.7% of all pesticide use in the province, and 71% when wood preservatives, anti-sapstains, and slimicides were excluded.[143] Of the pesticides used on agricultural land, 71% was applied by farmers to their own land, and 4.7% was applied through commercial services.[143]

The best known and most common pesticide active ingredients are the organochlorines, organophosphates, and carbamates. Organochlorines are persistent and fat soluble. Since the 1970s the registration of most organochlorine pesticides has been cancelled, suspended, or restricted due to concerns associated with human health and environmental impacts. Residues can still be found in the environment, particularly in sediments and sometimes biota.[47] While concentrations are less than the range which would cause human health concerns, implications for fish are unknown.[48] Organophosphate pesticides are among the most commonly applied pesticides in B.C. They are not very persistent in the environment, however, they are water soluble and are among the most toxic pesticides used in Canada.

Census data from 1986 were examined by Schreier, *et al.*, who reported that 90% of all insecticides and 56% of all herbicides used in British Columbia are applied in the Lower Fraser.[34] Pesticide residues have been measured in ditch water in the Lower Fraser for up to one year after spraying, and at very high concentrations immediately after spraying.[48] Endosulfan was measured at a concentration of 1,530 $\mu g \cdot L^{-1}$ in ditch water, about 1,100 times the 96 hour LC_{50} concentration for rainbow trout.[48] Other substances detected included azinphosmethyl, diazinon, dinoseb, and fensulfothion. Drainage ditches in the Lower Fraser typically flow into fish-bearing streams or may directly support fish. The report stated that where set-back distances for tractor-mounted spray application were less than 3 m, pesticide contamination of ditch water and streams was likely.

Government agencies and industry have been working successfully to reduce pesticide use in agriculture by encouraging integrated pest management (IPM) programs. IPM involves the use of biological controls, cultural controls (crop rotation, etc.) and pest monitoring information to reduce the need for chemical pesticides. Approximately 8% of berry and 17% of vegetable hectarage in the Lower Mainland are managed with IPM techniques.[49] Significant proportions of particular vegetable crops such as carrots (66%), onions (74%), and potatoes (42%) are grown under integrated programs.[49] The amounts of pesticides used to manage 15 arthropod species were reduced on over 50% of the participating farms. In addition, IPM programs have resulted in economic gains for most participating producers.[49]

2.4.2.4.4 Urban-rural pressures on streams

A critical situation is now developing in the semi-rural areas of the Lower Fraser sub-basin. More than 65% of Fraser River coho production and 85% of Fraser River chum production originate from tributary streams located between Hope and the estuary. Many of these streams are severely impacted by the intensive agricultural activities described above. Adult coho and chum salmon typically return to spawning streams in the fall months and may be prevented from migrating upstream until fall rains flush badly contaminated or deoxygenated water out of these streams.[39]

The life cycle of the coho makes this species particularly vulnerable to degraded water quality relative to the other anadromous salmonids of the Pacific region. Coho spawn in relatively small streams and the juveniles rear in these same streams for a year or longer before migrating to sea. The poor water quality resulting from agriculture often confines rearing fish to refuge areas in the upper stream reaches, where the land is too hilly to farm. Lowland areas are protected for agricultural use by the Agricultural Land Reserve, and now the upper reaches of these watersheds are facing increasing pressure from urban development. This urban development threatens the limited year-round rearing habitat remaining in these Lower Fraser tributary streams.

There is an urgent need to improve water quality in the lower reaches and protect water quality in the upper reaches if these coho populations are to survive. Stormwater management in these urbanizing areas is also a key issue which needs to be addressed, as increasing stormwater runoff results in downstream flooding of agricultural lands, which impacts crop production and leads to further water quality problems when soils, manure, and agrochemicals are washed into streams.

2.4.2.5 Hobby Farms

Hobby farms can play a large role in degrading water quality. They are often owned by people who do not have training or experience in farm management and therefore lack knowledge about livestock management, and manure storage or application. Hobby farmers are usually not associated with any producer group and as a result are not linked with information networks available to larger scale commercial producers. Although each land owner may own only a small number of livestock, animal densities can be high because land parcels are relatively small. Where there are large numbers of hobby farms water quality problems may be exacerbated by seepage from improperly maintained septic systems in addition to manure runoff. Hobby farms contribute to environmental problems in both coastal,[41, 50] and interior areas of the Fraser Basin.

2.4.3 Legislation

2.4.3.1 Federal Legislation

With regard to federal legislation, the general provisions of the *Fisheries Act* are among the most powerful tools for protecting water quality. Other pieces of legislation provide indirect protection to water quality. For example, the federal *Fertilizer Act* specifies standards for composition, packaging, and labelling of fertilizers, and also prohibits the use of harmful ingredients. The *Canadian Environmental Protecion Act* (CEPA) can also be used to restrict use of substances including pesticides, if they are considered to be persistent and toxic.

DOE-FRAP has developed an inspection program to address violations of the *Fisheries Act* by agricultural operations. This program will be implemented in the 1997-98 fiscal year, and targets farms in both the B.C. interior and the Lower Fraser Valley.

2.4.3.2 Provincial Legislation

Under the *Waste Management Act*, MELP enacted the Agricultural Waste Control Regulation in 1992, and the associated Code of Agricultural Practice for Waste Management, which describes appropriate waste management practices. A series of Environmental Guidelines documents has been prepared for specific producer groups (e.g. dairy, beef, poultry, mushroom, etc.), which provide "how to" information to help producers attain compliance with the Regulation and supporting Code. Producers who comply fully with the Code are exempt from the requirement to obtain a Waste Management Permit for discharging farm wastes. Producers who do not operate in compliance with the Code are required to obtain a Waste Management Permit from MELP, and abide by the conditions detailed within.

Enforcement of the Agricultural Waste Control Regulation has been phased in to allow producers time to bring their operations into compliance. While there are very few producers who actually have Waste Management Permits, there are still many producers who are not in compliance with the Regulation and supporting Code. This is likely due at least in part to limited enforcement capability which results from staff shortages. Two positions (1 in Kamloops and 1 in Surrey) were supported as part of DOE-FRAP/MELP regional initiatives to address agricultural issues and these positions are now supported by MELP.

Numerous other pieces of provincial legislation have indirect implications for water quality. The *Health Act*, for example, regulates farm practices which may cause health hazards, such as disposal of dead animals. The *Pesticide Control Act* applies to the sale, transportation, storage, preparation, application, and disposal of pesticides.

The *Water Act* requires the licensing of all surface water withdrawals in B.C. but does not require licensing of groundwater withdrawals. Water licenses are issued through the Water Management Branch of MELP. Provisions of the *Act* do not recognize instream water requirements for supporting aquatic life. MELP has been discussing revisions to the *Water Act* to address the needs of aquatic life, however, changes have yet to be made. While there is some degree of co-operation developing between the Water Management Branch and DFO in this regard, many streams are already over-licensed.

Most water licenses issued for irrigation withdrawals do not require anyone to monitor the amounts of water removed from a surface source, and actual withdrawals may exceed permitted volumes. In some areas of the Fraser Basin excessive water withdrawals result in very low stream flows, and may cause some streams to go dry during hot summer months. Other impacts from excessive withdrawals include increased water temperatures, reduced oxygenation, and increased concentrations of contaminants.

An overview of irrigation withdrawals for the Fraser Basin was provided by Schreier, *et al.*,[34] who indicated that about 27% of the 8,343 farms located in the Basin in 1986 were irrigating crops. In some sub-basins such as the Chilcotin, Bridge, Middle Fraser, Lillooet, and the North, South, and mainstem Thompson, the percentage using irrigation water varied between 41 and 76%. About 55% of the Fraser Basin farms which used irrigation water were obtaining it from the Fraser River or its tributaries. Lakes and rivers provide more than two thirds of all irrigation water in all sub-basins except for the Lower Fraser, where groundwater provides 47% of irrigation water. It should be recognized that groundwater withdrawals can detract from flows in streams which are groundwater fed.

Stream flow information and licensed water withdrawals have been summarized for most salmon-bearing streams in the Fraser Basin in a series of reports prepared by Rood and Hamilton,[51-62] on behalf of DFO-FRAP. The contents of these reports provided the basis of the stream summer low flow and water withdrawal information which is summarized in the HMA overviews provided in this report on a stream-by-stream basis.

2.4.3.3 Industry Initiatives

The Agriculture Environmental Protection Council (AEPC) is a joint partnership between industry and government, whose ultimate goal is to address environmental concerns within the farming community, without the necessity of regulatory action. To achieve this, the AEPC has developed a program under which volunteer peer advisors respond to and resolve nuisance and pollution complaints against farms. Under a co-operative agreement with MELP, advisors respond first unless there is an emergency situation, or a peer advisor is unable to respond within a reasonably short time period.

Ideally, peer advisors offer producers an educational opportunity, and MELP responds with regulatory tools only when other avenues have failed to bring about satisfactory results. Producers prefer to receive visits from fellow producers rather than enforcement officers. This approach aims to reduce the need for enforcement actions by government agencies, which reduces demands on staff. The peer advisor program has operated with varying degrees of success in different parts of the Fraser Basin.

A similar peer advisor program, Enviralert, has been implemented through the B.C. Cattlemen's Association (BCCA). The BCCA also fosters environmental protection and enhancement with its annual Environmental Stewardship Award. The Enviralert Program has been effective at increasing awareness among ranchers of the environmental issues associated with ranching, in some areas of the Fraser Basin. The BCCA is implementing training workshops for peer advisors, in co-operation with MAF, MELP, and DFO.

Numerous producer "conservation groups" have developed over the past several years with support from government programs such as the Agriculture Canada Green Plan. These groups have taken on leadership roles in developing new reduced-impact approaches to farming. Many of these groups have an impressive list of accomplishments in terms of identifying and promoting lower impact practices, modifying equipment to introduce new manure management options, developing markets for manure, to name a few. Many of these groups lacked sufficient funds to continue functioning in the same capacity following the end of the Green Plan (March 1997).

2.4.4 DFO-FRAP Actions to Address Agricultural Issues

A wide range of initiatives have focused on reducing the impacts of agriculture on water quality in the Fraser Basin. A Demonstration Project in the Fraser Basin on the Salmon River (Langley) has produced a large and valuable knowledge base to use in making land-use decisions, and provides a model for rural watershed management approaches. It has also highlighted the scale of problems which can be caused by hobby farms. A Demonstration Project on the Salmon River (Salmon Arm) is also addressing impacts from agriculture on aquatic systems, and has involved significant riparian restoration efforts. Both projects have raised awareness among local landowners of the importance of properly managing riparian areas.

A broad range of agencies and organizations including MELP, MAF, DOE, DFO, B.C. Federation of Agriculture, and Westwater-U.B.C., participated in developing a nutrient-flow model for agriculture in the Lower Fraser Valley. This model provided a tool for quantifying the scope of the nutrient management problem, identifying the "hot spot" areas, and estimating the potential effectiveness of different management tools at addressing identified problems. A summary report identifies the key findings from all component projects, and includes a recommended multi-agency management approach.[135]

An educational stewardship guide[147] has been developed via an inter-agency committee led by DFO and including representatives from DOE, MELP, MAF, and the BCFA. The purpose of the guide is to inform producers about the habitat requirements of healthy fish and wildlife populations, and how to make changes to their operations which will benefit these habitats, while often benefiting the farm as well. An education program based on the guide is now being implemented.

2.4.5 Summary

Agricultural land comprises a significant proportion of the Fraser Basin lowland areas which border on important fish-bearing streams. Unless precautions are taken agricultural activities have a significant likelihood of generating impacts to water quality, through basic activities such as tilling soil, removal of riparian vegetation, the generation and spreading of manure, and the use of chemical fertilizers and pesticides. Impacts to water quality from agriculture have been reported in many areas of the Fraser Basin, from Prince George to the estuary. While little new land is being brought into production, in many cases farming is becoming more intensive on existing farm land. While agriculture is a provincial responsibility, agencies such as DOE, DFO, MELP, and MAF need to expand upon existing co-operative efforts with producers if existing impacts on the environment and other resources are to be reversed and further impacts are to be prevented.

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2.5 Forestry

2.5.1 Introduction

Many aspects of wood harvesting and forest management have the potential to affect water quality and fish habitat. The Fraser Basin contains approximately 37% (9.6 million ha) of the productive forest on provincial crown land. The geographic scope of forested lands in the basin makes forestry a potentially dominant land use in many areas, and consequently good forest practices are key to protecting water quality throughout the Fraser Basin. The types of water quality impacts which can result from road building, logging, silvicultural activities, log handling, and the generation of woodwaste are briefly described here.

2.5.2 Timber Harvesting

2.5.2.1 Effects of Road Building and Timber Harvesting on Water Quality

Timber harvesting can affect the hydrology of a watershed through soil compaction and vegetation removal. The construction of logging roads and use of skid trails both cause soil compaction. Compaction reduces the rate of water infiltration into soils and the capacity of soils to store moisture, interrupts subsurface water flows, and increases the flow of water over compacted areas.[63, 64] Water is usually collected in ditches along logging roads, and is channelled under roads through culverts or across roads via water bars. While ditching and culverting may help to protect the integrity of roads, the channelling of runoff water also disrupts the natural hydrology of the watershed, and can generate considerable erosive force which leads to stream sedimentation. The improper sizing or location of culverts can cause road failures which often result in stream sedimentation. Poorly constructed roads and inadequate road drainage measures further contribute to stream sedimentation.

The removal of vegetation that occurs with logging (especially clear-cut logging) increases the amount of moisture that reaches the soil during precipitation events, and can also reduce evapo-transpiration rates,[65] resulting in increased rate and amount of runoff during and after precipitation events.[64] Canopy openings allow for greater snow accumulation and faster snow melt, again resulting in increased runoff.[66]

Increased runoff can promote erosion of surface soils, as well as streambank erosion and the scouring of streambed materials. Sediment deposition will then occur in lower-energy segments of streams, often infilling key habitat features. Mass soil movements such as landslides, earth flows, and slumps may also result from road and slope failures and contribute to stream sedimentation.

The Jones Creek watershed, near Hope, B.C., provides a sad example of the types of problems discussed above. Extensive logging of slopes with thin top soils over bedrock led to decreased soil strength (due to water-logged soils) and the destruction of root systems which effectively bound the soils together. Erosion problems have been ongoing since logging began in the watershed and culminated in huge debris torrents that filled the creek channel and destroyed the worlds first successful salmonid spawning channel in 1993-'95. Fish are no longer able to reach spawning grounds, and the genetically unique pink salmon run has virtually disappeared from this stream.[136]

When logging occurs right up to stream banks the loss of riparian vegetation results in an increased influence of solar radiation on streams, and removal of the insulating effect which riparian vegetation has on stream temperatures. The net result is higher summer daytime water temperatures and lower summer night time temperatures.[67] Loss of riparian vegetation can also lead to lower winter water temperatures, which increases the chances of anchor ice forming.

Increases in summer water temperature may place physiological stress upon aquatic organisms by increasing their metabolic rate while decreasing the capacity of water to hold dissolved oxygen. Other impacts to aquatic organisms associated with disruption of the thermal regime are discussed in Appendix 1.

While the loss of riparian vegetation with logging should be greatly reduced following introduction of the *Forest Practices Code of British Columbia Act* and supporting Code in 1995, there are thousands of kilometers of stream banks in the Fraser Basin that were cleared prior to introduction of the Code, and the problems described above will persist until riparian vegetation regenerates.

2.5.3 Silviculture

2.5.3.1 Site Preparation Effects on Erosion and Stream Sedimentation

The preparation of logged sites for replanting involves the removal of slash following scarifying or burning. These activities further disrupt exposed soils, and can increase the detachment and transport of sediment. They can also contribute to increased nutrient loading to streams.[68] Table 2.5.1. shows the scope of these activities in the Fraser Basin.

2.5.3.2 Pesticides

A variety of herbicides are used to control the growth of brush and tree species that may reduce growth or compete with the desired "crop" of trees. The herbicide glyphosate (trade names Roundup®, Vision®) is commonly used in B.C., while 2,4-D, hexazinone and triclopyr (trade names Garlon 4®, Release®) are used to a much lesser extent. Herbicide use in each of the Ministry of Forests (MOF) regions is summarized in Table 2.5.1. A study of pesticide use in B.C. for 1991 indicates that forestry is a relatively small user of pesticides, and accounted for 1.6% of total use, and 8% of use when wood preservatives, anti-sapstains, and slimicides were excluded.[143] Approximately 1,200 ha of the Vancouver Region area lies within the Fraser Basin.[70]

Insecticides are used to control defoliating insects and bark beetles. Insecticides commonly used in B.C. forests are Btk, monosodium methanearsonate and carbaryl (trade name Sevin®). Btk is a bacteria which is relatively harmless to non-target organisms, however, the chemical pesticides can be toxic to non-target species including aquatic organisms. Direct effects of silvicultural pesticide chemicals on the aquatic environment include acute and sublethal toxicity.[71-73] Over-spraying a stream with glyphosate resulted in increased invertebrate drift,[74] temporary signs of stress in caged coho fingerlings and avoidance of sprayed areas by resident coho.[75] Indirect effects of herbicides reaching riparian vegetation include short-term reductions in streamside vegetation, reduced leaf-litter fall, increased exposure to sunlight, warmer summer water temperatures, increased erosion, and increased nutrient concentrations in stream water.[76]

Pesticide use in B.C. is primarily regulated under the B.C. *Pesticide Control Act*. The Forest Practices Code establishes further restrictions on pesticide use on Crown forest lands, and builds on the MELP/DFO Coastal Fisheries/Forestry Guidelines[78] by requiring establishment of a "pesticide-free zone" (PFZ) around streams. A buffer zone between the treatment area and the PFZ helps to prevent movement of pesticides into the PFZ during or following treatment of an area.[77] The Forest Practices Code is the only legislation prescribing a PFZ.

Pesticides which are toxic to aquatic organisms would be considered deleterious substances as defined by Section 36(3) of the federal *Fisheries Act*, hence the introduction of pesticides into fish habitat could result in charges under the *Act*. Furthermore, buffer zones protect riparian vegetation from herbicide damage. Riparian vegetation is an integral part of fish habitat, and the loss of riparian habitat in B.C. has been equated with destruction of fish habitat in court cases.

2.5.3.3 Fertilization

Nitrogen is applied as a fertilizer to replanted areas to stimulate tree growth. Fertilizers are usually applied by aerial spraying on a site-specific basis depending upon needs of the tree species. Eutrophication or toxicity problems may result if excessive nitrogen enters water-bodies directly from aerial spraying and indirectly as a leachate from upland areas.[67]

The use of fertilizers in silviculture is administered by MOF through Silviculture Prescriptions. The Silviculture Practices Regulation of the Forest Practices Code only regulates broadcast fertilization in community water-sheds. The MOF Forest Fertilization Guidebook[69] recommends leaving a 10 m “no fertilizer application zone” around fish-bearing lakes, designated fisheries streams, and streams that flow into fisheries streams, to ensure that there is no direct deposition of fertilizer pellets and to minimize the leaching of fertilizer into a water body.[69] The guidelines are enforceable only when inserted into silviculture prescriptions. Fertilizer use in B.C. in 1992/93 is summarized in Table 2.5.1, but it varies greatly from year to year.[79, 80]

Table 2.5.1 Silvicultural activities on crown land in 1992/93, measured in hectares, classified by Ministry of Forests region.

Silvicultural Activity	Cariboo	Kamloops	Nelson	Prince George	Prince Rupert	Vancouver	Total
Surveying	134,128	146,461	126,692	181,916	103,847	117,538	810,582
Preparing sites							
Broadcast burn	3,246	1,600	2,263	588	535	784	9,016
Spot burn	3,537	2,177	501	6,412	479	1,577	14,683
Broadcast mechanical	14,402	18,802	6,492	40,556	8,244	176	88,672
Spot mechanical	1,305	1,138	996	3,924	650	1,054	9,067
Broadcast chemical	1,151	104	295	2,321	15	1,534	5,420
Spot chemical	-	3	907	13	-	149	1,072
Grass seeding [1]	3,991	205	251	43	343	109	4,942
Other treatments	1,289	1,506	1,004	206	1,534	27	5,566
Planting	17,990	30,426	17,600	62,346	27,215	25,015	180,592
Brushing [2]							-
Manual	2,219	5,514	7,821	5,649	3,992	4,349	29,544
Chemical (herbicides)	4,188	1,043	540	14,817	2,036	5,325	27,949
Spacing [3]	14,585	7,202	6,663	3,802	3,882	9,600	45,734
Fertilizing	822	720	1,043	679	-	4,565	7,829
Pruning	101	869	385	22	393	1,343	3,113
Other activities [4]	2,205	19	132	478	179	1,285	4,298

Notes:
[1] Includes grass seeding of roads, landings and cutblocks.
[2] A silvicultural activity done to control competing forest vegetation.
[3] The removal of undesirable trees within a young stand to control stocking, improve growth, or to increase wood quality.
[4] Includes commercial thinning, controlling mistletoe, and falling snags and residual trees.
Adapted from: B.C. Ministry of Forests, 1995. (See reference 69)

2.5.3.4 Forest Fire-Fighting

Forest fires cause considerable economic damage in British Columbia and loss of vegetation from fires can be detrimental to fish habitat. Forest fires are fought with a variety of methods, including the use of fire-retardant chemicals which are toxic to fish.[141] While it is necessary to extinguish some forest fires, the chemical industry should consider developing non-toxic fire-retardants, which would clearly have a market.

2.5.4 *Log handling, transportation and storage*

Log handling processes which can impact the aquatic environment include the dumping of cut timber into the water for sorting, the booming of logs as bundle booms or flat rafts, long-term storage of logs on land near watercourses, the storage of booms in fresh or marine water, and their transport from all areas of the province to processing facilities in the Lower Fraser Valley and on Vancouver Island.[81] The physical effects of log handling include scouring of soft substrates, smothering of natural benthic substrates by accumulation of bark and wood debris, shoreline erosion, sediment disturbance and redistribution in aquatic habitats, and a decrease in light penetration.[82] The major effects on water chemistry are increased BOD, the release of soluble organic compounds from logs stored on land or in the water [81, 83, 84] and the production of toxic leachates during the decomposition of bark and woody debris.

2.5.5 *Woodwaste from forest product mills*

2.5.5.1 Leachate From Woodwaste Disposal Sites

Sawmills, shake and shingle mills, pole mills and remanufacturing mills all produce woodwaste in the form of bark, shavings, sawdust, chips, edging, trim ends, rejects, breakages, and miscellaneous log yard debris.[85] Although much of this waste is utilized surplus residues are still incinerated or landfilled.[86] The most recent data available for mill residue production, utilization and disposal in the Fraser Basin are summarized in Table 2.5.2.

Woodwaste from both old fill sites and new disposal operations can affect water quality and aquatic biota through several mechanisms. Woodwaste leachates may be acidic, have high BOD or chemical oxygen demand (resulting in reduced oxygen levels in the vicinity of the woodwastes), or contain toxic concentrations of dissolved metals or organic chemicals.[3] Among the organic chemicals contributing to the toxicity of wood leachates are resin acids, present in most softwoods, and phenols, which are present at high concentrations in aspen leachate.[83, 84] The chemical characteristics of woodwaste leachate are influenced by the tree species,[87] and by the age of the woodwaste. In addition to the chemicals which originate from the wood itself, woodwaste may also be contaminated with oils from forestry operations, as well as heavy duty wood preservatives and anti-sapstain chemicals.[3]

Hogfuel is wood residue that has been hogged or chipped. It has been used as landfill in construction sites in parts of the Fraser Basin, resulting in numerous leachate problems in some areas. Large volumes of woodwaste were deposited in Richmond to meet B.C.'s flood-proofing requirements for construction of residential developments in 1980's. Leachates are still released into the Fraser Estuary from these sites.[146] The volume of leachate generated from a woodwaste disposal site generally increases with the amount of water that infiltrates the site. Lower Mainland fill sites have a higher risk of leachate production than sites in the interior of the province, due to a higher precipitation rate.

The disposal of woodwaste in landfills requires a permit under the B.C. *Waste Management Act*, although in the past it was much less carefully managed than it is today. There are numerous old woodwaste landfills which continue to generate leachates throughout the Fraser Basin. The discharge of woodwaste leachates into

Table 2.5.2 The production, utilization and disposal of mill residue in the Fraser River Basin.

Forest Region & District	Bark (BDT)			Other Wastes (m^3 SWE)		
	Production	Utilization	Surplus	Production	Utilization	Surplus
Vancouver Forest Region:						
Chilliwack (Forest District 1)	892,200	450,300	441,900	2,392,500	1,535,800	856,700
Kamloops Forest Region:						
Kamloops (Forest District 2)	80,100	43,200	36,900	281,000	245,000	36,000
Other districts (combined)	414,100	97,800	316,300	1,089,600	450,900	638,700
Prince George Forest Region:						
Prince George (Forest District 1)	375,000	9,200	365,800	843,200	142,500	700,700
Cariboo Forest Region:						
Quesnel (Forest District 1)	192,500	16,500	176,000	661,600	162,600	499,000
Williams Lake (Forest District 2)	159,800	5,500	154,300	642,400	126,500	515,900
100 Mile House (Forest District 4)	78,600	-	78,600	262,300	55,000	207,300

"BDT" - bone dry tonnes; "SWE" - solid wood equivalents.

Adapted from: Stewart and Ewing Assoc. Ltd., *et al.* 1990. (See reference 86) aquatic or riparian environments may violate subsection 36(3) of the *Fisheries Act*. DFO and DOE recently published a guide to managing woodwastes.[88]

2.5.6 Regulation of Forest Practices in B.C.

The forest industry in B.C. is largely regulated by the *Forest Practices Code of British Columbia Act*, which specifies administrative arrangements, establishes requirements for harvesting and silviculture plans, guides road building and harvesting practices, and contains enforcement and penalty provisions. The *Act* applies only to forestry activities on Crown lands, and does not regulate any forestry activities on private lands, contrary to earlier plans announced by the provincial government.

The *Act* and supporting Code became law in 1995. Prior to this time there was no legislation which pro-actively restricted forest practices that impinged on fish-bearing streams. At best, charges could be laid under the *Fisheries Act* after the damage was already done. MELP and DFO had jointly developed the Coastal Fisheries/ Forestry Guidelines, however, there were no similar guidelines developed for the B.C. interior, and a detailed study showed that the Guidelines were seldom applied in Coastal areas.[89]

2.5.7 Summary

Forestry is a major land use in the Fraser Basin, and involves numerous types of activities which are potentially detrimental to water quality and biophysical fish habitat. While the Forest Practices Code should increase the level of protection afforded to streams in association with forestry activities, careful monitoring will be needed to determine whether the Code adequately protects physical stream habitats and water quality. The Code, as written, leaves much to the discretion of the MOF district managers, so the level of protection which streams receive may vary widely across the province. DFO must therefore continue to devote significant efforts to reviewing harvesting and silvicultural plans, and increase audit and enforcement efforts where forestry activities impact water quality or physical fish habitat.

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2.6 Mining Operations

This overview of mining issues in the Fraser Basin is based on an unpublished report was prepared for DFO.[142]

2.6.1 Introduction

Mining operations extract materials by simple excavation (rock, limestone, some industrial materials), sorting and washing after excavation (placer gold, sand, gravel, coal, some industrial materials), and chemical processing to separate product from host rock (metal and gold mines). Numerous types of mines have extracted base metals (copper and molybdenum), precious metals (refined and placer gold), coal, industrial minerals (perlite, pumice, gypsum, silica, barite, magnesite, garnet, sodaspar), sand and gravel, limestone and quarried rock from the Fraser Basin.

2.6.1.1 Mining in the Fraser Basin

Metal production in the Fraser Basin comes mostly from four large copper/molybdenum operations. There are currently no gold mills or coal mines operating in the Fraser basin, and historic operations have been small relative to operations in other parts of the province. One new copper/gold mine is proposed in the Fraser Basin and has generated considerable controversy. The proposed Prosperity mine is located in the vicinity of Taseko Lake in the Chilcotin region of the Fraser Basin. The ore body is located beneath spawning habitat of a unique rainbow trout population, and the mine proponents planned to drain Fish Lake (considered to be among the top ten lakes in B.C. in terms of catch success rates), and convert it into a rock dump and tailings impoundment. The mining company is currently working on a new development proposal, as their first approach was rejected by DFO.

Gold is presently extracted in the Fraser Basin as a by-product of copper production, and from an estimated 750 placer gold mines. It is estimated that 65% to 75% of B.C. placer mining activity occurs in the Fraser Basin.

Up to 40 large mineral mines are operating in the Basin. There are approximately 1,000 commercial sand and gravel extraction operations in B.C., and an additional 3,000-4,000 gravel pits operated by the Provincial Ministry of Transportation and Highways (MOTH) and some forest companies. It was not possible to easily determine how many of these are located in the Fraser Basin but it is likely a significant proportion given that approximately 70% of the provincial sand and gravel demand is in the Fraser Basin. Operations are numerous but generally cover small areas of less than 2 to 3 hectares.

2.6.2 Water Quality Issues Associated With Mining

Some of the water quality issues associated with mining are common to all types of mines, while others are specific to the minerals present in parent materials and the processing methods used.

All types of mines have the potential to generate suspended sediment loads from both the access roads, and mine sites themselves. Most mines also have the potential to release nutrients to surface waters via suspended sediment loads. Explosives used at mine sites also release nutrients, especially nitrogen, to the environment; these nutrients can then be washed into surface waters with stormwater runoff.

Some mines are point sources of effluents which may contain a wide range of contaminants including suspended sediments, dissolved and particulate metals, and contaminants introduced via chemicals used for processing. These contaminants may affect fish directly through their toxicity, or indirectly by altering physical parameters of their environment (i.e. pH, alkalinity, oxygen saturation levels, sedimentation).

2.6.2.1 Exploration Activities

Water quality impacts from exploration activities (road building, drilling, trenching and small scale underground or surface mining) are largely related to sediment released by surface disturbances. Exploration also introduces the potential for fuel spills, as fuels are often stored onsite for equipment operation. When exploration camps are established, the generation of sewage and other camp wastes can cause water quality problems if adequate waste management practices are not implemented. The necessary approaches are usually specified in the terms of a provincial Waste Management Permit as they are for any other business which discharges a waste to the environment.

When mine exploration sites begin to look promising, underground exploration is often initiated, using quantities of water which are discharged into the aquatic environment after settling. These waters can contain metals.

2.6.2.2 Road Access

Water quality issues arising from the construction of mine site access roads are the same as those identified for forestry, and include sedimentation from road surfaces, as well as cut and fill slopes, altered surface water flows from culverts, and the potential for spills of transported materials. Roads also establish human access to remote areas which can encourage illegal dumping. Mitigation strategies include locating roads away from surface waters, following road building and de-activation standards established under the Forest Practices Code, adequately sizing culverts and surface water diversions, minimizing cut and fill slopes, re-vegetating slopes, and providing secure containers for potentially toxic supplies.

2.6.2.3 Base Metal Mines - Open Pit and Underground

Mineral-rich ores may be removed by surface excavations (large open pits) or underground tunnels, depending upon the location of the ore body. To access ore, rock containing uneconomic levels of minerals is removed and discarded as waste rock. Surface mining generates vastly greater amounts of waste rock compared with underground mining.

Ore with economically acceptable metal concentrations is extracted and transported to a mill, where it is crushed and ground to sand or silt sizes and mixed with water to form a slurry. Minerals containing desired metals such as copper, lead, zinc and molybdenum are removed from the slurry using chemicals which cause the minerals containing desired metals to preferentially attach to bubbles or 'float'. The float is skimmed off and dried, and the concentrated product is shipped to a smelter for further purification of metals. The remaining slurry ('tail') is discarded as waste to a tailings impoundment area.

Water quality issues associated with base metal mining include the potential release of:

- sediment from excavation activities, disturbed lands, and waste materials;
- flocculants and coagulants, used to lower suspended sediment levels (these substances can be toxic to fish);
- nutrients contained in the sediments or from the explosives used in excavations;
- particulate metals contained in the sediment, tailings, and waste rock;
- dissolved metals brought into solution during the milling process;
- acidic drainage resulting from an increased rate of sulfide oxidation in minerals exposed during excavation or road construction, and left as waste rock, tailings, open pit walls or underground tunnel walls;
- metals dissolved from waste material by the acid drainage (i.e., copper, cadmium, arsenic, zinc, iron);
- chemical reagents used in the milling process;
- alkaline drainage arising from an increased rate of carbonate dissolution in the minerals exposed during excavation, and left as waste rock, tailings, open pit walls or underground tunnel walls; and,
- metals associated with alkaline drainage (particularly molybdenum).

These potential water quality issues can often be satisfactorily resolved by good material handling practices, control of surface water and erosion, and containment and recycle of water associated with the tailings and milling process.

Most of the operating and potential metal mines in the Fraser Basin are low-grade with disseminated sulfides, and present a lower risk of generating acidic drainage compared with the massive sulfide deposits present in other areas of B.C. The relatively dry climate characteristic of much of the Fraser Basin reduces the generation of contaminated runoff from mine sites, and facilitates the effective management of surface water.

2.6.2.4 Gold Mill Operations

Coarse gold is recovered using simple gravity techniques. The ore is crushed, ground, and mixed with fresh water so that the gold can be separated due to its relatively high density. Water quality issues are related to the fine sediment left in wash water, possible particulate metals contained in the sediment, and potential residual nutrients from sediment and the explosives used to excavate gold ore. These issues can usually be managed by appropriate water handling procedures, settling ponds, water recycling, and the judicious use of chemical flocculants to enhance settling of very fine particles.

Gold contained in hard rock as minute particles is recovered by cyanidation. Rock is ground into fine silt and sand, and is then mixed in a slurry with cyanide to dissolve the gold. The fine rock waste is washed and discharged to a tailings impoundment, and the gold-rich cyanide solution is treated chemically to re-precipitate the gold and leave a barren cyanide solution that can be recycled.

As the cyanide solution becomes contaminated with other metals contained in the ore including copper, arsenic, iron and zinc, a portion must be discarded and replaced with fresh cyanide solution. Water quality issues unique to this process are related to the handling of rinsed tailings which may contain residual cyanide and unwanted metals, and the waste cyanide solution. The residual cyanide can be reduced to low concentrations using established methods of chemical oxidation. The waste streams are usually stored in a tailings impoundment, where further natural degradation of the cyanide and its by-products occur. If excess water is not contained on site for a sufficient length of time, a discharge containing low residual levels of contaminants occurs.

The present treatment technology cannot always guarantee a non-toxic effluent as determined by a static rainbow trout bioassay test. Cyanidation gold mills in the Fraser Basin have been small operations with effluent discharges containing elevated concentrations of copper, cyanide and ammonia, which have usually failed 96-hr LC_{50} static rainbow trout bioassays. Poor water management practices at a gold mine located on Ladner Creek, north of Hope, resulted in the release of cyanide-laced effluent from a tailings impoundment in the early 1980's. A massive fish kill resulted and the company was successfully prosecuted under the *Fisheries Act*. The mine has been out of operation since shortly after the spill occurred.

2.6.2.5 Placer Gold

The extraction of gold by placer mining involves the excavation of gravels along the base of a river bed. Coarse materials are screened from gravels, and the finer material is washed through sluices to recover gold nuggets and dust. Lighter materials are washed away as waste. Water quality issues associated with placer mining include:

- the use of large quantities of water for washing;
- the discharge of this sediment-loaded waste water; and
- sediment from erosion and runoff from piles of waste boulders and cobbles left adjacent to the creek beds.

Historically, waste water with a high sediment load was discharged directly into the aquatic environment. Present practice requires settling and re-use of the waste water. Sedimentation continues to be an issue beyond mine closure if sites are inadequately reclaimed or revegetated. Diversions of river beds to access placer gravels are common in some historically active areas, resulting in a direct disruption of fish habitat and the elimination of stream side vegetation that helps to capture sediment.

Water quality impacts from each site are generally minimized by sediment control and reclamation practices, as long as mining is kept an adequate distance away from surface streams. Despite precautions, a large number of operations in a localized region can result in significant cumulative effects, and historic rights may allow some operations to continue mining close to, in, or under surface streams. In these cases, extreme care is required to avoid undercutting the creek, disrupting groundwater flows that feed the creek, or causing subsidence that might disrupt spawning beds in the creek.

An additional water quality issue arises from the historic use of mercury to recover very fine gold from placer gravels. The process, called amalgamation, involves mixing mercury with fine gravel containing nearly invisible flakes of gold. The gold is absorbed by the mercury, separated from the waste, and heated to drive off the mercury, leaving the gold behind. A substantial amount of mercury was likely lost with the waste in this process. The presence of mercury globules in river gravels is still reported in the sand bars of the Fraser River, as well as the Lillooet and Cariboo placer areas.[90,91] Environmental concerns are related to potential methylation of the mercury, and uptake by biota. Apart from fish in Pinchi Lake, the site of an old cinnabar mine, sturgeon in the Upper Fraser are the only fish in the Fraser River watershed known to have elevated mercury levels. The source of the mercury in sturgeon tissues is unknown.

2.6.2.6 Sand and Gravel

Sand and gravel extraction involves stripping the topsoil to reach deposits. The sand and gravel may then be crushed and sorted by screening and/or washing. The primary water quality issue arises from the potential discharge of sediment-laden wash waters, and runoff from the topsoil stockpiles and disturbed land. Sediment problems can be controlled by the recycling of washwater and use of settling ponds, particularly as most gravel quarries are preferentially located at a considerable distance from surface streams and above natural groundwater tables for ease of operation. Problems arise when the sediment in the wash or runoff water is too fine to settle efficiently, the gravel operations are too close to surface streams, settling ponds are inadequate to treat the volume of runoff generated, or the settling systems are not operated in an optimal manner. Some gravel mining operations cause tremendous impacts to fish habitat by generating very high suspended sediment levels, and through sedimentation of spawning grounds and other areas.

Gravel extraction near streams can result in the loss of streamside vegetation which increases water temperatures, and eliminates cover and food sources (leaf litter and insect drop) for fish. Indirect impacts from gravel extraction occur through inadvertent alteration of groundwater and surface water flows that supply fish habitat. Poor operational practices may result in sediment releases or spills of fuel stored on site for trucks and gravel washing equipment.

2.6.2.7 Industrial Minerals, Quarries and 'Non - Mineral' Products

Water quality issues associated with the mining of industrial minerals and construction products include the control of sediment and nutrients released from residual explosives used in the quarrying process.

2.6.3 Environmental Management Mechanisms And Review Processes

2.6.3.1 *B.C. Environmental Assessment Act*

The *B.C. Environmental Assessment Act* was proclaimed in 1995. It places all major project reviews under the authority of the Provincial Environmental Assessment Agency, including projects previously addressed via the Mine Development Assessment Process. Projects which are too small to be captured by the *B.C. Environmental Assessment Act* or the federal *Canadian Environmental Assessment Act* (*CEAA* - section 3.3) are reviewed at the regional level.

2.6.3.2 *Canadian Environmental Assessment Act* (1995)

The *Canadian Environmental Assessment Act* (*CEAA*) generally captures larger projects than *BCEAA* (Table 2.6.1), and also covers construction, decommissioning and/or abandonment of mines (*BCEAA* does not cover mine decommissioning as reclamation plans are a prerequisite to start-up under the *Mines Act*).

The key triggers for CEAA with regard to mining projects include Coast Guard's decisions under the *Navigable Water Protection Act* (i.e., transportation to the mine site by bridges or port facilities in navigable waters), DFO's decisions as to whether there is a harmful alteration or destruction of habitat, and Section 5.2 of the Metal Mining Liquid Effluent Regulations (MMLER) which allows the Minister to designate tailings impoundment areas for the deposit of prescribed deleterious substances in any quantity or concentration. When triggered, CEAA requires either a screening report or a comprehensive study report. Generally, only the larger mining projects are captured by CEAA but moderate sized metal and gold mines may also trigger CEAA. Production expansions of 50% or more that bring existing mines up to the stated size (Table 2.6.1) are included in the comprehensive study list, but placer gold mines are excluded.

2.6.4 Provincial Legislation Pertaining to Water Quality

2.6.4.1 Mines Act

The *Mines Act* provides the authority for approving workplans for the exploration, development and operation of all mines, and to approve programs for the reclamation of the land and watercourses affected by a mine on mineral-tenured lands. The legislation indirectly influences the quality and quantity of effluent produced by a mine by defining the conditions under which the mine can operate, but it does not state any specific effluent criteria. Notices of Work submitted by mining proponents are reviewed by Regional MEMPR staff and circulated for comment to MDRC participants judged to have an interest in the project.

2.6.4.2 Waste Management Act

The *Waste Management Act* (1982) addresses the discharge of all business wastes to the environment. The permits issued under the *Act* normally specify maximum allowable concentrations of contaminants in effluent, the maximum volumes that can be discharged, effluent monitoring and reporting requirements, and may also establish requirements for non-acutely lethal effluents. Effluent criteria vary for each mine or exploration project, but are roughly governed by a range of concentrations for each contaminant identified in the 1979 Pollution Control Objectives for Mining, Smelting and Related Industries.

The permits allow the control of point source discharges which have a direct impact on water quality but they are not always successful in addressing non-point sources or groundwater contamination issues. A weakness of the permits is the easing of requirements as the operating mine demonstrates a need to discharge a greater effluent volume than originally anticipated, or an inability to meet originally targeted contaminant concentrations in effluent.

Table 2.6.1 Size of mining projects captured by CEAA[1] and BCEAA.[2]

	CEAA	BCCEA
Mineral Mines	*see more specific definitions*	*≥ 25000 TPY*[3] *≥ approx. 75 TPD*[4]
Metal Mine	≥3000 TPD ore production capacity	"
Metal Mill	≥4000 TPD ore input capacity	"
Gold Mine	≥600 TPD ore production capacity	"
Asbestos Mine	All	"
Graphite	≥1500 TPD production capacity	"
Gypsum	≥4000 TPD production capacity	"
Magnetite	≥1500 TPD production capacity	"
Coal Mines	≥3000 TPD coal production capacity	≥100,000 TPY coal product. ≥ approx. 300 TPD
Non-'Mineral' Mines:	*see more specific definitions*	*>250,000 TPY product*
Limestone	≥12000 TPD production capacity	
Clay	≥20000 TPD production capacity	
Stone Quarry	≥1 million TPY production capacity	
Sand & Gravel	≥1 million TPY production capacity	≥500,000 TPY, or ≥1,000,000 T over ≤4 years

[1] CEAA = *Canadian Environmental Assessment Act*
[2] BCEAA = *British Columbia Environmental Assessment Act*
[3] TPY = metric tonnes per year.
[4] TPD = metric tonnes per day.
Adapted from: Mehling, 1995. (See reference 142)

2.6.4.3 Water Act

The *Water Act* authorizes MELP to issue licenses for the use of water. This allows control of all water diversions and quantities of water withdrawn from the ground and from surface waters. These withdrawals can have an indirect influence on water quality.

2.6.4.4 Contaminated Sites Regulation

This regulation was introduced under the *Waste Management Act* and is intended to implement effective management of contaminated sites, develop a site registry, and implement the 'polluter pay' principle. In addition to protecting surface waters from leachates and runoff that can be generated at contaminated sites, this regulation will help to protect groundwater in the absence of groundwater legislation. Large volumes of stored waste solutions, contaminated soils, and discharges from exfiltration ponds can result in groundwater contamination over time.

2.6.5 Federal Legislation and Initiatives

2.6.5.1 Fisheries Act

The Federal *Fisheries Act* is the key legislative instrument for protecting water quality. Section 36(3) of the *Act* prohibits the deposit of deleterious substances into waters frequented by fish, or in any place or conditions that result in a deleterious substance reaching waters frequented by fish. The federal requirements under the *Fisheries Act* are usually incorporated in MELP's Waste Management Permits.

2.6.5.2 Metal Mining Liquid Effluent Regulations

The MMLER (1977) are regulations under the *Fisheries Act* which define maximum allowable concentrations of specific deleterious substances (arsenic, copper, lead, nickel, zinc, total suspended matter, radium 226 and low pH) which can be discharged from metal mines. They only apply to new, expanded, and re-opened metal mines (after 1977), and do not apply to gold mines using cyanidation processes. The MMLER do not cover discharges from closed or abandoned mines, or exploration projects, nor do they apply to the mining of coal, placer gold, industrial minerals, or sand and gravel. Only two mines in the Fraser Basin (Afton and Highland Valley Copper) are subject to the MMLER; neither has a direct discharge to the environment. The MMLER are somewhat out-dated, and established discharge limits are based more on treatment technologies which were available at the time the regulations were written, rather than needs of the receiving environment. DFO and DOE are leading a review of the MMLER and intend to require Environmental Effects Monitoring (EEM) programs for mines similar in intent to the Pulp and Paper EEM program.

2.6.6 General Compliance with Regulations

Metal mines operating in the Fraser Basin were in general compliance with the federal MMLER and MMLEG.[2]

With the exception of gravel operations on the Coquitlam River, little information on *Fisheries Act* compliance was available for gravel pits and perhaps an assessment of the gravel mining industry would be appropriate. Significant impacts from gravel removal operations on the Coquitlam River have been an on-going issue with DFO for more than a decade, without satisfactory resolution.

Poor mine reclamation practices and numerous illegal placer mine effluent discharges have been reported by DFO staff, particularly in the Cariboo region. With regard to placer mining, individual sites may be in compliance, but in some areas numerous operations located in confined areas have reportedly led to significant cumulative water quality impacts.[91]

2.6.7 Summary

A review of available information suggests that impacts from metal and gold mining in the Fraser Basin are limited as there are few of these mines which are currently active in the Fraser Basin and they are closely regulated. Placer and gravel mining require an increased audit and enforcement effort.

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2.7 "Atmospheric" Effects

2.7.1 Introduction

Many contaminants are released to the atmosphere in the form of gases and fine particulates, which eventually make their way back to the land and surface waters through precipitation. Contaminants which are released to the atmosphere can affect surface waters locally and/or globally. The Lower Fraser Valley receives some industrial contaminants from Washington State. Sulfur oxides originating from four oil refineries along the Washington coast are considered to be significant sources.[94]

Airborne contaminants known to affect water quality in parts of the Fraser Basin include sulfur and nitrogen oxides from industry and automobile exhaust, which can cause acid precipitation, and carbon dioxide, which is a greenhouse gas believed to cause global warming.

Recent sampling of snow at Mount Seymour (Lower Fraser) shows copper levels as high as 0.007 $mg{\cdot}L^{-1}$, almost double the guideline for protection of aquatic life and four times the level measured in 1982.[145] In 1995, zinc levels of 0.037 $mg{\cdot}L^{-1}$, approximately 3 times the guideline for protection of aquatic life, were measured at the top of Mount Blanshard, east of Pitt Lake.[145] If these metal concentrations continue to increase, they may eventually affect aquatic life. Other substances such as pesticides and organic contaminants are also circulated via the atmosphere. They will not be addressed here because atmospheric sources in the Fraser Basin are small compared with point source discharges and stormwater runoff.

2.7.2 Acid Precipitation

2.7.2.1 Effects on Biota

Many physiological and biochemical processes are very sensitive to changes in acidity. Soils and soil micro-organisms, vegetation, and surface waters, can all be affected by acid precipitation. Aquatic organisms are very sensitive to pH changes in their environment because many of the functions performed by gill tissues, including osmoregulation and uptake of oxygen, can be disrupted by pH changes. Studies on fish have shown that all life cycle phases can be adversely affected by acid precipitation although reproductive and early life stages are the most sensitive.[92] Salmon are reported to be very sensitive to low stream pH during smoltification, a period of physiological change in preparation for the marine phase of their life cycle, and during their spawning migration.[93]

2.7.2.2 Chemistry of Acid Precipitation

The largest sources of sulfur and nitrogen oxides in B.C. are automobile exhaust, pulp mills, and gas refineries, although other industries also discharge these substances to atmosphere. Agriculture is believed to be a significant source of nitrogen oxides, either directly, or indirectly from the oxidation of ammonia.[94] Sulfur and nitrogen compounds undergo a chemical reaction in the atmosphere to form sulfuric acid and nitric acid respectively, both of which can cause acid precipitation.

In addition to direct toxic effects on aquatic organisms, acid precipitation can reduce the pH of ground and surface waters, dissolving toxic heavy metals, thereby increasing their bioavailability.[95]

The potential impacts of acid precipitation on a water body are determined by two major factors:

1. the amount of acid inputs; and
2. the **alkalinity** of the receiving waters, which is a measure of the capacity of water to neutralize a specific amount of acid.

Waters with alkalinity in the range of 0-400 $Teq{\cdot}L^{-1}$, or 20 $mg{\cdot}L^{-1}$ $CaCO_3$ are considered to have inadequate buffering capacity to protect aquatic life from acid deposition,[96] as there is not enough capacity to resist pH change in response to acid deposition.

Alkalinity reflects the nature of the rocks in a drainage system, and the degree to which they are weathered. It largely results from carbon dioxide and water interacting with carbonate rocks, dissolving the carbonate to form bicarbonate. In polluted waters, organic ions and phosphate may contribute to total alkalinity. The influence of bedrock and soil on alkalinity and other water quality parameters is a function of duration of contact, types of rocks and soils to which water is exposed, among others.

Wiens[97] evaluated the geology and soils of B.C. for sensitivity to acid inputs using a range of parameters including: soil depth and texture; pH of soil and parent material; soil acidification; base saturation; cation exchange capacity; bedrock and soil type; and ability to dissolve aluminum. This information was summarized for the Fraser Basin by Hall, *et al.* (Table 2.7.1).[98] Of the six sub-basins that drain the western side of the Fraser Basin, two had low acid reduction potential in more than 60% of their area, and three of the remaining four had more than 70% of their areas in the low to moderately low categories. These sub-basins should therefore be considered as relatively susceptible to damage from acid inputs from any source.

The Nechako sub-basin was considered to have low to moderate-low buffering capacity. In the long term acid precipitation may become a concern if the population and level of industrial activity in the nearby City of Prince George increase greatly.

The Lower Fraser is particularly vulnerable to impacts from acid precipitation due to the large inputs of sulfur and nitrogen dioxides combined with relatively low capacity of many streams in the area to buffer acid inputs. Approximately 75% of the Lower Fraser Basin had a low to moderately low capacity to reduce acidity.[98] Sulfur dioxide levels are relatively low in the Lower Fraser compared with many other urban regions due to lower heating requirements, greater reliance on hydro-electricity instead of burning fossil fuels, and fewer industrial polluters. In contrast, nitrogen dioxide levels in the Lower Fraser Valley approach or exceed the Level A annual objective (30 ppb) on a continuous basis.[99]

Table 2.7.1 Potential in Fraser Basin HMAs to Reduce Acidity from Atmospheric Deposits.

HMA	Potential area (%) in HMA with capability to reduce acidity	
	Low to moderate	Moderate to High
Lower Fraser[1 2]	74	19
Lillooet[1]	82	8
Middle Fraser	41	59
Thompson-Nicola	15	85
South Thompson-Shuswap	56	44
North Thompson[1]	36	62
Seton-Bridge	32	68
Chicotin[1]	71	27
Quesnel	23	77
West Road	79	21
Nechako	79	21
Stuart	37	63
Upper Fraser[1]	15	82

[1] Remaining percentage covered by permanent ice
[2] Includes the Fraser Delta, Pitt-Stave and Chilliwack HMAs.
Based on: Hall, *et al.* 1991 (See reference 98).

2.7.2.2 Occurrence of Acid Precipitation in the Lower Fraser Basin.

Studies on rainfall pH in the Lower Fraser Valley indicate that acid precipitation is being generated in this area. Rain is naturally slightly acidic with a pH in the range of 5.5-6.0 as it dissolves some carbon dioxide from the atmosphere. Rainfall pH values less than 5.0 have been recorded in the Lower Fraser Basin.[100] Whitfield, *et al.* measured precipitation pHs as low as 4.5 near Kanaka Creek in the Lower Fraser Basin, which suggests the presence of strong acids in rainfall.[101]

2.7.2.3 The Effect of Acid Precipitation on Salmon Streams

Twenty-four salmon streams in the Lower Fraser Basin were sampled by DFO either weekly or monthly from January 1985 to July 1986, in order to determine sensitivity to acid depositions. An acidification index developed by Henriksen[102] was applied to data from thirteen of these streams. Results indicated that acidification may be ongoing.[103] The same study also determined that most Lower Mainland streams have a minimal capacity to withstand acidic inputs because of low buffer capacities, which are generally in the range of 0 to 50 Teq$\cdot$L^{-1}. Thus, for the Lower Fraser, field observations support predictions that the area is susceptible to impacts from acid precipitation. The mean pH values for the thirteen streams which were sampled ranged from 5.86 to 6.99, with short-term episodic declines to pH 5.30.

Using a continuous monitoring system, other researchers have measured short-term declines of up to 1.2 pH units in Kanaka Creek in the Lower Mainland in response to precipitation events.[104] All pH values measured in the creek were in the range of 5.2 to 6.2, below the minimum guideline of 6.5 which is considered to protect aquatic life.[105] A pH in the range of 5.0 to 6.0 is unlikely to be acutely lethal to aquatic organisms, however, there is a gradual deterioration of water quality as pH values go beyond the normal range. Also, sudden declines in pH can cause acid shock in fish, and potentially cause death at levels above those normally considered lethal.[106]

Whitfield and Dalley[104] found that the degree of pH depression which occurred with a rainfall event was strongly influenced by the base flow present in the stream - i.e. the largest pH depressions occurred when base flow was lowest. The authors hypothesized that this was because direct runoff becomes a larger proportion of the streamflow during a storm, and that this runoff has little time within the groundwater system, and hence remains unbuffered, or otherwise unmodified. This amplification of pH depression under low flow conditions is of concern, as one of the hydrological effects of urban development commonly observed is a decrease in stream flows between rainfalls. Thus, streams in the lower Fraser may become more susceptible to impacts from acid rain for two compounding reasons:

1. increasing amounts of acid-forming pollutants in the atmosphere; and
2. decreasing base flows due to hydrological changes which result from urban development.

Concentrations of dissolved heavy metals are known to increase with acidification of surface waters.[107] Furthermore, increasing acidity can enhance the toxicity of metals to aquatic organisms. Aluminum is considered to be the metal most likely to become problematic as waters become acidified because it is generally present at relatively high levels in forms which are not normally bio-available.[108] Of twenty-four streams monitored in the Lower Mainland by Sullivan and Samis,[103] eleven were found to periodically exhibit dissolved aluminum concentrations exceeding those reported to be acutely toxic to fish.[109, 110] Although the report did not specifically link elevated dissolved aluminum levels with precipitation events, acidic rain would likely be a contributing factor.

2.7.2.4 Summary of Acid Precipitation

Acid rain is a consequence of elevated sulfur dioxide and nitrogen dioxide levels in the atmosphere. In the Lower Fraser Valley most of the nitrogen oxides come from vehicle exhaust. The human population of the area is predicted to double from the present 1.8 million by about the year 2030. The number of trips per day per person is also increasing, and grew by 15.6% between 1985 and 1992.[111] An *Air Care* program was introduced to reduce air pollution from vehicles and has been successful to date, however, the growing numbers of cars and people will make it very difficult to prevent further degradation of air quality.

One recently identified issue of concern in the lower Fraser Valley is the large amount of nitrogen emitted to the atmosphere by agriculture.[112] In Holland the ammonia emitted from agricultural sources is known to be a major contributor to acid rain.[112] The ammonia emitted by agriculture in the Lower Fraser Valley appears to have a different chemical fate, and binds with sulfur compounds which effectively neutralizes the acid-generating capabilities of both the nitrogen and sulfur. This is a benefit from the perspective of acid rain, but is cause for concern with regard to human health, as the resulting small particulates are associated with respiratory ailments.[94]

2.7.3 Global Warming and Water Temperature

Global warming has the potential to substantially alter ocean temperatures, surface water temperatures and stream hydrology, and is therefore considered to be a water quality issue. A detailed review of global warming, Global Climate Models (GCMs), and general implications for salmonids, was prepared on behalf of the Fraser River Action Plan by Levy.[113] Discussion here will be limited to a very brief overview of global warming summarized from Levy,[113] and will address the issue in the context of thermal impacts resulting from other activities.

Global warming, also known as the greenhouse effect, is a result of trace gases with heat-trapping properties in the Earth's atmosphere. These heat-trapping gases absorb infrared radiation causing the average surface temperature of the earth to be approximately 33°C warmer than it would be without absorption of infrared radiation.[114] Greenhouse gases include water vapour, carbon dioxide, nitrous oxide, ozone, methane, halocarbons, and others. There is strong evidence that concentrations of carbon dioxide and other greenhouse gases in the atmosphere have increased over the past several decades. These increasing concentrations are related to industrialization, present agricultural practices, deforestation, and the use of fossil fuels.

There are several different methods available for predicting the climatic and hydrological impacts of future increases in greenhouse gases. These include comparisons of climatic conditions during warm and cold periods, known as the Comparative Method, as well as computer simulation of future conditions with GCMs. Both methods lead to predictions about changes in temperature and precipitation. Each method has limitations which must be considered, as outlined in Moore[115] and different methods can generate discrepancies.

Models are capable of producing reasonable climatic predictions over large spatial scales, however, they can be misleading when applied on a regional scale.[116] Even if realistic local, regional-scale climate change predictions could be obtained, ecological responses may be difficult to predict accurately due to our generally poor understanding of climate-ecosystem interactions.

2.7.3.1 Effects of Global Warming on Hydrology and Biota of Freshwater Systems

Global warming will affect not only temperatures, but also the amounts and seasonal distribution of precipitation. In turn these changes will directly influence seasonal runoff timing and volume. Watersheds where there is currently a close balance between water demand and water supply will be the most vulnerable to impacts. For aquatic life, seasonal cycles in water availability and temperature can influence life history events and biological production.

One scenario modelled by Ripley[117] predicts a substantial increase in winter precipitation, coupled with possible reductions during the summer months for British Columbia. This would result in greater seasonal flow fluctuations, and potentially lower summer flows in the Fraser Basin.

The impacts of climate warming on groundwater, and the role of groundwater in salmonid stream ecology, was reviewed by Meisner, *et al.*[118] who predicted that groundwater temperatures will follow the projected increases in mean annual temperature from climate warming. Many of the streams used by coho and chinook for rearing in the Fraser Basin during summer months have borderline temperature conditions already, and benefit from cool groundwater inputs. As well, in some streams summer temperatures already exceed lethal limits, and fish survive by clustering around cool groundwater inputs which act as thermal refugia.[119] Reduction of the cooling effects from groundwater in these streams would put further pressure on salmon populations which rely on them for rearing habitat.

Global warming will likely have a direct impact on lake temperatures and heating processes. Juvenile sockeye rear in lakes, hence disruption of the normal thermal regime of lakes in the Fraser system is of particular concern. A possible preview of potential impacts of global warming on lake physics, chemistry, and biology is available in a recent report by Schindler, *et al.*,[120] who monitored a Northern Ontario lake for over 20 years. During that time, both air and lake temperatures increased by 2°C, the length of the ice-free season increased by three weeks, and available habitat for cold water species diminished.

2.7.3.2 Effects of Global Warming on Fish Populations

Overall, warming can be expected to influence fish populations and distribution both within and between systems. For example, some lakes and streams may become too warm to support some fish species. In other cases, fish species may become restricted to occupying particular parts of a lake such as deeper, cooler waters, provided that food, oxygen, and other conditions are amenable. Geographical distribution patterns suggest that the northern distribution of a large number of freshwater fish species is governed by temperature (for an example, see Meisner, *et al.*[118]). It therefore seems likely that climate warming will promote the northern range expansion of a broad spectrum of freshwater fish, and cause some species to disappear from the southern limits of their present ranges. An analysis by Meisner[121] concludes that stenothermic fish species (e.g., salmonids) may experience the greatest habitat effects of climate warming, and that such effects will likely become noticeable first in populations located at the southern margins of the species' geographic distributions. They may also become noticeable early on in areas which already have high summer water temperatures, such as in the Nechako, the Stuart-Takla system, and the Thompson sub-basin.

2.7.3.3 Prediction of Freshwater Habitat Changes for B.C.

There are three different climatic and hydrologic regions within the Fraser River watershed: the Coast Mountains, the Interior Plateau, and the Eastern Mountains. There is approximately one order of magnitude difference in the amount of annual precipitation throughout the watershed. This variation, together with differences in seasonal timing of precipitation, snowpack storage and glacier melt imply differences in water storage capacity and runoff patterns for the different sub-basins in the Fraser River.[122] Climate change will most likely affect the three hydrologic regions of the Fraser River watershed in different ways that are not presently easy to predict. Anticipated changes which may occur in freshwater habitats of the Fraser River with global warming as summarized in Levy[113] are outlined below:

1. **Streamflows:** It is likely that there will be higher winter runoffs due to a reduction in the amount of precipitation falling as snow, and an increase in winter precipitation levels, particularly in the Coast Mountains portion of the watershed. Winter streamflow increases and flooding are anticipated to be most severe in the Lower Fraser, Lillooet, and Bridge-Seton watersheds. It is likely that summer runoff will be reduced throughout the entire Fraser, and particularly in the Interior Plateau region, including the North Thompson, South Thompson, and Thompson-Nicola watersheds. The overall timing of the spring freshet of the Fraser will probably occur several weeks earlier than it does at present.
2. **Thermal characteristics:** Average stream and groundwater temperatures in the Fraser watershed will increase and generally follow the future alterations in atmospheric temperature. Reduced future snowpack and accompanying reduced summer discharges will create higher peak and average stream temperatures, due to an interaction between temperatures and flows. Similarly, stream temperatures may further increase if extraction requirements intensify, since a smaller water volume will warm faster than a larger volume. The duration of cold winter water temperatures (<4°C) will be reduced. Lakes within the Fraser watershed will experience increases in surface water and epilimnetic temperatures.

2.7.3.4 Possible Implications of Global Warming for Fraser River Salmon

Impacts of future climate change may have major implications for British Columbia's freshwater fisheries resource. A preliminary evaluation of potential climate warming impacts was undertaken by Northcote[123] who identified the possible consequences of climate change for freshwater fisheries in B.C. (Table 2.7.2).

Due to their life histories and distributions, Northcote[123] concluded that cutthroat trout, pink salmon, and chum salmon should be less affected by climatic change than rainbow trout, dolly varden, lake char, and coho, sockeye and chinook salmon.

There will likely be regional disparities in the impacts of global warming on salmon within the Fraser watershed. Salmon populations in the interior portion of the watershed (Thompson, Middle, and Upper Regions) that are highly dependent upon the freshwater environment for juvenile rearing are particularly vulnerable to future global warming effects. The latter includes most of the chinook and sockeye populations, and many of the coho salmon stocks within the Fraser River watershed. Coho are considered to be particularly vulnerable because they spawn and rear for a year or more in small streams, many of which already have problems with high summer water temperatures. Pink and chum salmon populations in the coastal portions of the watershed may be vulnerable to the negative effects of winter flooding, and subsequent reductions in egg-to-fry survival.

This analysis does not include effects of global warming on the oceans, and the thermal requirements of salmon while they are at sea. Some scientists predict that within 50 years, global warming will result in ocean temperatures which are high enough to cause the collapse of some B.C. salmon stocks.[136]

2.7.3.5 Existing Water Temperature Problems in the Fraser River Basin

The issue of global warming must be examined within the context of existing issues which are already causing critical water temperature and hydrology problems in the Fraser Basin. Disruption of natural thermal and hydrological conditions occurs in streams already as a result of extensive land clearing related to forestry, agriculture, and urban development.

Land-clearing activities often result in the loss of riparian vegetation, which normally provides shade and is therefore a cooling influence to streams during warm and dry months. Numerous studies have reported substantial increases in stream temperatures during the summer due to land clearing.[124-127] A study on Slim Creek in the central interior of B.C. showed that maximum summer daytime temperatures were up to 9°C warmer than upstream shaded sites, and diurnal temperature fluctuations doubled as a result of land clearing.[128] Fish are vulnerable both to high temperatures and large temperature fluctuations.

Results of recent work in the Fraser Basin indicate that losses of riparian vegetation along Fraser Basin streams are extensive, at least in some areas such as the Thompson sub-basin, and the Lower Fraser Basin.[129-131] These losses have resulted from urban and agricultural development, forestry activities and linear developments. Many of the tributaries with extensive riparian losses are known to experience summer water temperatures which approach or exceed 20°C and are therefore potentially lethal to salmonids.

In addition to temperature problems in small streams, high water temperatures have recently been problematic in the Fraser mainstem. Record high water temperatures in the Fraser Basin during the summer of 1994 resulted from a combination of warm air temperatures and low precipitation. Temperatures recorded in the Fraser mainstem frequently exceeded 20°C, and likely had a significant role in the "missing fish" - salmon which were expected to reach spawning grounds but never arrived there.[132] Radio-tagging studies showed that salmon encountering the warm waters were actually swimming downstream rather than upstream. Fish which were swimming in the right direction had reduced chances of reaching their destinations due to increased susceptibility to infections, and increased energy requirements imposed by the warm waters. The summer of 1994 may provide some insight into the future of salmon runs, particularly those which migrate significant distances upstream to spawn, and those which spawn in the summer or early fall, when water temperatures are highest.

2.7.5 Relevant Policies and Legislation

Section V of the *Canadian Environmental Protection Act* contains provisions to control sources of air pollution in Canada where a violation of an international agreement would otherwise result, or where air pollution affects another country and reciprocal legislation exists to control the sources of pollution. Most efforts to address international concerns over air pollution have been

Table 2.7.2 Possible freshwater fisheries consequences of climate change in B.C.

Climate change impacts on:	Major concern:
•migration	•salmon stocks which presently experience high levels of pre-spawning mortality
•spawning	•early-fall spawners
•development timing and emergence	•premature emergence, reduced egg survival
•feeding, growth, survival	•reduced survival associated with oxygen depletion, increased frequency of "summer kill" events
•distribution and community structure	•altered fish distribution, invasions by exotics
•fisheries management	•greater variability and unpredictability

Source: Northcote. 1992. (See reference 123) focused on the acid rain issue in eastern Canada, and the north-eastern United States. Lakes in the area are typically poorly buffered and were being heavily impacted by long-term effects of acid rain.

Canadian initiatives to address the emission of greenhouse gases have fallen short of targets; inputs have increased significantly over the past 10 years instead of decreasing. Trends in British Columbia have mirrored the increases documented for the rest of Canada.

Issues such as acid rain and global warming are extremely complicated both politically, and in terms of chemical complexity. Countries are generally reluctant to invoke strict legislation to address emissions as they do not wish to "handicap" industry and consumers with expensive anti-pollution measures if the rest of the world is not willing to do the same. Consequently, remedial actions come about slowly at best. Often restrictions of emissions, such as the GVRD *Air Care Program*, are implemented to alleviate immediate human health impacts rather than environmental impacts.

2.7.6 Summary

Both local and global inputs of contaminants and greenhouse gases to the atmosphere can have potentially serious impacts on Fraser River salmon populations. These types of pollution problems are very difficult to manage, especially in the case of CO_2 concentrations, because of the global sources.

While acid rain is nowhere near the serious problem in B.C. as it is in eastern Canada, it is still a potentially serious problem in the Lower Fraser Basin. Controlling acid-generating substances such as nitrate and sulfate at source is the only viable long-term solution to addressing acid rain, and would have numerous benefits that extend beyond fish such as reducing damage to buildings, soils, and farm crops. Interim mitigative measures such as adding limestone to surface waters to help neutralize the pH have been successful in some cases and may be an option which DFO needs to explore in the future if rainfall becomes more acidic with the growing Lower Fraser population.

While there is considerable evidence to support the theory that increased emissions of greenhouse gases are resulting in a global warming trend, there appears to be little commitment among nations to address the problem.

Global warming may or may not prove to be a reality. What is a reality is the fact that there are already serious problems with high summer water temperatures in many salmon-bearing streams in the Fraser Basin. Temperature increases which occur due to extensive losses of riparian vegetation may exceed the increases predicted to occur due to global warming by several degrees. Temperature must be considered as an important water quality condition which needs to be protected. Actions need to be taken now to address existing problems and will at least provide some protection against additional temperature increases that may occur as a result of global warming effects. Two interim types of options exist for addressing existing large scale water temperature issues:

1. constructing water storage facilities for the purpose of providing cold water releases during hot summer months; and
2. restoring riparian vegetation in sub-basins which have experienced significant losses, and protecting existing riparian vegetation on all streams.

The first option is not desirable for numerous reasons including the additional problems that are typically created when a dam is constructed (loss of existing habitat, disruption of normal flow patterns). Furthermore, constructing dams is extremely expensive.

Riparian restoration may prove to be the best option for guarding against increasing water temperatures in the Fraser Basin, and would benefit numerous water quality and fish habitat issues in addition to temperature. Pilot projects to restore riparian vegetation on farm land and in urban areas are underway in a number of areas of the basin, and need to be encouraged on a broader scale. Large-scale riparian restoration could only be accomplished with the co-operation of land owners, which may prove to be an obstacle, as many land owners are unwilling to participate. Protection and restoration of riparian areas on agricultural land might be best addressed through education with the B.C. Federation of Agriculture, and the peer inspector program. Initiatives such as *Watershed Stewardship - A Guide for Agriculture*[147] can serve as effective educational tools, especially if they are backed up with training/education sessions. With regard to urban development, education of planners and developers (as per the *Stream Stewardship for Urban Planners and Developers*[33]), individual land owners, and municipal governments who have the power to pass bylaws, should all be effective means for protecting and restoring riparian areas.

With regard to forestry, the Forest Practices Code has provisions for the protection of riparian areas on Crown lands which are enforceable. These provisions should be monitored for effectiveness in protecting water temperatures, and buffer strips should be increased if necessary.

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Chapter 3 Methodology

3.1 Introduction

Data and information about land uses and summer low flow conditions were used to evaluate water quality and the potential for impaired water quality in each known salmon-bearing watershed in the Fraser Basin. Information used to evaluate water quality conditions and the potential for water quality concerns in all salmon-bearing streams of the Fraser Basin included:

- water quality, sediment, and fish tissue contaminant data collected between 1980 and 1995, compiled into a database for DFO and DOE-FRAP programs by LGL Consultants Ltd.;[1]
- fish tissue contaminant data collected at selected reaches by DOE in 1994;
- the quality and quantity of all effluent discharges to surface waters addressed via provincial Waste Management Permits, based on permit specifications for each discharge;[2]
- information about land uses which generate non-point source pollution, focusing on urban and agricultural uses, and forest harvesting;
- information on licensed water withdrawals and stream hydrology, particularly summer low flows; and
- input obtained from DFO and MELP staff with first-hand knowledge of streams, through circulation of a draft report and follow-up discussions.

The data sources and assessment criteria used are described in detail below.

Data and information have been organized on a stream-by-stream basis to provide an overall synopsis of measured water quality conditions, and any discharges or activities which may impair water quality in each watershed.

Where data were available an assessment of the measured conditions is provided. A series of hydrology reports prepared for DFO-FRAP [3-14] supplied land use information for most salmon-bearing streams identified in DFO Stream Information Summary System (SISS) catalogues,[15-26] and served as a basis for assessing the potential for land uses and summer low flow conditions to affect water quality. The types of water quality impacts which can result from different types of human activities are explained in Chapter 2.

Colour-coded icons are used in the stream summaries to provide a quick synopsis of the level of concern for water quality in each documented salmon-bearing stream in each HMA. In general, the colour-coding scheme applied to icons represents the following:

Red ◆Available information indicates that water quality conditions limiting to fish production are likely to occur in the watercourse.

Yellow ◆Available information indicates that there may be some impairment of water quality, with potential implications for fish.

Green ◆Information indicates that water quality is unimpaired and should not be limiting to fish production.

Blue ◆There was not enough information available to assess water quality conditions.

A more detailed explanation is provided below for each of the icons used in the report. A coloured symbol is not provided for land uses which are not present in a watershed.

A colour-coded map showing water quality sampling stations, and an assessment of measured conditions is provided for each HMA. Maps indicating the locations of all discharges to surface waters addressed by MELP Waste Management Permits, and tables summarizing permit discharge information are also provided for each HMA.

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3.2 Methodology

3.2.1 Evaluation of Water Quality and Contaminant Data

A database compiled on behalf of DFO and DOE FRAP programs[1] was the main source of data used to evaluate surface water, sediment and fish tissue quality for the Fraser River and tributaries. Where data from elsewhere are included, the sources are indicated.

The data in this FRAP database originate primarily from MELP's SEAM database and Environment Canada's ENVIRODAT database. Additional data obtained via the Continental and Oceanographic Data Information System (CODIS)[35] and several other limited sources were also incorporated into the FRAP database.[1]

The data initially downloaded from the above sources were screened in a number of ways. Only data collected after 1979 were included in the FRAP database. Data from sites located outside the Fraser Basin were eliminated, as were sites lacking geographical co-ordinates or other spatial information necessary for mapping the sampling site. Nutrient data collected prior to 1985 were not included in the FRAP database because analytical approaches have changed significantly since this time.

After compiling the data, Wainwright, *et al.*[1] standardized units of measure and parameter codings, and further screened the database for anomalous values. Values reported as zero were converted to the method detection limit. Extreme outliers and duplicated data were excluded.

3.2.1.1 Parameters

The parameters used to evaluate the condition of streams in this report include: physical measures, nutrients, metals, and microbes in surface water; metals and organic contaminants in sediments; and, chlorophenols, dioxins, furans, PCBs, pesticides and mercury in fish tissue (Table 3.2.1).

Specific parameters were selected for inclusion in this water quality assessment for a number of reasons:

- each has either a direct or indirect effect on aquatic life;
- the selected parameters are often affected by specific anthropogenic activities, therefore, management options for abatement may be implemented; and
- the parameters are commonly measured, so adequate data are likely to be available for site-specific assessment of water quality, and for between-site comparisons of the parameter.

3.2.1.2 Data Evaluation

Where possible water, sediment and fish tissue quality were evaluated in relation to existing relevant guidelines

Table 3.2.1 Guidelines and 80th percentiles for parameters used in this study.[29]

	Parameter	SEAM code	Guideline	For the protection of:	Guideline Source
Surface Water					
Physical	Temperature	0013	15 °C	Salmonids	DFO-FRAP
	Dissolved oxygen	0014	9.5 mg·L⁻¹ (minimum)	Aquatic life	CCME
	pH	0004	6.5 - 9.0	Aquatic life	CCME
Nutrients	Total nitrate/nitrite nitrogen	0109	0.123 mg·L⁻¹	N/A	80th percentile
	Dissolved ammonia-N	1108	0.01 mg·L⁻¹	N/A	80th percentile
	Total phosphorus	P--T	15 µg·L⁻¹	Aquatic life[1]	B.C. MELP
	Total phosphorus	P--T	90 µg·L⁻¹	N/A	80th percentile
Microbes	Fecal coliforms	0450	200 MPN·100mL⁻¹	N/A	LGL[2]
	Total coliforms	0451	240 MPN·100mL⁻¹	N/A	80th percentile
Metals	Arsenic	As-T	0.05 mg·L⁻¹	Aquatic life	CCME
	Cadmium	Cd-T	0.17 µg·L⁻¹	Aquatic life	CCME
	Chromium	Cr-T	2.0 µg·L⁻¹	Aquatic life	CCME
	Copper	Cu-T	2.0 µg·L⁻¹	Aquatic life	CCME
	Mercury	Hg-T	0.1 µg·L⁻¹	Aquatic life	CCME
	Lead	Pb-T	2 µg·L⁻¹	Aquatic life	CCME
	Zinc	Zn-T	0.03 mg·L⁻¹	Aquatic life	CCME
Sediments					
Metals	Arsenic	As-T	6 µg·g⁻¹	Aquatic life	B.C. MELP
	Cadmium	Cd-T	0.6 µg·g⁻¹	Aquatic life	B.C. MELP
	Chromium	Cr-T	26 µg·g⁻¹	Aquatic life	B.C. MELP
	Copper	Cu-T	16 µg·g⁻¹	Aquatic life	B.C. MELP
	Mercury	Hg-T	0.2 µg·g⁻¹	Aquatic life	B.C. MELP
	Lead	Pb-T	31 µg·g⁻¹	Aquatic life	B.C. MELP
	Zinc	Zn-T	120 µg·g⁻¹	Aquatic life	B.C. MELP
Organics	PAHs	various		see Appendix 2	
	Organochlorine pesticides	various		see Appendix 2	
Fish Tissues					
Metals	Mercury	Hg-T	0.65 µg·g⁻¹ wet wt.[4]	Humans[3]	Health Canada
Chlorophenols	2,4,6-Trichlorophenol	T042	64.6 µg·g⁻¹ wet wt.[4]	Humans[3]	B.C. MELP
	Pentachlorophenol	P022	2.59 µg·g⁻¹ wet wt.[4]	Wildlife	N.Y.
	Pentachlorophenol	P022	25.85 µg·g⁻¹ wet wt.[4]	Humans[3]	B.C. MELP
Dioxins	2,3,7,8,-T4CDD	T061	25.86 pg·g⁻¹ wet wt.[4]	Aquatic life/ humans[3]	Health Canada
PCBs	Total PCB		2 µg·g⁻¹ dry wt.	Aquatic life	B.C. MELP
Pesticides	p,p'-DDE		5 µg·g⁻¹ dry wt.	Humans	
	Total Toxaphene		0.1 µg·g⁻¹ dry wt.	Humans	Environment Canada

Guideline established for [1] Salmonid-bearing lakes
[2] LGL Ltd., see reference 1
[3] Human consumption
[4] Converted from criteria established for dry weight, based on fish moisture content of 77.35%.

(Table 3.2.1). For water quality parameters, data were compared with available CCREM (subsequently renamed to CCME) guidelines[33] established for the protection of aquatic life. For some parameters included in this study CCME guidelines do not exist. Therefore MELP Approved and Working Criteria for Water Quality[27] were applied. Sediment metal data were compared with MELP Approved and Working Criteria for Water Quality[27] which are similar to Threshold Effects Levels identified in CCME guidelines. Contaminants in fish tissue were evaluated using guidelines for the protection of aquatic life, and human health where applicable.

In some watercourses, one or more parameters may naturally exceed CCME and/or MELP guidelines due to local geology and soil types, hence, "high" levels of a parameter relative to guidelines do not necessary indicate anthropogenic impacts. Efforts have been made to identify the source of "high" levels of any parameter, natural or otherwise, in stream summaries.

For some parameters neither CCME nor MELP has established guidelines for the protection of aquatic life. In such cases the 80th percentile values, calculated using data for the entire Fraser Basin, were assumed to be a threshold above which the measured value indicates a deviation from naturally occurring conditions. Data collected during freshet (considered to be April to July) for metals were excluded from 80th percentile calculations because it was believed that high levels were associated with high suspended sediment loads.

Where the database permitted, upstream/downstream comparisons of water quality data were made to help distinguish between natural water quality conditions and degraded water quality. Inclusion of land use information in stream summaries enables the reader to place water quality data into some context.

There are several parameter-specific issues which require further discussion:

1) Surface Water Quality

A) _Dissolved Oxygen (DO)_

Percent saturation is more important in determining the availability of oxygen to aquatic organisms than is the absolute concentration of DO in the water column. However, percent saturation is temperature-dependent, and water temperature data were often not available in the database to accompany DO data. The measured DO concentrations were, therefore, compared with the CCME guideline for the minimum DO concentration considered to protect early life stages of cold water biota, including salmonids.

B) _Phosphorus_

There are no Canadian guidelines addressing concentrations of total phosphorus in rivers because many factors, such as temperature and turbidity, may influence the sensitivity of moving water to phosphorus inputs. Phosphorus is not directly harmful to aquatic organisms. Rather, negative effects from high phosphorus levels result from eutrophication. Water quality impacts associated with eutrophication relevant to fish include diurnal fluctuations in pH, low night-time DO concentrations, and low DO concentrations resulting from the die-off and decomposition of algal blooms.

The B.C. MELP guideline for phosphorous concentrations (15 $\mu g \cdot L^{-1}$), established to protect lakes containing salmonids, was used here to evaluate phosphorus concentrations in lake surface waters only. The 80th percentile phosphorus concentration calculated from the Fraser River database (90 $\mu g \cdot L^{-1}$) was used to evaluate concentrations of total phosphorous measured in streams and rivers. It should be noted, however, that the 80th percentile concentration is quite high and likely reflects particulate phosphorus associated with high turbidity in the Fraser River and some tributaries. Phosphorus is not readily bio-available until converted to ortho-phosphorus, however, this parameter has been seldom measured. Total phosphorus provides a measure of the maximum amount of the nutrient which may be available to aquatic biota.

C) _Ammonia_

As water temperature and pH increase, the percentage of ammonia in the toxic NH_3 state (rather than NH_4^+) increases. Unfortunately, temperature and/or pH data often do not accompany ammonia measurements in the database, making it impossible to assess whether or not measured ammonia concentrations are potentially harmful to aquatic life at the majority of sampling sites. Ammonia data were therefore always compared with the 80th percentile level; values which exceeded this level were considered to be a sign of contamination resulting from anthropogenic activities (e.g. sewage discharges, septic systems, agricultural runoff). Where temperature and pH data were available, ammonia concentrations were compared with MELP criteria for 30-day exposures and maximum concentrations in stream summaries.

There is some evidence that MELP ammonia measurements made between 1986 and 1994 are of poor precision and accuracy for low to medium concentrations, as determined from non-blind audit samples.[36] Data should therefore be considered with caution.

D) _Fecal Coliforms_

Levels of total coliforms and fecal coliforms are not considered to be a direct threat to fish, hence, criteria for the protection of aquatic life have not been established for these parameters. Coliform levels may be an indicator of pollution sources such as sewage discharges or seepages and manure runoff which contain other substances harmful to fish, so coliform data were included in water quality assessments.

E) *Metals*

Concentrations of total metals in surface water are influenced by geological conditions. There were not enough data at many sites to determine whether elevated concentrations of total metals were due to high suspended solid levels, local mineralization, or inputs from anthropogenic activities.

The effects of individual metals on aquatic organisms is influenced by a number of factors including ionic state of the metal, water hardness, and concentrations of other metals in the water.

MELP analyses of metals from 1986 to 1994 show poor precision and accuracy, particularly for low concentrations of chromium, copper, and zinc.[36] Where measured values are close to detection limits, confidence in the data is low. There have been numerous changes in analytical techniques and labs, and in detection limits over the time span from 1986 to 1994. Also, MELP no longer measures mercury in water as there is no appropriate sampling protocol for mercury in water. The few measurements reported should therefore be considered with caution.

2) Sediment Quality

Many factors, such as particle size distribution and levels of acid-volatile sulfides, influence both the types and levels of contaminants likely to accumulate in sediments and the bio-availability of contaminants to organisms living in or on sediments. These factors were usually not reported in the database, therefore conclusions regarding biological implications of sediment contaminants usually could not be made based on the database. Furthermore, the methods used to extract metals from sediment samples were unknown, and can significantly affect measured values. Comparisons of measured sediment contaminant levels with guidelines do, however, provide information about where potential problems may exist.

Freshwater sediment guidelines from the B.C. MELP *Approved and Working Criteria for Water Quality* were used to assess sediment quality data in this study.[27]

Table 3.2.2 A Comparison of BC MELP and CCME freshwater sediment guidelines.

Metal	CCME ($\mu g \cdot g^{-1}$)		BC MELP
	TEL	PEL	($\mu g \cdot g^{-1}$)
Arsenic	6	17	6
Cadmium	0.6	3.5	0.6
Chromium	37	90	26
Copper	36	197	16
Lead	35	91	31
Mercury	0.17	0.5	0.2
Zinc	123	315	120

TEL = Threshold Effects Level
PEL = Probable Effects Level

These criteria usually correspond with a Lowest Effect Level, based on Screening Level Concentration,[27] and are slightly more stringent than the recently developed Canadian (CCME) *Interim Sediment Quality Assessment Values* (Table 3.2.2). The CCME guidelines were derived through an empirical approach which implies a relationship between biological effects on aquatic organisms and the co-occurring sediment contaminant levels, rather than proof of causal relationship.[28]

The CCME guidelines include two sets of criteria to evaluate sediment quality: the "Threshold Effects Level" (TEL) and the "Probable Effects Level" (PEL). TEL indicates the level below which biological effects resulting from the contaminant are extremely unlikely, while PEL is the level above which biological effects resulting from the contaminant are very likely.

Clearly there is a need for particular caution in evaluating the sediment data, because natural background concentrations may exceed the guidelines, and bio-availability of substances in sediments is greatly influenced by many factors. In addition, differences in the methods used to extract metals from sediment samples can have a large influence on the levels measured, and consistent techniques must be used if samples are to be compared with one another, or with criteria or guidelines established by government authorities.

3) Contaminants in Fish Tissue

Organic contaminants in fish tissues, specifically total PCBs, total dioxins and furans, and select pesticide residues, were assessed according to guidelines established to protect the health of humans who consume fish flesh. Effects of these low concentrations of contaminants on fish are not well documented. Furthermore, these contaminants are usually found in mixtures, and their combined effects on fish at low concentrations are unknown.

In 1992, the Federal government promulgated regulations controlling pulp mill effluent quality and the levels of dioxins and furans in discharges, and mills were required to comply by 1994. Many mills, however, actually began implementing major process changes in 1989. As a result, there was a substantial decrease in the loading of dioxins and furans to the aquatic environment between 1989 and the early 1990's, and concentrations of these substances in sediments and fish tissues have declined rapidly. Dioxin and furan concentrations measured in fish tissues collected since 1992 are therefore evaluated separately from data collected prior to introduction of the legislation.

All consumption advisories which were applied to Fraser River stocks due to accumulation of dioxins and furans in fish tissues have now been lifted.

3.2.1.3 Evaluation Criteria applied to Water Quality Data

The objective of the data evaluation was to provide an indication of the level of concern for water quality in each watercourse, based upon available data. Evaluation criteria used to assess water quality, sediment, and fish tissue data were developed in an attempt to provide a meaningful assessment of available data despite a number of problems with the existing data.

Difficulties with the data include but are not limited to:

- numerous sites with few sampling events;
- few sites with numerous sampling events;
- lack of consistency in the parameters measured between sites, and within sites on different sampling days;
- data are often lacking for parameters which should be sampled together (e.g. when ammonia is measured, water temperature and pH should also be reported); and
- lack of Quality Control/Quality Assurance data, to assess data quality.

The evaluation criteria used to assess **surface water quality data** for each sampling site in the Fraser Basin were as follows:

Red •$n \geq 20$ and >25% of samples for any parameter exceed the guideline or 80th percentile value as indicated in Table 3.2.1.

Yellow •$n \geq 20$ and > 10% but < 25% of samples for any parameter exceed the guideline or 80th percentile level;

OR n < 20 and 2 or more samples exceed the guideline or 80th percentile for at least one parameter.

Green •$n \geq 20$ and fewer than 10% of samples exceed the guideline for any parameters measured, or the natural background levels for the watercourse as determined from the database;

OR $n \geq 10$ for 3 or more parameters, and none of the measured values exceed guidelines or 80th percentile levels, or natural background levels for the watercourse as determined from the database.

If the range of parameters measured was inadequate to support a conclusion about water quality (e.g. only pH measured), the icon colour would default to blue.

Blue •None of the above conditions are met.

Rationale:

A minimum sample size (n) of 20 for a parameter at a given site was selected as the basis for a reasonably certain conclusion of either good water quality (green) or impaired water quality (red). The category of green for $n \geq 10$ for three parameters or more was introduced to address situations where data are limited but indicate good water quality.

Where a sample size of less than 20 for a given parameter was available and more than 2 measurements of a parameter exceeded guideline or 80th percentile levels (Table 3.2.1), it was considered that water quality conditions may exist that negatively affect fish (yellow) and further sampling is required before conclusions can be made.

The number of samples measured per parameter often varies at a given site. The water quality assessment for each site was therefore based on the worst-rated parameter according to the above criteria.

Where available information was inadequate to support an assessment of water quality, a blue colour was assigned to the icon.

For **sediment contaminant** and **fish tissue contaminant** data, the above criteria were adjusted because sediments and biota tend to accumulate contaminants of concern. Hence, smaller sample sizes were considered to provide a viable basis for drawing conclusions about contaminants and the following evaluation criteria were applied:

Red •$n \geq 10$ and $\geq$30% of samples for any parameter exceed the guideline or 80th percentile value as indicated in Table 3.2.1.

Yellow •$n \geq 10$ and > 10% but < 30% of samples for any parameter exceed the guideline or 80th percentile level;

OR n > 5 and < 10, and 2 or more samples exceed the guideline or 80th percentile for at least one parameter.

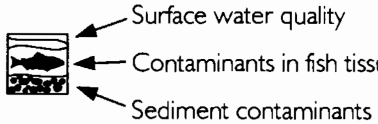
Green •$n \geq 10$ and fewer than 10% of samples exceed the guideline for any parameters.

OR $n \geq 5$ and <10, and none of the measured values exceed guidelines or 80 percentiles.

If data are inadequate to support an assessment of sediment or fish tissue quality (e.g. only three measurements of a parameter), the icon colour would default to blue.

Blue •None of the above conditions are met.

Assessments of water quality and contaminants in sediments and fish tissue have been made for each sampling site in the Fraser Basin, based on available data. Assessments are presented on HMA maps using three-part coloured icons to represent surface water quality condition, fish tissue contaminant levels and sediment quality:



Where application of the assessment criteria described above are considered to be inappropriate for a sampling site an asterisk (★) has been placed beside the water quality icon on the HMA map. An explanation of the discrepancy is provided with the stream summary information.

Occasionally data from a source other than the FRAP water quality database (e.g. DFO unpublished data) were used to assess water quality; in all such cases the data are included in the data summaries and the information source is indicated in both the stream summary and data tables.

All data used to evaluate surface water quality, sediment contaminant, and fish tissue contaminant levels are summarized in the HMA chapters, so readers have the opportunity to form their own assessments.

3.2.2 Evaluation of Waste Management Permit Specifications

The discharge conditions specified in each Waste Management permit addressing a discharge to surface waters were assessed in terms of the sensitivity of the receiving environment. This was a subjective assessment as monitoring data from the receiving environment are rarely available. However, permits of concern were discussed with field staff in an effort to confirm whether the permit conditions warranted review. Summary tables indicating the permits which should be re-visited (i.e. where specified conditions may need to be reconsidered) are provided for each HMA which contained permitted discharges of potential concern.

3.2.3 Evaluation of Land Uses and Hydrology Information

There are three main categories of land uses which are widespread in the Fraser Basin and cause characteristic water quality problems unless significant precautions are taken. These land uses are urban development, agriculture, and forestry, all of which can generate significant amounts of non-point source pollution. Indices were developed to evaluate the likelihood of water quality degradation in Fraser Basin salmon-bearing streams, based on these three categories of land uses. If a type of land use does not occur in a watershed, the relevant icon is omitted from the stream summary.

In addition, low flows and water demand were assessed for existing or potential concerns because of their influence on water quality. Low volumes of water in a stream can result in highly variable temperatures and dissolved oxygen concentrations, and can reduce the ability of a stream to moderate impacts from contaminant inputs.

The indices are based on information contained in DFO's SISS catalogues[15-26] and a series of hydrology and water use reports for each of the Habitat Management Areas in the Fraser Basin.[3-14]

These assessments of the level of concern for impacts to water quality arising from human activities in Fraser Basin watersheds are often based on imprecise information. Assessments were intended to provide some perspective of the predominant land uses in each watershed, and an idea of the major water quality issues likely to be present in each stream.

Impacts in a watershed may be disproportionate to the degree of a land use present, resulting in assessments which are not representative of actual conditions. It should be noted, however, that DFO and MELP field staff reviewed draft reports and their first-hand knowledge of streams was incorporated into assessments in an effort to address shortcomings of the approach taken here. Field staff who reviewed drafts of the HMA chapters were asked to identify what they considered to be misleading or missing information, and to add their first-hand knowledge to the summary information. Based on feedback received from field staff, it appears that assessments of effects of adjacent land uses on the water quality of a watercourse generally provided a realistic overview of land uses and water quality issues.

3.2.3.1 Urban development

Urban runoff contributes a variety of contaminants to streams. As well, the increased variability of stream flows resulting from runoff affects stream temperatures and suspended sediment loads.

The percentage of the total area in a watershed which is impermeable determines the potential for both alteration to stream hydrology, and the contribution of contaminated stormwater runoff. The Effective Impervious Area (EIA) for Lower Fraser salmon streams was provided by Rood and Hamilton,[3, 5, 9] and was used to assess the extent to which urban land use is likely to affect water quality in a watershed. For HMAs outside of the Lower Fraser Valley, assessment of the effects of urban development on water quality relied more on specific problems being reported.

Criteria:

Red — •Greater than 9% of the watershed consists of EIA;

OR a specific problem pertaining to impacts from urban development (e.g. extensive removal of riparian vegetation, erosion, etc.) are identified in a hydrology report, SISS Catalogue, or another reliable source. Water quality deterioration was assumed to accompany significant habitat disruptions - an assumption generally supported by field measurements and assessments.

Yellow — •The EIA for a watershed is between 2% and 9%;

OR a relatively small level of impact has been reported, or the potential for water quality/fish habitat problems to develop has been identified in a reliable information source.

Green •EIA is less than 2% for a watershed indicating minimal development;

OR urban development does exist in the stream, and reports specify that there are no impacts result from the urban development.

Blue •No EIA or land use information is available.

Rationale:

Rood and Hamilton[3, 5, 9] stated that an EIA of 10% in a watershed causes major stream channel enlargement due to higher peak flows resulting from stormwater runoff. Stormwater runoff carries significant contaminant loadings to urban streams, and can also cause scouring which leads to sedimentation. The hydrology reports and SISS catalogues consistently identified impacts to streams with more than 9% EIA.[3, 5, 9, 15-20] Therefore, an EIA greater than 9% was considered to present a high probability of water quality impacts resulting from urban stormwater runoff.

A lower limit of 2% EIA was assigned to the yellow ranking because almost all streams with less than 2% EIA had no reported impacts on fish habitat or water quality (green) resulting from urban development.

3.2.3.2 Agriculture

Agriculture can affect water quality in several ways. Loss of riparian vegetation and low water flows resulting from water withdrawals can affect stream temperatures and dissolved oxygen concentrations. Leaching and runoff from fields or animal holding areas can contribute nutrients that cause eutrophication, organic matter which consumes dissolved oxygen when it decomposes, as well as ammonia and/or pesticides which are highly toxic to fish. Livestock access to stream banks can lead to slumping and erosion of stream banks, contributing suspended sediments to a stream.

SISS catalogues and hydrology reports often indicate the extent of agricultural activity present in a watershed, or specifically identify fish habitat and water quality impacts. The intensity or extent of activity was considered to reflect the probability of impacts to water quality.

Criteria:

Red •Hydrology reports, SISS catalogues, or other reliable information sources identify extensive or intensive activities often associated with water quality impacts, or a specific agricultural impact on fish habitat or water quality resulting from widespread activities.

Yellow •Hydrology reports, SISS catalogues, or other reliable information sources identify localized negative effects on fish habitat or water quality, or the potential for agricultural land use to degrade water quality, but actual impacts are not documented.

Green •Agricultural activity exists but information indicates that it is not degrading water quality.

Blue •Agricultural activity exists but it is unknown whether or not it is degrading water quality.

Rationale:

The intensity and amount of agricultural activity in a watershed reflects the extent of resulting impacts to water quality and fish habitat. Where habitat impacts were identified in information sources, a similar degree of water quality degradation was assumed. Since significant impacts to fish habitat will be accompanied by degraded water quality, red, yellow, or green ratings were applied accordingly.

Impacts on water quality were considered unlikely for streams in which agricultural activity is very low, resulting in a green ranking.

3.2.3.3 Forestry

Forest harvesting can disrupt the normal thermal regime of a stream via disruption of the natural hydrology, and through the removal of extensive amounts of riparian vegetation. Extensive harvesting often results in decreased summer low flows and increased summer water temperatures. Loss of riparian vegetation can cause increased summer and decreased winter stream temperatures, and larger diurnal fluctuations. As well, extensive logging can increase nutrient leaching and the delivery of suspended and bedload sediment to streams.

Forestry-related water quality problems were assessed based on:

1. The extent of logging activity in a watershed as a percentage of the total watershed area cut, i.e. % cut, as determined by Rood and Hamilton[3-14] (this information usually dated back to the 1960s) ; plus
2. The percentage of the total watershed area proposed for logging in MOF Five Year Plans - this area (when available) was included in the 20% (see red criteria below) as most of this logging would have occurred by now given that 5 year plans dated from 1992 - 93.[3-14]

In addition, specific mention of water quality impacts related to forest activity in the SISS catalogues, hydrology reports, or other information sources, was considered in watershed assessments.

Criteria:

Red •Greater than or equal to 20% total and proposed cut area in a watershed;

OR impacts to fish habitat or water quality are identified in hydrology reports, SISS catalogues, or other reliable information sources.

Yellow •The total and proposed cut is less than 20% but greater than 3% of the watershed area;

OR localized impacts or possible concerns about logging activity are reported in hydrology reports, SISS catalogue, or other reliable sources.

Green •The total and proposed cut is equal to or less than 3% of the watershed area,

OR information indicates some logging activities with no impacts to water quality or fish habitat.

Blue •Logging activity exists but no information was available describing the extent or level of impacts.

Rationale:

The types of water quality impacts associated with logging (e.g. sedimentation) tend to accompany disruptions to hydrology and are therefore likely proportional to the disruption of hydrology. Rood and Hamilton[3-14] indicate that when total or recent harvesting has occurred over more than 20 percent of a watershed area, management concerns for fish habitat can be expected in association with disruption of the natural watershed hydrology, which is consistent with DFO's approach taken in negotiating on Ministry of Forests land use planning initiatives.[34] This approach does not directly address the fact that some hydrologic recovery would likely have occurred in older clearcuts due to forest regeneration. However, the estimates of percent cut provided in Rood and Hamilton[3-14] may be low because they only date back to the 1960's, while logging prior to this time may still have some effects on hydrology, and hence on water quality.

Rood and Hamilton[3-14] do not identify a minimum percent of logged area for which hydrology impacts are not likely. A value of 3% was used as a lower limit for a yellow ranking because neither the hydrology reports nor SISS catalogues mention forestry-related problems along streams if the cut was under 3% of the total watershed area.

If less than 3% of the watershed area was the subject of recent and proposed logging it was considered likely that impacts to water quality would not occur. In reality, even the smallest cuts can degrade water quality if efforts are not made to avoid damage to sensitive or erosion-prone areas.

3.2.3.4 Summer 7-day mean low flow

Low water flows influence maximum and minimum stream temperatures, as well as daily temperature fluctuations. Streams with very low flows are also more easily affected by contaminant inputs. Low flows can further affect habitat by reducing the total area of wetted habitat available to fish in a stream and by preventing fish migration.

An index based on summer 7-day low flows was used to assess the potential for low-flow conditions to negatively affect water quality. The 7-day low flows reflect naturalized (i.e. prior to water withdrawals) conditions in streams, based either on existing hydrometric data for streams with gauges or estimations for ungauged streams, as calculated by Rood and Hamilton,[3-14] and are presented as a percentage of the mean annual flow.

Criteria:

Red •The naturalized summer 7-day mean low flow is less than 10% of a stream's annual flow;

OR low flow problems are reported and there are no licensed withdrawals.

Yellow •The naturalized summer 7-day mean low flow is 10% to 30% of the stream's annual flow;

OR information indicates that low flow problems may exist, and there are no licensed withdrawals.

Green •The naturalized summer 7-day mean low flow is greater than 30% of the stream's annual flow;

Blue •No information about stream flows was available in the hydrology reports or SISS catalogues.

Rationale:

The criteria are based on studies of water flow effects on fish habitat. It is assumed that where summer low-flow conditions negatively affect fish habitat, there are accompanying water quality problems such as high stream temperatures. Tennant[31] and Orth and Leonard[32] reported that summer habitat for fish was generally poor if flows were less than 10% of annual flow. Summer flows greater than 30% of the mean annual flow for a stream usually support healthy fish habitat, assuming that other types of impacts are not present.

3.2.3.5 Water demand

A high water demand may result in low stream flows, in turn creating habitat and water quality impacts similar to those described for the previous index.

Water demand was calculated from licenses issued for consumptive uses including domestic, waterworks, irrigation and industrial withdrawals.[3-14]

- **Domestic** licenses are issued to individuals for household usage on a single property. Individuals are not obligated by law to obtain a water license, so it is likely that the licensed domestic withdrawals reported by Rood and Hamilton do not account for the actual usage by individuals.
- Licenses for **waterworks** address withdrawals which service as few as five properties, or a local authority the size of the GVRD.
- **Irrigation** licenses may be issued to individuals or to local authorities.

- Licenses issued for **industrial** purposes include, but are not limited to, the following uses: processing (sawmills, food, manufacturing); cooling; enterprise (hotels, restaurants); ponds; watering; bottling for sale; and mineral water used in swimming pools.

The potential water demand for August and September was assessed as a percentage of a stream's naturalized summer 7-day mean low water flow, or as a percentage of the naturalized mean August or September monthly flow (whichever was lowest). The *naturalized flow* value represents the natural flow regime of the stream[3-14] prior to any withdrawals. The total licensed water demand is the sum of the maximum water withdrawals for all water licenses and may not reflect the actual demand. Actual demand is unknown for all streams as most licenses do not require metering.

The impact of water demands on a stream depend partly on natural low flow conditions (see previous index criteria). The lower the natural flow in a stream the greater the impacts from water withdrawals will be on fish habitat and water quality.

Criteria:

The following table is a matrix of the naturalized summer 7-day low flow and summer water demand. The naturalized summer 7-day low flow criteria across the top of the table indicate the degree to which low flows are already a problem (see explanation in the previous index). The summer water demand, along the left side of the table, is the total licensed withdrawals for August and September expressed as a percentage of the naturalized summer 7-day mean low flow or August/September mean monthly flow.

Summer water demand (% of naturalized summer low-flow)	Naturalized summer low-flow (% of mean annual flow)		
	>30	10 to 30	<10
>40	Red	Red	Red
>15 to 40	Yellow	Red	Red
>5-15	Yellow	Yellow	Red
≤5	Green	Green	Red

Blue

- Streams without water demand information are given a blue symbol.

Rationale:

Water withdrawal information was considered with natural summer low flow information to determine the effect of withdrawals on stream flow. If the summer low-flow is already less than 10% of the mean annual flow (see low-flow index) or water withdrawals are greater than 40% of the summer low-flow (indicating a significant alteration of the natural flow regime), then the potential for water quality to be negatively affected was considered high. Withdrawal of less than 5% of the natural summer low flow was considered to be insignificant, given the natural variation which exists in every stream. Where withdrawals amounted to between 5% and 40% of natural low flows, red or yellow ratings were assigned based on % of summer low flows remaining.

If specific problems were reported for an individual stream which did not correspond with the criteria outlined above then a worse case ranking (for example red instead of yellow) was assigned to that stream, and the information source provided.

❖❖❖

3.3 References

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Chapter 4 Middle Fraser Habitat Management Area

4.1 Background

The 24,000 km^2 Middle Fraser HMA encompasses the Fraser mainstem from Hope, northward to the confluence of the West Road River with the Fraser. The Fraser River flows along a major fault separating the Coast Mountains to the west from the Cascades on the east side of the river. The Middle Fraser HMA includes many relatively small and steep tributaries to the Fraser mainstem, most of which have watersheds no larger than 1,000 km^2.[1]

4.1.1 *Hydrology*

The hydrology of the Fraser mainstem is governed primarily by snowmelt from the Rocky Mountains in the headwaters, and the combined influences of flows from major tributaries including the Salmon River, the Stuart-Takla system, the Nechako River, and the West Road River.[1]

Flows in small tributaries are governed mainly by local climate, which ranges from very dry interior type near the Williams Lake area, to wetter, modified maritime conditions at Hope.[1] Four distinct hydrologic regions can be identified within the HMA, with differing climatic and hydrological patterns.[1] Precipitation levels vary significantly both north-to-south and east-to-west, and range from 300 mm to 2,000 mm annually within the HMA.[1]

Nine salmon-bearing streams in the HMA were considered to have significant summer natural low flow problems.

4.1.2 *Fish*

There are 23 documented salmon-bearing streams within the Middle Fraser HMA.[3-6] In addition, there are numerous small tributaries to the Fraser River for which salmon use has not been documented, but some of these streams provide important salmon habitat. Juvenile salmonids, especially chinook, often utilize non-natal small tributaries for feeding and resting during their outmigration.[7] In addition, adult salmon on their spawning migrations are believed to use the lower reaches of cool, non-salmon bearing tributaries as thermal refugia, when water temperatures in the Fraser River become too high.

In addition to anadromous salmonids numerous other fish species are found in the HMA, including sturgeon, burbot, rainbow trout, bull trout, mountain whitefish, Dolly Varden, peamouth chub, and many others.[3-6]

4.1.3 *Predominant Land Uses*

Land uses include timber harvesting, agriculture, some mining, and recreation. There are several relatively small urban centers within the HMA.

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4.2 Point Sources of Contaminants

4.2.1 *Urban/Industrial Point Source Discharges to Surface Water*

The Middle Fraser HMA contains eight permitted discharges to surface waters (Figure 4.2.1).[2] Three discharges are directly to the Fraser mainstem, three are to Ladner Creek (all are associated with a former mine), one is to Williams Lake River, and one is to Lou Creek (Table 4.2.1).[2]

Three of the permitted discharges consist of STP effluent.[2] The largest discharge (8000 m^3·d^{-1}) originates from the town of Williams Lake and discharges the largest proportion of BOD and NFR (Table 4.2.2). The other two are very small discharges of processing effluent.

Large discharges of industrial and domestic effluents from the vicinity of Prince George (Upper Fraser HMA, Chapter 7) and Quesnel (Quesnel HMA, Chapter 8) must be considered here as they likely affect water quality in the Fraser River within the Middle Fraser HMA. The largest discharges include five pulp mills and several sewage treatment plants, which contribute the majority of BOD and NFR from permitted discharges to the Fraser mainstem (Tables 7.2.2 and 8.2.2). The pulp mills collectively discharge up to 610,400 m^3·d^{-1} to the Fraser River, about 3% of river flow during the winter low flow period.

Pulp mill effluents were formerly of concern as they contributed persistent and toxic organic contaminants to the river. Compounds such as dioxins and furans reached high levels in tissues of some fish species, and in the wildlife that consumed them.[19] Pulp mills implemented process changes and upgraded effluent treatment systems in the late 1980's and early 1990's to achieve compliance with the Pulp and Paper Liquid Effluent Regulations. These changes lead to a 90% reduction in the levels of dioxins and furans in pulp mill effluents,[8] and the consumption advisory on mountain whitefish for the upper Fraser River was lifted in 1994.[9] Recent studies show that although levels of organic contaminants are relatively low in Fraser Basin biota, they are still higher downstream from pulp mills in comparison with upstream sites.[19]

Concerns regarding sub-lethal impacts of effluents on juvenile salmonids using habitat in pulp mill effluent plumes remain.[10] Additional concerns relate to the large volumes of very warm pulp mill effluent (up to 38°C) discharged to the river. Aerial imaging showed that mill effluent from Prince George tracks the river banks for many kilometers downstream from the point of discharge.[27] Warm effluent may affect fish that use nearshore habitats, especially during summer months when water temperatures in the river sometimes exceed levels that are detrimental to salmon.[11]

The pulp mills and STPs discharge significant amounts of phosphorus, although phosphorus loadings are not restricted in Waste Management permits due to the relative insensitivity of the Fraser River to nutrient additions. During winter low flows pulp mill effluents contribute about 11% of the total phosphorus in the Fraser River downstream from Quesnel, of which about half is biologically available.[16] High suspended sediment levels inhibit primary production, hence eutrophication has not become a problem.

Comparison of data from Hansard, upstream from Prince George, and the downstream Marguerite site indicate that phosphorus concentrations approximately double between the Hansard and Marguerite sites (Table 4.5.1a). Statistical analysis of phosphorus data also suggest that concentrations at Marguerite are increasing over time.[14] This likely reflects human activities and the increasing discharge of industrial and domestic waste water to the river.

Results of mesocosm experiments indicate that pulp mill effluent in river water at concentrations equivalent to those which occur during low flows (3%) stimulated bacterial, algal, and macro-invertebrate productivity,[17] while higher concentrations (5%) had toxic effects on invertebrates. For further discussion of pulp mill effluents refer to Chapter 7, Upper Fraser HMA.

4.2.2 *Permitted Discharges to Ground*

There are 23 permitted discharges to ground, 16 of which are sewage effluent from commercial facilities. Remaining permits address wastes from placer gold operations, a discharge to a mine tailings impoundment, truck washing effluent, and wastes from an abattoir.[2]

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4.3 Non-Point Sources of Contaminants

Land uses such as timber harvesting, agriculture, and urban development introduce diffuse, non-point sources of contaminants to surface waters. Non-point sources of pollution are degrading water quality in some salmon-bearing streams of the Middle Fraser HMA.

4.3.1 *Urban Development*

The main urban centers in the Middle Fraser HMA are the western portion of the city of Quesnel (the balance of the city is in the Quesnel HMA), as well as Williams Lake, Lillooet, and Hope. The City of Prince George is in the Upper Fraser HMA, but effluents discharged from this urban center may affect water quality in the Fraser mainstem in the Middle Fraser HMA.

A study conducted on behalf of Environment Canada estimated loading of various contaminants to the Fraser Basin from urban runoff.[13] In the Middle Fraser HMA, non-point urban runoff is a significant source of contaminants such as nutrients, metals, oil and grease (Table 4.3.1).

Linear developments such as highways, railways, and pipelines, constructed to service urban centers, have affected some tributaries to the Fraser, e.g. the Coquihalla River. Bank stabilization projects and clearing of residential properties are problems in Quesnel.[12]

Four salmon-bearing streams in the HMA were considered likely to have water quality impacts associated with urban development (Table 4.6.2).

4.3.2 *Agriculture*

Production of beef cattle and hay are the primary agricultural activities in the Middle Fraser HMA. Cattle ranching is particularly intensive in the vicinity of Williams Lake. The main water quality concerns relate to runoff from cattle over-wintering areas and feedlots. MELP has been working with producers to reduce impacts of livestock on surface waters.

Ginseng production has grown over the past decade in the Fraser Basin. Large plantations have been developed in areas where the summer climate is hot and dry. Members of the public have expressed concerns about pesticides from these plantations reaching surface waters.

In many agricultural areas riparian vegetation was removed from Fraser River tributaries long ago.[3] Restoration efforts are now required to stabilize stream banks and reduce erosion and sedimentation.[3]

Only one salmon-bearing stream was considered to have water quality impacts resulting from agricultural activities.

4.3.3 *Timber Harvesting*

Logging of the Middle Fraser HMA began with the construction of the CP Rail line, and is ongoing in many Fraser River tributaries in the Middle Fraser HMA. The rate of harvesting in salmon-bearing watersheds has increased recently, and most cutblocks have been harvested since about 1980.[1]

MELP staff have expressed concern about issues such as poor road construction, drainage control, the encroachment of roads on streams, and slope failures affecting salmon streams and their tributaries. Some concern was expressed that roads were not meeting basic construction and maintenance standards.[1] Although practices may have improved with implementation of the Forest Practices Code, the legacy of past practices will not quickly be erased. The relative lack of protection afforded to small salmon-bearing streams (S4 streams under the Code), and changes to the Forest Practices Code which reduce environmental protection, are causes for concern over the potential for further impacts to fish habitat.

All salmon-bearing streams were assessed for impacts from forestry activities according to methods presented in Chapter 3. It should be noted that "recent" logging occurred from 1983-'92, and "proposed" logging was planned for 1993-'98, and in most cases has probably already occurred.

Four of the 23 salmon bearing streams in the HMA were considered to have a high level of concern for water qualtiy due to forestry activities (Table 4.6.2).

4.4 An Overview of Water Quality Conditions

Water quality conditions in Fraser River tributaries in the Middle Fraser HMA vary widely with local geological conditions. Land uses also affect water quality in some Fraser River tributaries in the HMA.

Water quality in the Fraser mainstem is largely determined by major tributaries and the geology of the mainstem corridor. Suspended sediment levels are high due to the natural erosion of silty materials, which begins slightly east of Prince George. The Fraser River is relatively insensitive to nutrient inputs due to the high levels of suspended sediments, which limit primary production. Water temperatures in the Fraser River often reach levels that are detrimental to salmonids during summer months, and in some years cause significant pre-spawning mortality.

Water quality in the mainstem may be influenced by large discharges originating from outside the Middle Fraser HMA, at Prince George and Quesnel. There are three pulp mills at Prince George and two at Quesnel, all of which discharge effluent to the Fraser mainstem. As well, these urban centers are sources of sewage effluent and urban runoff, which may also affect water quality in the Middle Fraser HMA. Pulp mill discharges were formerly of concern due to loadings of dioxins and furans to the river. These persistent and toxic substances have now been largely eliminated from pulp mill discharges due to process changes and upgrading of effluent treatment systems.[8,9]

Site-specific water quality assessments, and influencing factors and supporting data (Table 4.5.1a and b) are provided in Section 4.5 on a stream-by-stream basis.

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4.5 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Middle Fraser HMA.

Summary tables of:

- water quality data **(Table 4.5.1a)**
- fish tissue contaminant data **(Table 4.5.1b)**
- land use areas, stream flow, and water demand information for each salmon stream **(Table 4.6.1)**
- identified impacts for each salmon stream **(Table 4.6.2)**

are provided for reference.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals were based upon information provided in a series of hydrology reports,[1] and/or SISS catalogues[3-6] unless otherwise indicated. Assessment criteria are explained in the Methods section of this report.

Fraser River Mainstem (00)

(upstream from Hope to the confluence with the West Road River.)

• 2,3,7,8-T4CDD was measured in 10 fish samples, and both 2,4,6-trichlorophenol and pentachlorophenol were measured in 5 fish samples collected near Hope in 1989. None of these parameters exceeded the Health Canada consumption advisory levels. The long-term effects of low levels of contaminant mixtures on the health of aquatic organisms are unknown.

•There are localized impacts to water quality resulting from urban runoff, sewage effluent, and loss of riparian vegetation.

•Agriculture is a prevalent land use throughout the river valley. Cattle ranching is a significant land use, and ginseng production is becoming more common. Lower reaches of tributaries are affected by the loss of riparian vegetation and water withdrawals.[15]

•There are localized impacts from timber harvesting, especially to the lower reaches of tributaries.[15]

•Flows in the Fraser mainstem are relatively stable from year to year.[15]

•Water withdrawals from the Fraser River are not of concern from the perspective of implications for water quality in the mainstem.

•Other: Localized gravel removal and placer mining occurs throughout the Fraser mainstem.[15]

Three pulp mills are located in Prince George (Upper Fraser HMA) and two more located near Quesnel (Quesnel HMA, just outside of the Middle Fraser HMA) collectively discharge as much as 576,000 $m^3 \cdot d^{-1}$ of very warm effluent (up to 38°C) into the Fraser mainstem.

As effluent mixing does not occur for many kilometers downstream,[27] the warm effluent may impact a significant stretch of fish habitat.

Studies of Mixed Function Oxidase (MFO) in liver (a measure of contaminant exposure) of two resident fish species indicates induction in both species downstream from urban centers and pulp mills.[19] Induction is believed to result from cumulative effects of several contaminants, including PAHs, dioxins, and furans.[19]

The development of highways, railways, bridges, and pipelines have caused localized side channel alienation, loss of riparian vegetation and channelization, especially on smaller tributaries.[15]

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Fraser River up and downstream from Williams Lake River

•One measurement for pH and total phosphorus were reported for the two stations. The total phosphorus values were about ten times the guideline level. *See discussion for the Marguerite station below.*

Fraser River at Marguerite

•Between 83 and 322 measurements are reported for temperature, pH, total nitrate+nitrite-N, total phosphorus and a selection of metals in surface water. Half of the 322 total nitrate+nitrite-N values are above the 80th percentile and 113 of the 317 total phosphorus values exceeded the 80th percentile. 66 of 99 cadmium, 68 of 98 chromium, 69 of 99 copper and 36 of 99 lead values exceeded the guidelines.

★The high concentrations of arsenic, cadmium, chromium, copper, mercury, lead, and zinc are similar to levels measured at Hansard, upstream of Prince George, indicating that these metals likely occur naturally at elevated levels in Fraser River water. High total metal concentrations coincide with high suspended sediment levels, and probably reflect natural sediment levels of these elements rather than a pollution problem.[14]

Comparison of phosphorus data from Hansard and Marguerite shows concentrations at the downstream site are about double levels at Hansard. This reflects phosphorus inputs from pulp mills (about half is bioavailable) and STPs. High suspended sediment levels in the river help prevent eutrophication from occurring as a result of nutrient inputs.

About 12% of water temperatures reported exceed levels preferred by salmonids. Continuous monitoring in 1993 and 1994 revealed that daily minimum water temperatures exceeded 15°C constantly during July and August.[11] Maximum temperatures reached the lethal threshold for salmonids (20°C) in 1993 at Marguerite, but not during 1994.[11] High water temperatures contribute to pre-spawning mortality of salmonids.

One analysis of Fraser River water quality data indicates that five chemical parameters show consistent increasing trends at the Marguerite site – these include potassium, sulphate, arsenic, nitrate/nitrite, and orthophosphorus.[14]

Marguerite Reach

•Data from a 1994 study indicate that dioxin and furan concentrations in fish tissue are low.[19] No measured concentrations of dioxins, furans, PCB, or toxaphene exceeded consumption guidelines established for the protection of human health. Concentrations of tetra-chlorinated dioxins and furans were found to be higher in tissues of resident fish species (Table 4.5.1b) and sediments downstream from pulp mills, than at sites upstream of the mills.[19] The long-term effects of low levels of contaminant mixtures on the health of aquatic organisms are unknown.

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Coquihalla River (00-0800)

•One measurement each for pH, nonfilterable residue, dissolved ammonia, total phosphorus and zinc is reported. None of the parameters analyzed exceeded the guidelines or 80th percentiles.

•The lower Coquihalla River flows through the town of Hope, where development encroaches on the channel and development pressure continues along the floodplain.[1] The left side of the lower 6.4 km of river is diked, with rock protection along the bank. Various plans exist to manage the flood hazard along the lower river and to modify existing dikes.[18]

•Less than 1% of the watershed consists of old logging. About 3.5% of the watershed has been recently logged and another 1% was proposed for harvesting prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 20% of the mean annual flow.[1]

•The potential August water demand for domestic, irrigation, waterworks and industrial uses is <1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Riparian vegetation is lacking in some areas.[1] The Coquihalla Highway, completed in 1986, encroaches on the river in some areas, and delivers stormwater runoff and suspended sediments to the river. Other problems include the deposition of fine sediment, which is partly a natural occurrence. Riparian areas throughout have been impacted by placement of riprap.[18]

Consideration is being given to re-opening an inactive gold mine and tailings pond on Ladner Creek, a tributary to the Coquihalla. Poor design and/or operation of the tailings impoundment resulted in the release of cyanide in 1982, which caused a large fish kill in Ladner Creek and its confluence with the Coquihalla River.[20]

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Kawkawa Creek (00-0800-010)

◆Residential development around Kawkawa Lake is noted to affect water quality and fish habitat in the lake and its tributaries.[1] Development has been encroaching on coho and sockeye spawning habitat since 1969.[3]

◆The naturalized summer 7-day mean low flow is 75% of the mean annual flow.[1]

◆The potential August water demand for domestic, waterworks, and industrial uses is 1% of the naturalized summer 7-day mean low flow.[1]

◆**Other:** Flooding and erosion occur along some creek channels mostly due to insufficient channel capacity resulting from sediment and debris deposition.[1] There have been some enhancement efforts.

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Sucker Creek (00-0800-010-010)

◆Residential development may affect the creek.[1] SISS information from 1990 identifies "imminent" urban development.[3]

◆The naturalized summer 7-day mean low flow is 75% of the mean annual flow. Groundwater influences help to stabilize the flow regime.[3]

◆No water licenses have been issued.

◆**Other:** Flooding and erosion may occur due to insufficient channel capacity resulting from sediment and debris deposition.[1]

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Stevens Creek (00-0800-010-020)

◆There is potential for residential development and groundwater withdrawals to affect the creek.[1] Increasing residential construction was noted in 1990.[3]

◆The naturalized summer 7-day mean low flow is 75% of the mean annual flow,[1] however, low flow problems have been reported.[3] August and September flows can be as low as 30 - 40 $L\cdot s^{-1}$.[1]

◆No water licenses have been issued. DFO recommends that no future water withdrawals be allowed due to naturally low flows.[3]

◆**Other:** Flooding and erosion may occur due to insufficient channel capacity resulting from sediment and debris deposition.[1]

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Menz Creek (00-0800-010-030)

◆There is increasing residential construction (vicinity of Hope) in the watershed.[3]

◆The naturalized summer 7-day mean low flow is 75% of the mean annual flow,[1] however, low flow problems have been reported.[3] August and September flows can be as low as 30 - 40 $L\cdot s^{-1}$.[1]

◆No water licenses have been issued. Groundwater withdrawals would affect low flows.[1] DFO recommends that no future water withdrawals be permitted due to low flow problems.[3]

◆**Other:** Flows originate from a glacio-fluvial aquifer to the east of a fan formation.[1] The creek is therefore vulnerable to any type of development that can disrupt aquifer recharge. The creek experiences local erosion of sand and gravel deposits. A gravel pit operation is affecting the creek.[1]

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Kopp Creek (00-0800-010-030-010)

◆Increasing residential construction was noted in 1990.[3] There is some concern over development disrupting groundwater inputs to the creek.

◆The naturalized summer 7-day mean low flow is 75% of the mean annual flow,[1] however, low flow problems have been reported.[3] Groundwater development and development of impervious surfaces in the watershed would reduce already low flows.

◆The potential August and September water demand for domestic, waterworks, and industrial uses is 2% of the naturalized summer 7-day mean low flow.[1]

◆**Other:** Flooding and erosion may occur due to insufficient channel capacity resulting from sediment and debris deposition. Flow is dominated by groundwater inputs, and there are relatively constant flows through the summer.[1]

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Ladner Creek

◆Downstream from the mine site, 8 of 10 dissolved ammonia values were above the 80th percentile level. The maximum ammonia value reported (2.66 $mg\cdot L^{-1}$) exceeded the 30-d criteria for total ammonia at any temperature-pH combination possible at the site. One of 2 lead measurements in surface water (0.2 $mg\cdot L^{-1}$) greatly exceeded the guideline, and all three copper values also exceeded the guideline. At the Coquihalla confluence, 6 of 9 ammonia and 3 of 4 total copper concentrations exceeded guidelines, as did the single measurements of chromium and lead.

Only one measurement for metals in sediments is reported. Of these, arsenic, chromium and copper exceeded the guidelines.

•**Other:** A mine in the upper watershed is not currently operating, however, it still has a permit covering a discharge from the tailings pond to Ladner Creek (P05692). The permit allows high concentrations of cyanide, dissolved copper, and dissolved zinc to be discharged to the creek, which may be harmful to fish. An unlimited volume of another effluent containing high levels of nonfilterable residue (250 $mg \cdot L^{-1}$) is also permitted to be discharged.

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Sowaqua Creek

•No information was available to assess urban activities.

•No information was available to assess agricultural activity.

•2% of the total watershed has been logged, and harvesting of another 3.5% of the watershed was proposed by 1998.[1] Logging has caused degradation of riparian vegetation and logging road failures.[18]

•No information was available to assess flows.

•No water licenses have been issued.[1]

•**Other:** This is the main spawning tributary for steelhead in the Coquihalla.

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American Creek (00-0815)

•6% of the total watershed has been recently logged, and an additional 4% is proposed for harvest.[1] Activity is focussed in the headwaters, and threatens downstream fisheries values.[18]

•The naturalized summer 7-day mean low flow is 7% of the mean annual flow. Flows are described as widely fluctuating.[1]

•The potential August and September water demand for domestic use is <1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** A placer mine operated at the Fraser River confluence from the 1960's until 1986.[18]

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Squeah Lake Creek (00-0834)

•MOF records reportedly do not mention logging in this watershed,[1] however, DFO reports logging activity in the upper watershed, above the lake.[3]

•The naturalized summer 7-day mean low flow is 7% of the mean annual flow.[1]

•No water licenses have been issued.[1]

•**Other:** The creek has a flashy hydrologic regime.[1]

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Stulkawits Creek

•Both of 2 copper values exceeded the guideline. None of the 4 zinc measurements were above the guideline.

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Emory Creek (00-0841)

•7% of the total watershed has been logged, 6% recently. Harvesting of another 1% was planned by 1998.[1]

•The naturalized summer 7-day mean low flow is 7% of the mean annual flow.[1]

•The potential August and September water demand for domestic use is <1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** The creek has a flashy hydrologic regime, and a substantial potential for erosion.[1]

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Gordon Creek (00-0855)

•22% of total watershed has been logged, mostly since 1980.[1] No additional harvesting was planned prior to 1998.

•The naturalized summer 7-day mean low flow is 7% of the mean annual flow.[1]

•The potential August and September water demand for domestic use is <1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** The creek has a flashy hydrologic regime.[1]

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Yale Creek (00-0860)

•The creek flows through the community of Yale. No information was available describing the condition of the stream in this area.

•Irrigation licenses indicate agricultural activity.[1] There was not enough information to assess its effect on water quality.

•5% of total watershed was logged recently, and 0.5% is proposed for harvest.[1]

•The naturalized summer 7-day mean low flow is 4% of the mean annual flow.[1]

•The potential August and September water demand for domestic, irrigation, and waterworks uses is 4% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Yale Creek is steep with bouldery bed materials and rapid, turbulent flows.[1]

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Sawmill Creek

•No information was available to assess urban development.

•Irrigation licenses indicate agricultural activity.[1] There was not enough information to assess its effect on water quality.

•No information was available to assess stream flow.

•Licenses exist for domestic and irrigation uses.[1]

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Spuzzum Creek (00-0900)

•Irrigation licenses indicate the presence of agricultural activity.[1] There was not enough information to assess its effect on water quality.

•About 7% of the total watershed has been logged including 4.3% since 1983. Logging of another 1% was planned by 1998.[1]

•The naturalized summer 7-day mean low flow is 5% of the mean annual flow.[1]

•The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Flooding and bank erosion are common.[1] B.C. Hydro has proposed a power development on the creek.[1] Linear developments include highways, bridges, railways, and power lines.

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Scuzzy Creek (00-0948)

•No information available.

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Anderson River (00-1000)

•15% of the total watershed has been logged, including 12% since 1983. Another 8% was proposed for harvesting by 1998.[1] Cutblocks extend to the margins of the channel and riparian vegetation has been removed in many reaches.[1] Future harvesting is to be limited by a special resource management zone for spotted owls and deer winter range requirements.[18]

•The naturalized summer 7-day mean low flow is 9% of the mean annual flow.[1]

•No licenses have been issued.[1]

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Lower Anderson River

•16% of the total watershed has been logged including 11% recently. Harvesting of another 7.6% was planned by 1998.[1]

•No information was available to assess flows.

•No licenses have been issued.

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Upper Anderson River

•13% of the total watershed has been recently logged, and harvesting of another 10% was proposed by 1998.[1]

•No information was available to assess flows.

•No licenses have been issued.

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Utzlius Creek

•23% of the total watershed has been logged, including 15% which was recently harvested. Logging of another 6% was planned by 1998.[1]

•No information was available to assess flows.

•No licenses have been issued.

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East Anderson River

•8% of the watershed has been logged including 6% recently harvested. Logging of another 9% was planned by 1998.[1]

•No information was available to assess flows.

•No licenses have been issued.

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Stoyama Creek

•6% of the watershed has been recently logged, and harvesting of another 3% was planned by 1998.[1]

•No information was available to assess flows.

•Licenses have been issued for domestic, waterworks and industrial uses, but permitted withdrawals relative to summer low flows are unknown.[1]

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Nahatlatch River (00-1200)

•There are some summer homes in the watershed, but no indication of their effects on water quality is provided.

•2% of the total watershed has been recently logged, and another 1% was proposed for harvesting by 1998. Activity is concentrated in the upper watershed.[18] Significant losses of riparian vegetation adjacent to key spawning habitat have occurred.[12,18]

•The naturalized summer 7-day mean low flow is 33% of the mean annual flow. Lakes stabilize flows.

•The potential August and September water demand for irrigation and domestic uses is less than 1% of the naturalized summer 7-day mean low flow.[1] All licenses are for withdrawals in the lower watershed.

•**Other:** A natural slide occurred in the spring of 1995, and obstructed the spawning migration of salmon. The watershed has been included in numerous planning processes.[18] Logging roads penetrate much of the watershed except for Mehatl and Teapot Creeks.

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Log Creek

The stream is reported to support anadromous salmonids[21] but it is not identified as salmon-bearing in the SISS catalogue.

•6% of total watershed has been recently logged, and no further harvesting was planned prior to 1998.[1] Significant losses of riparian vegetation have occurred adjacent to valuable salmon spawning habitat.[18] More than 30% of the Coastal Western Hemlock biogeoclimatic zone has been logged.[18]

•No information was available to assess flows.

•No information was available to assess water demand.

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Kookipi Creek

•2% of the total watershed has been recently logged, and 2% was proposed for harvest by 1998. Significant losses of riparian vegetation have occurred.[18]

•No information was available to assess flows.

•No information was available to assess water demand.

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Mehatl Creek

•2% of the total watershed has been logged.[1]

•No information was available to assess flows.

•No information was available to assess water demand.

•**Other:** The watershed is virtually pristine, and received protection as a park in 1996 as part of the Protected Area Strategy Process.[18]

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Stein River (00-1400)

•The naturalized summer 7-day mean low flow is 29% of the mean annual flow.[1]

•The potential August water demand is 3% of the naturalized summer 7-day mean low flow.[1] Lillooet withdraws water for domestic and irrigation use.[1]

•**Other:** The Stein River is the last large, pristine watershed on the west side of the Fraser River and has recently received provincial park status.

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Texas Creek (00-1600)

•Limited agricultural activity includes alfalfa, corn, and ginseng production. Some riparian areas have been impacted in the north fork.[18]

•6% of the total watershed has been logged, including 3% recently. Another 2% was planned for harvest by 1998.[1] Logging roads penetrate much of the watershed.[18]

•The naturalized summer 7-day mean low flow is 27% of the mean annual flow.[1]

•The potential August and September water demand for irrigation and domestic uses is 15% of the naturalized summer 7-day mean low flow.[1]

•**Other:** There is some potential for jade and gold mining in the north fork.[18]

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Porcupine Creek

•Between 2 and 3 measurements are reported for pH, nonfilterable residue, dissolved ammonia, total phosphorus and metals in surface water. One of 3 phosphorus, 1 of 2 copper, 2 of 2 lead and 1 of 3 zinc values exceeded the guidelines.

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Churn Creek (00-2900)

•Metals measured in 1 to 3 headwater samples did not exceed guidelines. Downstream from Fairless Creek (which receives effluent from the Black Dome mine and mill, which ceased operating Dec. 12, 1990[25]) 1 to 3 measurements are reported. The only sample analyzed for lead exceeded the guideline. At the creek mouth, where mining has occurred, 1 of 1 cadmium, 2 of 2 chromium, 4 of 5 copper, 2 of 4 lead and 2 of 6 zinc values exceeded guidelines. These water quality data may have been affected by Quality Control problems.[25]

•Agricultural activity, mostly ranching, is concentrated in the lower reach.[18] There was not enough information to assess its effect on water quality.

•3% of the total watershed has been logged, including 2% since 1983. Another 10% was planned for harvesting by 1998.[1] There are logging roads and bridges throughout the watershed.[18] Future logging is of concern due to unstable soils.[18]

•The naturalized summer 7-day mean low flow is 47% of the mean annual flow.[1]

•The potential August water demand for is 1% of the naturalized summer 7-day mean low flow.[1] The Gang Ranch holds several licences.[1] Storage accounts for 62% of irrigation demand.

•**Other:** Placer mining occurs in the lower third of the stream.[18] Natural erosion of unstable lacustrine deposits along lower valley walls releases fine sediment, threatening spawning areas.[1] The Churn Creek Protected Area provides some protection to lower reaches of the watershed. MOF is preparing a Local Resource Use Plan for upper Churn Creek to address forestry concerns such as road location, creek crossings, harvesting on unstable soils and rate of cut.[18]

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Fairless Creek

•Upstream from Lou Branch, from 1 to 12 measurements were reported for pH, nonfilterable residue, dissolved ammonia, total phosphorus and metals in both surface water and sediments. Both of 2 lead values in surface water, and the single measurements of arsenic, chromium and copper in sediments exceeded guidelines. Downstream from Lou Branch, 9 of 10 phosphorus, 1 of 2 lead values, and all of 4 chromium and copper measurements in surface water exceeded guidelines. Sample results may have been affected by Quality Control problems.[25]

•**Other:** The Black Dome gold mine has a permitted waste discharge to Lou Creek, a tributary to Fairless Creek. The mine is not presently operating but may be re-opened. Chronic 21 day Daphnia bioassays were conducted on samples collected in 1992 from the mine portal discharge, Fairless Creek below Meadow Creek (receiving environment) , and from a control site on Meadow Creek. No Daphnia mortalities occurred in any of the mine or stream samples.[25]

Benthic invertebrate sampling of Fairless Creek upstream and downstream of the Black Dome Mine discharge in Sept. 1991 indicated no marked difference in benthic communities inhabiting the two streams. Both sites contained a high percentage of sensitive and facultative species relative to tolerant species.[25]

Fish have not been observed upstream of the canyon in Fairless Creek, about 7 km downstream from the sampling site.[25]

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Lou Branch

•Between 1 and 3 measurements were reported for pH, nonfilterable residue, dissolved ammonia, total phosphorus, and metals in surface water for 3 sites. Near the confluence with Fairless Creek, 2 of 3 ammonia values were above the 80th percentile but not the 30-d criteria for total ammonia. All of the 3 phosphorus, 2 chromium, 3 copper, 3 mercury, 2 lead, and 2 of 3 zinc values exceeded guidelines or 80th percentiles. The one nonfilterable residue measurement was high, at 1,051 $mg \cdot L^{-1}$. Of the single metal concentrations in sediments, the arsenic, cadmium, chromium, copper, mercury and zinc values exceeded guidelines. Water and sediment quality data may have been affected by Quality Control problems.[25]

Since 1991 all of the underground workings of the Black Dome Mine were connected to allow drainage of mine waters to Lou Branch of Fairless Creek.[25] The discharge, a receiving environment station in Fairless Creek, and a control station have been monitored seasonally, since closure. Water chemistry data indicate that exceedances of B.C. water quality criteria are usually for iron and aluminum, which are also high at the control station.[25]

Chronic 21 day *Daphnia* bioassays conducted from samples collected June 15, 1992, showed no significant differences between the control site, the portal discharge, and the Fairless Creek receiving station for reproduction, and no *Daphnia* mortalities occurred during the test.[26]

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Dog Creek

•Levels of 2,3,7,8-T4CDD, 2,4,6-Trichlorophenol, and Pentachlorophenol are reported for four fish tissue samples collected in 1990. Of these, one 2,3,7,8-T4CDD value exceeded the consumption guideline. Samples were collected prior to 1992, when more stringent regulations controlling the quality of pulp mill effluent were introduced.

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Gaspard Creek

•No information was available to assess urban development.

•No information was available to assess agricultural activity.

•17% of the total watershed has been logged, including 8% which has been recently harvested. Another 5% was proposed for harvesting before 1998.[1]

•No information was available to assess flows.

•No information was available to assess water demand.

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Chimney and Felker Lakes

•Two measurements for pH, nonfilterable residue, dissolved ammonia and total phosphorus are reported for Felker Lake. Only one phosphorus value exceeded the guideline. Between 1 and 8 measurements were reported for the same parameters for Chimney Lake. Near the lake center, 6 of 8 dissolved ammonia and all of eight phosphorus values exceeded the guideline/80th percentile.

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Williams Lake River, Williams Lake, and San Jose River u/s Williams Lake (00-3900)

•Between 66 and 138 measurements were reported for pH, dissolved ammonia, and total phosphorus for Williams Lake River near the outlet of Williams Lake. Of these, 31 of 66 ammonia and 16 of 138 phosphorus values exceeded the 80th percentiles. The high pH of 9.7 may result from high photosynthetic activity associated with eutrophication.

At the center of Williams Lake, between 2 and 145 measurements were reported for dissolved oxygen, temperature, pH, nonfilterable residue, dissolved ammonia, total phosphorus, and metals in surface water. Two measurements were reported for four metals in sediments. Sixty of 117 ammonia, 144 of 145 phosphorus and both of 2 chromium values in surface water exceeded the guidelines or 80th percentiles. Both of 2 chromium and copper, and 1 of 2 lead and zinc values in sediments exceeded the guidelines.

Eight sites were sampled on the San Jose River, between Williams Lake and Lac la Hache. One to 120 total phosphorus measurements are reported for these sites. At the outlet of Lac la Hache, only one of 120 phosphorus values exceeded the 80th percentile. Upstream from Borland Creek, 42 of 100 and downstream from the tributary, 33 of 71 phosphorus values exceeded the 80th percentile.

Evidence suggests that Williams Lake was eutrophic prior to settlement of the watershed, and many lakes in the Cariboo area naturally exceed phosphorus criteria.[26]

•Storm water discharges from the town of Williams Lake directly into Williams Lake River degrade water quality.[1] Removal of urban refuse from the lower river reaches is an ongoing activity.[18] Leaching from a landfill located close to the river needs to be addressed.[18]

•MELP has been working with ranchers to improve agricultural practices and most are now in compliance with the Agricultural Waste Control Regulation.[28] Grazing and fording are reported to impact riparian areas, especially in the San Jose River.[18]

•12% of the total watershed has been logged, including 7% which has been recently harvested. Plans involved logging another 4% by 1998.

•The naturalized summer 7-day mean low flow is 10% of the mean annual flow. San Jose River flows upstream of Williams Lake are regulated by storage on Lac la Hache.[1] Ducks Unlimited control a dam at the Williams Lake outlet.[18] During drought long stretches of the San Jose River and Williams Lake River go dry.[1, 18]

•The potential August and September water demand for irrigation, industrial, waterworks and domestic uses is 188% of the naturalized summer 7-day mean low flow. Storage on Williams Lake River accounts for 68% of the total volume needed for irrigation. Most water extraction is from the San Jose River and tributaries upstream of Williams Lake.[1]

•**Other:** Riparian vegetation has been removed along the middle section of river. No further licenses will be granted by the WMB, except for storage. Vehicles ford the river at 5 sites where bridges have been removed.[18] Industrial development downstream from Williams Lake generates runoff.[18] Williams Lake experiences low dissolved oxygen levels at depth during the summer.

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Borland Creek and tributaries

•Between 2 and 150 total phosphorus measurements were reported for several sites on Borland Creek and some tributaries. At the most upstream Borland Creek station, 1 of 18 values exceeded the 80th percentile, while near the San Jose River, 115 of 160 values were above 0.09 $mg \cdot L^{-1}$. 79 of the 114 measurements for Valley Creek near Borland Creek, and 37 of 91 for Jones Creek exceeded the 80th percentile level.

Note: data were collected as part of a non-point source (NPS) pollution study. Since the study MELP has worked with land owners to implement Best

Management Practices, and water quality is believed to have improved.[22]

•Runoff from ranching was degrading water quality in the creek. MELP has been working with ranchers to improve agricultural practices in the watershed.[22]

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Knife Creek (00-3900-250)

•26 of 96 total phosphorus values for Knife Creek near the San Jose River exceeded the 80th percentile. **Note:** data were collected as part of the NPS pollution study discussed above, and may not represent current conditions.

•Ranching is noted to negatively affect water quality, and has also caused loss of riparian vegetation along the lower river.[1] Following a study of NPS pollution, many producers have implemented Best Management Practices, so water quality may have improved.[22]

•11% of the total watershed has been logged, including 6% recently harvested. Plans included logging another 6% by 1998.[1]

•The naturalized summer 7-day mean low flow is 105% of the mean annual flow.[1]

•The potential August and September water demand is 75% of the naturalized summer 7-day mean low flow. Storage accounts for 73% of irrigation demand.

•**Other:** The creek is fully recorded, with exceptions for storage. However, a recent appeal to the WMB may lead to the issuing of new licenses.[1]

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Jones Creek

•Total phosphorus was the only parameter measured; 37 of 91 values exceeded the 80th percentile.

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Lac la Hache and tributaries

•About 95% of total phosphorus measurements from tributaries and several lake sites exceeded the guideline. 15 of 53 lake phosphorus levels exceeded the MELP guideline. As well, 27 of 52 dissolved ammonia levels from the lake exceeded the 80th percentile, but not the MELP guideline for a 30 day exposure period. **Note:** Since sampling occurred MELP has worked with farmers and residents to implement Best Management Practices. There has been no follow-up sampling but data do not necessarily reflect the current status of water quality.[22]

MELP did a fluorometer survey of Lac la Hache in 1996 and found no indication of significant leaching from septic systems.[22]

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Soda Creek

•Two of 8 fish tissue levels of 2,3,7,8-T4CDD exceeded the consumption advisory level. All 4 measurements of 2,4,6-Trichlorophenol and Pentachlorophenol were below guidelines.

★These data were collected prior to implementation of stringent pulp mill effluent discharge restrictions, promulgated in 1992.

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Soap Lake

•Both of the 2 dissolved ammonia values exceeded the 80th percentile but not the 30-d criteria for total ammonia. One measurement is reported for several metals in sediments, and none exceeded the guidelines.

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Cuisson River and tributaries

•Extensive spatial sampling was done on and near Cuisson Creek due to the nearby Gibraltar Mine. One to 3 measurements were reported for each of temperature, pH, and metals in surface water on Cuisson Creek near the Fraser River. None of the measured parameters exceeded guidelines/80th percentile levels.

Between 1 and 15 measurements for pH, temperature, nonfilterable residue, dissolved ammonia, total phosphorus and metals in surface water were reported for several sites on Cuisson Creek. Near the confluence with the Cuisson River, 2 of 4 copper, 1 of 5 lead and 1 of 5 zinc values exceeded guidelines. Upstream of Moffat Lake Road, 3 of 5 ammonia, 6 of 10 copper and 1 of 12 zinc values exceeded the guideline or 80th percentile.

Between 1 and 30 measurements were reported for pH, nonfilterable residue, dissolved ammonia, metals, and total phosphorus, in surface water at three sites on Lewis Creek. All 11 copper values from the creek near the mine access road, and all 7 near the outlet of Lewis Creek exceeded the guideline. The highest copper values are 70 times greater than the guideline. A low pH of 4.8 was measured near the mine access road.

Note: MELP reports Quality Control problems for samples collected prior to 1992, particularly with regard to chromium, copper, and zinc.[25]

MELP reports that levels of SO_4 exceed B.C. aquatic life criteria in the East Fork of Cuisson Creek downstream of the tailings dam during low flows.[25]

In the Lewis Creek tributary, copper levels exceeded criteria for the protection of aquatic life at the control site year round, and downstream of the mine during high flow conditions. There is a natural copper source in the creek headwaters, and levels increase downstream from the mine due to anthropogenic sources.[25] In the lower reaches copper levels decrease, likely due to natural organic complexing compounds in a series of beaver ponds between the mine, and the confluence of Lewis Creek with Cuisson Creek.[25]

•**Other:** While this is the only active mine in the Fraser Basin producing acid rock drainage, leachate is contained on site resulting in minimal losses and pollution problems.[20, 23] MELP is reviewing water quality data from the mine and may amend the permit monitoring program to identify sources of contaminants exceeding water quality criteria in receiving streams, as a step towards curtailing contaminant release.[25]

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Narcosli Creek (00-4700)

•Agricultural activity is located throughout the watershed. Livestock movement and grazing, and other farm activities have degraded riparian vegetation.[18]

•11% the total watershed has been logged, including 4.6% recently. Another 6% was proposed for harvesting by 1998.[24] MELP has indicated concern over the effects of logging in the upper watershed.[24]

•The naturalized summer 7-day mean low flow is 21% of the mean annual flow.[24]

•The potential August and September water demand for irrigation (and a small amount for industrial) use is 23% of the naturalized summer 7-day mean low flow.[24] Further licenses should not be granted until the actual water demand is established.[24]

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Baker Creek (00-4900)

•One measurement is reported at each of 2 sites (upstream and downstream of the Quesnel STP) for pH, nonfilterable residue, total and fecal coliforms. Both total and fecal coliforms were high at the downstream site (24,000 CFU·100 mL^{-1} for total coliforms).

•Stormwater outfalls from the City of Quesnel discharge directly into Baker Creek. The lower reach flows through an urban area, and diking, bank stabilization and pipeline crossings affect the stream.[24]

•Backflood irrigation practices are used in the upper reach[18] and the riparian zone has been degraded in localized areas.[15]

•11% the total watershed has been logged, and there is 7% recent or proposed harvesting.[24]

•The naturalized summer 7-day mean low flow is 18% of the mean annual flow,[24] and there is a potential for low flow problems during spawning.[6]

•The potential August and September water demand for domestic, irrigation, waterworks and industrial use is 26% of the naturalized summer 7-day mean low flow.[24]

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Tibbles Lake and Puntataenkut Creek

•Between 1 and 6 measurements were reported for pH, nonfilterable residue, dissolved ammonia and total phosphorus in Tibbles Lake. Two of 6 ammonia and all of 6 phosphorus levels exceeded the guideline or 80th percentile. The maximum phosphorus value, 0.172 $mg \cdot L^{-1}$, is 10 times greater than the guideline.

Between 1 and 7 measurements were reported for pH, nonfilterable residue, dissolved ammonia and total phosphorus in Puntataenkut Creek. Near Nazko Road, all of 6 ammonia and 5 of 6 phosphorus values exceeded the 80th percentiles. The maximum phosphorus value reported was 0.233 $mg \cdot L^{-1}$.

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Milburn Lake

•Between 3 and 5 measurements were reported for pH, dissolved ammonia and total phosphorus at three sites. The highest ammonia values were measured for the south end, west bay site, where the maximum was 0.893 $mg \cdot L^{-1}$. The highest phosphorus value, 0.202 $mg \cdot L^{-1}$, was also measured here.

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Table 4.2.1 Summary of Permitted Discharges to Surface Water in the Middle Fraser HMA.[1]

Record Id	Facility	Waste Type	Waste Num	Max. Flow ($m^3 \cdot d^{-1}$)	Receiving Water Body
P00255	WILLIAMS LAKE STP	STP	01	8,000	FRASER RIVER
P00392	HELL'S GATE AIRTRAM	STP	01	25.5	FRASER RIVER & LAND - HELL'S GATE
P05682	CAMP, MINE, & MILL NEAR HOPE	STP	01	45.5	LADNER CREEK; WEST FORK
P05692	GOLD MINE & MILL NEAR HOPE[2]	Process	01	10,800	LADNER CREEK
P05692	GOLD MINE & MILL NEAR HOPE	Process	02	4,400	LADNER CREEK
P05692	GOLD MINE & MILL NEAR HOPE[3]	Process	03	0	LADNER CREEK
P05692	GOLD MINE & MILL NEAR HOPE	Process	04	0	LADNER CREEK
P06358	WILLIAMS LAKE[3]	Process	01	2.5	WILLIAMS LAKE RIVER
P07378	GOLD/SILVER MINE/MILL, 71 KM W OF CLINTON	Process	01	1,600	LOU CREEK
P07667	GOLD PLACER MINE NEAR HOPE	Process	01	4,370	FRASER RIVER & LAND - HOPE

[1] Data were summarized from a 1994 version of the Environment Canada Effluent Point Source Inventory and Database for the Fraser River Basin. Prepared by Westwater Research Centre, University of British Columbia, for Environment Canada, Environmental Protection, Fraser Pollution Abatement Office, Vancouver, B.C. DOE-FRAP 1993-05. 14 p. + appendices.

[2] Permit allows the discharge of 10,800 $m^3 \cdot d^{-1}$ of effluent containing up to 0.1 $mg \cdot L^{-1}$ CN, 0.5 $mg \cdot L^{-1}$ dissolved zinc, and 0.1 $mg \cdot L^{-1}$ dissolved copper. At these concentrations, each of these three parameters is likely to be toxic. If the mine becomes operational again, the Waste Management Permit should be revised to conform with Section 36 of the Fisheries Act.

[3] The permit allows the discharge of an unlimited volume of effluent containing up to 250 $mg \cdot L^{-1}$ NFR to Ladner Creek. The permit would be re-visited if the mine were to become operational again.

Table 4.2.2a Summary of Permitted Daily Loading* to Surface Water in the Middle Fraser HMA ($kg \cdot d^{-1}$ except where noted).

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading
Bio. LC_{50}:Rainbow Tr [1]	1	na	-	-	-	-	-	-	-	-
Biochemical Oxygen Demand	-	-	-	-	-	-	3	363.2	-	-
Chlorine Res:Total [2]	1	0	-	-	-	-	-	-	-	-
Copper ($g \cdot d^{-1}$)	1	5.6	-	-	-	-	-	-	-	-
Copper Dissolved	2	1.52	-	-	-	-	-	-	-	-
Cyanide Total	1	1.08	-	-	-	-	-	-	-	-
Iron	1	0.48	-	-	-	-	-	-	-	-
Iron Dissolved	2	4.56	-	-	-	-	-	-	-	-
Lead Dissolved	2	1.52	-	-	-	-	-	-	-	-
pH [3]	3	na	-	-	-	-	-	-	-	-
Residue Nonfilt.	6	1596	-	-	-	-	3	484.26	-	-
Silver ($g \cdot d^{-1}$)	1	0.16	-	-	-	-	-	-	-	-
Zinc Dissolved	2	7.6	-	-	-	-	-	-	-	-

Table 4.2.2b Summary of Permitted Annual Loading* to Surface Water in the Middle Fraser HMA ($kg \cdot y^{-1}r$ except where noted).

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading
Bio. LC_{50}:Rainbow Tr [1]	1	na	-	-	-	-	-	-	-	-
Biochemical Oxygen Demand	-	-	-	-	-	-	3	132566	-	-
Chlorine Res:Total [2]	1	0	-	-	-	-	-	-	-	-
Copper ($g \cdot yr^{-1}$)	1	2044	-	-	-	-	-	-	-	-
Copper Dissolved	2	555	-	-	-	-	-	-	-	-
Cyanide Total	1	394	-	-	-	-	-	-	-	-
Iron	1	175	-	-	-	-	-	-	-	-
Iron Dissolved	2	1665	-	-	-	-	-	-	-	-
Lead Dissolved	2	555	-	-	-	-	-	-	-	-
pH [3]	3	na	-	-	-	-	-	-	-	-
Residue Nonfilt.	6	582540	-	-	-	-	3	176754	-	-
Silver ($g \cdot yr^{-1}$)	1	58	-	-	-	-	-	-	-	-
Zinc Dissolved	2	2774	-	-	-	-	-	-	-	-

na not applicable

[1] minimum requirement of 100% survival

[2] minimum requirement of 0 $mg \cdot L^{-1}$

[3] pH must be in the range of 6 - 8.5

* Loadings are calculated from permit information in Environment Canada's Fraser River Point Source Inventory and Database, (Reference #2).

Table 4.3.1 Comparison of Point Source Loadings with Estimated Non-point Source Loading from Urban Runoff of Selected Contaminants in the Middle Fraser HMA

Parameter	Units	Loading from Point Sources[1] Total	Estimated Loading from Urban Runoff[2] Min	Max	Mean
Nonfilterable residues	tonnes•d^{-1}	2.08	1.23	4.94	3.09
Biological Oxygen Demand	tonnes•d^{-1}	0.36	0.06	0.47	0.27
Ammonia	kg•d^{-1}	na	0.00	26.90	13.45
Nitrate	kg•d^{-1}	na	2.27	40.00	21.13
N-total	kg•d^{-1}	na	18.57	67.23	42.90
P-total	kg•d^{-1}	na	3.73	13.43	8.58
Pb	kg•d^{-1}	1.52	1.23	6.73	3.98
Cu	kg•d^{-1}	0.006	0.27	1.67	0.97
Zn	kg•d^{-1}	7.6	1.23	6.73	3.98
Cr	kg•d^{-1}	na	0.07	0.53	0.30
Phenols	kg•d^{-1}	na	0.00	3.87	1.93
Oil and grease	kg•d^{-1}	na	37.10	1,042.33	539.72
PAH	kg•d^{-1}	na	0.00	0.40	0.20

[1] Based on Waste management Permit information in Environment Canada's Fraser River Point Source Inventory and Database (Reference # 2).

[2] Based on Stanley 1993 (reference #13), estimated for the Cities of Williams Lake and Quesnel Point source and non-point souce loadings from the City of Prince George are not included here but could also affect water quality in the Middle Fraser HMA. See Upper Fraser HMA for Prince George figures.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
LOWER FRASER MILLS UPSTREAM							
Fish Tissue (1989)	2,3,7,8-T4CDD (pg/g wet wt.)	3	0	2	0.83	2.00	1.28
Hope							
Fish Tissue (1989)	2,3,7,8-T4CDD (pg/g wet wt.)	10	0	7	0.44	4.80	1.61
	2,4,6-Trichlorophenol (ng/g wet wt.)	5	0	4	1	26	6
	Pentachlorophenol (µg/g wet wt.)	5	0	4	0.002	0.006	0.003
FRASER R. BELOW WILLIAMS LAKE R.							
Surface Water	pH (pH units)	1	0	0	8.0	8.0	8.0
	Total Phosphorus (mg/L)	1	1	0	0.138	0.138	0.138
FRASER R. ABOVE WILLIAMS LAKE R.							
Surface Water	pH (pH units)	1	0	0	8.0	8.0	8.0
	Total Phosphorus (mg/L)	1	1	0	0.149	0.149	0.149
Fraser River at Marguerite							
Surface Water	Temperature (°C)	100	12	1	-2	20	6
	pH (pH units)	107	0	0	6.0	8.2	7.9
	Total Nitrate+nitrite-nitrogen (mg/L)	322	150	9	0.002	0.345	0.105
	Total Phosphorus (mg/L)	317	113	10	0.002	0.923	0.112
	Total Arsenic (mg/L)	98	0	3	0.0001	0.006	0.001
	Total Cadmium (mg/L)	99	66	16	0.0001	0.002	0.0004
	Total Chromium (mg/L)	98	68	1	0.0002	0.028	0.005
	Total Copper (mg/L)	99	69	1	0.0002	0.123	0.007
	Total Mercury (µg/L)	83	0	40	0.005	0.091	0.013
	Total Lead (mg/L)	99	36	17	0.0002	0.010	0.002
	Total Zinc (mg/L)	99	6	1	0.0002	0.048	0.010
COQUIHALLA R AT KAWKAWA LAKE RD							
Surface Water	pH (pH units)	1	0	0	7.4	7.4	7.4
	Nonfilterable Residue (mg/L)	1	na	0	2	2	2
	Dissolved Ammonia-nitrogen	1	0	0	0.007	0.007	0.007
	Total Phosphorus (mg/L)	1	0	0	0.010	0.010	0.010
	Total Zinc (mg/L)	1	0	1	0.010	0.010	0.010
STULKAWITS CR AT HWY 1							
Surface Water	Total Copper (mg/L)	2	2	0	0.010	0.020	0.015
	Total Zinc (mg/L)	4	0	4	0.005	0.010	0.009
LADNER CR U/S OF CAROLIN MINE							
Surface Water	pH (pH units)	1	0	0	7.5	7.5	7.5
	Nonfilterable Residue (mg/L)	1	na	0	1	1	1
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Copper (mg/L)	1	1	0	0.002	0.002	0.002
	Total Zinc (mg/L)	1	0	1	0.010	0.010	0.010

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.
nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
Sediments	Total Arsenic (µg/g)	1	1	0	36	36	36
	Total Chromium (µg/g)	1	1	0	492	492	492
	Total Copper (µg/g)	1	1	0	26	26	26
	Total Lead (µg/g)	1	0	0	19	19	19
	Total Zinc (µg/g)	1	0	0	38	38	38
<u>LADNER CR D/S OF LOWER POND DISCHARGE</u>							
Surface Water	Temperature (°C)	1	0		0.0	0.0	0.0
	pH (pH units)	10	0	0	7.2	7.9	7.6
	Nonfilterable Residue (mg/L)	10	na	0	1	10	4
	Dissolved Ammonia-nitrogen	10	8	2	0.005	2.660	0.672
	Total Copper (mg/L)	3	3	0	0.003	0.040	0.016
	Total Lead (mg/L)	2	1	1	0.001	0.200	0.101
	Total Zinc (mg/L)	10	0	10	0.005	0.010	0.010
Sediments	Total Arsenic (µg/g)	1	1	0	62	62	62
	Total Chromium (µg/g)	1	1	0	156	156	156
	Total Copper (µg/g)	1	1	0	40	40	40
	Total Lead (µg/g)	1	0	0	17	17	17
	Total Zinc (µg/g)	1	0	0	45	45	45
<u>LADNER CR AT COQUIHALLA CONFLUENCE</u>							
Surface Water	pH (pH units)	9	0	0	7.2	7.7	7.6
	Nonfilterable Residue (mg/L)	9	na	1	1	14	4
	Dissolved Ammonia-nitrogen	9	6	2	0.005	0.149	0.043
	Total Chromium (mg/L)	1	1	0	0.010	0.010	0.010
	Total Copper (mg/L)	4	3	0	0.001	0.050	0.018
	Total Lead (mg/L)	1	1	0	0.100	0.100	0.100
	Total Zinc (mg/L)	9	0	9	0.010	0.010	0.010
Sediments	Total Chromium (µg/g)	1	1	0	90	90	90
	Total Copper (µg/g)	1	1	0	32	32	32
	Total Lead (µg/g)	1	0	0	11	11	11
	Total Zinc (µg/g)	1	0	0	67	67	67
<u>PORCUPINE CREEK (PE07378)</u>							
Surface Water	pH (pH units)	3	0	0	7.6	8.0	7.8
	Nonfilterable Residue (mg/L)	3	na	0	2	5	4
	Dissolved Ammonia-nitrogen	2	0	2	0.005	0.005	0.005
	Total Phosphorus (mg/L)	3	0	0	0.013	0.02	0.017
	Total Arsenic (mg/L)	2	0	2	0.001	0.001	0.001
	Total Copper (mg/L)	2	1	0	0.001	0.002	0.002
	Total Mercury (µg/L)	3	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	2	2	0	0.002	0.002	0.002
	Total Zinc (mg/L)	3	1	2	0.005	0.030	0.013

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
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nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
CHURN CREEK AT MOUTH							
Surface Water	pH (pH units)	8	0	0	7.8	8.7	8.3
	Nonfilterable Residue (mg/L)	7	na	0	2	2450	422
	Dissolved Ammonia-nitrogen	5	0	3	0.005	0.008	0.006
	Total Phosphorus (mg/L)	4	1	0	0.005	0.109	0.043
	Total Arsenic (mg/L)	4	0	2	0.001	0.009	0.003
	Total Cadmium (mg/L)	1	1	0	0.0005	0.0005	0.0005
	Total Chromium (mg/L)	2	2	0	0.120	0.330	0.225
	Total Copper (mg/L)	5	4	0	0.001	0.090	0.022
	Total Lead (mg/L)	4	2	1	0.001	0.006	0.003
	Total Zinc (mg/L)	6	2	2	0.005	0.170	0.058
CHURN CREEK BELOW FAIRLESS CREEK							
Surface Water	pH (pH units)	3	0	0	7.7	7.9	7.8
	Nonfilterable Residue (mg/L)	2	na	1	1	7	4
	Dissolved Ammonia-nitrogen	3	0	1	0.005	0.009	0.007
	Total Phosphorus (mg/L)	3	0	0	0.017	0.046	0.035
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Mercury (µg/L)	2	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	1	1	0	0.003	0.003	0.003
	Total Zinc (mg/L)	3	0	3	0.005	0.010	0.008
CHURN CREEK ABOVE FAIRLESS CREEK							
Surface Water	pH (pH units)	3	0	0	7.7	8.0	7.9
	Nonfilterable Residue (mg/L)	3	na	1	1	1	1
	Dissolved Ammonia-nitrogen	3	0	3	0.005	0.005	0.005
	Total Phosphorus (mg/L)	3	0	0	0.003	0.008	0.006
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Mercury (µg/L)	2	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	1	0	0	0.001	0.001	0.001
	Total Zinc (mg/L)	3	0	3	0.005	0.010	0.008
BORIN CREEK ABOVE FAIRLESS CREEK							
Surface Water	pH (pH units)	1	0	0	7.6	7.6	7.6
	Nonfilterable Residue (mg/L)	1	na	0	3	3	3
	Dissolved Ammonia-nitrogen	1	0	0	0.006	0.006	0.006
	Total Phosphorus (mg/L)	1	1	0	0.119	0.119	0.119
	Total Arsenic (mg/L)	1	0	0	0.001	0.001	0.001
	Total Chromium (mg/L)	1	1	0	0.010	0.010	0.010
	Total Copper (mg/L)	2	1	1	0.001	0.010	0.006
	Total Mercury (µg/L)	2	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	1	1	0	0.005	0.005	0.005
	Total Zinc (mg/L)	2	0	2	0.005	0.010	0.008

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.
nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
FAIRLESS CREEK ABOVE CHURN CREEK (PE07378)							
Surface Water	pH (pH units)	3	0	0	7.5	8.0	7.8
	Nonfilterable Residue (mg/L)	2	na	0	1	8	5
	Dissolved Ammonia-nitrogen	3	0	0	0.005	0.006	0.005
	Total Phosphorus (mg/L)	3	0	0	0.037	0.073	0.06
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Mercury (µg/L)	3	0	2	0.050	0.060	0.053
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	3	0	3	0.005	0.010	0.008
Sediments	Total Chromium (µg/g)	1	1	0	42	42	42
	Total Copper (µg/g)	1	1	0	46	46	46
	Total Mercury (µg/g)	1	0	0	0.11	0.11	0.11
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	0	0	73	73	73
FAIRLESS CK. BELOW U/N CK. IN MEADOW							
Surface Water	pH (pH units)	13	0	0	7.4	8.3	7.8
	Nonfilterable Residue (mg/L)	9	na	1	1	30	7
	Dissolved Ammonia-nitrogen	4	0	4	0.005	0.005	0.005
	Total Phosphorus (mg/L)	9	8	0	0.075	0.319	0.168
	Total Arsenic (mg/L)	5	0	1	0.001	0.003	0.002
	Total Chromium (mg/L)	2	2	0	0.006	0.010	0.008
	Total Copper (mg/L)	3	2	0	0.001	0.004	0.003
	Total Mercury (µg/L)	2	0	1	0.050	0.080	0.065
	Total Lead (mg/L)	3	1	1	0.001	0.002	0.001
	Total Zinc (mg/L)	7	2	4	0.005	0.070	0.021
Sediments	Total Cadmium (µg/g)	1	1	0	2	2	2
	Total Chromium (µg/g)	2	2	0	27	41	34
	Total Copper (µg/g)	2	2	0	30	31	31
	Total Mercury (µg/g)	2	0	0	0.13	0.17	0.15
	Total Lead (µg/g)	2	0	2	10	10	10
	Total Zinc (µg/g)	2	0	0	62	78	70
UNNAMED CREEK IN FAIRLESS MEADOW							
Surface Water	pH (pH units)	5	0	0	7.5	7.8	7.7
	Nonfilterable Residue (mg/L)	4	na	0	1	6	3
	Dissolved Ammonia-nitrogen	4	0	2	0.005	0.005	0.005
	Total Phosphorus (mg/L)	3	0	0	0.009	0.013	0.011
	Total Arsenic (mg/L)	3	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	3	0	0	0.001	0.001	0.001
	Total Mercury (µg/L)	2	0	1	0.050	0.080	0.065
	Total Lead (mg/L)	3	1	2	0.001	0.002	0.001
	Total Zinc (mg/L)	3	1	2	0.005	0.070	0.027

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.
nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
Sediments	Total Cadmium (µg/g)	1	1	0	2	2	2
	Total Chromium (µg/g)	2	0	0	21	24	22.5
	Total Copper (µg/g)	2	2	0	26	33	30
	Total Mercury (µg/g)	2	0	0	0.11	0.13	0.12
	Total Lead (µg/g)	2	0	2	10	10	10
	Total Zinc (µg/g)	2	0	0	53	73	63
<u>FAIRLESS CREEK BELOW LOU BRANCH</u>							
Surface Water	pH (pH units)	13	0	0	7.3	7.9	7.7
	Nonfilterable Residue (mg/L)	9	na	0	2	136	42
	Dissolved Ammonia-nitrogen	4	1	1	0.005	0.016	0.009
	Total Phosphorus (mg/L)	10	9	0	0.036	0.710	0.345
	Total Arsenic (mg/L)	5	0	1	0.001	0.004	0.002
	Total Chromium (mg/L)	4	4	0	0.008	0.020	0.012
	Total Copper (mg/L)	4	4	0	0.002	0.010	0.004
	Total Mercury (µg/L)	3	0	2	0.050	0.080	0.060
	Total Lead (mg/L)	2	1	1	0.001	0.005	0.003
	Total Zinc (mg/L)	8	0	2	0.007	0.020	0.013
<u>FAIRLESS CREEK ABOVE LOU BRANCH</u>							
Surface Water	pH (pH units)	13	0	0	7.4	7.9	7.7
	Nonfilterable Residue (mg/L)	12	na	0	1	16	4
	Dissolved Ammonia-nitrogen	4	0	2	0.005	0.006	0.005
	Total Phosphorus (mg/L)	10	0	0	0.006	0.037	0.012
	Total Arsenic (mg/L)	5	0	1	0.001	0.002	0.001
	Total Copper (mg/L)	3	0	2	0.001	0.001	0.001
	Total Mercury (µg/L)	3	0	3	0.050	0.050	0.050
	Total Lead (mg/L)	2	2	0	0.002	0.005	0.004
	Total Zinc (mg/L)	8	0	6	0.005	0.020	0.012
Sediments	Total Arsenic (µg/g)	1	1	0	26	26	26
	Total Chromium (µg/g)	1	1	0	44	44	44
	Total Copper (µg/g)	1	1	0	26	26	26
	Total Mercury (µg/g)	1	0	0	0.1	0.1	0.1
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	0	0	60	60	60
<u>LOU BRANCH ABOVE FAIRLESS CREEK</u>							
Surface Water	pH (pH units)	5	0	0	7.2	7.6	7.3
	Nonfilterable Residue (mg/L)	1	na	0	1,050	1,050	1,050
	Dissolved Ammonia-nitrogen	3	2	0	0.009	0.019	0.013
	Total Phosphorus (mg/L)	3	3	0	0.094	0.516	0.238
	Total Arsenic (mg/L)	2	0	0	0.004	0.012	0.008
	Total Chromium (mg/L)	2	2	0	0.030	0.040	0.035
	Total Copper (mg/L)	3	3	0	0.005	0.030	0.018
	Total Mercury (µg/L)	3	3	0	0.100	0.250	0.190

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
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nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Lead (mg/L)	2	2	0	0.003	0.004	0.004
	Total Zinc (mg/L)	3	2	0	0.006	0.060	0.032
Sediments	Total Arsenic (µg/g)	1	1	0	37	37	37
	Total Cadmium (µg/g)	1	1	0	2	2	2
	Total Chromium (µg/g)	1	1	0	43	43	43
	Total Copper (µg/g)	1	1	0	68	68	68
	Total Mercury (µg/g)	1	1	0	0.77	0.77	0.77
	Total Lead (µg/g)	1	0	0	16	16	16
	Total Zinc (µg/g)	1	1	0	186	186	186
LOU BRANCH DIVERSION							
Surface Water	pH (pH units)	1	0	0	8.0	8.0	8.0
	Fecal Coliforms (MPN/100mL)	1	0	1	2	2	2
	Total Coliforms (MPN/100mL)	1	0	0	2	2	2
	Dissolved Ammonia-nitrogen	1	0	0	0.008	0.008	0.008
	Total Phosphorus (mg/L)	1	1	0	0.78	0.78	0.78
LOU BRANCH HEADWATERS							
Surface Water	pH (pH units)	2	0	0	6.7	7.7	7.2
	Nonfilterable Residue (mg/L)	1	na	0	2	2	2
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.013	0.013	0.013
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Mercury (µg/L)	1	0	1	0.050	0.050	0.050
	Total Lead (mg/L)	1	0	0	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	1	0.005	0.005	0.005
Dog Creek							
Fish Tissue (1990)	2,3,7,8-T4CDD (pg/g wet wt.)	4	1	0	1.70	50.00	18.83
	2,4,6-Trichlorophenol (ng/g wet wt.)	4	0	2	1	62	21
	Pentachlorophenol (µg/g wet wt.)	4	0	2	0.002	0.005	0.004
FELKER LK. NEAR CENTER							
Surface Water	pH (pH units)	2	0	0	8.9	8.9	8.9
	Nonfilterable Residue (mg/L)	2	na	0	5	5	5
	Dissolved Ammonia-nitrogen	2	0	2	0.005	0.005	0.005
	Total Phosphorus (mg/L)	2	1	0	0.014	0.022	0.018
CHIMNEY LK. AT NW END							
Surface Water	pH (pH units)	2	0	0	8.8	8.9	8.9
	Dissolved Ammonia-nitrogen	2	1	0	0.009	0.046	0.028
	Total Phosphorus (mg/L)	2	2	0	0.02	0.029	0.025
CHIMNEY LAKE NEAR CENTER							
Surface Water	pH (pH units)	8	0	0	8.6	8.9	8.8

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.
nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Nonfilterable Residue (mg/L)	4	na	4	4	4	4
	Dissolved Ammonia-nitrogen	8	6	2	0.005	0.306	0.066
	Total Phosphorus (mg/L)	8	8	0	0.02	0.026	0.023
CHIMNEY LK. AT SE END							
Surface Water	pH (pH units)	1	0	0	8.8	8.8	8.8
	Nonfilterable Residue (mg/L)	1	na	1	4	4	4
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.009	0.009	0.009
WILLIAMS LAKE R. NEAR MOUTH							
Surface Water	pH (pH units)	2	0	0	8.5	8.7	8.6
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	2	1	0	0.038	0.179	0.1085
WILLIAMS LAKE R. AT LAKE OUTLET							
Surface Water	pH (pH units)	74	**nc**	0	8.0	9.7	8.5
	Dissolved Ammonia-nitrogen	66	31	28	0.005	0.189	0.026
	Total Phosphorus (mg/L)	138	16	0	0.023	0.87	0.076
WILLIAMS LAKE AT WEST END							
Surface Water	pH (pH units)	1	0	0	8.3	8.3	8.3
	Nonfilterable Residue (mg/L)	1	na	0	2	2	2
	Dissolved Ammonia-nitrogen	5	2	2	0.005	0.020	0.010
	Total Phosphorus (mg/L)	5	5	0	0.049	0.08	0.058
WILLIAMS LAKE AT CENTER							
Surface Water	Dissolved Oxygen	25	4		4.3	13.8	10.4
	Temperature (°C)	6	2		6.0	17.5	11.2
	pH (pH units)	90	**nc**	0	8.0	9.2	8.4
	Nonfilterable Residue (mg/L)	45	na	2	1	14	4
	Dissolved Ammonia-nitrogen	117	60	41	0.005	9.700	0.141
	Total Phosphorus (mg/L)	145	144	0	0.014	0.23	0.063
	Total Chromium (mg/L)	2	2	0	0.050	0.070	0.060
	Total Zinc (mg/L)	10	0	7	0.010	0.010	0.010
Sediments	Total Chromium (µg/g)	2	2	0	32	33	32.5
	Total Copper (µg/g)	2	2	0	37	41	39
	Total Lead (µg/g)	2	1	0	23	55	39
	Total Zinc (µg/g)	2	1	0	59	210	135
WILLIAMS LK. AT EAST END							
Surface Water	Total Phosphorus (mg/L)	1	1	0	0.075	0.075	0.075
SAN JOSE R. BELOW BORLAND CR.							
Surface Water	pH (pH units)	31	0	0	8.0	8.7	8.3
	Dissolved Ammonia-nitrogen	1	1	0	0.014	0.014	0.014

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
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nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Phosphorus (mg/L)	71	33	0	0.03	0.523	0.106
<u>SAN JOSE R. ABOVE BORLAND CR.</u>							
Surface Water	Total Phosphorus (mg/L)	100	42	0	0.04	0.947	0.120
<u>SAN JOSE R. AT ONWARD</u>							
Surface Water	Total Phosphorus (mg/L)	1	1	0	0.16	0.16	0.16
<u>SAN JOSE R. AT ENTERPRISE RD.</u>							
Surface Water	Total Phosphorus (mg/L)	21	4	0	0.027	0.114	0.058
<u>SAN JOSE RIVER AT OLD DIVERSION DAM</u>							
Surface Water	Total Phosphorus (mg/L)	3	0	0	0.028	0.036	0.032
<u>SAN JOSE RIVER AT DYCK'S PASTURE</u>							
Surface Water	Total Phosphorus (mg/L)	6	1	0	0.022	0.145	0.05
<u>SAN JOSE RIVER AT 132 MILE RANCH</u>							
Surface Water	pH (pH units)	3	0	0	7.8	8.6	8.2
	Dissolved Ammonia-nitrogen	3	1	2	0.005	0.033	0.014
	Total Phosphorus (mg/L)	4	2	0	0.043	0.118	0.081
<u>130 MILE LAKE</u>							
Surface Water	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	2	1	0	0.014	0.015	0.015
Sediments	Total Arsenic (µg/g)	1	0	0	4.5	4.5	4.5
	Total Chromium (µg/g)	2	0	0	21	22	21.5
	Total Copper (µg/g)	2	2	0	24	29	27
	Total Mercury (µg/g)	1	0	0	0.07	0.07	0.07
	Total Lead (µg/g)	2	0	1	10	16	13
	Total Zinc (µg/g)	2	0	0	34	42	38
<u>SAN JOSE R. AT OUTLET OF LAC LA HACHE</u>							
Surface Water	pH (pH units)	70	0	0	7.6	8.8	8.4
	Fecal Coliforms (MPN/100mL)	1	0	1	20	20	20
	Total Coliforms (MPN/100mL)	1	1	0	260	260	260
	Dissolved Ammonia-nitrogen	65	21	30	0.005	0.705	0.029
	Total Phosphorus (mg/L)	120	1	0	0.009	0.95	0.031
<u>BORLAND CR. AT SUGAR CAN</u>							
Surface Water	pH (pH units)	14	0	0	8.1	8.6	8.4
	Total Phosphorus (mg/L)	160	115	2	0.003	1.53	0.175
<u>BORLAND CR. ABOVE SANDMAN SIGN - HWY 97</u>							
Surface Water	pH (pH units)	12	0	0	8.0	8.3	8.2
	Total Phosphorus (mg/L)	12	6	0	0.037	0.282	0.105

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MDL = method detection limit
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nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
BORLAND CR. BELOW VALLEY CR.							
Surface Water	pH (pH units)	13	0	0	7.9	8.3	8.2
	Total Phosphorus (mg/L)	24	9	0	0.034	0.189	0.089
BORLAND CR. ABOVE VALLEY CR.							
Surface Water	pH (pH units)	14	0	0	7.9	8.3	8.2
	Total Phosphorus (mg/L)	14	5	0	0.031	0.484	0.097
BORLAND CR. AT HWY 97							
Surface Water	pH (pH units)	14	0	0	7.9	8.3	8.2
	Total Phosphorus (mg/L)	15	6	0	0.031	0.451	0.120
BORLAND CR. AT PIPELINE - PIGEON RD.							
Surface Water	pH (pH units)	11	0	0	8.0	8.2	8.1
	Total Phosphorus (mg/L)	11	4	0	0.029	0.364	0.103
BORLAND CR. ABOVE 150 MILE - PIGEON RD.BRIDGE							
Surface Water	pH (pH units)	14	0	0	8.1	8.4	8.2
	Total Phosphorus (mg/L)	15	2	0	0.028	0.344	0.089
BORLAND CREEK JUST DS OF POWERLINE							
Surface Water	Total Phosphorus (mg/L)	2	0	0	0.028	0.035	0.032
BORLAND CREEK ABOVE HOFF'S RANCH							
Surface Water	Total Phosphorus (mg/L)	18	1	0	0.019	0.114	0.038
CK. INLET INTO 5 MILE LAKE AT LIKELY RD.							
Surface Water	Total Phosphorus (mg/L)	43	42	0	0.089	0.675	0.234
CK. OUTLET OF DUGAN LK. AT HORSEFLY RD.							
Surface Water	Total Phosphorus (mg/L)	47	10	0	0.021	2.01	0.150
VALLEY CR. ABOVE BORLAND CR.							
Surface Water	pH (pH units)	13	0	0	8.0	8.4	8.2
	Total Phosphorus (mg/L)	114	79	0	0.042	0.876	0.146
VALLEY CR. ABOVE TURCOTTE'S							
Surface Water	Total Phosphorus (mg/L)	29	0	0	0.017	0.083	0.039
JONES CR. AT MISSION RD.							
Surface Water	Total Phosphorus (mg/L)	1	1	0	2.07	2.07	2.07
JONES CR. AT HWY 97							
Surface Water	Total Phosphorus (mg/L)	91	37	0	0.030	0.277	0.097
KNIFE CR. ABOVE SAN JOSE R. (AT 141 M.H.)							
Surface Water	Total Phosphorus (mg/L)	96	26	0	0.024	1.26	0.097

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Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
LAC LA HACHE NEAR OUTLET							
Surface Water	pH (pH units)	2	0	0	7.7	7.7	7.7
	Dissolved Ammonia-nitrogen	2	0	0	0.007	0.008	0.008
	Total Phosphorus (mg/L)	2	2	0	0.038	0.04	0.039
LAC LA HACHE AT N.W. END							
Surface Water	pH (pH units)	16	0	0	8.0	8.7	8.5
	Nonfilterable Residue (mg/L)	1	na	1	4	4	4
	Dissolved Ammonia-nitrogen	15	4	10	0.005	0.049	0.012
	Total Phosphorus (mg/L)	18	5	0	0.007	0.023	0.013
	Total Zinc (mg/L)	1	0	1	0.010	0.010	0.010
LAC LA HACHE OFF EMERALD ISLAND							
Surface Water	pH (pH units)	54	0	0	8.1	8.7	8.5
	Nonfilterable Residue (mg/L)	7	na	7	4	4	4
	Dissolved Ammonia-nitrogen	52	27	19	0.005	0.041	0.013
	Total Phosphorus (mg/L)	63	15	0	0.005	0.024	0.012
	Total Chromium (mg/L)	3	3	0	0.030	0.040	0.037
	Total Zinc (mg/L)	10	0	10	0.010	0.010	0.010
LAC LA HACHE AT LAC LA HACHE							
Surface Water	pH (pH units)	5	0	0	8.4	8.6	8.5
	Dissolved Ammonia-nitrogen	4	0	4	0.005	0.005	0.005
	Total Phosphorus (mg/L)	5	5	0	0.017	0.024	0.019
	Total Zinc (mg/L)	1	0	0	0.010	0.010	0.010
KARL CREEK AT ROAD NEAR N. END OF D.L. 2803							
Surface Water	Total Phosphorus (mg/L)	2	1	0	0.055	0.158	0.1065
HELENA CK. AT HELENA LAKE RD.							
Surface Water	pH (pH units)	1	0	0	8.4	8.4	8.4
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.013	0.013	0.013
KOKANEE BAY, LAKE WATR ST. NO. 5							
Surface Water	pH (pH units)	4	0	0	8.3	8.6	8.5
	Dissolved Ammonia-nitrogen	4	2	1	0.005	0.032	0.015
	Total Phosphorus (mg/L)	4	3	0	0.014	0.056	0.027
FORBES CR. AT MOUTH							
Surface Water	pH (pH units)	2	0	0	8.3	8.4	8.4
	Total Phosphorus (mg/L)	35	0	0	0.014	0.086	0.039
FORBES C. AT FIRST CROSSING							
Surface Water	pH (pH units)	2	0	0	7.8	8.1	8.0
	Dissolved Ammonia-nitrogen	2	1	1	0.005	0.017	0.011

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Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Phosphorus (mg/L)	2	0	0	0.027	0.055	0.041
FORBES C. AT PIPELINE							
Surface Water	pH (pH units)	10	0	0	7.7	8.3	8.0
	Dissolved Ammonia-nitrogen	10	4	3	0.005	0.135	0.025
	Total Phosphorus (mg/L)	10	0	0	0.023	0.063	0.039
FORBES C. NR D.L. 354, L.D							
Surface Water	Total Phosphorus (mg/L)	1	0	0	0.021	0.021	0.021
117 MILE CREEK AT HIGHWAY 97							
Surface Water	Total Phosphorus (mg/L)	2	0	0	0.063	0.071	0.067
111 MILE CR. NEAR MOUTH - LLH STN. RD.							
Surface Water	pH (pH units)	26	0	0	7.6	8.4	8.1
	Dissolved Ammonia-nitrogen	11	5	3	0.005	1.500	0.152
	Total Phosphorus (mg/L)	92	8	0	0.011	0.537	0.055
111 MILE CREEK AT WEST BOUNDARY OF D.L. 191							
Surface Water	Total Phosphorus (mg/L)	1	1	0	0.161	0.161	0.161
111 MILE CREEK NEAR S. BOUNDARY OF D.L. 131							
Surface Water	Total Phosphorus (mg/L)	1	0	0	0.024	0.024	0.024
111 MILE CR. BELOW LARSEN CR.							
Surface Water	pH (pH units)	9	0	0	7.7	8.3	7.9
	Dissolved Ammonia-nitrogen	9	3	4	0.005	0.035	0.012
	Total Phosphorus (mg/L)	12	0	0	0.015	0.031	0.021
RAIL CREEK AT TIMOTHY LAKE ROAD BRIDGE							
Surface Water	Total Phosphorus (mg/L)	2	0	0	0.035	0.035	0.035
RAIL CREEK UPSTREAM OF D.L.1112 AT ROAD							
Surface Water	Total Phosphorus (mg/L)	2	0	0	0.022	0.027	0.025
RAIL CREEK AT RAIL LAKE RD.							
Surface Water	Total Phosphorus (mg/L)	3	0	0	0.03	0.036	0.034
SUCKER LAKE CREEK AT HWY 97							
Surface Water	Total Phosphorus (mg/L)	1	0	0	0.037	0.037	0.037
SEPA LAKE AT CENTRE							
Surface Water	pH (pH units)	3	0	0	8.8	8.9	8.9
	Dissolved Ammonia-nitrogen	3	3	0	0.015	0.031	0.023
	Total Phosphorus (mg/L)	3	0	0	0.036	0.047	0.040
WATSON LAKE							
Surface Water	pH (pH units)	2	2	0	9.2	9.2	9.2

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Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Phosphorus (mg/L)	2	2	0	0.022	0.023	0.023
Sediments	Total Arsenic (µg/g)	1	0	0	2	2	2
	Total Chromium (µg/g)	2	0	0	4	5	4.5
	Total Copper (µg/g)	2	0	0	8	14	11
	Total Mercury (µg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (µg/g)	2	0	1	10	10	10
	Total Zinc (µg/g)	2	0	0	12	17	15
ROCK CREEK AT ROAD NEAR LILY PAD LAKE INLET							
Surface Water	Total Phosphorus (mg/L)	1	0	0	0.034	0.034	0.034
ROCK CREEK AT ROAD NEAR ABLE LAKE OUTLET							
Surface Water	Total Phosphorus (mg/L)	1	0	0	0.041	0.041	0.041
Soda Creek							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	8	2	0	2.80	80.00	23.74
(1990-1992)	2,4,6-Trichlorophenol (ng/g wet wt.)	4	0	3	1	86	22
	Pentachlorophenol (µg/g wet wt.)	4	0	3	0.002	0.006	0.003
SOAP LAKE							
Surface Water	pH (pH units)	2	2	0	9.1	9.1	9.1
	Dissolved Ammonia-nitrogen	2	2	0	0.012	0.015	0.014
	Total Phosphorus (mg/L)	4	0	0	0.012	0.014	0.013
Sediments	Total Arsenic (µg/g)	1	0	0	0.8	0.8	0.8
	Total Chromium (µg/g)	1	0	1	1	1	1
	Total Copper (µg/g)	1	0	0	13	13	13
	Total Mercury (µg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (µg/g)	1	0	0	14	14	14
	Total Zinc (µg/g)	1	0	0	21	21	21
CUISSON R. NEAR ALEXANDRIA							
Surface Water	Temperature (°C)	1	0		14.5	14.5	14.5
	pH (pH units)	3	0	0	7.1	8.5	8.0
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	0	0.007	0.007	0.007
CUISSON CREEK AT 12.7 KM ROAD (TRAIL)							
Surface Water	pH (pH units)	6	0	0	7.7	8.2	8.0
	Nonfilterable Residue (mg/L)	6	na	0	1	7	3
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Arsenic (mg/L)	3	0	3	0.040	0.040	0.040
	Total Copper (mg/L)	4	2	0	0.001	0.002	0.002
	Total Lead (mg/L)	5	1	4	0.001	0.002	0.001

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nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Zinc (mg/L)	5	1	2	0.005	0.080	0.024
<u>CUISSON CREEK AT 15.4 ROAD</u>							
Surface Water	pH (pH units)	8	0	0	8.0	8.3	8.2
	Nonfilterable Residue (mg/L)	6	na	1	1	2	1
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.015	0.015	0.015
	Total Arsenic (mg/L)	3	0	3	0.040	0.040	0.040
	Total Copper (mg/L)	4	2	0	0.001	0.010	0.004
	Total Lead (mg/L)	5	0	4	0.001	0.001	0.001
	Total Zinc (mg/L)	6	1	2	0.005	0.070	0.023
<u>E. CUISSION CK BELOW SEEPAGE POND</u>							
Surface Water	pH (pH units)	2	0	0	8.1	8.1	8.1
	Nonfilterable Residue (mg/L)	1	na	0	2	2	2
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	0	0.001	0.001	0.001
	Total Lead (mg/L)	1	0	0	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	0	0.005	0.005	0.005
<u>CUISSON CR. ABOVE GIBRALTAR</u>							
Surface Water	pH (pH units)	1	0	0	7.7	7.7	7.7
	Nonfilterable Residue (mg/L)	1	na	0	1	1	1
	Total Copper (mg/L)	1	0	0	0.001	0.001	0.001
<u>CUISSON CREEK 375 M U/S OF MOFFAT LK. RD.</u>							
Surface Water	pH (pH units)	11	0	0	7.7	8.3	7.9
	Nonfilterable Residue (mg/L)	10	na	2	1	4	2
	Dissolved Ammonia-nitrogen	5	3	2	0.005	0.229	0.056
	Total Phosphorus (mg/L)	1	0	0	0.011	0.011	0.011
	Total Arsenic (mg/L)	8	0	8	0.001	0.040	0.035
	Total Chromium (mg/L)	4	0	4	0.002	0.002	0.002
	Total Copper (mg/L)	10	6	2	0.001	0.020	0.004
	Total Lead (mg/L)	6	0	4	0.001	0.001	0.001
	Total Zinc (mg/L)	12	1	8	0.002	0.030	0.010
<u>CUISSON CR BELOW SOURAN LAKE</u>							
Surface Water	Temperature (°C)	1	1		19.0	19.0	19.0
	pH (pH units)	15	0	0	6.7	8.3	7.8
	Nonfilterable Residue (mg/L)	11	na	0	1	24	4
	Dissolved Ammonia-nitrogen	3	3	0	0.019	0.125	0.057
	Total Phosphorus (mg/L)	3	0	0	0.007	0.015	0.012
	Total Arsenic (mg/L)	4	0	4	0.040	0.040	0.040
	Total Copper (mg/L)	5	4	0	0.001	0.020	0.008
	Total Lead (mg/L)	7	1	6	0.001	0.002	0.001
	Total Zinc (mg/L)	6	2	3	0.005	0.090	0.033

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Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
LEWIS CR - LOWER							
Surface Water	pH (pH units)	6	0	0	7.0	8.1	7.8
	Nonfilterable Residue (mg/L)	4	na	1	1	4	2
	Dissolved Ammonia-nitrogen	1	1	0	0.010	0.010	0.010
	Total Phosphorus (mg/L)	1	0	0	0.016	0.016	0.016
LEWIS CK AT MINE ACCESS ROAD							
Surface Water	Temperature (°C)	4	1		5.0	15.0	11.0
	pH (pH units)	30	**nc**	0	4.8	8.7	7.7
	Nonfilterable Residue (mg/L)	17	na	0	1	70	13
	Dissolved Ammonia-nitrogen	3	0	1	0.005	0.006	0.005
	Total Phosphorus (mg/L)	3	2	0	0.013	0.06	0.030
	Total Arsenic (mg/L)	2	0	2	0.040	0.040	0.040
	Total Chromium (mg/L)	1	1	0	0.010	0.010	0.010
	Total Copper (mg/L)	11	11	0	0.010	0.140	0.048
	Total Lead (mg/L)	5	0	2	0.001	0.001	0.001
	Total Zinc (mg/L)	11	5	1	0.007	0.090	0.030
LEWIS CREEK NEAR OUTLET OF LEWIS LAKE							
Surface Water	pH (pH units)	7	0	0	7.4	7.8	7.6
	Nonfilterable Residue (mg/L)	7	na	0	1	5	3
	Total Phosphorus (mg/L)	1	1	0	0.23	0.23	0.23
	Total Arsenic (mg/L)	3	0	3	0.040	0.040	0.040
	Total Cadmium (mg/L)	1	1	0	0.0006	0.0006	0.0006
	Total Copper (mg/L)	7	7	0	0.010	0.160	0.045
	Total Lead (mg/L)	6	1	3	0.001	0.002	0.001
	Total Zinc (mg/L)	7	2	1	0.005	0.070	0.028
GRANITE CR. AT GIBRALTER RD.							
Surface Water	Temperature (°C)	3	2		7.0	18.0	13.3
	pH (pH units)	7	**nc**	0	4.6	8.2	7.0
	Nonfilterable Residue (mg/L)	2	na	0	51	90	71
CUISSON LAKE AT INLET END							
Surface Water	pH (pH units)	1	0	0	8.1	8.1	8.1
	Dissolved Ammonia-nitrogen	1	1	0	0.026	0.026	0.026
	Total Phosphorus (mg/L)	1	0	0	0.014	0.014	0.014
	Total Arsenic (mg/L)	1	0	1	0.040	0.040	0.040
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
BAKER C. BELOW W. QUESNEL STP							
Surface Water	pH (pH units)	1	0	0	8.3	8.3	8.3
	Nonfilterable Residue (mg/L)	1	0	0	68	68	68
	Fecal Coliforms (MPN/100mL)	1	1	0	9,200	9,200	9,200
	Total Coliforms (MPN/100mL)	1	1	0	24,000	24,000	24,000

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.
nc = not calculated.

Table 4.5.1a Summary of Receiving Envrionment Data used to Assess Surface Water, Sediment and Fish Tissue Quality in the Middle Fraser HMA.

		n	# > Guideline*	# < MDL	Min	Max	Mean
BAKER C. ABOVE WEST QUESNEL STP.							
Surface Water	pH (pH units)	1	0	0	8.7	8.7	8.7
	Nonfilterable Residue (mg/L)	1	0	0	1	1	1
	Fecal Coliforms (MPN/100mL)	1	0	0	8	8	8
	Total Coliforms (MPN/100mL)	1	0	0	130	130	130
TIBBLES LAKE NEAR CENTRE							
Surface Water	pH (pH units)	1	1	0	9.2	9.2	9.2
	Dissolved Ammonia-nitrogen	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	1	0	0.056	0.056	0.056
TIBBLES LAKE INLET NO. 1 @ NAZKO RD.							
Surface Water	Nonfilterable Residue (mg/L)	6	na	0	20	41	27
	Dissolved Ammonia-nitrogen	6	2	1	0.005	0.014	0.009
	Total Phosphorus (mg/L)	6	6	0	0.077	0.156	0.102
PUNTATAENKUT CR @ NAZKO RD							
Surface Water	Nonfilterable Residue (mg/L)	6	na	0	4	39	28
	Dissolved Ammonia-nitrogen	6	6	0	0.014	0.032	0.020
	Total Phosphorus (mg/L)	6	5	0	0.077	0.172	0.128
PUNTATAENKUT CR. AT DOIG RD.							
Surface Water	pH (pH units)	1	0	0	7.1	7.1	7.1
	Nonfilterable Residue (mg/L)	6	na	0	4	86	42
	Dissolved Ammonia-nitrogen	7	4	1	0.005	0.016	0.010
	Total Phosphorus (mg/L)	7	5	0	0.076	0.223	0.115
MILBURN LAKE NORTH END							
Surface Water	pH (pH units)	3	0	0	7.4	8.8	7.9
	Dissolved Ammonia-nitrogen	4	3	0	0.009	0.179	0.099
	Total Phosphorus (mg/L)	4	4	0	0.017	0.069	0.04
MILBURN LAKE SOUTH END EAST BAY							
Surface Water	pH (pH units)	3	0	0	7.6	8.0	7.7
	Dissolved Ammonia-nitrogen	3	0	2	0.005	0.005	0.005
	Total Phosphorus (mg/L)	3	2	0	0.014	0.049	0.028
MILBURN LAKE SOUTH END WEST BAY							
Surface Water	pH (pH units)	4	0	0	7.4	8.0	7.9
	Dissolved Ammonia-nitrogen	5	4	0	0.007	0.893	0.280
	Total Phosphorus (mg/L)	5	3	0	0.013	0.202	0.067

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.
nc = not calculated.

Table 4.5.1b Summary of Contaminants Measured in Fish Tissue in 1994, for the Marguerite Reach of the Middle Fraser HMA.[1]

Guidelines:			
	Total PCB	$2\ \mu g \cdot g^{-1}$ dry wt.	(for the protection of aquatic life; B.C. MELP)
	Total T4CDD	$20\ pg \cdot g^{-1}$ dry wt.	(for the protection of humans; USEPA)
	Total toxaphene	$0.1\ \mu g \cdot g^{-1}$ dry wt.	(for the protection of humans; Environment Canada)
	p,p'-DDE	$3\ \mu g \cdot g^{-1}$ dry wt.	(for the protection of humans; Environment Canada)

		Total PCB (ng/g)			Total T4CDD (pg/g)			Total O8CDD (pg/g)			Total T4CDF (pg/g)			Total O8CDF (pg/g)			p,p'-DDE (246) (ng/g)			Total Toxaphene (ng/g)		
Species	Tissue	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max
Marguerite																						
Peamouth Chub	*Liver*	1	19.62	19.62	1	0.4	0.4	1	<2	<2	1	1.2	1.2	1	<2	<2	2[a]	7	7.2	2[a]	12	14
	Muscle	4	4.5	27.13	4	<0.1	<0.1	4	<0.5	3.4	4	0.4	0.5	4	<0.6	<0.4	4	2.6	4.3	4	3.7	7.4
Mountain Whitefish	*Liver*	1	4.0	4.0	1	1.5	1.5	1	<4	<4	1	2.3	2.3	1	<4	<4	1	1	1	1	<1.4	<1.4
	Muscle	4	2.3	6.2	4	0.5	0.9	4	<0.5	<0.4	4	0.6	1	4	<0.5	<0.4	5	0.81	1.9	5[a]	2	5.5

[1] Data summarized from: Raymond, *et al*. 2000 (see reference 15)

n* is the number of composite samples. For the Marguerite reach there are five fish per muscle composite and 25 - 41 fish per liver composite.

[a] - includes laboratory duplicates.

Table 4.6.1 Summary of Land Use Areas, Summer and Winter Low-flows, and Water Demand for the Middle Fraser HMA.[1]

Stream	SISS code	Watershed area (km sq.)	Total logged	Recent/ proposed activity*	Naturalized Stream Flow (L/s) Summer 7-day mean low-flow	Winter 7-day mean low-flow	Mean annual flow	Potential August Water Demand (L/s) Domestic	Irrigation	Water-works	Industrial	Storage (ac-ft)
Coquihalla R.	00-0800	932	39	39.9	5900	7800	30000	0.4	0.4	1.9	22.3	0
Kawkawa Ck.	00-0800-010	9	0	0	240	400	320	0.2	0	1.9	0.5	0
Sucker Ck.	00-0800-010-010	3	0	0	90	150	120	0	0	0	0	0
Stevens Ck.	00-0800-010-020	1	0	0	30	50	40	0	0	0	0	0
Menz Ck.	00-0800-010-030	1	0	0	30	50	40	0	0	0	0	0
Kopp Ck.	00-0800-010-030-010	3	0	0	90	150	120	0.05	0	1.8	0.3	0
Sowqua Ck.	no SISS #	153	3.2	8.5	-	-	-	0	0	0	0	0
American Ck.	00-0815	32	1.8	3	200	110	3070	0.05	0	0	0	0
Squeah Lake Ck.	00-0834	14	0	0	90	50	1360	0	0	0	0	0
Emory Ck.	00-0841	65	4.7	4.4	380	390	5100	0.2	0	0	0	0
Gordon Ck.	00-0855	11	2.3	2.3	60	60	830	0.1	0	0	0	0
Yale Ck.	00-0860	37	1.8	2	100	170	2410	0.1	2.5	1.3	0	0
Sawmill Ck.	no SISS #	31	0	0	-	-	-	0.59	2.07	0	0	0
Spuzzum Ck.	00-0900	224	16.4	12.5	770	1020	14460	0.03	7.5	2.5	0.9	0
Anderson R.	00-1000	500	75.2	99.6	870	550	10240	0	0	0	0	0
Lower Anderson R.	no SISS #	350	55.8	65.5	-	-	-	0	0	0	0	0
Upper Anderson R.	no SISS #	150	19.4	34.1	-	-	-	0	0	0	0	0
Utzlius Ck.	no SISS #	160	37.1	33.2	-	-	-	0	0	0	0	0
East Anderson R.	no SISS #	125	10.6	19.4	-	-	-	0	0	0	0	0
Stoyama Ck.	no SISS #	38	2.2	3.4	-	-	-	0.66	0	0.26	2.79	0
Nahatlatch R.	00-1200	1256	24	35.8	12550	7600	38020	0.3	0.8	0	0	0
Lower Nahatlatch R.	no SISS #	946	21.1	24.7	-	-	-	0	0	0	0	0
Upper Nahatlatch R.	no SISS #	310	3	11.2	-	-	-	0	0	0	0	0
Log Ck.	no SISS #	84	5	5	-	-	-	-	-	-	-	-
Kookipi Ck.	no SISS #	159	2.6	6.4	-	-	-	-	-	-	-	-
Unnamed Ck.	no SISS #	53	0	0	-	-	-	-	-	-	-	-
Mehatl Ck.	no SISS #	293	8.7	0.8	-	-	-	-	-	-	-	-
Stein R.	00-1400	1084	0	0	5100	3800	17500	0.2	122.5	9.2	0	0
Texas Ck.	00-1600	171	9.7	8.4	760	600	2800	0.1	112	0	0	0
Churn Ck.	00-2900	992	27.6	120.9	2820	1580	6000	1	36.9	0	0	165
Gaspard Ck.	no SISS #	943	156.1	123.1	-	-	-	-	-	-	-	-
Williams Lake R.	00-3900	2240	273.1	235.2	260	160	2600	5.2	269.7	187.8	25.9	0
Knife Ck.	00-3900-250	232	24.8	27.4	210	50	200	0.3	157	0	0.03	3309
Narcosli Ck.	00-4700	1700	179.04	176.74	700	880	3300	0	161	0	0.3	0
Baker Ck.	00-4900	1570	174.84	103.16	660	810	3700	0.7	117	52.6	0.8	0

* Recent logging occurred from 1983-1992, and proposed logging estimates were based on logging plans for 1993-1998.

[1] Adapted from references 1 and 24.

Table 4.6.2 Summary of Red-coded Indicators[1] for Streams in the Middle Fraser HMA. (Streams are ordered by SISS code.)

Stream Name	Indicator				
	Urban	Agriculture	Logging	Stream Flow	Demand
Coquihalla River	*				
Kawkawa Creek	*				
Sucker Creek					
Stevens Creek				*	
Menz Creek					
Kopp Creek				*	
Sowqua Creek2					
American Creek				*	
Squeah Lake Creek				*	
Emory Creek				*	
Gordon Creek			*	*	
Yale Creek				*	
Sawmill Creek[2]					
Spuzzum Creek				*	
Anderson River			*	*	
Utzlius Creek[2]			*		
East Anderson Creek					
Stoyama Creek[2]					
Nahatlatch River					
Log Creek					
Kookipi Creek[2]					
Mehatl Creek[2]					
Stein River					
Texas Creek					
Churn Creek					
Gaspard Creek[2]					
Williams Lake River, San Jose River u/s Williams Lake.	*			*	*
Knife Creek[2]				*	*
Narcosli Creek		*	*		
Baker Creek	*				

[1] "Red -coded" = likely to have water quality impacts associated with given land use, stream flow, or water demand conditions in the stream. See Chapter 3 for assessment methodology.

[2] Stream does not directly support anadromous salmon.

Chapter 5 Nechako Habitat Management Area

5.1 Background

The Nechako HMA comprises 31,500 km^2, or 13.6% of the Fraser River Basin. The Nechako River originates in the Nechako Plateau, and flows east to its confluence with the Fraser River near Prince George. The three largest tributaries to the Nechako are Stuart River (addressed as a separate HMA in Chapter 6), Nautley River and Stellako River. Numerous smaller tributaries including the Chilako, Nadina, and Endako Rivers provide important fish habitat, and contribute to flows in the Nechako River. The HMA lies in the rain shadow of the Coast Mountains; Prince George receives only about 500-600 mm of precipitation annually.[1] Near the Coast Ranges the climate is characterized as modified maritime, and changes to an interior climate further east, with short, hot summers, and long, cold winters.[1] The HMA is characterized by gently rolling terrain with elevations less than 1,500 m.[1] Only the upper watershed (upstream of Kenney Dam) extends into the Tahtsa Ranges.[1]

5.1.1 Hydrology

The hydrology of the Nechako River is largely controlled by dams. The Nechako Reservoir was created to divert flows from the Nechako basin to generate hydroelectric power for the Alcan aluminum smelter at Kitimat.[1] Since 1952, water released from the Skins Lake Spillway has provided almost all of the Nechako River flow upstream of the Nautley River. Natural flows from the Nautley watershed influence flows downstream to the Stuart River confluence.[1] Effects of regulation on hydrologic regime decrease downstream from the Stuart River.[1]

Nechako instream flow requirements for meeting the needs of rearing and spawning fish, and for temperature management, are established under the Nechako Settlement Agreement. Maximum water releases generally occur in July and August to provide a cooling influence on the river.[1] Summer flows are still much lower under this regulated regime compared with natural conditions, amounting to approximately half the natural mean annual flood level at Vanderhoof.[1]

Snowmelt is the primary source of water. For tributaries that are not controlled by the dam, maximum flows generally occur in early summer.[1] Lakes within some tributary sub-watersheds in the HMA help to moderate stream flows, with lake size determining the degree to which this happens. Intensive fall rains result in flow increases before freeze-up. Minimum flows typically occur under ice in the winter.

Low flows in many of the small tributaries are likely sustained by groundwater inputs during late summer and early fall.[1] Some tributaries are experiencing downcutting in their lower reaches to match water levels in the Nechako River, resulting in erosion and the deposition of sediment in the Nechako mainstem.

Two salmon-bearing streams in the Nechako HMA are considered to have natural summer low flows of concern from a water quality perspective (Table 5.6.2). Three salmon-bearing streams were considered likely to have water quality impacts resulting from excessive water withdrawals.

5.1.2 Fish

In addition to the Nechako River mainstem there are twelve salmon-bearing streams in the Nechako HMA.[1,2] Sockeye and chinook are the only anadromous salmon normally occurring in the Nechako HMA. However, pink salmon were reported in the Nechako River in 1989. The lower Nechako River is an important migratory corridor for the famous Stuart River sockeye salmon stocks. The Stellako system supports the largest run of sockeye in the HMA, with an average escapement of more than 100,000 fish.[2] Spawning occurs throughout the river from the mouth to Francois Lake.[2] The river also provides a major spawning area for Fraser Lake trout.[2]

Non-anadromous species identified in the Nechako HMA include Dolly Varden, rainbow trout, mountain whitefish, northern squawfish, and white sturgeon.

5.1.3 Predominant Land Uses

Predominant land uses in the HMA are forestry and some ranching. Recreational opportunities also draw people to the area, especially in the vicinity of Tweedsmuir Park.

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5.2 Point Sources of Contaminants

5.2.1 Urban/Industrial Point Source Discharges to Surface Water

There are 11 permitted discharges of wastes to surface waters in the Nechako HMA (Figure 5.2.1), including 7 of sewage effluent and 5 of processing effluent ((Table 5.2.1).[3] Three of the 5 processing effluents are from fish hatchery or holding facilities. The largest loadings of BOD and NFR come from the STPs (Table 5.2.2).[3] It should be noted that some large point source discharges originating from the city of Prince George, such as the Prince George STP, actually discharge to the Fraser River in the Upper Fraser HMA. They are therefore addressed in Chapter 7 of this report.

5.2.2 Permitted Discharges to Ground

There are 10 permitted discharges of wastes to the ground in the Nechako HMA, including 6 of sewage effluent, and 4 of processing effluent.[3] All of these discharges are less than 60 $m^3 \cdot d^{-1}$.

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5.3 Non-Point Sources of Contaminants

Non-point sources of contaminants can put water quality at risk in some of the salmon-bearing streams of the Nechako HMA. The main sources of NPS pollution in the HMA include agriculture, forestry, and urban development in the vicinity of Prince George and Vanderhoof.

5.3.1 Urban Development

Most of the HMA population is concentrated in the city of Prince George, which is centered in a triangle south of the Nechako River on the west bank of the Fraser River. The population was estimated to be about 76,500 in 1995, and is growing relatively rapidly. It is expected that another 3,000 to 5,000 lots will be developed by the year 2000, resulting in more sedimentation, stormwater runoff, and damage to riparian areas, unless significant precautions are taken.[4]

The second largest population center in the HMA is Vanderhoof, which numbers approximately 4,500. There are also several small towns located along the Nechako River west to Fraser Lake, including Fort Fraser, and along the Endako River from it's confluence with the Nechako up to Burns Lake.

The Nechako River is the only salmon bearing system in the HMA for which significant water quality issues associated with urban development were identified (Table 5.6.2).

5.3.2 Agriculture

Cattle ranching is the predominant agricultural land use in the Nechako HMA. Removal of riparian vegetation is resulting in sediment release in both new and established farming areas of the Nechako and Chilako watersheds.[4] In some agricultural areas dyking is resulting in stream bank degradation.[4] In the vicinity of Prince George, the development of "hobby" ranches by individuals with little experience in stewarding the land is resulting in some impacts.

Agricultural land use was considered to cause significant water quality impacts in the Nechako, Chilako, and Endako Rivers (Table 5.6.2).

5.3.3 Timber Harvesting

Extensive logging affects several important salmon streams.[4] Poor road building and maintenance practices disrupt hydrology and soils, resulting in erosion and sedimentation problems. Numerous complaints of habitat damage resulting from logging on private land have been received by DFO. There are very few staff to address compliance monitoring and enforcement in a large geographic area, and compliance with regulations is often very poor.[4]

The potential for impacts to water quality from forestry activities are assessed below for each salmon-bearing stream in the HMA. Assessments are largely based on the percent of the watershed area which has been harvested.[1] The areas for proposed harvest were determined from five-year plans for 1992-'97, therefore most of the "proposed" logging has likely already occurred.

Six of the 13 salmon-bearing systems in the HMA were considered to be significantly impacted by forest development activities (Table 5.6.2).

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5.4 Overview of Water Quality Conditions

Water quality data in the database for the Nechako HMA are mostly limited to the Nechako River near Prince George (Table 5.5.1a).

Data reported elsewhere indicate that lakes within the HMA generally have moderate buffer capacity (0.004 - 0.015 $mol \cdot L^{-1}$), and low total dissolved solids (1 - 100 $mg \cdot L^{-1}$).[6] The dominant bedrock types in the HMA are volcanic and sedimentary, and about 79% of the watershed area is considered to have low to moderate-low potential to reduce acidity.[6] Water in the Nechako Reservoir is reportedly soft and low in dissolved solids, nutrients, and metals.[9]

High summer water temperatures are the primary water quality concern in the HMA. As noted earlier, maximum flows in the Nechako are still less than half the natural mean annual flood level at Vanderhoof, which contributes to warmer summer water temperatures in the river. The Nechako River is 1 of the 2 warmest Fraser River tributaries, and is a potential source of thermal stress to migratory salmon.[7] High water temperatures have the potential to negatively affect the Stuart-Takla sockeye populations as well as the stocks that originate from the Nechako watershed.

Virtually all of the water in the Nechako River upstream of the Nautley River confluence originates from the Murray-Cheslatta Lake system, via the Skins Lake Spillway. This lake system acts as a settling pond, resulting in relatively low levels of suspended sediments in Nechako River water. The spillway releases surface waters from the lake system to the Nechako River, resulting in relatively warm summer water temperatures.

Site-specific water quality assessments and influencing factors are provided in Section 5.5 on a stream-by-stream basis. Water quality and fish tissue contaminant data are provided in Tables 5.5.1a and b.

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5.5 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Nechako HMA.

Summary tables of:

- water quality data **(Table 5.5.1a)**
- fish tissue contaminant data **(Table 5.5.1b)**
- land use areas, stream flow, and water demand information for each salmon stream **(Table 5.6.1)**
- identified impacts for each salmon stream **(Table 5.6.2)**

are provided for reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 5.5.1.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals were based upon information provided in a series of hydrology reports,[1] and/or SISS catalogues[2] unless otherwise indicated. Assessment criteria are explained in the Methods section of this report (Chapter 3).

Nechako River (08)

•Near Prince George about 20% of temperature measurements in the database exceeded guidelines. In addition, one tenth of the 231 total phosphorus values exceeded the 80th percentile, and about 25% of the 12 of 69 cadmium, 17 of 72 chromium and 28 of 74 copper measurements in surface water exceeded guidelines. The limited data available do not provide for meaningful upstream-downstream comparisons. The phosphorous and metal concentrations may represent natural conditions for the river, or may result at least in part from contaminant inputs from Fort Fraser, Vanderhoof, and Prince George.

Continuous temperature monitoring in 1993 shows that maximum water temperatures frequently exceeded 20°C, the lower end of the lethal range for salmonids, between late July and late August.[8]

•Urban development is concentrated at Vanderhoof and Prince George, where some loss of riparian vegetation and encroachment on the river has occurred. Vanderhoof and Prince George contribute urban stormwater runoff to the lower river reaches.

•Agricultural activity consists primarily of livestock and forage production and is concentrated in the river reach between the Nautley River and Stuart River confluences with the Nechako River.[1,2] There are extensive riparian impacts from agriculture throughout the mainstem and tributaries.[5]

•6% of the total watershed has been logged, including 3% from recent harvesting.[1] Logging of another 1% was proposed by 1997.[1] Logging has been most intensive downstream from the Nautley River confluence, where 25% of the total watershed has been logged, including 13% recently, with another 4% proposed for cutting by 1997.[1]

•The naturalized summer 7-day mean low flow is 59% of the mean annual flow.[1] Naturalized flow for the Nechako was calculated using licensed extractions and the regulated releases from the Skins Lake Spillway from 1981 to 1990, rather than true natural flows, which were much greater than regulated releases.

•The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 8% of the naturalized (based on regulated releases from Skins Lake) summer 7-day mean low flow.[1] Storage accounts for 13% of the total irrigation demand. The river is de-watered downstream from the Kenney Dam to Cheslatta Falls.

The river is classified as Office Reserved - no further licenses will be granted by the WMB. Most water withdrawals are from small tributary streams rather than directly from the Nechako River, and storage is required.[1] A cap for total water extraction between the Nautley and Stuart Rivers is being negotiated between DFO and the WMB. There are no licensing restrictions below the Stuart River confluence.

•**Other:** During their spawning migration Stuart River sockeye pass through the lower Nechako where warm water can cause pre-spawning mortality.

Sawmills at Vanderhoof and Fort Fraser may generate runoff. Runoff from the rail yard in Prince George delivers oil, grease, and other contaminants to the back channels and seasonally flooded areas at the Nechako-Fraser River confluence.

Sediment samples from the Nechako Reservoir had four times the mercury concentrations found in control lakes, and deep water samples had double the level of control lakes.[13] Fish at upper trophic levels are contaminated with heavy metals, especially mercury.[14] About 13% of rainbow trout from the reservoir reportedly exceeded the consumption guideline established by Health and Welfare Canada to protect the health of humans who consume large quantities of fish.[13]

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Nechako Reach

•Levels of mercury, PCBs, T4CDD and T4CDF, were measured in fish tissues in 1994-1995 (Table 5.5.1b). None of these parameters exceeded the federal guidelines for the protection of human health. The long-term effects of contaminant mixtures in low concentrations on the health of aquatic organisms are unknown. Peamouth chub and mountain whitefish from the Nechako River had higher levels of mercury in both muscle and liver compared with the same species from the Fraser mainstem upstream of Agassiz.[15] Mercury concentrations decreased in Fraser River fish moving downstream from the Nechako River confluence to Marguerite. Tissue mercury levels were well below consumption advisory levels, but are of interest given the high concentrations found in Nechako Reservoir rainbow trout.

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Nechako River at Vanderhoof

•Three sites were sampled downstream from the Vanderhoof STP outfall. 100 m downstream from the outfall 32 of 50 fecal coliform levels and 41 of 53 ammonia levels exceeded 80th percentile concentrations. At 500 m downstream from the outfall about half of the approximately 50 measurements of fecal coliforms and ammonia exceeded 80th percentile levels. At 2 km downstream 13 of 37 ammonia concentrations still exceeded the 80th percentile level, although the average concentration was less than at upstream sites.

The maximum ammonia value reported (500 m downstream from the STP discharge) was 68 $mg \cdot L^{-1}$, which exceeded the maximum concentrations of total ammonia permitted for the protection of aquatic life, at any temperature or pH.

•Upstream from the Vanderhoof STP outfall, 1 of 22 dissolved oxygen measurements was below the guideline and 7 of 39 dissolved ammonia values exceeded the 80th percentile level.

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Nechako River at Fort Fraser

•Three sites were sampled downstream from the Fort Fraser STP discharge, with the largest number of samples collected from 200 m below the STP outfall (P00288). At this site, 3 of 22 dissolved oxygen measurements were below the guideline, and 2 of 55 fecal coliform and 7 of 50 dissolved ammonia values exceeded the guideline or 80th percentile. Other parameters measured included temperature, pH, non-filterable residue and total phosphorus, and all were below the guidelines or 80th percentile levels.

•Upstream from Fort Fraser, available data indicate that surface water quality is good. Only 1 of 23 dissolved oxygen values was below the guideline, and 1 of 61 fecal coliform, 6 of 75 ammonia levels exceeded 80th percentile levels.

★The single copper measurement available exceeded the guideline. Overall the water quality appears to be good, hence the rating was not down-graded because of this one copper measurement.

•Urban development is present at Fort Fraser, but implications for water quality are undocumented.

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Upper Nechako River (u/s Nautley River)

•Water licenses indicate agricultural activity. There was not enough information to assess the effect that it may have on water quality.

•2.3% of the total watershed has been logged, including 1.3% from recent harvesting.[1] Logging of another 0.7% was proposed by 1997.[1]

•No information was available to assess stream flow.

•Water demand is for domestic, irrigation, waterworks and industrial uses, and is expected to increase in the future.[1] No further licenses will be granted by the WMB unless storage is provided or it is demonstrated that withdrawals will not affect chinook salmon. Storage accounts for 6% of the total irrigation demand.[1]

•**Other:** Releases from the Skins Lake Spillway contribute most of the flow. Following construction of dams, morphological changes such as encroachment of terrestrial vegetation onto bars and abandonment of secondary channels, have occurred. Sediment deposition at tributary fans and in low velocity zones may affect spawning areas.

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Chilako River (08-0500)

•Three of the 10 dissolved ammonia values reported were above the 80th percentile, but none exceeded the 30-d criteria for total ammonia. All of the 5 pH values and 10 fecal coliform levels were within guideline/80th percentile levels.

•Agriculture is concentrated in the area downstream from Punchaw. The loss of streamside vegetation from farming has resulted in erosion and increased sedimentation.[1] There are extensive riparian impacts in lower reaches due to damage by cattle.[5] Cattle graze along most of the river and tributaries in upper reaches.[1]

•18% of the total watershed has been logged, including 8% from recent harvesting.[1] Logging of another 4% was proposed by 1997.[1] Some tributaries have much greater rates of cut due to salvage logging of beetle kill and blowdown. Loss of streamside vegetation from logging is aggravating erosion processes.[1] DFO requested a review of the rate-of-cut in 1993.[5] An IWAP has now been completed.[10]

•The naturalized summer 7-day mean low flow is 44% of the mean annual flow.[1]

•The potential August and September water demand for domestic, irrigation and industrial uses is 2% of the naturalized summer 7-day mean low flow.[1] DFO recommends that no future withdrawals be permitted to ensure fisheries maintenance flows.[2] Storage accounts for 29% of the total irrigation demand.

•**Other:** Water temperatures are noted as a possible concern.[2] The lower mainstem is highly turbid from erosion of lacustrine deposits along the lower river reaches especially downstream from Punchaw Lake.[1]

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Nadsilnich Lake

•36 of the 42 total phosphorus values exceeded the guideline. None of the 3 pH or dissolved ammonia values were above the guideline/80th percentile levels.

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St. George Creek

•Eight measurements each of fecal coliforms and phosphorus were reported. Of these, only 1 total phosphorus value exceeded the 80th percentile level.

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Norman Lake and tributaries

•26 of 39 total phosphorus values reported for the lake exceeded the guideline. Of the 3 fecal coliform and 4 total phosphorus measurements reported for each of the Norman Lake tributary stations, none exceeded the guideline or 80th percentile.

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Tachick Lake

•Eight of 9 total phosphorus values exceeded the guideline. Two of 6 dissolved ammonia values were above the 80th percentile, but none exceeded the 30-d criteria for total ammonia.

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Nukli Lake

•All of the 13 total phosphorus values exceeded the guideline. Two of 11 dissolved ammonia values exceeded the 80th percentile, but not the 30-d criteria for total ammonia. The single measurements of arsenic and chromium were both below guidelines. Both of 2 copper values and 1 of 2 zinc values exceeded the guidelines.

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Nautley River

•No more than 5 measurements of the following parameters were available: pH, nonfilterable residue, fecal coliform, dissolved ammonia and total phosphorus. No measurements exceeded guidelines or 80th percentile levels.

•Water licenses indicate that some development is present. There was not enough information to assess the effect on water quality.

•Irrigation licenses indicate agricultural activity is present, but potential for effects on water quality is undocumented.

•No information was available to assess forest harvesting.

•The naturalized summer 7-day mean low flow is 55% of the mean annual flow.[1]

•The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 4% of the naturalized summer 7-day mean low flow.[1] The creek status is Office Reserve-no licensing and Fully Recorded with exceptions for storage by the WMB. Storage accounts for 10% of the total irrigation demand.[1]

•**Other:** Reduced water levels in the Nechako River created an elevation difference between Fraser Lake and the mouth of the Nautley River that resulted in downcutting of the river channel.[1] A rock weir and groynes were constructed to prevent the downcutting and to maintain the lake level.[1]

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Fraser Lake

•One station is located near the middle of the lake, and 4 others are near the Fraser Lake village STP outfall. At the middle lake station, 30 of 34 total phosphorus values exceeded the guideline and 2 of 25 dissolved ammonia were above the 80th percentile. North of the village sewage lagoons, 19 of 23 phosphorus and 6 of 20 ammonia values exceeded the guideline or 80th percentile.

•Closer to the STP outfall, fewer than 8 samples were reported. Of these, 5 of 8 phosphorus and 3 of 7 ammonia were above the guideline or 80th percentile.

•Settlement is concentrated at the Nautley and Stellako Reserves, and Fraser Lake Village.

•There is some agricultural land use along the lake shore.

•There is moderate logging activity around the lake and small tributaries.[5]

•**Other:** Aquatic weeds (Canadian pondweed) proliferate along the lake shores, most notably at the Nautley outlet, and at the west end of the lake.[5, 10]

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Stellako River (08-2700)

•Parameters were sampled at 2 stations a maximum of 8 times per site. Measurements were reported for pH, nonfilterable residue, fecal coliform, dissolved ammonia and total phosphorus. Only 1 total phosphorus and 1 dissolved ammonia level exceeded the 80th percentiles.

•There is an Indian Reserve in the lower reaches, and a lodge at the Francois Lake outlet.[5] They do not present concerns for fish.

•Irrigation licenses indicate that agricultural activity is present.[1] No further information was available.

•25% of the total watershed has been logged, including 17% from recent harvesting. Logging of another 3% was planned by 1997.[1]

•The naturalized summer 7-day mean low flow is 42% of the mean annual flow.[1] Francois Lake helps to stabilize flows.

•The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 6% of the naturalized summer 7-day mean low flow.[1] Storage accounts for 13% of the total irrigation demand.[1]

•**Other:** High summer water temperatures have been noted as a potential problem.[2]

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Francois Lake

•Some of the tributaries have been heavily logged.[5]

•There is some localized agricultural activity along the lake shore.[5]

•**Other:** The Endako molybdenum mine (P01307) is located at the east end of the lake. The lake receives an average of 9,200 $m^3 \cdot d^{-1}$ of process effluent and run-off indirectly via 4 discharges to 3 creeks. The Waste Management Permit authorizes maximum discharges that are much higher – up to 123,234 $m^3 \cdot d^{-1}$ could be discharged on any given day. The permitted discharge concentrations for copper, molybdenum and iron may be of concern because they are addressed as dissolved concentrations, rather than total concentrations. Water quality parameters such as pH in the receiving environment normally fluctuate to some degree both daily and seasonally and may significantly change the solubility of these metals, thereby affecting actual toxicity of the effluent in the receiving environment. Also, see comments for the Endako River.

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Ormond Creek (08-2700-080)

•4% of the total watershed has been logged, including 1% recently.[1] Earlier information indicates that the watershed was logged extensively in the past.[2] No further harvesting was proposed prior to 1997.[1]

•The naturalized summer 7-day mean low flow is 39% of the mean annual flow.[1]

•No water licenses have been issued.[1]

•**Other:** The creek is often silty as it flows through lacustrine sediments, and deposits sediment at the mouth.[1] Low flows and beaver dams may impede fish migration.[2]

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Endako River (08-2700-140)

•Between 1 and 8 measurements have been recorded for pH, fecal coliforms, dissolved ammonia and total phosphorus at each of 3 stations. Two of 8 ammonia values at 2 stations, and 3 of 8 ammonia values at 1 station, exceeded the 80th percentile.

•Settlement is concentrated around Burns, Decker, and Fraser Lakes.[5] A golf course and sub-division have been proposed at Shovel Creek, an important tributary from a fish habitat perspective.[5]

•There is a high level of concern regarding agricultural activity, which occurs throughout the watershed.[5] Riparian vegetation has been damaged in localized areas.[5]

•8% of the total watershed has been logged, including 1% from recent or proposed activity. Logging of another 1% was planned by 1997.[1] A large portion of the watershed is deciduous.[5]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1] Lakes in the watershed help to stabilize flows.

•The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 9% of the naturalized summer 7-day mean low flow.[1] DFO recommends that no future water withdrawals be permitted to ensure maintenance of adequate flows for fish, as there are low flow problems.[2]

•**Other:** The CN Rail and Hwy. 5 parallel the Endako River and encroach on the floodplain.[5] Crossings, encroachments, and bank channelization affect the river.[5] Wood waste may create a leachate problem on Sheraton Creek.[5] The Endako River is suspected of being eutrophic.[5]

A molybdenum mine-mill complex located between Francois Lake and the Endako River discharges effluent to 3 tailings ponds (P01307). Seepage from tailings ponds and the Denak open pit reaches the Endako

River via 2 tributary creeks.[12] Permit criteria allow a maximum total discharge of up to 53,000 $m^3 \cdot d^{-1}$ to the tributaries. Elevated molybdenum concentrations have been reported in water at Endako, but are considered more of a concern for wildlife and livestock than for fish.[11]. Lower species richness and diversity of invertebrates, and a shift to pollution tolerant macroinvertebrates relative to control sites have been reported.[12] See comments for Francois Lake.

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Burns Lake

•Four stations have been sampled for phosphorus and ammonia. At two stations 44 of 45 and all of 21 total phosphorus values exceeded the guideline. 18 of 38 and 6 of 18 dissolved ammonia values were above the 80th percentile. Only 3 samples were taken from the other 2 sites.

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Decker Lake

•All of 5 total phosphorus and 1 of 5 dissolved ammonia values exceeded the guideline or 80th percentile at the Decker Lake site.

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Lower Higginbotham Creek

•Between 1 and 7 measurements for pH, non-filterable residue, total phosphorus and metals were reported. Of these, 1 of 1 cadmium, both of 2 chromium, and all of 3 copper exceeded the guidelines. This creek receives runoff from the mine discussed in the Endako River section above.

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Sweetnam Creek

•Between 1 and 4 measurements of pH, non-filterable residue and metals were reported. Both of 2 chromium, 1 of 1 copper, 1 of 1 lead and 1 of 4 zinc values exceeded the guidelines. This creek receives runoff from the mine discussed in the Endako River section above.

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Tchesinkut Creek (08-2700-140-150)

•Irrigation licenses indicate agricultural activity is present.[1]

•12% of the total watershed has been logged, including 8.5% recently.[1] Harvesting of another 1% was planned by 1997.[1]

•No information was available to assess flows.

•Water demand is for domestic, irrigation and industrial uses.[1]

•**Other:** The creek channel is stable with a heavy growth of willow.[1]

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Shovel Creek (08-2700-140-170)

•8% of the total watershed has been logged, including 1.5% recently. Another 1% was proposed for harvest by 1997.[1]

•The naturalized summer 7-day mean low flow is 39% of the mean annual flow.

•No water licenses have been issued.

•**Other:** A golf course and subdivision have been proposed in the Shovel Creek watershed.[5]

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Nithi River (08-2700-190)

•The north side along the lower 12 km is all pasture, suggesting extensive agricultural activity.[2]

•15% of the total watershed has been logged, including 12% from recent or proposed activity. Harvesting of another 5% was planned by 1997.[1] Intensive logging of the lakes area has occurred, and the river now goes dry in that area.[2]

•The naturalized summer 7-day mean low flow is 39% of the mean annual flow.[1] The channel dewaters in the upper reaches during summer.[2] The channel is ground water fed downstream from Larson Ranch.[1] The lower reaches of the south branch often dewater in late summer and winter as a result of bed aggradation.[1]

•The potential August and September water demand is 7% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Weed growth in the lower 2 km restricts fish passage.[2]

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Uncha Creek (08-2700-410)

•Irrigation licenses indicate agricultural activity is present[1] but no further information was available.

•21% of the total watershed has been logged, including 14% recently. Logging of another 2% was planned by 1997.[1]

•The naturalized summer 7-day mean low flow is 39% of the mean annual flow.[1]

•The potential August and September water demand is 2% of the naturalized summer 7-day mean low flow.[2] Storage accounts for 3% of the total irrigation demand.[2]

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Binta Creek (08-2700-410-030)

•37% of the total watershed has been logged, including 22% recently.[1] Logging of another 2% was planned by 1997.[1]

•No information was available to assess stream flow.

•No water licenses have been issued.

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Nadina River (08-2700-990)

•23% of the total watershed has been logged, including 16% recently.[1] Harvesting of another 2% was proposed by 1997.[1] Logging in the watershed is managed under a Local Resource Use Plan. Along the Nadina River corridor (400 m on each side of the river), management guidelines call for a windfirm buffer, seeding of road right-of-ways and skid trails, and erosion control plans.[1]

•The naturalized summer 7-day mean low flow is 25% of the mean annual flow.[1]

•The potential August and September water demand for domestic use is less than 1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Log drives in the 1960's resulted in deposition of fine sediments in the spawning gravel.[2] Results of DFO temperature studies show that small, forested tributaries provide cool water to the Nadina River main-stem.[2] An IWAP has been done on the watershed.

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Tagetochlain Creek (08-2700-990-250)

•40% of the total watershed has been logged, including 30% recently.[1] Harvesting of an additional 1% was planned by 1997.[1]

•The naturalized summer 7-day mean low flow is 39% of the mean annual flow.[1]

•No water licenses have been issued.[1]

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Cow Lake

•One to 2 measurements for phosphorus and metals in surface water and/or sediments were reported. The single copper measurement for sediments exceeded the guideline.

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Moose Lake

•One to 2 measurements for pH, total phosphorus, and metals in surface water and/or sediments were reported. One of 2 phosphorus values in surface water and the 1 available copper value for sediments exceeded the guidelines.

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Laidman Lake

•The 2 surface water phosphorus values both exceeded the guideline, and the single measurements of arsenic and cadmium in sediments exceeded the guideline.

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Williamson Lake

•One measurement was reported for several metals in sediments. The chromium and copper levels exceeded the guidelines.

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Table 5.2.1 Summary of Permitted Discharges to Surface Waters in the Nechako HMA.[1]

Record Id	Facility	Waste Type	Waste Num	Max. Flow $(m^3 \cdot d^{-1})$	Receiving Water Body
P00192	STP AT FRASER LAKE	STP	01	1,180	FRASER LAKE
P00288	FORT FRASER STP	STP	01	182	NECHAKO RIVER
P00296	VANDERHOOF SEWAGE LAGOONS	STP	01	1,640	NECHAKO RIVER
P00403	STP AT BURNS LAKE	STP	01	4,550	BURNS LAKE
P01307	ENDAKO MINE	Process		19,000	Un-named tributary to Endako River.
P01307	ENDAKO MINE	Runoff		34,000	Watkins Creek to Endako River
P01307	ENDAKO MINE	Process		13,000	Lower Sweetnam Creek to Francois Lake
P01307	ENDAKO MINE	Process		30,000	Higginbotham Creek to Francois lake
P01307	ENDAKO MINE	Process		9,000	Un-named tributary to Francois Lake
P01307	ENDAKO MINE	Runoff, STP, Process		71,234	Un-named tributary to Francois Lake
P01397	PACIFIC WESTERN BREWING CO. AT PRINCE GEORGE	Process	01	310	NECHAKO RIVER
P03172	LOGGING CAMP AT OOTSA LAKE, NEAR HENSON LANDING	STP	01	23	OOTSA LAKE
P05884	STP AT STONY CREEK INDIAN RESERVE	STP	01	70,980	STONY CREEK
P07310	FISH HATCHERY AT PRINCE GEORGE-RIVER ROAD	Process	01	1,310	NECHAKO RIVER
P07919	FISH HOLDING PONDS AT PRINCE GEORGE	Process	01	1,650	NECHAKO RIVER
P08043	TROUT HATCHERY AT TCHESINKUT LAKE	Process	01	265	TCHESINKUT CREEK

[1] Data were summarized from a 1994 version of the Effluent Point Source Inventory and Database for the Fraser River Basin (Reference 3), except for Permit P01307, for which data were obtained directly from the Waste Management Permit.

Table 5.2.2a Summary of Permitted Daily Contaminant Loadings* to Surface Water in the Nechako HMA ($kg \cdot d^{-1}$ except where noted)

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading
Ammonia	1	0.5	-	-	-	-	-	-	-	-
Biochemical Oxygen Demand	3	28.2	-	-	-	-	6	636.5	-	-
Copper (dissolved)	1	0.4	-	-	1	0.2	-	-		
Chlorine	1	1.7	-	-	-	-	-	-	-	-
Cyanide (total)	1	0.9	-	-	1	0.4	-	-		
Iron (dissolved)	1	6.9	-	-	1	3.6	-	-		
Molybdenum (dissolved)	1	88.0	-	-	1	97.0	-	-		
Nitrate-Soluble	2	6.4	-	-	-	-	-	-	-	-
Nitrogen Amm. (total)	2	2.1	-	-	-	-	-	-	-	-
Nitrogen NO_3 (total)	1	1.1	-	-	-	-	-	-	-	-
Phosphate-Soluble	2	0.4	-	-	-	-	-	-	-	-
Phosphorous (total)	1	1.1	-	-	-	-	1	0.3	-	-
Suspended solids (total)	1	430.0	-	-	1	230.0	-	-		
Residue Nonfilt.	3	28.2	-	-	-	-	6	424.5	-	-
Temperature [1]	1	na	-	-	-	-	-	-	-	-

Table 5.2.2b Summary of Permitted Annual Contaminant Loadings* to Surface Water in the Nechako HMA ($kg \cdot yr^{-1}$ except where noted)

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading
Ammonia	1	193	-	-	-	-	-	-	-	-
Biochemical Oxygen Demand	3	10,275	-	-	-	-	6	197,764	-	-
Copper (dissolved)	1	161					1	84		
Chlorine	1	602	-	-	-	-	-	-	-	-
Cyanide (total)	1	314					1	150		
Iron (dissolved)	1	2,511					1	1,314		
Molybdenum (dissolved)	1	32,120					1	35,405		
Nitrate-Soluble	2	2,345	-	-	-	-	-	-	-	-
Nitrogen Amm. Total	2	777	-	-	-	-	-	-	-	-
Nitrogen NO_3 Total	1	387	-	-	-	-	-	-	-	-
Phosphate-Soluble	2	157	-	-	-	-	-	-	-	-
Phosphorous Total	1	383	-	-	-	-	1	27	-	-
Residue Nonfilt.	3	10,275	-	-	-	-	6	151,727	-	-
Total suspended solids	1	156,950					1	83,950		
Temperature [1]	1	na	-	-	-	-	-	-	-	-

na = not applicable

[1] requirement for maximum temperature is 30°C

* Loadings are calculated from the Fraser River Point Source Inventory and Database (See reference 3).

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
NECHAKO RIVER AT PRINCE GEORGE							
Surface Water	Temperature (°C)	69	15	0	-2	22	7
	pH (pH units)	175	1	0	5.4	8.3	7.8
	Nonfilterable Residue (mg/L)	175	na	31	1	88	10
	Fecal Coliform (MPN/100mL)	145	1	42	1	422	12
	Total Coliform (MPN/100mL)	1	0	0	33	33	33
	Total NO2/NO3 Nitrogen	224	9	68	0.002	0.770	0.027
	Dissolved Ammonia Nitrogen (mg/L)	170	18	103	0.005	0.023	0.006
	Total Phosphorus (mg/L)	231	27	3	0.002	0.204	0.035
	Total Arsenic (mg/L)	70	0	3	0.0001	0.002	0.0005
	Total Cadmium (mg/L)	69	12	47	0.0001	0.0005	0.0001
	Total Chromium (mg/L)	72	17	1	0.0002	0.043	0.003
	Total Copper (mg/L)	74	28	0	0.0004	0.129	0.006
	Total Lead (mg/L)	72	4	41	0.0002	0.006	0.0006
	Total Mercury (µg/L)	64	2	37	0.005	0.530	0.023
	Total Zinc (mg/L)	107	6	26	0.0002	0.100	0.008
NECHAKO R AT P.G.ONE LANE BRIDGE MIDSTR.							
Surface Water	pH (pH units)	29	0	0	7.6	8.1	7.8
	Nonfilterable Residue (mg/L)	8	na	0	1	20	5
	Fecal Coliforms (MPN/100mL)	14	0	2	2	46	10
	Total Coliforms (MPN/100mL)	2	0	1	2	49	26
	Dissolved Ammonia Nitrogen (mg/L)	28	6	20	0.005	0.015	0.007
	Total Phosphorus (mg/L)	21	0	0	0.008	0.046	0.019
	Total Copper (mg/L)	1	1	0	0.010	0.010	0.010
	Total Zinc (mg/L)	20	1	17	0.010	0.060	0.013
NECHAKO							
Fish Tissue (1990)	2,3,7,8-T4CDD (pg/g wet wt.)	6	0	6	0.50	2.00	1.22
	2,4,6-Trichlorophenol (ng/g wet wt.)	4	0	4	1	1	1
	Pentachlorophenol (µg/g)	4	0	4	0.002	0.002	0.002
NECHAKO R AT FINMORE. SOUTH BANK							
Surface Water	pH (pH units)	13	0	0	7.3	8.0	7.6
	Nonfilterable Residue (mg/L)	6	na	0	2	8	4
	Fecal Coliforms (MPN/100mL)	7	0	2	2	13	7
	Total Coliforms (MPN/100mL)	3	0	0	2	33	19
	Dissolved Ammonia Nitrogen (mg/L)	13	5	6	0.005	0.022	0.010
	Total Phosphorus (mg/L)	13	0	0	0.009	0.041	0.020
	Total Zinc (mg/L)	6	0	6	0.010	0.010	0.010
NECHAKO R 2 KM D/S OF VANDERHOOF DISCHARGE							
Surface Water	Dissolved oxygen (mg/L)	23	1	0	8.9	15.0	11.9
	Temperature (°C)	26	0	0	0.0	12.0	3.0
	pH (pH units)	37	0	0	7.3	8.1	7.6
	Nonfilterable Residue (mg/L)	13	na	0	1	3	2
	Fecal Coliforms (MPN/100mL)	33	3	2	2	2000	127
	Dissolved Ammonia Nitrogen (mg/L)	37	13	17	0.005	0.057	0.011

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
	Total Phosphorus (mg/L)	14	1	0	0.007	0.130	0.019
	Total Arsenic (mg/L)	7	0	7	0.001	0.040	0.029
	Total Chromium (mg/L)	5	0	5	0.002	0.002	0.002
	Total Copper (mg/L)	5	5	0	0.002	0.004	0.002
	Total Lead (mg/L)	2	1	1	0.001	0.002	0.002
	Total Zinc (mg/L)	18	4	7	0.002	0.090	0.020
NECHAKO R 0.5 KM D/S OF VANDERHOOF DISCHARGE							
Surface Water	Dissolved oxygen (mg/L)	21	2	0	8.8	15.0	12.0
	Temperature (°C)	24	0	0	0.0	12.0	2.8
	pH (pH units)	60	0	0	6.9	8.0	7.6
	Fecal Coliforms (MPN/100mL)	56	18	1	2.2	2,000	230
	Dissolved Ammonia Nitrogen (mg/L)	58	24	26	0.005	68.000	1.187
	Total Phosphorus (mg/L)	2	0	0	0.007	0.021	0.014
NECHAKO R 100 M D/S VANDERHOOF DISCHARGE. IDZ							
Surface Water	Dissolved oxygen (mg/L)	27	3	0	8.5	14.0	11.3
	Temperature (°C)	30	0	0	0.0	12.0	2.7
	pH (pH units)	56	0	0	6.8	8.2	7.6
	Nonfilterable Residue (mg/L)	5	0	0	2	10	5
	Fecal Coliforms (MPN/100mL)	50	32	3	2	24,000	2,296
	Dissolved Ammonia Nitrogen (mg/L)	53	41	12	0.005	1.730	0.354
	Total Phosphorus (mg/L)	7	1	0	0.007	0.219	0.048
NECHAKO R U/S OF VANDERHOOF DISCHARGE							
Surface Water	Dissolved oxygen (mg/L)	22	1	0	8.9	15.0	12.0
	Temperature (°C)	25	0	0	0.0	12.0	3.1
	pH (pH units)	38	0	0	7.0	7.9	7.6
	Nonfilterable Residue (mg/L)	2	0	0	2	6	4
	Fecal Coliforms (MPN/100mL)	37	0	4	1	94	17
	Dissolved Ammonia Nitrogen (mg/L)	39	7	21	0.005	0.026	0.007
	Total Phosphorus (mg/L)	4	0	0	0.007	0.017	0.013
NECHAKO R AT VANDERHOOF U/S HWY 27 BRIDGE							
Surface Water	pH (pH units)	17	0	0	7.3	8.1	7.6
	Nonfilterable Residue (mg/L)	9	na	0	1	8	3
	Fecal Coliforms (MPN/100mL)	9	0	2	2	17	8
	Total Coliforms (MPN/100mL)	3	0	0	2	49	22
	Dissolved Ammonia Nitrogen (mg/L)	17	3	8	0.005	0.285	0.023
	Total Phosphorus (mg/L)	17	1	0	0.011	0.248	0.029
	Total Zinc (mg/L)	7	0	7	0.010	0.010	0.010
NECHAKO RIVER 1.5 KM D/S FT. FRASER DISCHARGE							
Surface Water	pH (pH units)	9	0	0	7.3	7.8	7.5
	Fecal Coliforms (MPN/100mL)	8	0	2	2	46	16
	Dissolved Ammonia Nitrogen (mg/L)	10	1	7	0.005	0.014	0.006

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
NECHAKO R 200 M D/S FORT FRASER DISCHARGE							
Surface Water	Dissolved oxygen (mg/L)	22	3	0	8.2	15.0	11.8
	Temperature (°C)	25	0	0	0.0	13.0	3.4
	pH (pH units)	55	0	0	6.7	8.2	7.6
	Nonfilterable Residue (mg/L)	4	na	0	2	23	8
	Fecal Coliforms (MPN/100mL)	55	2	9	1	350	26
	Dissolved Ammonia Nitrogen (mg/L)	50	7	33	0.005	0.141	0.009
	Total Phosphorus (mg/L)	5	0	0	0.006	0.034	0.015
NECHAKO R 50 M D/S FORT FRASER DISCHARGE							
Surface Water	pH (pH units)	3	0	0	6.8	7.7	7.3
	Nonfilterable Residue (mg/L)	3	na	0	3	18	9
	Fecal Coliforms (MPN/100mL)	4	0	0	2	110	43
	Dissolved Ammonia Nitrogen (mg/L)	3	0	2	0.005	0.009	0.006
	Total Phosphorus (mg/L)	3	0	0	0.011	0.027	0.018
NECHAKO R 200 M U/S FORT FRASER DISCHARGE							
Surface Water	Dissolved oxygen (mg/L)	23	1	0	9.2	15.0	12.1
	Temperature (°C)	25	0	0	0.0	13.5	3.4
	pH (pH units)	80	0	0	6.8	8.2	7.6
	Nonfilterable Residue (mg/L)	14	na	0	2	22	4
	Fecal Coliforms (MPN/100mL)	61	1	18	1	2000	41
	Total Coliforms (MPN/100mL)	3	0	0	4.5	33	24
	Dissolved Ammonia Nitrogen (mg/L)	75	6	52	0.005	0.016	0.006
	Total Phosphorus (mg/L)	31	0	0	0.006	0.031	0.011
	Total Copper (mg/L)	1	1	0	0.010	0.010	0.010
	Total Zinc (mg/L)	15	0	14	0.010	0.010	0.010
CHILAKO R AT LOWER MUD RIVER RD BRIDGE							
Surface Water	pH (pH units)	5	0	0	8.2	8.3	8.3
	Fecal Coliforms (MPN/100mL)	10	0	1	2	31	13
	Dissolved Ammonia Nitrogen (mg/L)	10	3	3	0.005	0.031	0.010
WEST (NADSILNICH) LAKE SOUTH STATION							
Surface Water	pH (pH units)	3	0	0	7.7	7.7	7.7
	Dissolved Ammonia Nitrogen (mg/L)	3	0	2	0.005	0.005	0.005
	Total Phosphorus (mg/L)	42	36	0	0.013	0.073	0.027
ST. GEORGE CREEK							
Surface Water	Fecal Coliforms (MPN/100mL)	8	0	1	1	50	14
	Total Phosphorus (mg/L)	8	1	0	0.037	0.153	0.080
NORMAN LAKE WEST END STN.							
Surface Water	Total Phosphorus (mg/L)	39	26	0	0.008	0.029	0.017
NORMAN LK TRIB. #1 100 M U/S OF MOUTH							
Surface Water	Fecal Coliforms (MPN/100mL)	3	0	0	1	12	7
	Total Phosphorus (mg/L)	4	0	0	0.014	0.047	0.032

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
NORMAN LK TRIB #4 AT MOUTH							
Surface Water	Fecal Coliforms (MPN/100mL)	3	0	1	2	38	14
	Total Phosphorus (mg/L)	4	0	0	0.028	0.067	0.040
TACHICK L NEAR CENTER							
Surface Water	pH (pH units)	7	0	0	8.0	8.6	8.3
	Dissolved Ammonia-Nitrogen (mg/L)	6	2	3	0.005	0.028	0.010
	Total Phosphorus (mg/L)	9	8	0	0.012	0.044	0.033
NULKI L NEAR CENTER							
Surface Water	pH (pH units)	9	0	0	7.9	9.6	8.3
	Dissolved Ammonia Nitrogen (mg/L)	11	2	5	0.005	0.093	0.015
	Total Phosphorus (mg/L)	13	13	0	0.027	0.080	0.048
	Total Arsenic (mg/L)	1	0	1	0.040	0.040	0.040
	Total Chromium (mg/L)	1	0	1	0.002	0.002	0.002
	Total Copper (mg/L)	2	2	0	0.005	0.010	0.008
	Total Zinc (mg/L)	2	1	1	0.010	0.030	0.020
NAUTLEY R D/S OF CROSSING NEAR SOUTH BANK							
Surface Water	pH (pH units)	5	0	0	7.7	8.1	8.0
	Nonfilterable Residue (mg/L)	4	na	0	2	8	4
	Fecal Coliforms (MPN/100mL)	1	0	1	2	2	2
	Dissolved Ammonia Nitrogen (mg/L)	5	0	5	0.005	0.005	0.005
	Total Phosphorus (mg/L)	5	0	0	0.011	0.020	0.016
FRASER L NEAR MIDDLE 1 KM E LOT 3229							
Surface Water	pH (pH units)	26	0	0	7.3	8.2	7.8
	Nonfilterable Residue (mg/L)	10	na	0	1	3	2
	Dissolved Ammonia Nitrogen (mg/L)	25	2	16	0.005	0.016	0.006
	Total Phosphorus (mg/L)	34	30	0	0.009	0.029	0.021
FRASER L 0.8 KM NORTH OF VILLAGE LAGOONS							
Surface Water	pH (pH units)	23	0	0	7.2	8.2	7.7
	Nonfilterable Residue (mg/L)	8	na	0	1	3	2
	Dissolved Ammonia Nitrogen (mg/L)	20	6	8	0.005	1.130	0.076
	Total Phosphorus (mg/L)	23	19	0	0.009	0.072	0.025
FRASER L 300 M EAST OF VILLAGE DISCHARGE							
Surface Water	pH (pH units)	1	0	0	7.1	7.1	7.1
	Fecal Coliforms (MPN/100mL)	5	0	3	0	20	6
	Dissolved Ammonia Nitrogen (mg/L)	1	0	0	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	1	0	0.020	0.020	0.020
FRASER L AT VILLAGE DISCHARGE							
Surface Water	pH (pH units)	8	1	0	7.6	9.8	8.1
	Nonfilterable Residue (mg/L)	5	na	0	1	6	3
	Fecal Coliforms (MPN/100mL)	8	0	4	0	20	4

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
	Dissolved Ammonia Nitrogen (mg/L)	7	3	3	0.005	0.042	0.014
	Total Phosphorus (mg/L)	8	5	0	0.013	0.044	0.023
FRASER L 300 M WEST OF VILLAGE DISCHARGE							
Surface Water	pH (pH units)	1	0	0	7.5	7.5	7.5
	Nonfilterable Residue (mg/L)	1	na	0	12	12	12
	Fecal Coliforms (MPN/100mL)	1	0	1	2	2	2
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	1	0	0.041	0.041	0.041
STELLAKO R 10 M U/S CNR BRIDGE							
Surface Water	pH (pH units)	6	0	0	7.6	8.3	7.9
	Nonfilterable Residue (mg/L)	5	na	0	2	63	15
	Dissolved Ammonia Nitrogen (mg/L)	6	1	4	0.005	0.012	0.006
	Total Phosphorus (mg/L)	6	1	0	0.011	0.093	0.026
STELLAKO R 500 M U/S ENDAKO R							
Surface Water	pH (pH units)	7	0	0	7.6	8.0	7.8
	Fecal Coliforms (MPN/100mL)	1	0	0	2	2	2
	Dissolved Ammonia Nitrogen (mg/L)	8	0	6	0.005	0.005	0.005
	Total Phosphorus (mg/L)	7	0	0	0.006	0.008	0.007
ENDAKO R 500 M U/S OF MOUTH							
Surface Water	pH (pH units)	7	0	0	7.1	8.0	7.6
	Fecal Coliforms (MPN/100mL)	1	0	0	5	5	5
	Dissolved Ammonia Nitrogen (mg/L)	8	2	3	0.005	0.037	0.013
	Total Phosphorus (mg/L)	8	0	0	0.022	0.061	0.032
ENDAKO R AT HWY 16 BRIDGE, WEST OF ENDAKO							
Surface Water	pH (pH units)	7	0	0	7.0	8.1	7.7
	Fecal Coliforms (MPN/100mL)	1	0	0	79	79	79
	Dissolved Ammonia Nitrogen (mg/L)	8	2	6	0.005	0.037	0.013
	Total Phosphorus (mg/L)	8	0	0	0.019	0.086	0.035
ENDAKO R AT HWY 16 AND PREISTLEY STN RD							
Surface Water	pH (pH units)	7	0	0	7.1	8.0	7.6
	Fecal Coliforms (MPN/100mL)	1	0	0	33	33	33
	Dissolved Ammonia Nitrogen (mg/L)	8	3	5	0.005	0.027	0.013
	Total Phosphorus (mg/L)	8	0	0	0.023	0.051	0.033
BURNS L NEAR DEADMAN'S ISLAND							
Surface Water	Dissolved Ammonia Nitrogen (mg/L)	38	18	12	0.005	0.583	0.053
	Total Phosphorus (mg/L)	45	44	0	0.013	0.162	0.037
BURNS L NEAR OUTFALL							
Surface Water	Dissolved Ammonia Nitrogen (mg/L)	3	1	1	0.005	0.016	0.009
	Total Phosphorus (mg/L)	3	3	0	0.018	0.023	0.021

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
BURNS L WEST OF SEWAGE OUTFALL							
Surface Water	Dissolved Ammonia Nitrogen (mg/L)	3	1	0	0.005	0.016	0.010
	Total Phosphorus (mg/L)	3	3	0	0.018	0.021	0.020
BURNS LAKE WEST BASIN IN MIDDLE							
Surface Water	Dissolved Ammonia Nitrogen (mg/L)	18	6	3	0.005	0.144	0.023
	Total Phosphorus (mg/L)	21	21	0	0.017	0.084	0.031
DECKER LAKE SOUTH NEAR OUTLET							
Surface Water	Dissolved Ammonia Nitrogen (mg/L)	5	1	1	0.005	0.012	0.007
	Total Phosphorus (mg/L)	5	5	0	0.017	0.125	0.050
LOWER HIGGINBOTHAM CR							
Surface Water	pH (pH units)	6	0	0	8.0	8.2	8.1
	Nonfilterable Residue (mg/L)	6	na	0	3	5	4
	Total Phosphorus (mg/L)	4	0	0	0.040	0.060	0.050
	Total Arsenic (mg/L)	5	0	5	0.040	0.040	0.040
	Total Cadmium (mg/L)	1	1	0	0.040	0.040	0.040
	Total Chromium (mg/L)	2	2	0	0.070	0.080	0.075
	Total Copper (mg/L)	3	3	0	0.002	0.080	0.037
	Total Lead (mg/L)	6	1	4	0.001	0.500	0.084
	Total Zinc (mg/L)	7	1	5	0.010	0.050	0.017
SWEETNAM CREEK ABOVE RD XING PE1307							
Surface Water	pH (pH units)	4	0	0	7.8	7.9	7.9
	Nonfilterable Residue (mg/L)	4	na	1	1	4	2
	Total Chromium (mg/L)	2	2	0	0.010	0.030	0.020
	Total Copper (mg/L)	1	1	0	0.040	0.040	0.040
	Total Lead (mg/L)	1	1	0	0.200	0.200	0.200
	Total Zinc (mg/L)	4	1	1	0.010	0.030	0.018
COW LAKE							
Surface Water	Total Phosphorus (mg/L)	2	0	0	0.013	0.014	0.014
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	1	0.010	0.010	0.010
Sediments	Total Arsenic (μg/g)	1	0	0	2.8	2.8	2.8
	Total Chromium (μg/g)	1	0	0	16	16	16
	Total Copper (μg/g)	1	1	0	34	34	34
	Total Mercury (μg/g)	1	0	0	0.07	0.07	0.07
	Total Lead (μg/g)	1	0	0	24	24	24
	Total Zinc (μg/g)	1	0	0	38	38	38
MOOSE LAKE							
Surface Water	pH (pH units)	2	0	0	7.3	7.8	7.6
	Total Phosphorus (mg/L)	2	1	0	0.014	0.061	0.038
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001

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MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Nechako HMA

		n	# > Guide-line*	# < MDL	Min	Max	Mean
	Total Zinc (mg/L)	1	0	1	0.010	0.010	0.010
Sediments	Total Arsenic (µg/g)	1	0	0	1.6	1.6	1.6
	Total Chromium (µg/g)	1	0	0	8	8	8
	Total Copper (µg/g)	1	1	0	24	24	24
	Total Mercury (µg/g)	1	0	0	0.10	0.10	0.10
	Total Lead (µg/g)	1	0	0	12	12	12
	Total Zinc (µg/g)	1	0	0	45	45	45
LAIDMAN LAKE							
Surface Water	Total Phosphorus (mg/L)	2	2	0	0.016	0.023	0.020
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	0	0.010	0.010	0.010
Sediments	Total Arsenic (µg/g)	1	1	0	22.6	22.6	22.6
	Total Chromium (µg/g)	1	1	0	29	29	29
	Total Copper (µg/g)	1	0	0	9	9	9
	Total Mercury (µg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (µg/g)	1	0	0	15	15	15
	Total Zinc (µg/g)	1	0	0	75	75	75
WILLIAMSON LAKE							
Sediments	Total Chromium (µg/g)	1	1	0	32	32	32
	Total Copper (µg/g)	1	1	0	170	170	170
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	0	0	77	77	77

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 5.5.1b Summary of Contaminants Measured in Fish Tissue Collected in the Nechako Reach of the Nechako HMA (1994-1995).[1]

Guidelines:			
	Total PCB	2 µg•g^{-1} dry wt.	(for the protection of aquatic life; B.C. MELP)
	Total Toxaphene	0.1 µg•g^{-1} dry wt.	(for the protection of aquatic life; Environment Canada)
	p,p'-DDE	5 µg•g^{-1} dry wt.	(for the protection of aquatic life; Environment Canada)
	Mercury	0.5 µg•g^{-1} dry wt.	(for the protection of aquatic life; Environment Canada)

		Total PCB (ng/g)[2]				p,p'-DDE (246) (ng/g)[2]			Total Toxaphene (ng/g)[2]			Mercury (µg/g)[2]			
Species	Tissue	n*	Mean	Min	Max	n*	Mean	Std. error of the mean	n*	Mean	Std. error of the mean	n*	Mean	Min	Max
Nechako															
Peamouth Chub															
1994	*Liver*	2	24.5	19.66	29.31	2	4.08	-	2	4.73	-	1-2	0.19	-	-
	Muscle	4	3.97	3.14	6.05	4	0.32	0.04	4	nd	-	4-5	0.22	0.19	0.26
1995	*Liver*	2	12.2	10.41	13.89	2	5.95	-	2	4.4	-	-	-	-	-
	Muscle	4	2.02	1.89	2.25	4	0.26	0.02	4	nd	-	4-5	0.3	0.25	0.33
Mountain Whitefish															
1994	*Liver*	2	5.1	5.03	5.17	2	0.31	-	2	0.45	-	1-2	0.25	-	-
	Muscle	4	4.29	2.2	10.15	4	1.32	0.3	4	nd	-	4-5	0.09	0.07	0.13
1995	*Liver*	2	7.72	6.55	8.9	2	0.45	-	2	3.36	0.53	1-2	0.07	-	-
	Muscle	4	2.36	1.47	4.08	4	0.48	0.14	4	-	-	4-5	0.1	0.08	0.16

[1] Data summarized from Raymond, *et al.,* 2000 (see reference 15).

[2] As wet weight.

n* is the number of composite samples. For the Nechako reach there are five fish per muscle composite and 25 - 32 fish per liver composite. Where n>4, the laboratory duplicate was included in results.

nd = not detected.

Table 5.6.1 Summary of Land Use Areas, Summer and Winter Low-flows, and Water Demand for the Nechako HMA.[1]

			Landuse area (km sq.)		Naturalized Stream flow (L/s)			Potential August water demand (L/s)				
Stream	SISS code	Water-shed area (km sq.)	Total logged	Recent/ proposed logging*	Summer 7-day mean low-flow	Winter 7-day mean low-flow	Mean annual flow	Domestic	Irrigation	Water-works	Industrial	Storage (ac-ft)
Nechako River	08	51,900	2,936	2,197	144,670	97,620	244,650	10.1	1,616.59	2,982.88	6,308.30	2984
Lower Nechako River		7,729	1,930	1,296	-	-	-	9.42	1,453.40	2,982.88	6,046.20	2813
Upper Nechako River		44,171	1,006	901	-	-	-	0.68	163.3	5.26	262.09	135
Chilako River	08-0500	3,578	659	432	5,350	4,910	12,300	0.39	118	0	1.59	472
Lower Chilako River		1,442	271	159	-	-	-	0.32	118	0	0.53	472
Upper Chilako River		2,136	387	272	-	-	-	0.24	0	0	1.05	0
Nautley River		6,048	-	-	12,130	6,230	21,880	5.3	266	55	168	356
Stellako River	08-2700	3,600	911	628	6,580	4,280	15,750	3.74	175	54.74	138.65	312
Ormond Creek	08-2700-080	251	10	2	430	330	1,100	0	0	0	0	0
Endako River	08-2700-140	2,033	171	103	1,430	1,330	6,130	1.58	91	0.26	30.3	45
Lower Endako River		1,018	88	48	-	-	-	0.84	59.15	0.26	14.58	2
Upper Endako River		1,015	83	55	-	-	-	0.74	31.93	0	15.7	43
Tchesinkut Creek	08-2700-140-150	348	41	33	-	-	-	0.5	23.97	0	14.53	2
Shovel Creek	08-2700-140-170	371	30	8	630	480	1,620	0	0	0	0	0
Nithi River	08-2700-190	322	161	37	550	420	1,410	0	0	0	35.5	0
Uncha Creek	08-2700-410	614	131	100	1,040	800	2,680	0.63	23.2	0.21	0.5	10
Binta Creek	08-2700-410-030	190	70	46	-	-	-	0	0	0	0	0
Nadina River	08-2700-990	1,093	254	193	2,040	1,620	8,270	0.08	0	0	0	0
Lower Nadina River		721	243	169	-	-	-	0.08	0	0	0	0
Upper Nadina River		372	11	24	1,080	730	5,240	0	0	0	0	0
Tagetochlain Creek	08-2700-990-250	176	70	55	300	230	770	0	0	0	0	0

* Recent logging occurred from 1983-1992, and proposed logging estimates were based on logging plans for 1993-1998.

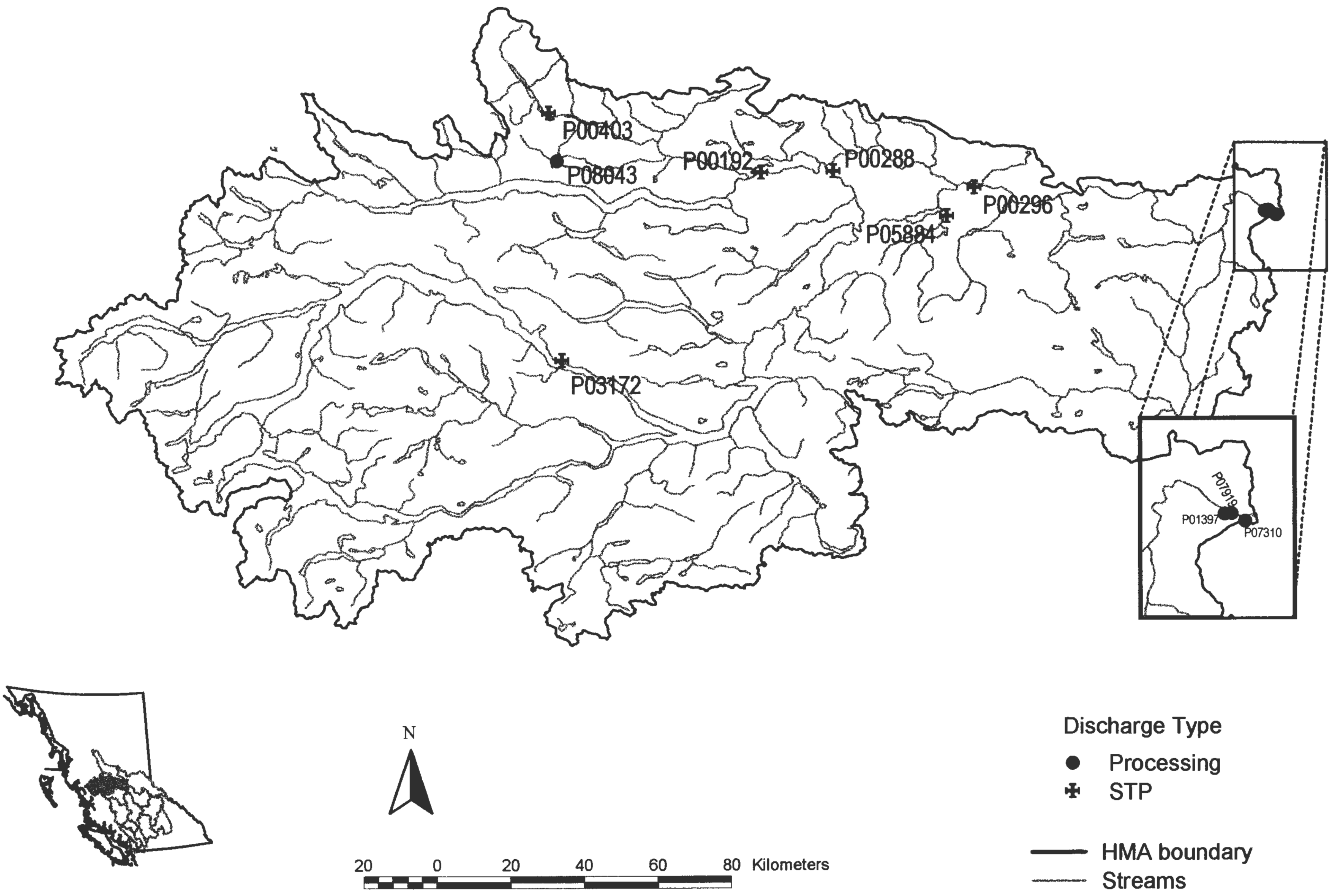
[1] Adapted from Rood and Hamilton, 1995 (see reference 1).

Table 5.6.2 Summary of Red-coded Indicators[1] for salmon-bearing streams in the Nechako HMA. (Streams are ordered from downstream to upstream.)

Stream Name	**Indicator**				
	Urban	Agriculture	Logging	Stream Flow	Demand
Nechako River	*	*			*
Chilako River		*	*		
Nautley River			*		
Stellako River					
Ormond Creek				*	
Endako River		*			*
Tchesinkut Creek					
Shovel Creek					
Nithi River				*	*
Uncha Creek			*		
Binta Creek			*		
Nadina River			*		
Tagetochlain Creek			*		

[1] "Red -coded" = likely to have water quality impacts associated with given land use, stream flow, or water demand conditions in the stream. See Chapter 3 for assessment methodology.

Figure 5.2.1 Location of Permitted Discharges to Surface Water in the Nechako HMA



Chapter 6 Stuart-Takla Habitat Management Area

6.1 Background

The Stuart-Takla HMA encompasses about 18,000 km^2 or about 7% of the Fraser Basin.[1] It is the northernmost sub-basin of the Fraser River and consists of a major river system draining from the north, interrupted by three large lakes. The Stuart-Takla watershed drains into the Nechako River near Vanderhoof.

6.1.1 Hydrology

Annual precipitation in the Stuart-Takla HMA is about 500 mm with approximately 40% occurring as snowfall.[1] The timing of snowmelt varies across the region.

Snowmelt freshet has a pronounced influence on the hydrology of tributaries to the Middle and Stuart Rivers. Many of these tributaries (33 of 44 salmon-bearing streams) experience natural summer low flows problems (Table 6.6.1). Some also experience winter low flows that may be limiting to salmon populations.

The large basin size and moderating influences of Takla, Trembleur, and Stuart Lakes help to stabilize flows in the Stuart and Middle Rivers.

6.1.2 Fish

There are 41 salmon bearing streams in the Stuart-Takla HMA, in addition to the Stuart, Middle, and Driftwood Rivers. These watersheds support sockeye and chinook salmon.[2] The Stuart-Takla HMA comprises only 7% of the area of the Fraser Basin, yet its famous salmon runs account for 24% of the Fraser River sockeye production.[1] The early Stuart stock returns to spawning grounds earlier than any other Fraser Basin salmon stock.[3] Stuart sockeye are extremely important to both commercial and aboriginal fisheries.

Resident fish species include: lake trout, bull trout, kokanee, lake whitefish, Dolly Varden char, white sturgeon and burbot, among others.[1] Two distinct populations of rainbow trout are also present, including 1 of very large fish (about 10 kg), and the standard smaller race.[1]

6.1.3 Predominant Land Uses

The human population within the Stuart-Takla HMA is small. The town of Fort St. James is the largest settlement in the area, with a population estimated to slightly exceed 2,000 in 1995.[4] Timber harvesting is by far the predominant land use. Mineral exploration and minor ranching activities are also ongoing within the HMA.

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6.2 Point Sources of Contaminants

There are 9 waste management permits addressing discharges to surface waters within the Stuart-Takla HMA (Figure 6.2.1), all of which are for sewage discharges (Table 6.2.1, Table 6.2.2).[5]

6.2.1 Urban/Industrial Point Source Discharges to Surface Water

According to Environment Canada's effluent point source database there are no permitted discharges of industrial processing or cooling water within the HMA.[5] The former Pinchi Lake mercury mine, which has not operated since 1975, still has a Waste Management Permit (PE 224) which applies to water discharged to Pinchi Lake from the mine site. Several sawmills in Fort St. James may generate stormwater runoff which reaches Stuart Lake.[6]

6.2.2 Permitted Discharges to Ground

There are 2 permitted discharges to ground, 1 for car and truck wash effluent, and 1 for a sewage discharge.[5]

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6.3 Non-Point Sources of Contaminants

6.3.1 Urban Development

The HMA is sparsely inhabited, with a population of 6,564 reported in 1985.[7] The only major settlement within the HMA is Fort St. James, where approximately one third of the HMA population resides. Snow dumps in the vicinity of Nahounli Creek in Fort St. James likely contribute contaminants to the creek, although the municipality has agreed to pursue alternate snow disposal sites.[9]

Destruction of riparian vegetation, increased sedimentation, and changes in water quality and flow regimes have affected streams in settled areas of the Stuart-Takla HMA.[8] Sewage effluent from Fort St. James degrades water quality in the lower reaches of the Necoslie River, and possibly also near the outlet of Stuart Lake.

6.3.2 Agriculture

In general there is little agricultural land use in the HMA, however, private land is being cleared for forage production and grazing. High timber prices tend to encourage land clearing.[8]

In 1997 DFO and DOE conducted a flight to identify potential problems associated with feedlots along the Stuart River. No serious impacts were noted.[9]

6.3.3 *Timber Harvesting*

Logging is ongoing throughout the HMA.[9] Extensive logging has occurred around most of Stuart Lake, and on the southwest shore of Tezzeron Lake.[1] In addition, poor road building and maintenance practices can disrupt the stability of sensitive soils in the area.[8] Seven of 44 salmon-bearing systems in the HMA were considered to have significant water quality concerns associated with timber harvesting (Table 6.6.1).

Compliance with regulations is poor in many operations.[8] There have been many complaints about habitat damage resulting from logging on private lands, that are exempt from the Forest Practices Code (FPC).[8] In addition, there are significant concerns regarding timber harvesting adjacent to small (< 1.5 m wide) streams (classified as "S4" under the FPC), which often provide critical chinook rearing habitat. The FPC does not require a riparian reserve zone for these streams, and decisions about harvesting within the 30 m wide riparian management zone are made by the MOF District Managers.

Many streams in the Stuart-Takla HMA experience very low summer flows, which make them susceptible to warming during hot and dry summer months. Failure to maintain healthy natural riparian vegetation when logging occurs will result in the loss of shade and further warming of these streams, many of which provide critical habitat for the summer-spawning Early Stuart sockeye run.

6.3.4 *Mining*

There are no large operating mines in the Stuart-Takla HMA. A cinnabar mercury mine adjacent to Pinchi Lake was operated in the 1940's and closed after World War II. The mine was re-opened and enlarged in 1967, and operated until September, 1975. Fish in Pinchi Lake have high mercury concentrations in their tissues, likely due to a combination of naturally high mercury levels in lake waters and sediments, and contamination from the mine site. A fish consumption advisory was issued in the 1970's and is still in place today. More recent sampling indicates that mercury concentrations in drainage water from the mine, and in fish tissues, are declining.[10]

Numerous gravel pits located within the HMA are sources of sediments to streams.[9] A few small placer mines are also located within the HMA, and are not considered to be of concern at this time.[8]

6.3.5 *Linear Development*

A railway runs from Stuart Lake north along the entire Stuart-Takla basin, through the headwaters of the Driftwood River and over into the Sustut watershed. Historically, this linear development has caused significant sediment problems throughout its length.[9]

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6.4 Overview of Water Quality Conditions

Water quality sampling to date has focussed on the Necoslie River downstream from the Fort St. James sewage treatment plant, and on several streams which flow into the south end of Takla Lake and are the focus of a DFO-FRAP led research project.

A limited amount of data for Stuart River (west shore) suggests that the water is generally low in nutrients.

Site-specific water quality assessments, and influencing factors and supporting data (Table 6.5.1) are provided in Section 6.5 on a stream-by-stream basis.

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6.5 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Stuart-Takla HMA.

Summary tables of:

- surface water quality data (Table 6.5.1)
- red-coded indicators for each salmon stream (Table 6.6.1)

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 6.5.1.

Assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals are provided and information sources are referenced. Assessment criteria are explained in the Methods section of this report.

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Stuart River (09-0000)

•(West shore - Hwy. 27 Bridge) Between 6 and 23 measurements for dissolved oxygen, temperature, pH, fecal coliforms, dissolved ammonia and total phosphorus have been reported for this site. Of these, only 1 of 22 ammonia values exceeded the 80th percentile, but not the 30-d criteria for total ammonia.

•(East shore, Hwy. 27 Bridge) The number of samples reported for dissolved oxygen, temperature, pH, fecal coliforms, dissolved ammonia and total phosphorus ranged from 10 to 33. Of these, 7 of 33 coliform, 21 of 27 ammonia and 3 of 11 phosphorus values exceeded the guidelines or 80th percentile. Levels of these parameters are much higher on the east shore than on the west, due to the Fort St. James STP.

•Fort St. James is located at the outlet of Stuart Lake. Effluent from the Fort St. James STP negatively affects water quality, especially on the east bank.

•Some agricultural activity occurs along the middle reach in the Chinohchey Creek area, but no further information is available.

•Logging has occurred in the past and more is planned, particularly along tributaries. There has not been any streamside logging to date.[11]

•The stream is stable.[11]

•No information on water withdrawals was available.

•Other: There are some designated placer mining areas in the Stuart River watershed, though such areas are mostly confined to tributaries. High summer water temperatures have been recorded, with levels commonly exceeding 20°C during July and August.[14] A gravel pit is located on Dog Creek, a tributary to the Stuart River.[9] A sewage spill into Stuart Lake occurred at the Nakazdli Reserve in 1996.[9]

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Necoslie River

•At a site 50 m downstream from the Fort St. James STP outfall very few measurements (between 3 and 7) of pH, fecal coliform, dissolved ammonia and total phosphorus have been reported. All 3 coliform, 7 ammonia, and 5 of 6 phosphorus values exceeded the guideline or 80th percentiles. Fecal coliform values of up to 920,000 were reported. The maximum ammonia value of 18.1 mg·L^{-1} exceeded the maximum guideline (30-d exposure) for protection of aquatic life at any temperature for the pH range observed.

•Upstream from Hwy. 27, between 10 and 34 measurements were reported for dissolved oxygen, temperature, pH, fecal coliform, dissolved ammonia and total phosphorus. Six of 34 fecal coliform, 28 of 30 ammonia and 12 of 14 phosphorus values exceeded the guideline or 80th percentiles. Some ammonia concentrations were very high, reaching 4.08 mg·L^{-1}. The mean dissolved ammonia nitrogen concentration (0.907 mg·L^{-1}) is very close to the objective level for the protection of aquatic life for a 30-d exposure (0.922 mg·L^{-1}) for the average temperature and pH conditions measured at the site.

Upstream from the outfall, 6 of 11 ammonia and 5 of 11 phosphorus exceeded the 80th percentiles.

•Other: Designated placer areas are located in a corridor along the Necoslie River and on some tributaries.[11]

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Sowchea Creek (09-6200)

•There is some residential development in lower reaches, with a low level of concern for impacts to fish habitat.[11]

•Moderate logging activity has occurred in the watershed, and more is proposed for Nielsp Creek, a tributary.[11]

•Low flow problems have been noted to affect productivity.[11]

•No information on water withdrawals was available.

•Other: The watershed is a designated placer area. Mining has been active on and off since 1930's, although it has been light in recent years.[2] Designated placer areas are located on some tributaries, particularly Dog Creek. Unstable valley walls are resulting in slope failures.

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Pinchi Lake

•Fish from Pinchi Lake were sampled for mercury concentrations in 1986. Of 24 measurements, 15 exceeded levels safe for human consumption. Data showed that mercury levels in fish tissue decreased from 1975 to 1986, however, in 1986 levels still exceeded the guideline established to protect human health.[12]

Data collected by B.C. Environment in 1993 indicate that mercury concentrations in mine portal water greatly exceeded the maximum criterion for the protection of aquatic life (0.1 µg·L^{-1}). Lake sediment data indicate that sediments in the vicinity of the mine site are contaminated with mercury, but that mercury concentrations in surface sediments are declining.[13]

•Other water quality information: A historical mercury mine disposed of untreated tailings into the lake from 1940 to 1947, resulting in mercury concentrations rising above the naturally high background levels.[12] The mine was re-opened in 1968 and operated until 1975. Since this time mercury concentrations in water and sediment have declined.[10, 13]

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Pinchi Creek (09-7000)

•Only 1 measurement each for pH, nonfilterable residue, dissolved ammonia, total phosphorus and metals in surface water was reported. One copper and 1 lead value exceeded the guidelines.

•Localized minor impacts are associated with a small village located in the watershed.[11]

•Past logging is noted, and more is planned. There are extensive logging roads throughout upper watershed.

•The creek has relatively stable flows.[11]

•**Other:** Rock in the Pinchi Lake area is rich in mercury-bearing ores also known as cinnabar. There are 5 mercury claims in the upper watershed.[2] There are also placer mining stakes in the upper reaches, however, activity is minimal. Valley walls are unstable in places.[15]

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Tachie River/Takla Lake (09-8100-000-000-000-000-991)

•Tachie Village is located at the river mouth, and has not cause water quality concerns.[11]

•There has been logging in the past, and harvesting has extended to the river banks in some areas.[11]

•The river has stable flows.[11]

•Limited water withdrawals are permitted.[11]

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Kuzkwa River (09-8100-100)

•There has been extensive logging in the upper watershed, and more is planned.[2] There are logging roads throughout the watershed.

•Stream flows are stabilized by Tezzeron Lake in the upper watershed.[11]

•**Other:** Tezzeron Lake acts as a sediment trap for materials eroded from upstream areas. The watershed upstream of Tezzeron Lake is within a designated placer mining area, though there has been little recent activity.[11] Unstable valley walls in lower reaches contribute clay and silt inputs.[2] High summer water temperatures have been noted.[11]

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Fleming Creek (09-8100-220)

•Extensive logging has occurred upstream of Fleming Lake. No logging is planned downstream from Fleming Lake (up to 1997).[11]

•Low flow problems are noted in Tildesley Creek, a tributary to Fleming Creek.[11]

•**Other:** Unstable valley walls contribute significant amounts of sediment to the creek. Algal growth and low dissolved oxygen limit fish production upstream from Fleming Lake.[11] The creek experiences very high summer water temperatures during the sockeye spawning period.[1]

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Paula Creek (09-8100-225)

•Logging is ongoing in the upper watershed. There is potential for major impacts to water quality and fish habitat if logging occurs in unstable areas such as on the fan or valley walls.[11]

•Low flow problems have been noted.[11]

•**Other:** The creek carries high sediment loads due to unstable valley walls.[11] There is an access road to the upper watershed.

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Sidney Creek (Felix Creek) (09-8100-230)

•A lodge and some private land holdings are located at mouth but do not cause water quality concerns.[11]

•Logging in the upper basin is ongoing. If logging occurs in unstable areas such as on the fan or valley walls, water quality and fish habitat may be impacted.[1]

•Low flow problems have been noted.[11]

•No information on water extraction was available.

•**Other:** Unstable valley walls result in high sediment loads.[11]

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Kazchek Creek (09-8100-300)

•A small Indian Reserve and a logging camp located adjacent to the creek do not present water quality concerns.[11]

•Extensive logging has occurred throughout the upper watershed, and more is planned.[11]

•No information was available to assess stream flows.

•No information on water extraction was available.

•**Other:** High summer temperatures sometimes cause pre-spawning mortality in sockeye, which has amounted to over 50% in some years.[1] Unstable valley walls contribute sediment to the lower reaches.

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Middle River (09-8100-000-000-000-000-992)

•Some timber was harvested prior to 1982, and more logging is planned.[11] There is 1 logging road along the east river bank.

•No information was available to assess stream flow, however, this river is fed by Takla Lake therefore flows should be stable.

•No information on water extraction was available.

•**Other:** High stream temperatures have been noted to cause pre-spawning mortality in some years.[11] Aquatic weeds are common on the river bottom.[1] The river has a very low gradient with an estimated drop of only 3 m over it's entire 36 km length. Substrates are mostly silt and sand; spawning gravels are restricted to the mouths of Rosette, O'Ne-eil (Kynock), Forfar, and Kazchek Creeks.

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Van Decar Creek (Rosette Creek) (09-8100-375)

•Some logging has occurred in the past and more is proposed.[11]

•Low flows during the sockeye incubation period constrain production in some years.[1]

•**Other:** The watershed has highly unstable valley walls and hill slopes and the stream is sensitive to natural terrain instability.[2] Disruption of the natural sediment regime by logging or other land uses could seriously harm spawning gravels at the confluence with the Middle River.

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O'Ne-eil Creek (Kynock Creek) (09-8100-410)

•Between 6 and 14 measurements have been reported for temperature, pH, non-filterable residue, total phosphorus and metals in surface water. Of these, only 2 of 8 copper values exceeded the guideline.

•Natural low flow conditions limit fish production in some years.[11]

•No information on water withdrawals was available.

•**Other:** The watershed has highly unstable valley walls and hill slopes and the stream is sensitive to natural terrain instability. Disruption of the natural sediment regime from logging or other land uses could seriously harm spawning gravels at the confluence with the Middle River.

O'Ne-eil Creek is being assessed as part of the *Stuart-Takla Fish/Forestry Study.*

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Forfar Creek (09-8100-450)

•Between 7 and 15 measurements are reported for temperature, pH, non-filterable residue, total phosphorus, and metals. Two of the 15 pH values were below the guideline and 1 of 8 copper and cadmium concentrations exceeded the guidelines.

•Past road construction and logging activity have caused siltation.[2] Disruption of the natural sediment regime could seriously harm spawning gravels at the confluence with the Middle River.

•No information was available to assess stream flows.

•**Other:** The watershed has highly unstable valley walls and high summer water temperatures are of concern.[11] Forfar Creek is being assessed as part of the *Stuart-Takla Fish/Forestry Study.*

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Gluskie Creek (09-8100-465)

•Between 5 and 12 measurements are reported for temperature, pH, non-filterable residue, total phosphorus, and metals in surface water. Only 1 of 6 copper values exceeded the guideline.

•Some logging has occurred and further activity is now deferred. Logging road construction and maintenance and timber harvesting have resulted in silt inputs to the stream.[11]

•There is high concern regarding low flows.[11]

•**Other:** The stream is sensitive to natural terrain instability.[11] Gluskie Creek is being assessed as part of the *Stuart-Takla Fish/Forestry Study.*

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Casimer Creek (09-8100-480)

•Stream flow is adequate.[11]

•**Other:** Soils are highly erodible in the watershed.[2] One forestry bridge and 1 B.C. Rail line cross the creek.[11]

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Bivouac Creek (09-8100-485)

•Between 5 and 11 measurements were reported for temperature, pH, non-filterable residue, total phosphorus, and metals in surface water. Only 2 of 6 copper values exceeded the guideline and values likely reflect natural background levels for the watershed.

•There has been some logging in the lower watershed. There is potential for localized erosion at logging road bridge crossings.[11]

•Low flow problems have been noted.[11]

•No information on water withdrawals was available.

•**Other:** Bank erosion has been noted.[11] Bivouac Creek is being assessed as part of the *Stuart-Takla Fish/Forestry Study.*

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Leo Creek (09-8100-490)

•Extensive logging has occurred in the upper watershed, and more is planned.[2] Logging has resulted in some riparian impacts.[11]

•Low flow problems have been noted.[11]

•**Other:** Numerous slope failures are evident on valley walls.[2]

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Sandpoint Creek (09-8100-525)

•Low flow problems have been noted. The creek sometimes de-waters at the mouth during low flows.[2]

•**Other:** The watershed has unstable valley walls.[2] High summer water temperatures have been noted.[11]

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Sakeniche River (09-8100-545)

•Logging has occurred previously, and more is planned for the upper watershed.[11] There is an extensive network of logging roads in the watershed.

•River flows are stabilized by large lakes in the watershed.[11]

•No information on water withdrawals was available.

•**Other:** High summer temperatures have caused pre-spawning mortalities.[2] Removal of streamside vegetation could cause an increase in already high temperatures. Some valley walls are unstable.[11] A designated placer mining area is located in the upper watershed.[2]

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McDougall Creek (09-8100-560)

•Logging has occurred throughout the watershed and more logging has been proposed.[11]

•The creek headwaters are lake-fed which helps to stabilize flows, however, low flow problems have been noted.[11]

•**Other:** Possible temperature concerns have been identified, due to the numerous lakes and swamps in the watershed.[11]

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Sinta Creek (09-8100-574)

•Low flow problems have been noted.[11]

•**Other:** There has been no logging in the watershed, however, a logging road is present.[11]

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Dust Creek (09-8100-577)

•A limited amount of logging has occurred in the past.[11]

•Low flow problems have been noted.[11]

•**Other:** Both summer and winter water temperatures are of high-level concern.[11]

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Crow Creek (09-8100-585)

•Low flow problems have been noted.[11]

•**Other:** The watershed has highly unstable valley walls.[2] Crow Creek is fed by a glacier.[2]

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Hooker Creek (09-8100-588)

•Low flows are considered to be of high concern.[11]

•**Other:** The valley walls are highly unstable.[2] To date there is no development of any sort in the watershed.

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Point Creek (09-8100-590)

•Low flow problems have been noted.[11]

•**Other:** The valley walls are highly unstable.[2] One summer home is located near the creek.[2] There is reportedly no past or planned logging in the watershed, however, the presence of a logging road and bridge crossing is noted.[11]

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Narrows Creek (09-8100-625)

•A lodge is located at the creek mouth.[11]

•No information on water withdrawals was available.

•**Other:** The valley walls are very unstable.[2] There has reportedly been no logging in the watershed. A logging road, a bridge, and a B.C. Rail crossing are present.[11]

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Twenty Five Mile Creek (09-8100-655)

•Low flow problems have been noted,[11] and there are large seasonal fluctuations in flow.[2]

•**Other:** The valley walls are very unstable.[2] Stream temperature concerns have been noted.[1] No logging has occurred, and none is planned for the near future.[11]

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Shale Creek (09-8100-660)

•Low flow problems have been noted.[11]

•Other: The valley walls are highly unstable.[2] Temperature concerns have been noted.[1] Although no logging has occurred and none is planned for the near future, the presence of a forestry road and one bridge crossing is noted.[11]

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Blanchet Creek (09-8100-665)

•Logging was scheduled for 1995/96 in the lower reaches.[11]

•Other: The valley walls are highly unstable.[2]

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Fifteen Mile Creek (09-8100-694)

•Low flow problems have been noted.[11]

•Other: There is concern that the fan will become unstable if logging occurs,[11] and there is high erosion potential in upper watershed.[2] Although no logging has occurred to date, and none is reportedly planned for the near future, a logging road and B.C. Rail line pass through the watershed.[11]

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McLaing Creek (Five Mile Creek) (09-8100-750)

•Some logging has occurred in the lower watershed, but has not caused water quality concerns.[11]

•Low flow problems during spawning have been noted.[1]

•Other: The valley walls are generally unstable.[2]

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Hudson Bay Creek (09-8100-775)

•The small village of Takla Landing is located in the watershed, and does not cause concerns.[11]

•Extensive logging has occurred throughout the watershed, and substantial logging is planned. There are some localized riparian impacts and stream road crossing impacts.[11]

•Low flows limit access to spawners.[2]

•No information on water withdrawals was available.

•Other: The valley walls are generally unstable.[1]

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Frypan Creek (09-8100-815)

•Very low flows during the sockeye incubation period have been noted.[11]

•Other: The stream banks and valley walls are unstable.[2] There is no development in the watershed.

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Forsythe Creek (09-8100-840)

•Some logging has occurred in the past and more is planned.

•Low flow problems have been noted.[11]

•Other: The stream banks and valley walls are highly unstable.[2]

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French Creek (09-8100-945)

•There has been some logging in the watershed, and more is planned.[11]

•Low flow problems have been noted.[11]

•Other: The valley walls are highly unstable.[2]

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Ankwill Creek (09-8100-950)

•There has been a moderate degree of logging, concentrated in lower portion of the watershed. Logging has occurred right up to the stream banks in some locations. Planned logging and road building could have a major impact on water quality and fish habitat.[15]

•Very low flows have been reported during the sockeye incubation period.[15]

•Other: The stream banks and valley walls are very unstable.[2] The stream is glacier fed.

❖❖❖

Bates Creek (09-8100-990)

•Low flow problems have been noted.

•Other: The valley walls are unstable.[2] Linear development is minimal, with 1 B.C. Rail crossing, and 1 forestry road crossing.[15]

❖❖❖

Driftwood River (09-8100-995)

•A logging camp is located in the lower watershed.

•Past logging has occurred along the lower mainstem and extensive logging is planned. There has not been any streamside logging to date. There are logging access roads from Takla Lake to the upper watershed on both sides of the river. Roads and bridges are considered to be of high concern.[15]

•Concerns over low winter flows have been noted.[15]

•No information about water withdrawals was available.

•**Other:** The valley walls are highly unstable.[2] The Banana Lake tributary may contribute to siltation during floods. Glacial sediments are contributed from the Elmore Creek tributary. The overall proposed rate of development (logging) is considered to be of high concern.[11]

❖❖❖

Blackwater Creek (09-8100-995-100)

•Proposals for extensive logging result in significant concerns for water quality and fish habitat.[11]

•Very low winter flows have been reported.[11]

•**Other:** The valley walls are highly unstable.[2]

❖❖❖

Lion Creek (09-8100-995-150)

•Although there are reportedly no plans for logging in the watershed a new logging road has been proposed.[11]

•Winter low flow problems have been noted.[15] The creek is glacier fed.

•**Other:** The stream banks and valley walls are very unstable.[2]

❖❖❖

Porter Creek (09-8100-995-220)

•The stream is fed by a glacier.[15]

•**Other:** The stream banks and valley walls are very unstable.[2] To date there has been no development in the watershed.

❖❖❖

Kotsine River (09-8100-995-300)

•The Kostine Indian Reserve is located in the watershed but no water quality concerns have been noted.[15]

•Winter low flows are considered to be of concern.[15] The river is glacier fed.

•No information about water withdrawals was available.

•**Other:** The river banks and valley walls are highly unstable.[2]

❖❖❖

Consolidate Creek (09-8100-995-350)

•Logging began in 1994[15] but no information about impacts was available. Logging roads extend along the mainstem and tributaries.

•Very low winter flows are of concern.[11]

•**Other:** The stream banks and valley walls are very unstable.[1]

❖❖❖

Kastberg Creek (09-8100-995-500)

•A significant amount of harvesting is proposed for the lower watershed.[15] Numerous logging roads are planned.[15]

•Low flow problems have been noted.[15]

•**Other:** The valley walls are highly unstable.[2]

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6.7 References

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Table 6.2.1 Summary of Permitted Discharges to Surface Water in the Stuart-Takla HMA.[1]

Record Id	Facility	Waste Type	Waste Num	Max. Flow $(m^3 \bullet d^{-1})$	Receiving Water Body
P00239	FORT ST. JAMES STP	STP	01	3,200	NECOSLIE RIVER
P00344	SAWMILL AT FORT ST. JAMES	STP	01	432	DITCH - NAHOUNLI CREEK
P00364	FORT TRAILER PARK AT FORT ST JAMES	STP	01	60	STUART RIVER
P02246	FORT ST JAMES DISTRICT FOREST OFFICE	STP	01	7	STUART LAKE
P02572	MOBILE HOME PARK, 5 KM SOUTH OF FORT ST JAMES	STP	01	40	STUART RIVER
P04243	LOGGING CAMP AT LOVELL COVE, TAKLA LAKE	STP	01	182	TEEGEE CREEK
P06038	TACHIE I.R. #1, NE SIDE OF STUART LAKE	STP	01	93,000	STUART LAKE
P07411	NANCUT I.R. #3 (PORTAGE)	STP	01	280	WETLANDS - NANCUT CREEK
P09100	LOGGING CAMP, TAKLA LAKE	STP	01	190	TEEGEE CREEK

[1] Data were summarized from a 1994 version of the Environment Canada Effluent Point Source Inventory and Database for the Fraser River Basin (see reference 5).

Table 6.2.2a Summary of Permitted Daily Contaminant Loading* to Surface Water in the Stuart-Takla HMA ($kg \cdot d^{-1}$ except where noted)

	Processing		**Cooling**		**Stormwater**		**Sewage Treatment**		**Leachate**	
	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading
Biochemical Oxygen Demand	-	-	-	-	-	-	9	153	-	-
Coliform - Fecal	-	-	-	-	-	-	2	5	-	-
Residue Nonfilt.	-	-	-	-	-	-	9	171	-	-

Table 6.2.2b Summary of Permitted Annual Contaminant Loading* to Surface Water in the Stuart-Takla HMA ($kg \cdot yr^{-1}$ except where noted).

	Processing		**Cooling**		**Stormwater**		**Sewage Treatment**		**Leachate**	
	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading
Biochemical Oxygen Demand	-	-	-	-	-	-	9	40,144	-	-
Coliform - Fecal	-	-	-	-	-	-	2	522	-	-
Residue Nonfilt.	-	-	-	-	-	-	9	41,358	-	-

* Loadings are calculated from permit information in Environment Canada's Fraser River Point Source Inventory and Database (see reference 5).

Table 6.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Stuart-Takla HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
STUART R 2 KM D/S OF HWY 27 AT CAMPGROUND							
Surface Water	pH (pH units)	3	0	0	7.0	7.8	7.5
	Nonfilterable residue (mg/L)	1	na	0	3	3	3
	Fecal Coliforms (MPN/100 mL)	3	0	0	33	170	104
	Dissolved Ammonia-Nitrogen (mg/L)	3	1	0	0.008	0.012	0.010
	Total Phosphorus (mg/L)	3	0	0	0.009	0.054	0.025
STUART R AT HWY 27 BRIDGE. WEST SHORE.							
Surface Water	Dissolved Oxygen (mg/L)	10	0	0	9.8	11.0	10.3
	Temperature (°C)	10	0	0	5	12	8
	pH (pH units)	21	0	0	7.3	8.1	7.8
	Fecal Coliforms (MPN/100 mL)	23	0	14	1	8	3
	Dissolved Ammonia-Nitrogen (mg/L)	22	1	14	0.005	0.019	0.006
	Total Phosphorus (mg/L)	6	0	0	0.006	0.013	0.009
STUART R AT HWY 27 EAST SHORE							
Surface Water	Dissolved Oxygen (mg/L)	10	0	0	10.0	11.0	10.5
	Temperature (°C)	10	0	0	4	13	8
	pH (pH units)	25	0	0	7.5	8.1	7.9
	Nonfilterable residue (mg/L)	2	na	0	6	259	133
	Fecal Coliforms (MPN/100 mL)	33	7	4	2	9200	519
	Total Coliforms (MPN/100 mL)	1	0	0	33	33	33
	Dissolved Ammonia-Nitrogen (mg/L)	27	21	4	0.005	0.215	0.047
	Total Phosphorus (mg/L)	11	3	0	0.022	0.354	0.094
STUART L F.S. JAMES RCMP WATER INTAKE							
Surface Water	Fecal Coliforms (MPN/100 mL)	1	0	1	2	2	2
STUART LK. EAST END 15 M CONTOUR.							
Surface Water	pH (pH units)	5	0	0	7.4	8.0	7.8
	Dissolved Ammonia-Nitrogen (mg/L)	5	0	3	0.005	0.008	0.006
	Total Phosphorus (mg/L)	5	0	0	0.004	0.010	0.007
	Total Arsenic (mg/L)	2	0	2	0.001	0.001	0.001
	Total Copper (mg/L)	2	2	0	0.005	0.010	0.008
	Total Mercury (µg/L)	2	0	2	0.05	0.05	0.05
	Total Lead (mg/L)	2	1	1	0.001	0.002	0.002
	Total Zinc (mg/L)	2	1	1	0.01	0.03	0.02
NECOSLIE R 50 M D/S OF FT ST JAMES DISCHARGE							
Surface Water	pH (pH units)	5	0	0	7.5	8.2	7.7
	Fecal Coliforms (MPN/100 mL)	3	3	0	230	920000	423410
	Dissolved Ammonia-Nitrogen (mg/L)	7	7	0	0.032	18.100	4.597
	Total Phosphorus (mg/L)	6	5	0	0.066	4.050	1.276
NECOSLIE R BACK CHANNEL NEAR FT ST JAMES DUMP							
Surface Water	pH (pH units)	3	0	0	7.5	7.7	7.6
	Nonfilterable residue (mg/L)	1	na	0	6	6	6
	Dissolved Ammonia-Nitrogen (mg/L)	3	2	0	0.007	0.027	0.018
	Total Phosphorus (mg/L)	2	0	0	0.047	0.075	0.061

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 6.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Stuart-Takla HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
NECOSLIE R 50 M U/S FT ST JAMES DISCHARGE							
Surface Water	pH (pH units)	9	0	0	7.6	8.0	7.8
	Nonfilterable residue (mg/L)	1	na	0	323	323	323
	Fecal Coliforms (MPN/100 mL)	7	0	0	2	49	16
	Dissolved Ammonia-Nitrogen (mg/L)	11	6	4	0.005	0.046	0.015
	Total Phosphorus (mg/L)	11	5	0	0.024	0.390	0.141
NECOSLIE R 20 M U/S HWY 27 MIDSTREAM							
Surface Water	Dissolved Oxygen (mg/L)	10	2	0	8.8	12.0	10.4
	Temperature (°C)	10	0	0	3	12	7
	pH (pH units)	28	0	0	7.5	8.8	8.1
	Nonfilterable residue (mg/L)	1	na	0	344	344	344
	Fecal Coliforms (MPN/100 mL)	34	6	7	1	24000	1520
	Total Coliforms (MPN/100 mL)	3	2	0	4.5	16000	6135
	Dissolved Ammonia-Nitrogen (mg/L)	30	28	1	0.005	4.080	0.907
	Total Phosphorus (mg/L)	14	12	0	0.063	0.760	0.278
NECOSLIE R 4 KM U/S FT ST JAMES DIS							
Surface Water	pH (pH units)	4	0	0	7.5	7.8	7.6
	Nonfilterable residue (mg/L)	1	na	0	287	287	287
	Fecal Coliforms (MPN/100 mL)	2	0	0	7	49	28
	Dissolved Ammonia-Nitrogen (mg/L)	4	2	1	0.005	0.032	0.015
	Total Phosphorus (mg/L)	3	1	0	0.052	0.362	0.157
PINCHI C AT TACHIE RD BRIDGE							
Surface Water	pH (pH units)	1	0	0	8.3	8.3	8.3
	Nonfilterable residue (mg/L)	1	na	0	3	3	3
	Dissolved Ammonia-Nitrogen (mg/L)	1	0	0	0.008	0.008	0.008
	Total Phosphorus (mg/L)	1	0	0	0.018	0.018	0.018
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	1	0	0.005	0.005	0.005
	Total Mercury (µg/L)	1	0	1	0.05	0.05	0.05
	Total Lead (mg/L)	1	1	0	0.003	0.003	0.003
	Total Zinc (mg/L)	1	0	1	0.01	0.01	0.01
PINCH L SOUTH SHORE 3.5 KM E OF PINCHI CR.							
Fish Tissue (1986)	Mercury (µg/g)	24	15	0	0.15	3.05	0.90
O'NE'ELL CREEK aka KYNOCK CREEK (data from the Stuart-Takla Fish/Forestry Research Program)							
Surface Water	Temperature (°C)	14	0	0	2.0	12.4	8.0
	pH	14	0	0	7.4	7.8	7.6
	Nonfilterable residue (mg/L)	14	0	14	0	0	0
	Total Phosphorus (mg/L)	6	0	0	0.004	0.017	0.011
	Total Arsenic (mg/L)	6	0	0	0.0001	0.0002	0.0002
	Total Cadmium (mg/L)	8	0	8	0	0	0
	Total Chromium (mg/L)	8	0	2	0.0009	0.003	0.002
	Total Copper (mg/L)	8	2	0	0.0005	0.021	0.004

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

n = number of samples
d/s = downstream
u/s = upstream

Table 6.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Stuart-Takla HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
FORFAR CREEK (data from the Stuart-Takla Fish/Forestry Research Program)							
Surface Water	Temperature (°C)	14	0	0	2.0	11.9	7.3
	pH	15	2	0	5.8	7.5	7.1
	Nonfilterable residue (mg/L)	15	0	15	0	0	0
	Total Phosphorus (mg/L)	7	0	0	0.003	0.009	0.006
	Total Arsenic (mg/L)	7	0	2	0.0003	0.0005	0.0004
	Total Cadmium (mg/L)	8	0	8	0	0	0
	Total Chromium (mg/L)	8	1	2	0.0002	0.006	0.001
	Total Copper (mg/L)	8	1	2	0.0007	0.005	0.002
GLUSKIE CREEK (data from the Stuart-Takla Fish/Forestry Research Program)							
Surface Water	Temperature (°C)	12	0	0	0.8	11.5	7.6
	pH	12	0	0	7.4	7.7	7.5
	Nonfilterable residue (mg/L)	12	0	11	10	10	10
	Total Phosphorus (mg/L)	5	0	0	0.003	0.011	0.008
	Total Arsenic (mg/L)	5	0	0	0.0003	0.002	0.001
	Total Cadmium (mg/L)	6	0	6	0	0	0
	Total Chromium (mg/L)	6	0	1	0.0004	0.001	0.0009
	Total Copper (mg/L)	6	1	1	0.0008	0.003	0.001
BIVOUAC CREEK (data from the Stuart-Takla Fish/Forestry Research Program)							
Surface Water	Temperature (°C)	11	0	0	0.9	11.9	7.7
	pH	11	0	0	7.6	8.0	7.8
	Nonfilterable residue (mg/L)	11	0	11	0	0	0
	Total Phosphorus (mg/L)	5	0	0	0.003	0.011	0.007
	Total Arsenic (mg/L)	5	0	1	0.0001	0.0003	0.0002
	Total Cadmium (mg/L)	6	0	6	0	0	0
	Total Chromium (mg/L)	6	0	3	0.0002	0.0006	0.0004
	Total Copper (mg/L)	6	2	0	0.001	0.009	0.003

* Note that dissolved oxygen is # < guideline, and that pH is # < or > guideline levels.
MDL = method detection limit
na = no guideline was applicable.

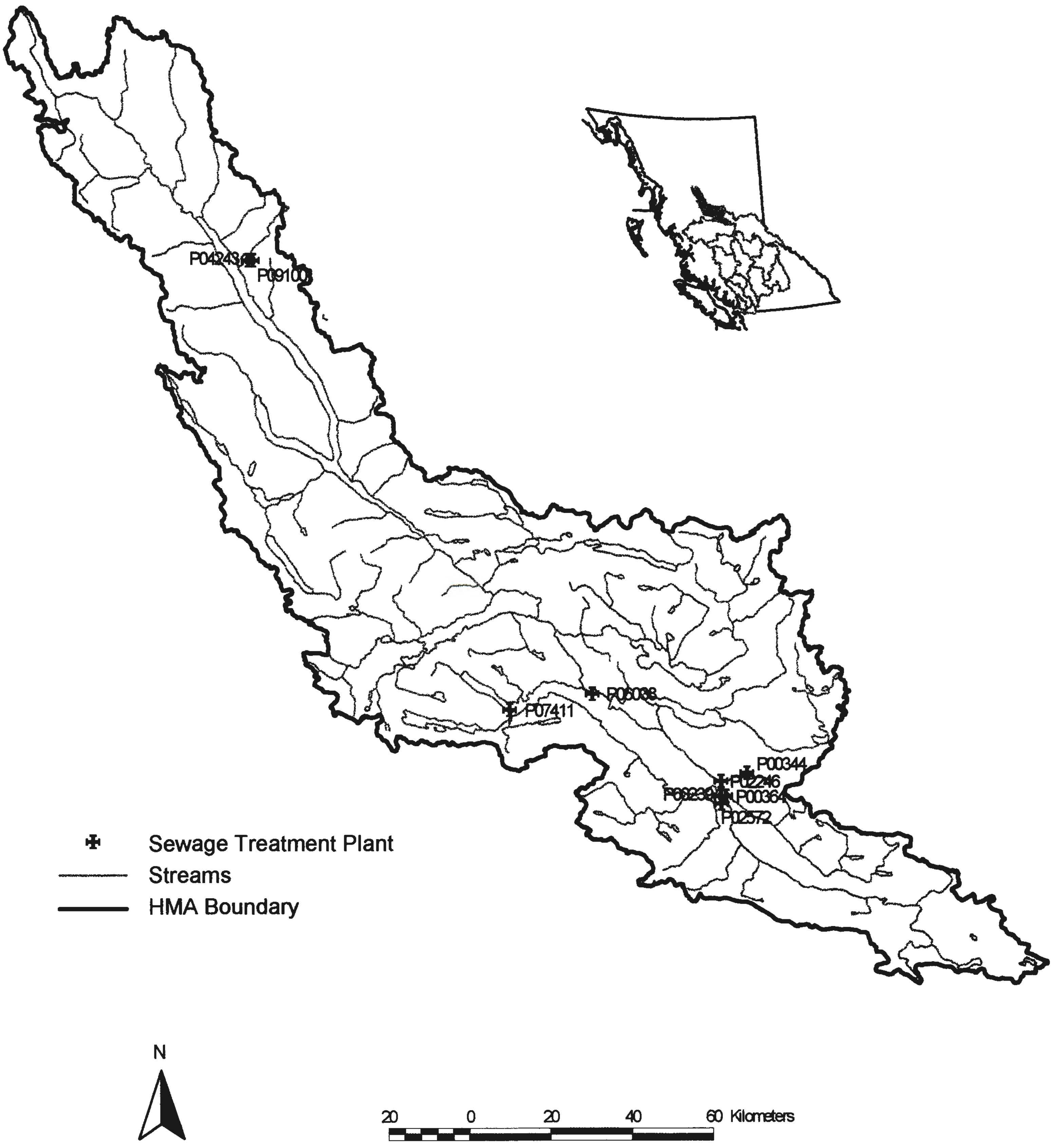
n = number of samples
d/s = downstream
u/s = upstream

Table 6.6.1 Summary of Red-coded Indicators[1] for Salmon-Bearing Streams in the Stuart-Takla HMA. (Streams are ordered by SISS code.)

Stream Name	Indicator				
	Urban	Agriculture	Logging	Stream Flow	Demand
Stuart River					
Sowchea Creek				*	
Pinchi Creek					
Tachie River					
Middle River					
Kuzkwa River			*		
Fleming Creek				*	
Paula Creek				*	
Sidney Creek				*	
Kazchek Creek			*		
Van Decar Creek				*	
O'Ne-ell Creek				*	
Forfar Creek					
Gluskie Creek				*	
Casimer Creek					
Bivouac Creek				*	
Leo Creek			*	*	
Sandpoint Creek				*	
Sakeniche Creek					
McDougall Creek				*	
Sinta Creek				*	
Dust Creek				*	
Crow Creek				*	
Hooker Creek				*	
Point Creek				*	
Narrows Creek				*	
Twenty Five Mile Creek				*	
Shale Creek				*	
Blanchet Creek					
Fifteen Mile Creek				*	
McLaing Creek				*	
Hudson Bay Creek			*	*	
Frypan Creek				*	
Forsythe Creek				*	
French Creek				*	
Ankwill Creek			*	*	
Bates Creek				*	
Driftwood River			*	*	
Blackwater Creek			*	*	
Lion Creek				*	
Porter Creek					
Kotsine River				*	
Consolidate Creek				*	
Kastberg Creek				*	

[1] "Red-coded" = likely to have water quality impacts associated with given land use, stream flow, or water demand conditions in the stream. See Chapter 3 for assessment methodology.

Figure 6.2.1 Location of Permitted Waste Discharges to Surface Water in the Stuart/Takla HMA



Chapter 7 Upper Fraser Habitat Management Area

7.1 Background

The Upper Fraser HMA covers an expanse of about 33,700 km^2.[1] The headwaters of the Fraser River originate in the Rocky Mountain Trench in this HMA. From there, the river flows northwest through rugged and mountainous terrain before turning south through the interior plateau.

7.1.1 Hydrology

Melting snow and ice are the main sources of water for stream flows in the Upper Fraser HMA. The HMA has a typical interior climate with long, cold winters and short, hot summers.[1] Precipitation (about 500 – 600 mm per year at Prince George) is relatively evenly distributed throughout the year, and about 40% is deposited as snow.[1]

In the eastern portion of the HMA, where the Fraser River headwaters are located, snow and glacier melt result in June peak flows and maintain high flows through to early fall.[1] Flows in the western portion of the HMA also peak in early summer, but decline toward fall.[1] Some of the smaller tributary watersheds may experience summer low flow problems, especially in dry years,[1] although only 3 systems were considered to have extremely low summer flows (Table 7.6.3).

7.1.2 Fish

There are 38 salmon bearing streams in the Upper Fraser HMA.[1] Two of the 5 Pacific salmon species make use of these streams for spawning and rearing.[2,3] Chinook are present in all of these streams, while sockeye are apparently limited to the Bowron system.[2,3] The chinook are of the spring run type, which remain in freshwater streams until their second spring.[4] Studies indicate that juveniles use non-natal streams for rearing,[5] however, only the spawning streams are well documented.

Resident species include Dolly Varden char, kokanee, rainbow trout, lake trout, mountain whitefish, burbot, suckers, dace and shiner.

7.1.3 Predominant Land Uses

Land uses include logging, agriculture (mostly ranching), and some placer mining. Most human activity occurs in the lower reaches of tributaries, and along the Fraser River corridor. Mount Robson Provincial Park and Bowron Lakes Provincial Park offer many recreational opportunities and draw tourists to the area. Fishing is a popular activity in the many small lakes in the region.[6] There is a significant amount of linear development in the HMA, including gas pipelines, hydro lines, railways, and highways.[6]

7.2 Point Sources of Contaminants

7.2.1 Urban/Industrial Point Source Discharges to Surface Water

There are 21 permitted discharges to surface water in the Upper Fraser HMA: 6 for processing, 2 for cooling and 14 for STP effluents (Figure 7.2.1).[7] Estimated daily and annual loadings, based on Waste Management Permit criteria, are summarized in Tables 7.2.2a and 7.2.2b.

The largest volumes of discharge come from 3 pulp mills located in Prince George (Table 7.2.1), 2 of which share effluent treatment and discharge facilities. Effluent temperature is one of the primary concerns associated with these discharges. Collectively the mills discharge 458,000 m^3 of effluent to the Fraser River, with a maximum temperature between 35 and 38°C, depending upon the mill. One study conducted at Prince George during winter months showed that water temperature was elevated by 0.6°C at a distance of 530 m downstream from the discharge site, compared with the reference site.[9] During hot summers this temperature increase could be enough to have significant impacts on returning spawners.

A study conducted at Prince George showed that overwintering juvenile chinook did not avoid a pulp mill effluent plume, and therefore may experience prolonged exposure to relatively concentrated effluents.[8] Limited water quality data from the study clearly showed the influence of effluent on nearshore habitat as far as 830 m downstream from the point of discharge.[8] The sublethal effects of long-term exposure of fish to pulp mill effluents have recently been studied, however, results are not yet available.[9]

The largest STP in the Upper Fraser HMA services the Prince George area, and is permitted to discharge up to 45,000 $m^3 \cdot d^{-1}$ of effluent to the Fraser River. This STP formerly released effluent containing high ammonia concentrations, with corresponding toxicity problems.[13,14] The STP was upgraded to provide full secondary treatment in 1995, with improved effluent quality.[16]

Several Waste Management Permits should be revisited, as discharge criteria may not be adequate to protect water quality for fish (Table 7.2.1). These include the pulp mill effluent permits, due to temperature concerns, and permits for 2 sewage discharges. One of the sewage discharges is very small, but permit information indicates effluent is discharged to a Fraser River slough. Sloughs often provide valuable fish habitat and experience far less flushing compared with river mainstems, and hence can be vulnerable to water quality impacts.

A sewage discharge to Cranberry Marsh is also of concern, as receiving environment data from the marsh outlet show quite high concentrations of ammonia and phosphorus.

7.2.2 Permitted Discharges to Ground

There are 7 discharges of processing effluent to ground, which come from chemical plants, food processing plants, mines and petroleum storage facilities. Ten STPs discharge to ground, and service a variety of municipalities, campgrounds and forest service facilities. In most rural areas houses have private septic systems.

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7.3 Non-Point Sources of Contaminants

Non-point sources of contaminants may negatively affect water quality in some of the salmon-bearing systems of the Upper Fraser HMA.

7.3.1 Urban Development

Most of the HMA population is concentrated in the city of Prince George, which is centered in a triangle south of the Nechako River on the west bank of the Fraser River. Prince George straddles the Fraser River, and the portion of the city on the west side of the river falls within the Nechako HMA. The population of Prince George was estimated at about 75,150 in 1996 and is growing relatively rapidly (increase of 7.9% between 1991 and 1996).[10] It is expected that another 3,000 to 5,000 lots will be developed by the year 2000, resulting in more sedimentation, stormwater runoff, and damage to riparian areas, unless significant precautions are taken.[11]

There are 17 stormwater outfalls that discharge to the Fraser River in the vicinity of Prince George. In addition, several industrial sites, including rail yards, also discharge stormwater runoff to surface waters.

Estimates of contaminant loadings to the Fraser Basin from urban stormwater runoff suggest that urban runoff is a significant source of nutrients, non-filterable residues and BOD in the Upper Fraser HMA (Table 7.2.3). The estimated point-source loadings of some parameters do not provide for a true comparison with non-point sources, as Waste Management Permits do not restrict their discharge. For example, waste management permits for the pulp mills and STPs do not restrict loadings of phosphorus, even though these facilities discharge large loadings of phosphorus to the Fraser River. Discharges are not restricted because the Fraser River is not very sensitive to phosphorus inputs.

There are at least 3 snow dumps along the Fraser River near Prince George,[15] which have been significant sources of contaminants to surface waters. The City of Prince George is seeking an alternative dump site which is far removed from any surface water body.[17]

None of the salmon-bearing tributaries to the Fraser River in the Upper Fraser HMA experience significant water quality impacts as a result of urban development (Table 7.6.3). Water quality and fish habitat in the Fraser mainstem are impacted by urban development in relatively localized areas.

7.3.2 Agriculture

There is a relatively small amount of agricultural activity, including several feed lots, within the HMA. Private land is being cleared for forage production and grazing, resulting in erosion along the Fraser especially where vegetation has been removed.[11] Hobby ranches are becoming increasingly common, and are often operated by people who are not very aware of the environmental impacts which can result from agricultural activities. Only 3 of the 40 salmon-bearing systems in the HMA were considered to be significantly impacted by agriculture (Table 7.6.3).

7.3.3 Timber Harvesting

Forest harvesting began in the HMA in about 1960.[6] Extensive logging now affects many salmon-bearing streams in the HMA (15 of 40 salmon streams were considered to be significantly impacted by logging) (Table 7.6.3). Poor road building and maintenance practices, particularly in winter conditions, have disrupted soil conditions, resulting in erosion. Compliance with regulations is considered to be poor in many operations.[11] Logging on private land, where compliance with the Forest Practices Code is not required, generates numerous complaints about habitat damage.[11]

7.3.4 Mining

Some historic and recent hard rock mining in the headwaters of the Willow River have resulted in local water quality issues. Much of the HMA is in the No Staking Placer Reserve, however, there is placer mining in some areas of the HMA. There is a high level of concern with regard to impacts on fish habitat in the HMA.[18] DFO, MELP, and Ministry of Energy and Mines all perform some compliance monitoring. DFO is placing increasing efforts on providing on-site education and awareness for proponents as a means of addressing water quality and fish habitat concerns.[25]

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7.4 Overview of Water Quality Conditions

Water quality conditions in the Fraser River change significantly between the headwaters at Red Pass, and the Hansard sampling site. The river is well buffered to acidic inputs, with a mean alkalinity of 67.9.[15] Water hardness is considered to be moderate, and increases from Red Pass to Hansard, due to inputs from other tributaries and anthropogenic activities.[15]

The headwaters of the Fraser River are relatively clear, however, by the time the river reaches Prince George it has attained its characteristic muddy appearance. Inputs from other tributaries and possibly anthropogenic activities such as logging, increase suspended sediment levels between Red Pass and Hansard.[15] Several tributaries including McGreggor and Torpy Rivers, and natural erosion processes along the Fraser mainstem, contribute further to suspended sediment levels.[15]

Site-specific water quality assessments, and influencing factors and supporting data (Table 7.6.1a and Table 7.6.1b) are summarized in Section 7.6 on a stream-by-stream basis.

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7.5 Factors Modifying Contaminant Behaviour

The high suspended sediment levels make the Fraser River somewhat insensitive to nutrient inputs, as light penetration limits primary production. The high suspended sediment levels also result in relatively high total concentrations of some metals, however, these metals are mostly not bio-available.

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7.6 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Upper Fraser HMA.

Summary tables of:

- surface water, sediment and fish tissue data (Tables 7.6.1a and 7.6.1b)
- land use areas, stream flow, and water demand information for each salmon stream (Table 7.6.2)
- identified impacts for each salmon stream (Table 7.6.3)

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 7.6.1.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals were based upon information provided in hydrology reports prepared for DFO[1] and/or SISS catalogues[2,3] unless otherwise indicated. Assessment criteria are explained in the Methods section (Chapter 3) of this report.

Fraser River at Stoner

•Stoner is located downstream from Prince George. At the station east of midstream, 8 of 24 fecal coliform, 21 of 40 ammonia, 2 of 14 phosphorus, 7 of 7 chromium, 5 of 5 copper and 4 of 36 zinc values exceeded the guidelines or 80th percentiles. All 14 mercury measurements were below guidelines.

★In fish tissue samples, 3 of 12 T4CDD values exceeded the guideline, but all the samples were collected prior to 1991, when the federal government introduced more stringent regulations controlling the quality of pulp mill effluent. More recent sampling (1994) in the mainstem showed low concentrations of dioxins and furans. All 5 measurements of trichlorophenol and pentachlorophenol were below guidelines.

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Woodpecker Reach

•Fish samples (4 each of peamouth chub and mountain whitefish composite muscle samples, each composed of tissue from 4 fish) were collected in a 1994 DOE/DFO-FRAP study. None of the measured parameters (T4CDD, T4CDF, O8CDD, O8CDF, PCB, and toxaphene) exceeded the consumption guidelines for the protection of human health. Concentrations of some substances in liver were higher (Table 7.6.1b). The long-term effects of low levels of contaminant mixtures on the health of aquatic organisms is unknown.

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Fraser River at Prince George

•Between 3 and 8 measurements were reported for T4CDD in fish in the vicinity of Prince George, at each of 3 sites. Of these, only one of 8 T4CDD values exceeded the guideline, and this sample was collected prior to 1992, when the federal government introduced more stringent regulations controlling the quality of pulp mill effluent.

There are 13 Waste Management Permits addressing the discharge of effluents (up to a total volume of 528,593 $m^3 \cdot d^{-1}$) to the Fraser River in the vicinity of Prince George. In addition, there are 17 stormwater outfalls which direct urban runoff to the Fraser River.[15]

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Fraser River at Hansard

•Four sites were sampled. At the main site, 161 of 303 total nitrate+nitrite-N, 20 of 167 ammonia, 45 of 304 phosphorus, 46 of 95 cadmium, 68 of 114 chromium, 62 of 102 copper, 28 of 97 lead and 14 of 139 zinc values exceeded the guidelines or 80th percentiles. The maximum copper value was 100 times greater than the guideline and the maximum chromium value was 20 times greater. Older chromium data are suspect, as sample bottles used to be washed with chromic acid.[15] Arsenic (n=97) and mercury (n=86) never exceeded guidelines. A maximum water temperature of 25°C was reported.

★This site is upstream of most urban and industrial development on the Fraser River, and water quality at this site is therefore considered representative of natural background conditions in the river.[15] The high levels of some metals may result from the naturally high suspended sediment loads in the river.

No parameter was analyzed more than 14 times at the other three sampling sites.

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Hansard Reach

•Fish samples (4 each of peamouth chub and mountain whitefish composite muscle samples, each composed of tissue from 4 fish) were collected at this station upstream of Prince George in a 1994 DOE/DFO-FRAP study. None of the measured parameters (T4CDD, T4CDF, O8CDD, O8CDF, PCB, and toxaphene) exceeded the consumption guidelines for the protection of human health. Concentrations of some substances in liver were higher (Table 7.6.1b). The long-term effects of low levels of contaminant mixtures on the health of aquatic organisms is unknown.

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Fraser River at Red Pass

•Between 92 and 319 measurements were reported for temperature, pH, nonfilterable residue, total nitrate+nitrite-N, total phosphorus, and metals in surface water. Of these, 10 of 318 total nitrate+nitrite-N, 14 of 99 chromium, and 11 of 99 copper values exceeded the guidelines or 80th percentiles. The maximum copper value was 40 times greater than the guideline.

★This site is located upstream from most urban and industrial development, and water quality is therefore considered to be representative of natural conditions in the river.

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Moose Lake

•Levels of PCBs in burbot livers were up to an order of magnitude higher than in fish sampled from other Fraser Basin lakes.[20] Levels of PCBs in lake trout are reported to be high in Moose Lake compared with other Rocky Mountain lakes.[15]

★While data were not available for evaluation relative to guidelines, the fact that PCB levels in some Moose Lake fish species appear high relative to the same species in near-by lakes is potentially cause for concern. PCB sources are believed to include direct contamination from adjacent linear developments including a major highway, railway, and hydro lines,[15] as well as atmospheric transport and the release of past deposits stored in snow fields and glaciers draining into the lake. Continued monitoring and investigation of sources could provide valuable information about persistent organic contaminants in northern B.C. lakes.

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Tabor Lake and Creek

•Between 15 and 75 measurements for fecal coliform and total phosphorus are reported for Tabor Lake and its un-named tributaries. At the north end of the lake, 54 of 75 phosphorus values exceeded the guideline. The numerous cottages and homes which surround the lake may contribute to elevated nutrient concentrations. In 1993 a group of citizens oversaw the illegal diversion of a tributary to Tabor Lake. Their intent was to increase flushing to reduce nutrient concentrations, however, the result was increased suspended sediment loads to the lake.

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Salmon River (00-5800)

•None of the 1 or 2 pH, fecal coliform, dissolved ammonia or zinc measurements exceeded the guidelines or 80th percentile levels.

•Residential development is localized in the lower reaches, and is not believed to raise concerns.[18]

•Agricultural activity is concentrated in the lower reaches and lower tributaries.[1,18] There was not enough information to assess the effect it may have on water quality.

•17% of the total watershed has been logged, including 9% from recent activity.[1] Harvesting of another 5% by 1998 was proposed.[1] Some cut blocks extend to the river bank but most end at the terrace edge.[1] Much of the riparian vegetation consists of brush species of no commercial value. Lower reaches are mostly privately owned and were cleared many years ago.[1] There is an extensive network of logging roads.[18]

•The naturalized summer 7-day mean low flow is 13% of the mean annual flow. Low flow problems have been reported.

•The potential August water demand for domestic, irrigation and industrial uses is 1% of the naturalized summer 7-day mean low flow.[1] DFO recommends no future water withdrawals.[2]

•**Other:** The lower part of the river is unstable with major shifts in channel location and occasional ice jam flooding. Gravel removal has been permitted downstream from the Highway Crossing.[1] The river has been channelized at the Hydro crossing.[22] Summer water temperatures are of concern, and may reach 25°C.[6,18] There is high summer recreational activity and vehicle fording in the reach near the Highway 97 bridge.[6]

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Willow River (00-5900)

•There are 7 surface water sampling sites located in the headwaters of Willow River. At the most frequently sampled station 9 of 28 fecal coliform, 29 of 36 ammonia, 1 of 1 cadmium, 3 of 3 chromium, 12 of 18 copper and 5 of 15 lead values in surface water exceeded the guidelines or 80th percentiles. For the 1 sediment sample reported, arsenic, chromium, copper, lead and zinc exceeded the guidelines.

•Impacts in the towns of Barkerville and Wells are of concern.[18]

•Agricultural activity occurs in the lower river reaches, with some removal of riparian vegetation.[18] Some farmers have attempted to control bank erosion with tree revetments or riverbed rock.[1]

•45% of the total watershed has been logged, including 16.5 % from recent activity. Logging of another 7.5% was proposed by 1998.[1] Logging activity has been focussed in the upper watershed. Much of the riparian vegetation along the mainstem is still intact,[1] however, removal of riparian vegetation from some tributaries has resulted in significant concerns.[18]

•The naturalized summer 7-day mean low flow is 27% of the mean annual flow.[1] Forest harvesting may affect stream hydrology.[18]

•The potential August and September water demand for domestic, waterworks and industrial uses is <1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Extensive placer mining occurs in the headwaters, resulting in significant sedimentation.[18] Several tributaries have been damaged by historic placer mining and have not been restored.[1] Mining in the 1970's and 1980's may have blocked access to some streams.[1] Tregillus, Hyde, Rucheon, Dragon, Montgomery, Williams, and Slough Creeks have all been mined. Tailings from an old gold mine near Wells are eroded by the river and are resulting in raised mercury concentrations in the fish of Jack of Clubs Lake.[1]

Wansa Creek (00-5900-070)

•58% of the total watershed has been logged, including 9% from recent activity.[1] Harvesting of another 7.3% was proposed by 1998.[1] Logging extends to the stream bank along part of the creek.[1] Road washouts have occurred, resulting in significant sediment inputs to the creek.[6]

•The naturalized summer 7-day mean low flow is 17% of the mean annual flow.[1] Low flows are a consistent problem.[2]

•No licenses have been issued.

Mosquito Creek

•One of 2 ammonia, one of one cadmium, 6 of 6 chromium, 8 of 11 copper, 6 of 11 lead and 5 of 11 zinc values exceeded the guidelines or 80th percentiles.

Williams Creek

•In surface water samples, one of 4 ammonia, one of one chromium, 3 of 7 copper, and 3 of 7 lead measurements exceeded the guidelines or 80th percentiles.

Lowhee Creek

•Four sites were sampled on Lowhee Creek, with a maximum of 14 measurements for any parameter at each of the sites. Both of 2 cadmium, 4 of 4 chromium, 11 of 14 copper, 7 of 12 lead and 8 of 14 zinc exceeded the guidelines upstream from Jack of Clubs Lake, and pH ranged from 7.8 to 8.3. Several seepages to Lowhee Creek were also sampled, and had some very low pH values (2.6 pH units), as well as high concentrations of arsenic, cadmium, chromium copper, lead, and zinc.

Jack of Clubs Lake

•One to two measurements of pH, dissolved ammonia, total phosphorus and metals in surface water have been reported. Of these, one copper, one chromium and 2 lead values exceeded the guidelines. An acid seepage draining to the lake had values that exceeded guideline levels for 2 of 9 arsenic, all of 3 cadmium, both of 2 chromium, 5 of 9 copper, 7 of 9 lead and 4 of 9 zinc measurements. pH measurements of this seepage were as low as 2.8.

•**Other:** Historical gold mill tailings were deposited on the lake shores and contain elevated levels of arsenic,[23] and low levels of residual cyanide. Fish have elevated mercury levels due to the erosion of a mine tailings pile near Wells.[1] An acid seepage which drains to Jack of Clubs Lake contains relatively high concentrations of arsenic, cadmium, chromium, copper, lead, and zinc.

McGregor River (00-6200)

•7% of the total watershed has been logged, including 4% from recent activity. Harvesting of another 2.5% was proposed by 1998.[1] Impacts include landings constructed in channels, soil failures and ditch erosion.[1] Extensive harvesting has occurred in the flood plain, resulting in a high level of concern over fish habitat and water quality issues.[18]

•The naturalized summer 7-day mean low flow is 45% of the mean annual flow. The river has a flashy hydrologic regime.[1]

•No licenses have been issued.

•**Other:** Unstable soils, high eroding banks and glaciers in the upper watershed produce moderately high suspended sediment loads.[1] The lower section of the river is braided and unstable and some riparian vegetation has been removed.[2] A water diversion project has been proposed for the river.[18]

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Seebach Creek (00-6200-020)

•2% of the total watershed has been logged recently, and 9% is proposed for harvesting. Localized impacts in the lower reach are reported.[18]

•The naturalized summer 7-day mean low flow is 17% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** Some riparian vegetation has been removed in the lower section.[2]

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Horn Creek (00-6200-020-010)

•4% of the total watershed has been logged recently, and 8% is proposed for harvest.[1]

•The naturalized summer 7-day mean low flow is 18% of the mean annual flow.[1]

•No licenses have been issued.[1]

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East Seebach Creek (00-6200-020-020)

•2% of the total watershed has been logged recently, and 7% was proposed for harvest prior to 1998.[1] Fairly extensive blowdown has occurred, and salvage operations were conducted in 1997 in the upper watershed.[6]

•The naturalized summer 7-day mean low flow is 18% of the mean annual flow.[1]

•No licenses have been issued.[1]

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Otter Creek (00-6200-060)

•1.5% of the total watershed was logged long ago, and another 4% of the watershed has been recently logged. An additional 3% was planned for harvest prior to 1998.[1] There is some localized sedimentation from logging roads and bridge crossings.[18]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]

•No licenses have been issued.[1]

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Herrick Creek (00-6200-070)

•Ministry of Forest records indicate 1% of the total watershed has been logged, and that harvesting of another 2% was proposed by 1998.[1] Extensive logging in the upper watershed is reported elsewhere.[2] A Land and Resource Use Plan is in place in the watershed.[22]

•The naturalized summer 7-day mean low flow is 20% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** The creek has a flashy hydrologic regime.[18] A significant portion of the watershed is composed of lacustrine silts and clay which results in suspended sediment loads. The watershed is characterized by steep terrain and receives a high snow pack.[6]

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Captain Creek (00-6200-070-020)

•3% of the total watershed consists of old logging, and recent logging has occurred in 1.5% of the watershed. Another 6% of the watershed was planned by 1998.[1] Logging roads cross streams[2], and result in localized sedimentation.[18] There is localized removal of riparian vegetation in the lower reach.[18]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1] Low summer flow problems are reported.[18]

•No licenses have been issued.

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James Creek (00-6200-070-030)

•3% of the total watershed has been logged recently, and no additional harvesting is planned prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]

•No licenses have been issued.[1]

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Fontoniko Creek (00-6200-070-050)

•Less than 1% of the total watershed has been logged, and no further logging was planned prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 22% of the mean annual flow.[1]

•No licenses have been issued.[1]

•Other: The west fork is glacier fed and subject to high turbidity, cold temperatures and fluctuating flows.[2]

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Spakwaniko Creek (00-6200-070-070)

•Less than 1% of the total watershed has been logged, and no further harvesting was planned prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 22% of the mean annual flow.[1]

•No licenses have been issued.[1]

•Other: The stream is turbid with glacial silt.

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Framstead Creek

•Less than 1% of the total watershed has been logged recently, and another 2% was proposed for harvest prior to 1998.[1]

•No information was available to assess stream flow.

•No licenses have been issued.[1]

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Muller Creek

•Less than 1% of the total watershed has been logged recently, and 3% was proposed for harvest prior to 1998.[1]

•No information was available to assess stream flow.

•No licenses have been issued.[1]

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Olivington Creek

•No information was available to assess stream flow.

•No licenses have been issued.[1]

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Bowron River (00-6300)

•14% of the total watershed consists of old logging, and an additional 25% has been recently harvested. Another 3% was proposed for harvesting prior to 1998.[1] Much riparian vegetation has been removed and the hydrologic regime may have been affected.[1] Extensive logging roads have affected the river.[18] Washouts of these logging roads and bridges have occurred.[1]

•The naturalized summer 7-day mean low flow is 34% of the mean annual flow.[1]

•The potential August and September water demand for domestic, waterworks and industrial uses is <1% of the naturalized summer 7-day mean low flow.[1]

•Other: Forest harvesting appears to have extended the duration of high turbidity.[1] There is some channel instability and erosion in the mid and upper sections.[1]

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Haggen Creek (00-6300-210)

•2% of the total watershed consists of older logging (pre 1982), and an additional 40% has been recently harvested (1983 – 1992).[1] Washouts of logging roads and bridges have occurred and there are a number of unstable slopes with small failures.[1]

•The naturalized summer 7-day mean low flow is 43% of the mean annual flow.[1]

•No licenses have been issued.[1]

•Other: Riparian vegetation has been removed from the lower section, and the channel has been destabilized. Potential sedimentation of the creek is a concern.[1]

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Indianpoint Creek (00-6300-240)

•6% of the total watershed consists of old logging (pre 1982), and an additional 36% has been recently harvested. No further harvesting was proposed prior to 1998.[1] Washouts of roads and bridges along logging roads have occurred and there are numerous unstable slopes with small failures.[1]

•The naturalized summer 7-day mean low flow is 44% of the mean annual flow.[1]

•The potential August and September water demand for industrial use is 3% of the naturalized summer 7-day mean low flow.[1]

•Other: Riparian vegetation has been removed from the lower section.[1]

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Kruger Creek (00-6300-240-050)

•6% of the total watershed consists of older logging (pre 1982), and an additional 37% has been recently harvested. No additional harvesting was proposed prior to 1998.[1] Washouts of roads and bridges along logging roads have occurred and there are numerous unstable slopes with small failures.[1]

•The naturalized summer 7-day mean low flow is 43% of the mean annual flow.[1]

•No licenses have been issued.[1]

•Other: Riparian vegetation has been removed from the lower section.[1]

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Antler Creek (00-6300-310)

•4% of the total watershed consists of older logging, and 6% of recent logging. An additional 4% was proposed prior to 1998 for timber harvesting. Road building on the floodplain and logging activities are affecting the stream.[1]

•The naturalized summer 7-day mean low flow is 44% of the mean annual flow.[1]

•The potential August and September water demand for domestic and industrial uses is less than 1% of the naturalized summer 7-day mean low flow.[1]

•Other: Placer mining causes sediment loading which degrades water quality. All the tributaries to the valley have been mined at one time and there are unstable areas along the channels because of old hydraulic mining operations.[1]

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Kenneth Creek (00-6425)

•65% of the total watershed was logged prior to 1982, and an additional 12% has been recently harvested.[1] Logging of another 2.3% was proposed prior to 1998.[1] Logging has resulted in removal of much riparian vegetation. Regeneration is occurring in some areas.[1] The stream channel has been destabilized in mid and upper reaches, and washouts have occurred along roads and stream crossings.[6]

•The naturalized summer 7-day mean low flow is 17% of the mean annual flow.[1] Summer low flows may limit fish access to habitat.[18]

•No licenses have been issued.[1]

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Hungary Creek (00-6500)

•29% of the total watershed was logged prior to 1982, and another 7% has been recently harvested.[1] Logging of another 5% of the watershed was proposed prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1] The creek has a flashy hydrologic regime.[18]

•No licenses have been issued.

•Other: Riparian vegetation has been removed from the lower section.[2]

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Slim Creek (00-6600)

•9% of the total watershed was logged prior to 1982, and an additional 10% has been recently harvested.[1] Logging of another 1.6% of the watershed was proposed prior to 1998.[1] Upstream of use by anadromous salmon, cross-stream yarding, logging and blowdown have filled the channel with sediment. The stream now flows sub-gravel during dry periods.[1] Roads and road cutbanks have been the main sources of sediment to the stream though some sources have healed or been repaired.

•The naturalized summer 7-day mean low flow is 21% of the mean annual flow.[1]

•No licenses have been issued.[1]

•Other: High summer water temperatures are problematic for salmonids. Riparian vegetation has been removed from the lower section.[1]

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Everet Creek

•6% of the total watershed was logged prior to 1982, and an additional 16% was recently harvested.[1] Another 3% was proposed for harvest prior to 1998.[1] Logging resulted in some loss of riparian vegetation.[1]

•No information was available to assess stream flow.

•No licenses have been issued.[1]

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Dome Creek (00-6660)

•Farming in the lower reaches has resulted in some localized impacts to the riparian zone.[18]

•3% of the total watershed was logged prior to 1982, and an additional 8% was recently harvested.[1] Logging of another 3% was proposed prior to 1998.[1] Riparian areas have been extensively cleared in the upper reaches.[18]

•The naturalized summer 7-day mean low flow is 22% of the mean annual flow.[1]

•The potential August and September water demand for industrial use is less than 1% of the naturalized summer 7-day mean low flow.[1]

•Other: The stream has a flashy hydrologic regime. It has been channelized and dyked through the town of Dome Creek and there are on-going problems because of deposition in its alluvial fan.[1] Linear developments including a railway, Highway 16, and stream crossings are collectively of high concern.[18]

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Torpy River (00-6700)

•6% of the total watershed consists of old logging and 2.5% has been recently logged.[1] Harvesting of an additional 4% of the watershed was proposed for by 1998.[1] Most activity has been concentrated in the upper watershed, where about 30% has been harvested, resulting in concerns for this area. A severe hemlock looper infestation has led to extensive salvage logging in the lower watershed.[18] Logging and road crossings of tributary streams have increased suspended sediment loads and silted spawning areas.[1]

•The naturalized summer 7-day mean low flow is 21% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** Several slope failures occurred in 1994.[1] There are extensive logging roads and numerous stream crossings resulting in localized impacts.[18]

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Walker Creek (00-6700-030)

•6% of the total watershed has been logged, including 1% which was recently harvested.[1] Most of the logging has been in the lower valley. No further logging was proposed prior to 1998.[1] A hemlock looper infestation has resulted in intensive salvage logging.[22]

•The naturalized summer 7-day mean low flow is 22% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** There are heavy lacustrine deposits in the lower reaches.[6]

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West Torpy River (00-6700-100)

•1% of the total watershed has been logged, and 5% was proposed for harvest prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** The river originates in a large swamp and is humic stained.[2]

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Ptarmigan Creek (00-6710)

•14% of the total watershed has been logged, including 7% which was recently harvested.[1] No further logging was proposed prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]

•No licenses have been issued.

•**Other:** Occasional high fall flows produce high suspended sediment levels in the lower creek. CN Rail has diverted part of the creek to prevent flooding of its quarry adjacent to the creek.[1] A small "run of the river" hydro project and a constructed chinook spawning channel are present.[2]

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Snowshoe Creek (00-6782)

•Agricultural activity occurs in the lower reaches.[2] There was not enough information to assess the effect it may have on water quality.

•4% of the total watershed has been recently logged, and an additional 7% was proposed for harvest prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]

•The potential August and September water demand for domestic use is less than 1% of the naturalized summer 7-day mean low flow.[1]

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Morkill River (00-6800)

•1% of the total watershed has been logged, and an additional 4% was proposed for harvest prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 21% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** The river is cold and experiences flashy flows and a high suspended sediment load during rainstorm floods and snowmelt freshet.[1] Riparian vegetation has been removed along some river reaches. There are extensive soil and slope instability problems associated with the development of roads and crossings.[22]

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Hellroaring Creek

•Logging of 5% of the watershed was proposed by 1998.[1]

•No information was available to assess stream flow.[1]

•No licenses have been issued.[1]

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Forget-me-not Creek

- 3% of the watershed was proposed for harvest prior to 1998.[1]
- No information was available to assess stream flow.
- No licenses have been issued.[1]

Cushing Creek

- 3% of the total watershed has been recently logged, and an additional 7.5% was proposed for harvest prior to 1998.[1]
- No information was available to assess stream flow.
- No licenses have been issued.[1]

Goat River (00-6900)

- 5% of the total watershed has been logged, including 4% which was recently harvested. An additional 1% was proposed for logging prior to 1998.[1]
- The naturalized summer 7-day mean low flow is 21% of the mean annual flow.[1]
- No licenses have been issued.

- **Other:** The river is cold and suspended sediment concentrations are high during freshet and during rainstorms.[1]

Killian Creek

- 41% of the total watershed has been logged, including 39% recent logging activity. No further harvesting was proposed prior to 1998.[1]
- No information was available to assess stream flow.
- No licenses for water withdrawals have been issued.[1]

Kendall Creek

- No information was available to assess stream flow.
- No licenses for water withdrawals have been issued.[1]

- **Other:** No logging has occurred and none was planned prior to 1998.[1]

Milk River (00-6900-060)

- 5% of the total watershed has been logged recently, and another 2% was proposed for harvest prior to 1998.[1]
- The naturalized summer 7-day mean low flow is 22% of the mean annual flow.[1]
- No licenses have been issued.[1]

North Star Creek

- No information was available to assess stream flow.
- No licenses have been issued.[1]

- **Other:** No logging has occurred and none was planned prior to 1998.[1]

East Twin Creek (00-6950)

- Some agricultural activity is present.[3] There was not enough information to assess the effect it may have on water quality.
- 2% of the total watershed was logged prior to 1982 and 4% has been recently harvested. Logging of an additional 2% was planned prior to 1998.[1]
- The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]
- No licenses have been issued.

West Twin Creek (00-6955)

- Some agricultural activity is present.[3] There was not enough information to assess the effect it may have on water quality.
- 7% of the total watershed has been logged, including 4% from recent activity. No further harvesting was proposed prior to 1998.[1]
- The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]
- The potential August and September water demand for domestic use is less than 1% of the naturalized summer 7-day mean low flow.[1]

McKale River (00-7000)

- Grazing occurs in the area.[3] There was not enough information to assess the effect it may have on water quality.

•Older logging (prior to 1982) occurred in 1.5% of the total watershed, and an additional 3% has been recently harvested. Another 1.5% of the watershed was scheduled for logging prior to 1998.[1] Logging and road encroachments have impacted lower river reaches.[1]

•The naturalized summer 7-day mean low flow is 32% of the mean annual flow.[1]

•No licenses have been issued.[1]

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Holmes River (00-7200)

•Farming and ranching operations are located in the flat bottom valley lands.[3] There was not enough information to assess the effect they may have on water quality.

•Ministry of Forests records indicate that 7% of the total watershed has been logged, and that there is 4% recent or proposed activity. Others report extensive logging in the watershed.[3]

•The naturalized summer 7-day mean low flow is 21% of the mean annual flow.[1]

•No licenses have been issued.[1]

•**Other:** Some trees along the stream have blown down and been removed. Large ice fields drain from the upper reaches, and contribute to high suspended sediment levels and variable discharges.

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Chalco Creek

•5% of the total watershed has been logged, including 4% recent logging activity. No further logging was planned prior to 1998.[1]

•No information was available to assess stream flow.

•No licenses have been issued.[1]

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Nevin Creek (00-7500)

•Less than 1% of the total watershed has been logged recently, and no further harvesting was planned prior to 1998.[1]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[1]

•The potential August and September water demand for domestic and industrial uses is <1% of the naturalized summer 7-day mean low flow.[1]

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Horsey Creek (00-7700)

•Farming and ranching operations are located in the watershed, and negatively affect the creek.[1]

•2% of the total watershed has been logged, including less than 1% recent activity. No further harvesting was proposed prior to 1998. The creek has been negatively affected by logging.[1]

•The naturalized summer 7-day mean low flow is 22% of the mean annual flow.[1]

•The potential August and September water demand for irrigation use is 1% of the naturalized summer 7-day mean low flow.[1]

•**Other:** Road encroachments are affecting the creek.[1]

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McLennan River (00-8200)

•There is some agricultural activity in the watershed,[3] but no information was available to assess the effect it may have on water quality.

•4% of the total watershed has been logged, including 2% from recent or proposed activity.[1]

•The naturalized summer 7-day mean low flow is 45% of the mean annual flow.[1]

•The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 2% of the naturalized summer 7-day mean low flow.[1]

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Hogan Creek

•Licenses for irrigation withdrawals indicate agricultural activity,[1] but no further information was available for assessing implications.

•11% of the total watershed has been logged, including 6% recent activity. No further harvesting was proposed prior to 1998.[1]

•No information was available to assess stream flow.

•Water demand is for domestic and irrigation uses.[1]

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Swift Creek (00-8200-050)

•Between 1 and 4 measurements of pH, non-filterable residue, fecal coliform, dissolved ammonia and metals in surface water were reported. The single measures of both copper and chromium exceeded the guidelines.

•Cranberry Marsh, the receiving water body for the Valemount STP (P05955), drains into Swift Creek. Near the marsh outlet, 10 of 13 ammonia and 12 of 13 phosphorus values exceeded the guidelines. Near the STP outfall, the maximum values measured were 7.88 $mg \cdot L^{-1}$ ammonia-N and 5.35 $mg \cdot L^{-1}$ phosphorus. At the marsh outlet, the maximum values were 2.23 $mg \cdot L^{-1}$ ammonia-N and 3.17 $mg \cdot L^{-1}$ phosphorus. Both of these ammonia values exceeded the 30-day criteria for total ammonia for any temperature at the pH range measured at the site, and may at times exceed the maximum concentration of total ammonia-N for the protection of aquatic life.

- The town of Valemount is located in the watershed. There was not enough information to assess the effect it may have on water quality aside from the STP discharge.

- Water quality concerns associated with agricultural and rural development are reported.[3]

- 2% of the total watershed has been logged, including 1% recent activity. No further harvesting was planned prior to 1998.[1]

- The naturalized summer 7-day mean low flow is 25% of the mean annual flow.[1]

- The potential August demand for domestic, irrigation, waterworks and industrial uses is 7% of the naturalized summer 7-day mean low flow.[1] Storage accounts for 11% of the irrigation water demand.[1]

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Table 7.2.1 Summary of Permitted Discharges to Surface Water in the Upper Fraser HMA.[1]

Record Id	Facility	Waste Type	Waste Num	Maximum Flow	Receiving Water Body
P00076	INTERCONTINENTAL & PG PULP MILLS AT PRINCE GEORGE	STP	01	432 $m^3 \cdot d^{-1}$	FRASER RIVER
P00112	PULP MILL AT PRINCE GEORGE[3]	STP	01	145 $m^3 \cdot d^{-1}$	SLOUGH - FRASER RIVER
P00146	PRINCE GEORGE LANSDOWNE STP	STP	01	45,000 $m^3 \cdot d^{-1}$	FRASER RIVER
P00157	PULP MILL AT PRINCE GEORGE[2]	Proc.	01	190,000 $m^3 \cdot d^{-1}$	FRASER RIVER
P00157	PULP MILL AT PRINCE GEORGE[2]	Cool.	02	28,000 $m^3 \cdot d^{-1}$	FRASER RIVER
P00190	CHEMICAL PLANT AT PRINCE GEORGE	Cool.	01	6,500 $m^3 \cdot d^{-1}$	FRASER RIVER
P00201	PETROLEUM REFINERY AT PRINCE GEORGE	Proc.	01	275 $m^3 \cdot d^{-1}$	LAND - PRINCE GEORGE
P00254	H2SO4, ALUM, SO2 PLANT AT PRINCE GEORGE	Proc.	03	100 $m^3 \cdot d^{-1}$	FRASER RIVER
P00402	STP AT MCBRIDE	STP	01	750 $m^3 \cdot d^{-1}$	FRASER RIVER
P01763	PRINCE GEORGE REGIONAL CORRECTIONAL CENTRE	STP	01	100 $m^3 \cdot d^{-1}$	FRASER RIVER
P02655	STP AT UPPER FRASER	STP	01	273 $m^3 \cdot d^{-1}$	FRASER RIVER
P03868	STP AT BLACKBURN	STP	01	1,375 $m^3 \cdot d^{-1}$	FRASER RIVER
P03900	PRINCE GEORGE PULP & PAPER[2]	Proc.	01	240,000 $m^3 \cdot d^{-1}$	FRASER RIVER
P04337	STP AT WELLS	STP	01	273 $m^3 \cdot d^{-1}$	WILLOW RIVER
P04905	STP AT DANSON INDUSTRIAL PARK, PRINCE GEORGE	STP	01	1,000 $m^3 \cdot d^{-1}$	FRASER RIVER
P05032	BUCKHORN SCHOOL & FIREHALL, PRINCE GEORGE	STP	01	8,405 $m^3 \cdot y^{-1}$	TABOR CREEK
P05132	STP AT BCR INDUSTRIAL SITE, PRINCE GEORGE	STP	01	936 $m^3 \cdot d^{-1}$	FRASER RIVER
P05955	STP AT CRANBERRY MARSH, VALEMOUNT[4]	STP	01	800 $m^3 \cdot d^{-1}$	CRANBERRY MARSH
P06272	SALMON VALLEY SCHOOL	STP	01	275 $m^3 \cdot d^{-1}$	SALMON RIVER
P06298	STP 3 Km NORTH OF BARKERVILLE	STP	01	181 $m^3 \cdot d^{-1}$	WILLIAMS CREEK - BARKERVILLE
P07385	HATCHERY AT RANKIN CREEK, PENNY	Proc.	01	700 $m^3 \cdot d^{-1}$	RANKIN CREEK
P09033	H202 PLANT AT PRINCE GEORGE	Proc.	01	7,700 $m^3 \cdot d^{-1}$	FRASER RIVER

[1] Data were summarized from a 1994 version of the Environment Canada Effluent Point Source Inventory and Database for the Fraser River Basin (see reference 2).

[2] These discharges are of concern due to the high temperature of effluent (up to 38°C) when it is discharged to the Fraser River.

[3] This discharge may be of concern as it appears to be released to a slough, rather than the main river current.

[4] This discharge may be of concern as receiving environment data indicate elevated levels of ammonia and phosphorus at the marsh outlet.

Table 7.2.2a Summary of Daily Contaminant Loading* to Surface Water in the Upper Fraser HMA (kg•d^{-1} except where noted).

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading
Ammonia	1	8.5	-	-	-	-	-	-	-	-
Bio. LC50:Rainbow Tr [1]	2	na	-	-	-	-	-	-	-	-
Bioassay (Pass/Fail) [1]	-	-	1	na	-	-	-	-	-	-
Biochemical Oxygen Demand	5	23,823	-	-	-	-	14	3,404	-	-
Carbon Total Organic	1	269.5	-	-	-	-	-	-	-	-
Chlorine Res:Total	1	0.77	-	-	-	-	-	-	-	-
Coliform - Fecal	-	-	-	-	-	-	2	22	-	-
Cyanide S.A.D.	1	0.06	-	-	-	-	-	-	-	-
Hydrogen Peroxide	1	385	-	-	-	-	-	-	-	-
Lead	1	0.06	-	-	-	-	-	-	-	-
Nitrogen Amm. Total	1	0.35	-	-	-	-	-	-	-	-
Nitrogen NO_2 Diss (N)	1	0.07	-	-	-	-	-	-	-	-
Nitrogen NO_3 Total	1	1.05	-	-	-	-	-	-	-	-
Oil & Grease	1	5.23	-	-	-	-	-	-	-	-
Organo-Chlorines [2]	2	na	-	-	-	-	-	-	-	-
Oxygen Dissolved [3]	1	na	-	-	-	-	1	na	-	-
pH [a]	5	na	-	-	-	-	1	na	-	-
Phosphate-Soluble	1	0.65	-	-	-	-	-	-	-	-
Phosphorous Total	1	0.21	-	-	-	-	-	-	-	-
Residue Nonfilt.	4	5.5	-	-	-	-	14	2,780	-	-
Specific Conductance	-	-	1	na	-	-	-	-	-	-
Sulphide Total	1	0.14	-	-	-	-	-	-	-	-
Temperature ^	3	na	2	na	-	-	-	-	-	-

na = not applicable

[1] minimum requirement of 100% survival

[2] maximum concentration not specified

[3] minimum requirement for dissolved oxygen varies from 2.0 to 5.5 mg/L

[a] requirement for pH is within range of 6.5 to 8.5

^ requirement for maximum temperature varies from 30°C to 38°C

* loadings are calculated from permit data in Environment Canada's Fraser River Point Source Inventory and Database. (see refence 7).

Table 7.2.2b Summary of Annual Contaminant Loading* to Surface Water in the Upper Fraser HMA ($kg \bullet yr^{-1}$ except where noted).

	Processing		**Cooling**		**Stormwater**		**Sewage Treatment**		**Leachate**	
	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Daily Loading	# of Facilities	Annual Loading	# of Facilities	Daily Loading
Ammonia	1	3,102	-	-	-	-	-	-	-	-
Bio. LC50:Rainbow Tr [1]	3	na	-	-	-	-	-	-	-	-
Bioassay (Pass/Fail) [1]	-	-	1	na	-	-	-	-	-	-
Biochemical Oxygen Demand	5	8,925,265	-	-	-	-	14	1,232,444	-	-
Carbon Total Organic	1	98,368	-	-	-	-	-	-	-	-
Chlorine Res:Total	1	281	-	-	-	-	-	-	-	-
Coliform - Fecal	-	-	-	-	-	-	2	6,093	-	-
Cyanide S.A.D.	1	20	-	-	-	-	-	-	-	-
Hydrogen Peroxide	1	140,525	-	-	-	-	-	-	-	-
Lead	1	20	-	-	-	-	-	-	-	-
Nitrogen Amm. Total	1	128	-	-	-	-	-	-	-	-
Nitrogen NO_2 Diss (N)	1	26	-	-	-	-	-	-	-	-
Nitrogen NO_3 Total	1	383	-	-	-	-	-	-	-	-
Oil & Grease	1	1,907	-	-	-	-	-	-	-	-
Organo-Chlorines [2]	2	na	-	-	-	-	-	-	-	-
Oxygen Dissolved [3]	1	na	-	-	-	-	1	na	-	-
pH [a]	5	na	-	-	-	-	1	na	-	-
Phosphate-Soluble	1	237	-	-	-	-	-	-	-	-
Phosphorous Total	1	77	-	-	-	-	-	-	-	-
Residue Nonfilt.	5	58,218	-	-	-	-	14	1,003,086	-	-
Specific Conductance	-	-	1	na	-	-	-	-	-	-
Sulphide Total	1	50	-	-	-	-	-	-	-	-
Temperature ^	3	na	2	na	-	-	-	-	-	-

na = not applicable
[1] minimum requirement of 100% survival
[2] maximum concentration not specified
[3] minimum requirement for dissolved oxygen varies from 2.0 to 5.5 mg/L
[a] requirement for pH is within range of 6.5 to 8.5
^ requirement for maximum temperature varies from 30°C to 38°C
* loadings are calculated from permit data in Environment Canada's Fraser River Point Source Inventory and Database.
(see refence 7).

Table 7.2.3 Comparison of Point Source Loadings with Estimated Non-point Source Loading from Urban Runoff of Selected Contaminants in the Upper Fraser HMA.

Parameter	Units	Loading from Point Sources[1] Total	Estimated Loading from Urban Runoff[2] Min	Max	Mean
Nonfilterable residues	tonnes•d^{-1}	2.76	7.47	30.79	19.13
Biological Oxygen Demand	tonnes•d^{-1}	27.2	0.37	2.87	1.62
Ammonia	kg•d^{-1}	8.5	0.00	164.23	82.12
Nitrate	kg•d^{-1}	1.05	12.70	244.27	128.48
N-total	kg•d^{-1}	na	112.03	410.57	261.30
P-total	kg•d^{-1}	0.21	22.40	82.10	52.25
Pb	kg•d^{-1}	0.06	7.47	41.07	24.27
Cu	kg•d^{-1}	na	1.50	10.27	5.88
Zn	kg•d^{-1}	na	7.47	41.07	24.27
Cr	kg•d^{-1}	na	0.37	3.07	1.72
Phenols	kg•d^{-1}	na	0.07	23.60	11.83
Oil and grease	kg•d^{-1}	5.23	224.10	6,363.57	3,293.83
PAH	kg•d^{-1}	na	0.03	2.47	1.25

[1] based on waste permits

[2] based on Stanley 1993, estimated for the City of Prince George (see reference 12).

Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
FRASER R AT STONER EAST OF MIDSTREAM							
Surface Water	pH (pH units)	51	0	0	7.5	8.3	7.9
	Fecal Coliforms (MPN/100mL)	24	8	4	2	1600	259
	Dissolved Ammonia-Nitrogen (mg/L)	40	21	10	0.005	0.050	0.016
	Total Phosphorus (mg/L)	14	2	0	0.024	0.161	0.053
	Total Chromium (mg/L)	7	7	0	0.010	0.020	0.013
	Total Copper (mg/L)	5	5	0	0.010	0.020	0.014
	Total Mercury (µg/L)	14	0	10	0.050	0.070	0.051
	Total Zinc (mg/L)	36	4	26	0.010	0.080	0.014
FRASER R AT STONER WEST OF MIDSTREAM							
Surface Water	pH (pH units)	8	0	0	7.9	8.2	8.0
	Fecal Coliforms (MPN/100mL)	5	2	0	23	1100	412
	Dissolved Ammonia-Nitrogen (mg/L)	5	1	2	0.005	0.014	0.008
	Total Chromium (mg/L)	2	2	0	0.010	0.020	0.015
	Total Zinc (mg/L)	8	0	6	0.010	0.020	0.011
Stoner							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	12	3	3	0.6	53.0	13.1
	2,4,6-Trichlorophenol (ng/g wet wt.)	5	0	3	1.0	24.0	8.2
	Pentachlorophenol (µg/g)	5	0	5	0.002	0.002	0.002
FRASER R 10 KM D/S OF P.G. SEWAGE DIS. WEST							
Surface Water	Fecal Coliforms (MPN/100mL)	3	0	0	110	140	130
Below Prince George							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	8	1	4	0.7	35.0	8.0
	2,4,6-Trichlorophenol (ng/g wet wt.)	6	0	4	1.0	9.5	3.1
	Pentachlorophenol (µg/g)	6	0	3	0.002	0.003	0.002
CANFOR PRINCE GEORGE PULP MILLS D/S							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	3	0	1	2.0	4.4	2.8
NORTHWOOD PULP & TIMBER D/S (PR GEORGE)							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	3	0	0	5.4	19.5	12.2
PRINCE GEORGE PULP MILLS U/S (HANSARD)							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	3	0	3	2.0	2.0	2.0
FRASER R AT HANSARD EAST SIDE CNR BRIDGE							
Surface Water	pH (pH units)	13	0	0	7.7	8.1	7.9
	Nonfilterable Residue (mg/L)	9	na	0	1	334	94
	Fecal Coliforms (MPN/100mL)	10	0	1	2	95	30
	Total Coliforms (MPN/100mL)	2	0	0	23	49	36
	Dissolved Ammonia-Nitrogen (mg/L)	13	4	4	0.005	0.078	0.013
	Total Phosphorus (mg/L)	13	3	0	0.006	0.214	0.052
	Total Copper (mg/L)	1	1	0	0.010	0.010	0.010
	Total Mercury (µg/L)	6	0	4	0.050	0.070	0.055

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Zinc (mg/L)	6	0	3	0.010	0.020	0.015
FRASER R AT HANSARD MIDSTREAM CNR BRIDGE							
Surface Water	pH (pH units)	14	0	0	7.5	8.0	7.8
	Fecal Coliforms (MPN/100mL)	3	0	2	2	33	12
	Dissolved Ammonia-Nitrogen (mg/L)	14	2	10	0.005	0.017	0.007
	Total Phosphorus (mg/L)	8	0	0	0.004	0.052	0.025
	Total Chromium (mg/L)	2	2	0	0.006	0.030	0.018
	Total Copper (mg/L)	4	4	0	0.010	0.020	0.015
	Total Mercury (µg/L)	7	0	5	0.050	0.060	0.051
	Total Lead (mg/L)	1	1	0	0.200	0.200	0.200
	Total Zinc (mg/L)	14	1	9	0.010	0.040	0.014
FRASER R AT HANSARD WEST SIDE CNR BRIDGE							
Surface Water	pH (pH units)	13	0	0	7.4	8.0	7.8
	Nonfilterable Residue (mg/L)	9	na	0	1	354	95
	Fecal Coliforms (MPN/100mL)	8	0	1	2	33	13
	Total Coliforms (MPN/100mL)	2	0	0	17	33	25
	Dissolved Ammonia-Nitrogen (mg/L)	13	4	5	0.005	0.032	0.009
	Total Phosphorus (mg/L)	13	3	0	0.005	0.239	0.051
	Total Mercury (µg/L)	6	0	5	0.050	0.070	0.053
	Total Zinc (mg/L)	6	0	4	0.010	0.020	0.012
Fraser River at Hansard							
Surface Water	Temperature (°C)	86	8	0	0	25	7
	pH (pH units)	183	-	0	5.4	8.3	7.8
	Nonfilterable Residue (mg/L)	199	na	18	1	893	50
	Fecal Coliforms (MPN/100mL)	151	0	28	1	126	8
	Total Nitrate/nitrite-Nitrogen (mg/L)	303	161	3	0.002	0.455	0.117
	Dissolved Ammonia-Nitrogen (mg/L)	167	20	101	0.005	0.165	0.008
	Total Phosphorus (mg/L)	304	45	7	0.002	0.750	0.056
	Total Arsenic (mg/L)	97	0	5	0.0001	0.010	0.001
	Total Cadmium (mg/L)	95	46	22	0.0001	0.003	0.0003
	Total Chromium (mg/L)	114	68	2	0.0002	0.045	0.005
	Total Copper (mg/L)	102	62	0	0.0004	0.250	0.008
	Total Mercury (µg/L)	86	0	51	0.005	0.050	0.009
	Total Lead (mg/L)	97	28	16	0.0002	0.023	0.002
	Total Zinc (mg/L)	139	14	23	0.0004	0.308	0.015
Hansard							
Fish Tissue	2,3,7,8-T4CDD (pg/g wet wt.)	6	0	6	0.4	1.8	1.1
	2,4,6-Trichlorophenol (ng/g wet wt.)	3	0	3	1.0	1.0	1.0
	Pentachlorophenol (µg/g)	3	0	3	0.002	0.002	0.002
Fraser River at Red Pass							
Surface Water	Temperature (°C)	103	1	0	-1	15	5
	pH (pH units)	107	-	0	6.1	8.2	8.0

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Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Nonfilterable Residue (mg/L)	104	na	103	5	10	9
	Total Nitrate/nitrite-Nitrogen (mg/L)	318	10	4	0.002	0.311	0.071
	Total Phosphorus (mg/L)	319	3	79	0.002	0.116	0.005
	Total Arsenic (mg/L)	100	0	36	0.0001	0.0003	0.0001
	Total Cadmium (mg/L)	99	1	86	0.0001	0.0002	0.0001
	Total Chromium (mg/L)	99	14	22	0.0002	0.017	0.001
	Total Copper (mg/L)	99	11	1	0.0002	0.081	0.003
	Total Mercury (µg/L)	92	0	57	0.005	0.068	0.010
	Total Lead (mg/L)	99	0	67	0.0002	0.002	0.000
	Total Zinc (mg/L)	99	1	4	0.0002	0.057	0.002
<u>TABOR UNNAMED CK (PUMPHOUSE) END LAKEVIEW RD.</u>							
Surface Water	Fecal Coliforms (MPN/100mL)	17	5	1	2	1600	189
	Total Phosphorus (mg/L)	17	5	0	0.039	0.125	0.074
<u>TABOR MT. CREEK ROAD CROSSING AT GROVEBURN RD</u>							
Surface Water	Fecal Coliforms (MPN/100mL)	16	0	9	1	29	4
	Total Phosphorus (mg/L)	19	0	0	0.003	0.010	0.006
<u>TABOR LAKE NORTH STATION</u>							
Surface Water	pH (pH units)	18	0	0	7.7	8.0	7.9
	Dissolved Ammonia-Nitrogen (mg/L)	15	5	6	0.005	0.021	0.009
	Total Phosphorus (mg/L)	75	54	0	0.006	0.109	0.021
<u>TABOR UNNAMED CK (3 CULVERT) ON GROVEBURN RD.</u>							
Surface Water	Fecal Coliforms (MPN/100mL)	16	0	4	1	46	8
	Total Phosphorus (mg/L)	16	0	0	0.016	0.059	0.027
<u>TABOR CULVERT AT SONS OF NORWAY PICNIC GROUND</u>							
Surface Water	Fecal Coliforms (MPN/100mL)	20	2	2	1	570	70
	Total Phosphorus (mg/L)	22	4	0	0.021	0.175	0.066
<u>SALMON R AT HWY 97 BRIDGE</u>							
Surface Water	pH (pH units)	2	0	0	7.6	8.1	7.9
	Fecal Coliforms (MPN/100mL)	1	0	1	2	2	2
	Dissolved Ammonia-Nitrogen (mg/L)	2	0	2	0.005	0.005	0.005
	Total Zinc (mg/L)	2	0	2	0.010	0.010	0.010
<u>WILLOW R.ABOVE SLOUGH CR.</u>							
Surface Water	pH (pH units)	14	0	0	7.4	8.3	7.9
	Nonfilterable Residue (mg/L)	17	na	0	1	319	25
	Fecal Coliforms (MPN/100mL)	17	0	2	2	12	6
	Total Coliforms (MPN/100mL)	16	0	1	2	216	58
	Dissolved Ammonia-Nitrogen (mg/L)	15	7	6	0.005	0.015	0.009
	Total Phosphorus (mg/L)	16	3	5	0.003	0.069	0.012
	Total Arsenic (mg/L)	17	0	12	0.001	0.009	0.002
	Total Chromium (mg/L)	1	1	0	0.008	0.008	0.008

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Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Copper (mg/L)	17	4	7	0.001	0.005	0.001
	Total Lead (mg/L)	17	2	9	0.001	0.013	0.002
	Total Zinc (mg/L)	17	0	13	0.005	0.021	0.007
Sediments	Total Chromium (μg/g)	1	1	0	35	35	35
	Total Copper (μg/g)	1	1	0	40	40	40
	Total Mercury (μg/g)	1	0	0	0.06	0.06	0.06
	Total Lead (μg/g)	1	0	0	18	18	18
	Total Zinc (μg/g)	1	0	0	112	112	112
WILLOW R. BELOW BRIDGE ON HARDSCRABBLE RD.							
Surface Water	pH (pH units)	1	0	0	7.9	7.9	7.9
	Fecal Coliforms (MPN/100mL)	1	0	0	110	110	110
	Total Coliforms (MPN/100mL)	1	1	0	350	350	350
	Total Phosphorus (mg/L)	1	1	0	0.029	0.029	0.029
WILLOW R. BELOW MOSQUITO CR.							
Surface Water	pH (pH units)	36	0	0	7.4	8.1	7.7
	Nonfilterable Residue (mg/L)	25	na	0	1	149	14
	Fecal Coliforms (MPN/100mL)	28	9	3	2	2000	236
	Total Coliforms (MPN/100mL)	24	9	0	8	14000	1648
	Dissolved Ammonia-Nitrogen (mg/L)	36	29	4	0.005	0.131	0.045
	Total Phosphorus (mg/L)	33	0	0	0.005	0.032	0.015
	Total Arsenic (mg/L)	17	0	11	0.001	0.004	0.001
	Total Cadmium (mg/L)	1	1	0	0.0006	0.0006	0.0006
	Total Chromium (mg/L)	3	3	0	0.005	0.006	0.006
	Total Copper (mg/L)	18	12	3	0.001	0.011	0.003
	Total Lead (mg/L)	15	5	6	0.001	0.009	0.002
	Total Zinc (mg/L)	18	1	11	0.005	0.120	0.013
Sediments	Total Arsenic (μg/g)	1	1	0	113	113	113
	Total Chromium (μg/g)	1	1	0	29	29	29
	Total Copper (μg/g)	1	1	0	38	38	38
	Total Mercury (μg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (μg/g)	1	1	0	34	34	34
	Total Zinc (μg/g)	1	1	0	121	121	121
WILLOW R. ABOVE MOSQUITO C.							
Surface Water	pH (pH units)	9	0	0	7.4	7.9	7.6
	Nonfilterable Residue (mg/L)	11	na	0	1	123	17
	Fecal Coliforms (MPN/100mL)	8	3	0	2	1600	440
	Total Coliforms (MPN/100mL)	8	5	0	33	6600	1909
	Dissolved Ammonia-Nitrogen (mg/L)	10	7	0	0.006	0.100	0.035
	Total Phosphorus (mg/L)	9	0	0	0.006	0.039	0.016
	Total Arsenic (mg/L)	11	0	3	0.001	0.004	0.001
	Total Chromium (mg/L)	2	2	0	0.005	0.005	0.005
	Total Copper (mg/L)	11	5	4	0.001	0.008	0.002
	Total Lead (mg/L)	11	3	7	0.001	0.009	0.002

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Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Zinc (mg/L)	11	0	8	0.005	0.012	0.006
Sediments	Total Arsenic (µg/g)	1	1	0	172	172	172
	Total Chromium (µg/g)	1	0	0	19	19	19
	Total Copper (µg/g)	1	1	0	29	29	29
	Total Mercury (µg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (µg/g)	1	0	0	25	25	25
	Total Zinc (µg/g)	1	0	0	84	84	84
WILLOW R. AT BRIDGE ON HWY 26							
Surface Water	pH (pH units)	28	0	0	7.0	8.0	7.4
	Nonfilterable Residue (mg/L)	12	na	0	1	34	8
	Fecal Coliforms (MPN/100mL)	23	0	17	1	130	9
	Total Coliforms (MPN/100mL)	22	1	5	2	350	32
	Dissolved Ammonia-Nitrogen (mg/L)	22	10	9	0.005	0.029	0.010
	Total Phosphorus (mg/L)	23	0	1	0.003	0.033	0.008
	Total Arsenic (mg/L)	21	0	9	0.001	0.008	0.002
	Total Chromium (mg/L)	5	5	0	0.005	0.020	0.011
	Total Copper (mg/L)	21	11	4	0.001	0.010	0.002
	Total Mercury (µg/L)	1	0	1	0.050	0.050	0.050
	Total Lead (mg/L)	21	9	6	0.001	0.013	0.003
	Total Zinc (mg/L)	22	1	17	0.005	0.120	0.012
Sediments	Total Arsenic (µg/g)	1	1	0	92	92	92
	Total Chromium (µg/g)	1	0	0	22	22	22
	Total Copper (µg/g)	1	1	0	32	32	32
	Total Mercury (µg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (µg/g)	1	1	0	31	31	31
	Total Zinc (µg/g)	1	0	0	112	112	112
WILLOW R. CONTROL NEAR JACK O CLUBS L.							
Surface Water	pH (pH units)	14	0	0	7.1	7.7	7.4
	Nonfilterable Residue (mg/L)	8	na	0	1	39	9
	Dissolved Ammonia-Nitrogen (mg/L)	3	0	2	0.005	0.008	0.006
	Total Phosphorus (mg/L)	3	0	1	0.003	0.003	0.003
	Total Arsenic (mg/L)	16	0	6	0.001	0.049	0.006
	Total Copper (mg/L)	16	9	2	0.001	0.006	0.002
	Total Mercury (µg/L)	1	0	1	0.050	0.050	0.050
	Total Lead (mg/L)	16	8	5	0.001	0.048	0.006
	Total Zinc (mg/L)	16	1	12	0.005	0.040	0.008
Sediments	Total Arsenic (µg/g)	1	1	0	2540	2540	2540
	Total Cadmium (µg/g)	1	1	0	1	1	1
	Total Chromium (µg/g)	1	0	0	8	8	8
	Total Copper (µg/g)	1	1	0	17	17	17
	Total Mercury (µg/g)	1	0	1	0.05	0.05	0.05
	Total Lead (µg/g)	1	1	0	317	317	317
	Total Zinc (µg/g)	1	0	0	65	65	65

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Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
MOSQUITO C. AT WILLOW R.							
Surface Water	pH (pH units)	3	0	0	7.5	8.3	8.0
	Nonfilterable Residue (mg/L)	3	na	0	2	188	64
	Dissolved Ammonia-Nitrogen (mg/L)	2	1	0	0.009	0.034	0.022
	Total Phosphorus (mg/L)	1	0	0	0.020	0.020	0.020
	Total Arsenic (mg/L)	11	0	8	0.001	0.030	0.005
	Total Cadmium (mg/L)	1	1	0	0.018	0.018	0.018
	Total Chromium (mg/L)	6	6	0	0.005	0.030	0.012
	Total Copper (mg/L)	11	8	2	0.001	0.080	0.012
	Total Lead (mg/L)	11	6	4	0.001	0.105	0.013
	Total Zinc (mg/L)	11	5	1	0.005	0.150	0.037
POOLEY ST. CULVERT, E. END, WELLS, B.C.							
Surface Water	pH (pH units)	9	0	0	6.9	8.2	7.4
	Nonfilterable Residue (mg/L)	2	na	0	6	15	11
	Fecal Coliforms (MPN/100mL)	2	0	1	2	5	4
	Total Coliforms (MPN/100mL)	2	0	1	2	11	7
	Dissolved Ammonia-Nitrogen (mg/L)	1	1	0	0.077	0.077	0.077
	Total Phosphorus (mg/L)	1	0	0	0.013	0.013	0.013
	Total Arsenic (mg/L)	10	0	2	0.001	0.008	0.003
	Total Chromium (mg/L)	1	1	0	0.005	0.005	0.005
	Total Copper (mg/L)	11	6	2	0.001	0.011	0.003
	Total Mercury (µg/L)	2	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	11	4	4	0.001	0.002	0.001
	Total Zinc (mg/L)	11	6	3	0.005	0.090	0.029
WILLIAMS C. ABOVE WELLS							
Surface Water	pH (pH units)	5	0	0	7.8	8.5	8.1
	Nonfilterable Residue (mg/L)	3	na	0	1	7	4
	Fecal Coliforms (MPN/100mL)	3	0	1	2	4	3
	Total Coliforms (MPN/100mL)	3	0	1	2	108	37
	Dissolved Ammonia-Nitrogen (mg/L)	4	1	3	0.005	0.013	0.007
	Total Phosphorus (mg/L)	5	0	0	0.003	0.040	0.014
	Total Arsenic (mg/L)	7	0	5	0.001	0.002	0.001
	Total Chromium (mg/L)	1	1	0	0.005	0.005	0.005
	Total Copper (mg/L)	7	3	0	0.001	0.006	0.003
	Total Lead (mg/L)	7	3	3	0.001	0.014	0.004
	Total Zinc (mg/L)	7	0	6	0.005	0.010	0.006
LOWHEE CK U/S ACID SEEPAGE							
Surface Water	pH (pH units)	5	0	0	7.8	8.3	8.1
	Total Arsenic (mg/L)	6	0	3	0.001	0.003	0.002
	Total Cadmium (mg/L)	1	1	0	0.005	0.005	0.005
	Total Chromium (mg/L)	2	2	0	0.005	0.050	0.028
	Total Copper (mg/L)	6	4	1	0.001	0.070	0.014
	Total Mercury (µg/L)	3	0	1	0.050	0.050	0.050
	Total Lead (mg/L)	5	2	2	0.001	0.050	0.011

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Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Zinc (mg/L)	6	1	4	0.005	0.150	0.030
SITE B, S.E. SEEPAGE TO LOWHEE CK.							
Surface Water	pH (pH units)	6	-	0	2.6	7.6	5.3
	Total Arsenic (mg/L)	7	3	3	0.001	1.020	0.238
	Total Cadmium (mg/L)	3	3	0	0.0008	0.0800	0.0403
	Total Chromium (mg/L)	2	2	0	0.007	0.017	0.012
	Total Copper (mg/L)	7	3	2	0.001	0.019	0.007
	Total Mercury (µg/L)	2	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	7	5	1	0.001	0.500	0.152
	Total Zinc (mg/L)	7	4	1	0.005	0.900	0.202
SITE A, E. SEEPAGE TO LOWHEE CK							
Surface Water	pH (pH units)	8	-	0	3.3	8.0	6.9
	Total Arsenic (mg/L)	11	3	1	0.001	0.194	0.054
	Total Cadmium (mg/L)	3	3	0	0.0006	0.0012	0.0009
	Total Chromium (mg/L)	4	4	0	0.005	0.011	0.007
	Total Copper (mg/L)	11	8	3	0.001	0.023	0.008
	Total Mercury (µg/L)	2	1	1	0.050	2.000	1.025
	Total Lead (mg/L)	11	8	2	0.001	0.500	0.130
	Total Zinc (mg/L)	11	7	4	0.005	0.540	0.140
LOWHEE CK U/S JACK OF CLUBS LAKE							
Surface Water	pH (pH units)	12	0	0	6.7	8.0	7.3
	Nonfilterable Residue (mg/L)	2	na	0	65	78	72
	Total Arsenic (mg/L)	14	1	5	0.001	0.063	0.013
	Total Cadmium (mg/L)	2	2	0	0.0006	0.009	0.005
	Total Chromium (mg/L)	4	4	0	0.005	0.023	0.011
	Total Copper (mg/L)	14	11	1	0.001	0.020	0.005
	Total Mercury (µg/L)	3	0	2	0.050	0.060	0.053
	Total Lead (mg/L)	12	7	3	0.001	0.050	0.011
	Total Zinc (mg/L)	14	8	4	0.005	0.130	0.043
ACID SEEPAGE TO JACK OF CLUBS LAKE							
Surface Water	pH (pH units)	8	-	0	2.8	7.0	5.6
	Nonfilterable Residue (mg/L)	1	na	0	64	64	64
	Total Arsenic (mg/L)	9	2	2	0.001	2.700	0.366
	Total Cadmium (mg/L)	3	3	0	0.001	0.070	0.024
	Total Chromium (mg/L)	2	2	0	0.009	0.012	0.011
	Total Copper (mg/L)	9	5	2	0.001	0.020	0.005
	Total Mercury (µg/L)	3	0	3	0.050	0.050	0.050
	Total Lead (mg/L)	9	7	1	0.001	0.500	0.139
	Total Zinc (mg/L)	9	4	0	0.005	0.330	0.083
JACK OF CLUBS LAKE AT NORTHEAST END							
Surface Water	pH (pH units)	2	0	0	7.4	7.6	7.5
	Dissolved Ammonia-Nitrogen (mg/L)	2	0	1	0.005	0.006	0.006

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Table 7.6.1a Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Upper Fraser HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Phosphorus (mg/L)	2	0	0	0.007	0.009	0.008
	Total Arsenic (mg/L)	2	0	2	0.001	0.001	0.001
	Total Chromium (mg/L)	1	1	0	0.005	0.005	0.005
	Total Copper (mg/L)	2	1	1	0.001	0.005	0.003
	Total Mercury (µg/L)	2	0	2	0.050	0.050	0.050
	Total Lead (mg/L)	2	2	0	0.002	0.002	0.002
	Total Zinc (mg/L)	2	0	0	0.005	0.005	0.005
SWIFT CK AT VALEMOUNT VILLAGE WATER INTAKE.							
Surface Water	pH (pH units)	4	0	0	7.5	8.0	7.8
	Nonfilterable Residue (mg/L)	4	na	0	1	2	1
	Fecal Coliforms (MPN/100mL)	4	0	4	2	2.2	2
	Dissolved Ammonia-Nitrogen (mg/L)	4	0	4	0.005	0.005	0.005
	Total Chromium (mg/L)	1	1	0	0.010	0.010	0.010
	Total Copper (mg/L)	1	1	0	0.010	0.010	0.010
	Total Zinc (mg/L)	2	0	1	0.010	0.020	0.015
CRANBERRY MARSH PE05955 IDZ							
Surface Water	pH (pH units)	9	0	0	6.8	7.6	7.2
	Nonfilterable Residue (mg/L)	1	na	0	13	13	13
	Fecal Coliforms (MPN/100mL)	9	4	1	2	9200	1473
	Dissolved Ammonia-Nitrogen (mg/L)	9	9	0	0.386	7.880	3.047
	Total Phosphorus (mg/L)	9	9	0	1.550	5.350	3.079
CRANBERRY MARSH OUTLET, VALEMOUNT							
Surface Water	pH (pH units)	13	0	0	7.0	8.6	7.6
	Fecal Coliforms (MPN/100mL)	7	1	1	2	220	55
	Dissolved Ammonia-Nitrogen (mg/L)	13	10	1	0.005	2.230	0.524
	Total Phosphorus (mg/L)	13	12	0	0.082	3.170	1.118

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 7.6.1b Summary of Contaminants Measured in Fish Tissue Collected by DOE-FRAP, 1994, from the Woodpecker and Hansard Reaches of the Upper Fraser HMA

Guidelines:			
	Total PCB	2 μg•g^{-1} dry wt.	(for the protection of aquatic life; B.C. MELP)
	Total T4CDD	20 μg•g^{-1} dry wt.	(for the protection of aquatic life; USEPA)
	Total Toxaphene	0.1 μg•g^{-1} dry wt.	(for the protection of aquatic life; Environment Canada)
	p,p'-DDE	5 μg•g^{-1} dry wt.	(for the protection of aquatic life; Environment Canada)

		Total PCB (ng/g)			Total T4CDD (pg/g)			Total O8CDD (pg/g)			Total T4CDF (pg/g)			Total O8CDF (pg/g)		
Species	Tissue	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max
Woodpecker																
Peamouth Chub	*Liver*	1	23.2	23.24	1	nd	nd	1	nd	nd	1	1.7	1.7	1	nd	nd
	Muscle	4	0.8	9.7	4	nd	0.1	4	nd	0.5	4	0.2	0.6	4	nd	nd
Mountain Whitefish	*Liver*	2	1.3	2.4	2	1.9	2.9	2	nd	nd	2	1.5	1.5	2	nd	nd
	Muscle	4	1.0995	7.1	5	nd	1.8	5	nd	0.6	5	0.3	2.2	5	nd	nd
Hansard																
Peamouth Chub	*Liver*	2	18.2	26.25	2	nd	nd	2	nd	nd	2	1.1	1.9	2	nd	nd
	Muscle	4	0.9	2.1	4	nd	nd	4	nd	1.8	4	nd	0.4	4	nd	nd
Mountain Whitefish	*Liver*	1	0.7	0.7	1	nd	nd	1	nd	nd	1	nd	nd	1	nd	nd
	Muscle	4	0.4	1.3	5	nd	nd	5	nd	nd	5	nd	nd	5	nd	nd

		p,p'-DDE (246) (ng/g)			Total Toxaphene (ng/g)			PCB #77 (ng/g)			PCB #126 (ng/g)			PCB #169 (ng/g)		
Species	Tissue	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max	n*	Min	Max
Woodpecker																
Peamouth Chub	*Liver*	1	4.8	4.8	1	21	21	1	1	16	1	2.7	2.7	1	nd	nd
	Muscle	4	nd	2.4	4	nd	2	4	4	48	4	0.45	1.3	4	nd	0.21
Mountain Whitefish	*Liver*	3	0.37	0.63	3	nd	2	2	2	12	2	0.52	0.76	2	nd	nd
	Muscle	5	0.38	2.4	5	0.58	8.2	4	4	2.2	4	0.45	0.66	4	0.42	0.62
Hansard																
Peamouth Chub	*Liver*	2	8.6	13	2	0.77	47	2	2	41	2	3.7	4.6	2	1.2	1.3
	Muscle	5	0.85	2	5	0.73	1.8	4	4	21	4	0.46	1.1	4	0.24	0.29
Mountain Whitefish	*Liver*	1	0.6	0.6	1	24	24	1	1	nd	1	nd	nd	1	nd	nd
	Muscle	4	0.58	1.4	4	0.95	2.8	4	4	1.2	4	0.23	0.43	4	0.42	0.45

n* is the number of composite samples. For the Woodpecker and Hansard reaches there are five fish per muscle composite and 15 - 33 fish per liver composite. Where n>4, the number includes the replicate analyses done by the analytical laboratory.

Where n=2 for liver samples, results include the paired laboratory duplicates.

nd = not detected

Table 7.6.2 Summary of Land Use Areas, Summer and Winter Low-flows, and Water Demand for the Upper Fraser HMA

					Naturalized Stream flow (L/s)			Potential August water demand (L/s)				
Stream	SISS code	Water-shed area (km sq.)	Total logged	Recent/proposed logging	Summer 7-day mean low-flow	Winter 7-day mean low-flow	Mean annual flow	Domestic	Irrigation	Water-works	Industrial	Storage (ac-ft)
Salmon R	00-5800	4,437	742	611	3,100	7,800	24,300	0.63	25.6		1	0
Lower Salmon R		3,159	620	490	-	-	-	0	0	0	0	0
Upper Salmon R		1,278	121	121	-	-	-	0	0	0	0	0
Willow R	00-5900	2,875	1,292	689	9,830	7,370	36,500	0.24	2.63	0	7.34	0
Wansa Ck	00-5900-070	293	170	47	780	850	4,490	0	0	0	0	0
McGregor R	00-6200	5,550	379	379	95,000	950	209,000	0	0	0	0	0
Seebach Ck	00-6200-020	421	8	46	1,120	1,220	6,460	0	0	0	0	0
Horn Ck	00-6200-020-010	66	3	8	180	190	1,010	0	0	0	0	0
East Seebach Ck	00-6200-020-020	160	3	15	430	460	2,450	0	0	0	0	0
Otter Ck	00-6200-060	167	7	22	1,580	450	6,980	0	0	0	0	0
Herrick Ck	00-6200-070	2,058	18	55	17,470	5,930	86,000	0	0	0	0	0
Captain Ck	00-6200-070-020	135	7	11	1,290	360	5,640	0	0	0	0	0
James Ck	00-6200-070-030	116	4	0	1,110	310	4,850	0	0	0	0	0
Fontoniko Ck	00-6200-070-050	321	0	0	2,950	880	13,400	0	0	0	0	0
Spakwaniko Ck	00-6200-070-070	190	1	0	1,780	510	7,940	0	0	0	0	0
Farmstead Ck		465	4	12	-	-	-	0	0	0	0	0
Muller Ck		134	1	6	-	-	-	0	0	0	0	0
Olivington Ck		75	0	0	-	-	-	0	0	0	0	0
Upper Herrick Ck		207	3	5	-	-	-	0	0	0	0	0
Bowron R	00-6300	3,600	1,385	994	21,700	15,500	63,400	0.32	0.11	0	99.6	0
Haggen Ck	00-6300-210	649	787	269	5,770	3,510	13,300	0	0	0	0	0
Indianpoint Ck	00-6300-240	396	166	143	3,520	2,040	8,090	0	0	0	97.7	0
Kruger Ck	00-6300-240-050	113	49	42	1,000	610	2,310	0	0	0	0	0
Antler Ck	00-6300-310	359	35	35	3,190	1,940	7,340	0.080	0	0	0.39	0
Kenneth Ck	00-6425	216	155	25	580	630	3,310	0	0	0	0	0
Hungary ck	00-6500	96	34	12	930	250	4,010	0	0	0	0	0
Slim Ck	00-6600	856	168	97	7,540	2,400	35,800	0	0	0	0	0
Everet Ck		156	35	31	-	-	-	0	0	0	0	0
Dome Ck	00-6660	273	30	30	2,520	740	11,400	0	0	0	0.320	0
Torpy R	00-6700	1,285	121	81	11,130	3,650	53,700	0	0	0	0	0
Walker Ck	00-6700-030	364	20	3	3,320	1,000	15,200	0	0	0	0	0
Upper Torpy R		102	30	20	-	-	-	0	0	0	0	0
West Torpy R	00-6700-100	168	1	9	1,580	450	7,020	0	0	0	0	0

					Naturalized Stream flow (L/s)			Potential August water demand (L/s)				
Stream	SISS code	Water-shed area (km sq.)	Total logged	Recent/proposed logging	Summer 7-day mean low-flow	Winter 7-day mean low-flow	Mean annual flow	Domestic	Irrigation	Water-works	Industrial	Storage (ac-ft)
Ptarmigan Ck	00-6710	183	25	12	1,720	490	7,650	0	0	0	0	0
Snowshoe Ck	00-6782	100	4	11	960	260	4,180	0	0	0	0	0
Morkill R	00-6800	1,333	14	70	11,530	3,790	55,700	0	0	0	0	0
Hellroaring Ck		72	0	4	-	-	-	0	0	0	0	0
Forget-me-not Ck		388	0	13	-	-	-	0	0	0	0	0
Cushing Ck		164	6	17	-	-	-	0	0	0	0	0
Goat R	00-6900	661	31	31	5,890	1,840	27,600	0	0	0	0	0
Killian Ck		11	5	4	-	-	-	0	0	0	0	0
Kendall Ck		28	0	0	-	-	-	0	0	0	0	0
Milk R	00-6900-060	191	9	13	1,790	510	7,970	0	0	0	0	0
North Star Ck		100	0	0	-	-	-	0	0	0	0	0
McLeod Ck		82	0	0	-	-	-	0	0	0	0	0
East Twin Ck	00-6950	128	7	7	1,220	340	5,350	0	0	0	0	0
West Twin Ck	00-6955	174	14	8	1,640	470	7,270	0	0	0	0	0
McKale R	00-7000	280	10	10	2,700	1,050	8,380	0	0	0	0	0
Holmes R	00-7200	785	53	30	6,940	2,200	32,800	0	0	0	0	0
Chalco Ck		179	10	8	-	-	-	0	0	0	0	0
Nevin Ck	00-7500	137	0	0	1,300	360	5,730	0.13	0	0	3.9	0
Horsey Ck	00-7700	201	1	0	1,880	540	8,400	0	10.4	0	0	0
McLennan R	00-8200	396	31	16	6,500	4,640	14,500	0.45	72.4	19.46	4.1	0
Hogan Ck		14	2	1	-	-	-	0	20.7	0	0	0
Swift Ck	00-8200-050	135	3	2	810	320	3,190	0.21	30.5	19.46	3.26	25

* Recent logging occurred from 1983-1992, and proposed logging estimates were based on MOF logging plans for 1993-1998.

[1] Adapted from Rood and Hamilton, 1995 (see reference 1)

Table 7.6.3 Summary of Red-coded Indicators[1] for Streams in the Upper Fraser HMA

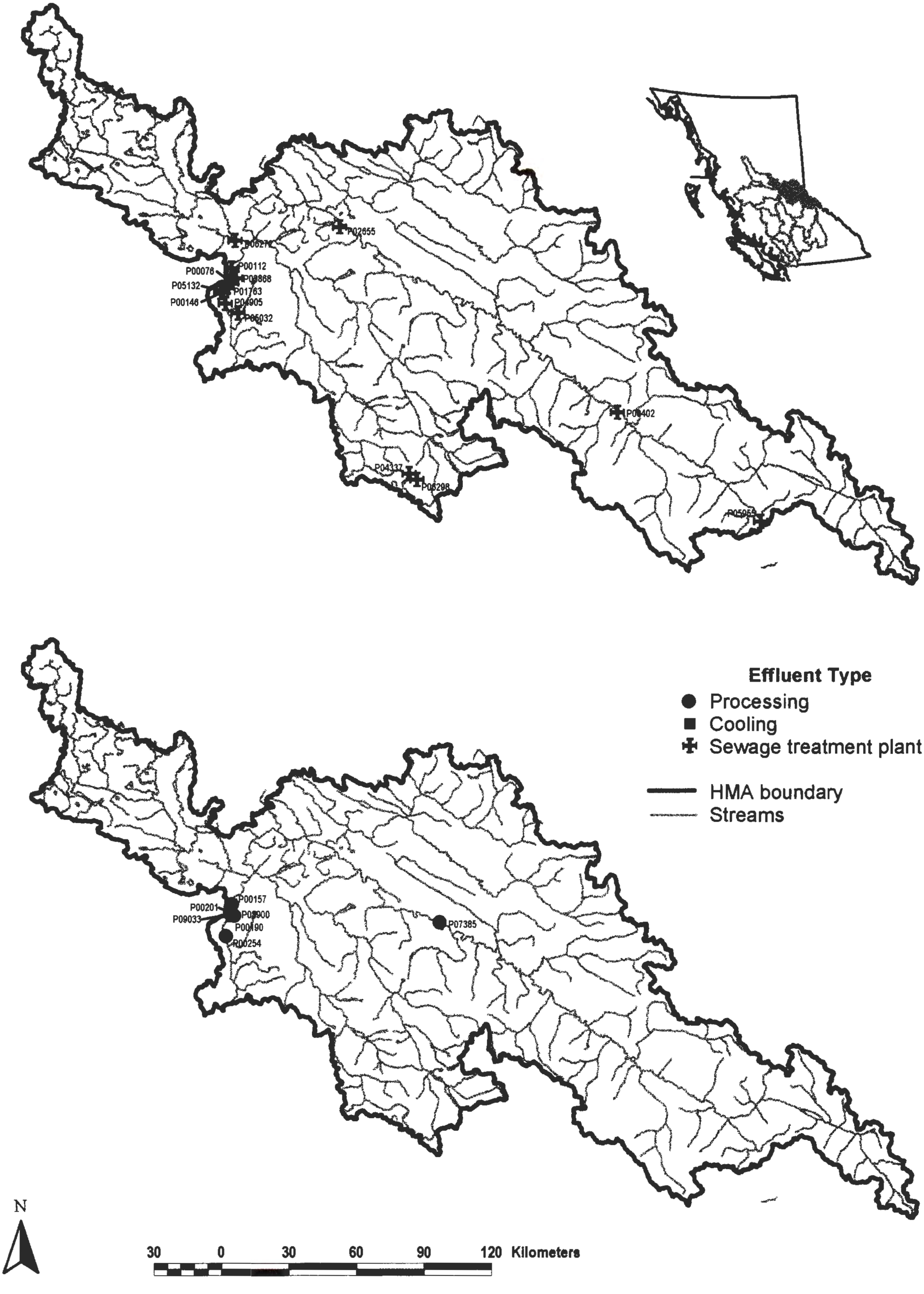
Stream Name	Indicator				
	Urban	Agriculture	Logging	Stream Flow	Demand
Fraser River	*				
Salmon River			*	*	
Willow River		*	*		
Wansa Creek			*	*	
McGregor River			*		
Seebach Creek					
Horn Creek					
East Seebach Creek					
Otter Creek					
Herrick Creek					
Captain Creek				*	
James Creek					
Fontoniko Creek					
Spakwaniko Creek					
Bowron River			*		
Haggen Creek			*		
Indianpoint Creek			*		
Kruger Creek			*		
Antler Creek			*		
Kenneth Creek			*		
Hungary Creek			*		
Slim Creek			*		
Everet Creek[2]			*		
Dome Creek					
Torpy River			*		
Walker Creek					
Upper Torpy River			*		
West Torpy River					
Ptarmigan Creek					
Snowhoe Creek					
Morkill River					
Hellroaring Creek[2]					
Forget-me-not Creek[2]					
Cushing Creek[2]					
Goat River					
Killian Creek[2]			*		
Kendall Creek[2]					
Milk River					
North Star Creek[2]					
East Twin Creek					
West Twin Creek					
McKale River			*		
Homes River					
Chalco Creek[2]					

Stream Name	Indicator				
	Urban	Agriculture	Logging	Stream Flow	Demand
Nevin Creek					
Horsey Creek		*			
McLennan River					
Hogan Creek[2]					
Swift Creek		*			

[1] "Red-coded" = likely to have water quality impacts associated with given land use, stream flow, or water demand conditions in the stream. See Chapter 3 for assessment methodology.

[2] Streams do not directly support anadromous salmon.

Figure 7.2.1 Location of Permitted Waste Discharges to Surface Water in the Upper Fraser HMA



Chapter 8 Quesnel Habitat Management Area

8.1 Background

The 16,000 km^2 Quesnel HMA encompasses the Quesnel River and the Cottonwood River watersheds to the east of the Fraser River. A number of small tributaries draining directly to the Fraser River are also located within this HMA.

8.1.1 Hydrology

The hydrology of streams within the Quesnel HMA differs among three areas.[1] On the Cariboo Plateau, annual maximum monthly flows occur between mid-April and mid-June, and result from snowmelt or rain-on-snow events. Rain on snow during the fall can also produce very large discharges. Annual precipitation is 500 – 700 mm, which is evenly distributed throughout the year. In the Quesnel Highland, annual maximum discharges usually occur between mid-May and mid-June. Annual precipitation is 1,000 – 1,100 mm and is distributed evenly throughout the year. In the Cariboo Mountains precipitation has not been measured. However, maximum daily discharge normally occurs between early June and mid-July, and results from snowmelt.

Flows in the Quesnel system are moderated by Cariboo and Quesnel Lakes. The Cottonwood River watershed does not contain any large lakes, and flows in this system depend largely upon snowmelt and climatic conditions.

Only 3 of 28 salmon-bearing streams in the HMA were considered to have very low summer flows, potentially putting fish at risk (Table 8.5.3). Two others were considered to be impacted by water withdrawals.

8.1.2 Fish

There are 28 streams in the Quesnel HMA known to support anadromous salmonids.[2] The Quesnel River watershed supports very large sockeye populations, and the Horsefly River is a particularly large producer. Escapement records show returns approaching 1.6 million fish in 1989.[3]

Chinook, pink, and coho salmon also utilize some tributaries to the Quesnel HMA.[3] Numerous non-anadromous species including kokanee, rainbow trout, Dolly Varden char, burbot, and mountain whitefish, are also found in the HMA.

8.1.3 Predominant Land Uses

Resource extraction activities have played a major part in shaping the landscape of the Quesnel HMA.[1] The area was intensively mined during the Cariboo gold rush of the mid 1800s. The small community of Quesnel grew as a service center for the mining industry and agricultural activities began soon after to feed the growing population. More recently, the forest industry has become a mainstay of the local economy.

Tourism is becoming an increasingly important component of the economy. Both the historical sites such as Barkerville and the proximity to the Bowron Lakes and Wells Gray Provincial Parks draw visitors to the area.

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8.2 Point Sources of Contaminants

There are 3 large effluent discharges to surface waters resulting from activities in the Quesnel HMA.[4] These are Cariboo Pulp and Paper, Quesnel River Pulp, and the City of Quesnel STP, and effluents from all are released to the Fraser River mainstem in the vicinity of Quesnel.

8.2.1 Urban/Industrial Point Source Discharges to Surface Water

Six facilities have permitted discharges to surface waters within the Quesnel HMA, although 5 of them discharge to the Fraser River mainstem rather than the Quesnel watershed (Table 8.2.1).[4] Estimated daily and annual loadings of various parameters from these facilities are provided in Tables 8.2.2a and 8.2.2b. These effluents are discussed more extensively in the Middle River HMA chapter (Chapter 4) of this report, as their effects on water quality may extend for a considerable distance downstream, beyond the Quesnel HMA. The high temperatures (up to 38°C) at which the large volumes of pulp mill effluent may be released to the environment are of particular concern, especially during summers when water temperatures in the Fraser River exceed levels tolerated by salmon during their spawning migration.

The most significant loading of biological oxygen demand and nonfilterable residues come from the pulp mills (Tables 8.2.2a and 8.2.2b).[4] The sewage treatment plant for the City of Quesnel directs sewage to Cariboo Pulp and Paper in Quesnel, where the effluent is mixed with pulp mill effluent as part of the pulp mill effluent treatment system.[6] The STP therefore does not have a separate waste management permit. All together there are 8 process effluent discharges and 1 sewage treatment plant discharge in the HMA, the locations of which are shown in Figure 8.2.1.

8.2.2 Permitted Discharges to Ground

Thirteen liquid effluent discharges to ground are permitted in the Quesnel HMA: 7 for processing and 6 for STP effluents.[4] In addition to these point source discharges there are numerous private septic systems, especially around the city of Quesnel. Concerns have been expressed that leaking and malfunctioning septic systems may be contaminating groundwater in the city.[1]

There are numerous permitted refuse disposal sites located within the HMA, including 7 municipal landfills and 6 industrial landfills in the vicinity of Quesnel alone.[1] A woodwaste landfill which was operated from 1972 to 1979 generates leachate that drains to 2 watersheds. Toxic leachate draining to the southwest enters Black Lake, Black Sand Creek, and then the Quesnel River.[1] Leachate draining to the north enters Frye Creek, a tributary of the Cottonwood River.[1]

The City of Quesnel operates the largest municipal landfill in the HMA. The landfill is located about 200 m south of the Quesnel River, and concerns have been expressed about leachate from the landfill entering the river.[1] Monitoring information was not available to determine whether or not leachate is actually reaching the river.

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8.3 Non-Point Sources of Contaminants

Diffuse, non-point sources of contaminants can put water quality at risk, in the smaller salmon-bearing streams of the Quesnel HMA, and along the shorelines of larger systems.

8.3.1 Urban Development

Approximately 10,000 people currently live in the HMA and the growth rate is near zero. The City of Quesnel is the main urban center in the Quesnel HMA, and had an estimated population of about 8,500 in 1996.[5] Quesnel is the processing and distribution center of the Cariboo region.

Otherwise, the HMA has only a few small towns such as Horsefly and Likely, and is sparsely populated. The population fluctuates in response to intensity of exploration activities and markets in the forestry sector. Of the 28 known salmon-bearing systems in the HMA, only the lower Quesnel River was considered to be significantly affected by urbanization (Table 8.5.3).

Most urban development is occurring in the form of dispersed subdivisions which depend on on-site septic systems for sewage disposal.[1] As a result, there is increased pressure on the absorption capacity of the soil as well as increased risk of septic system failure for older developments. The groundwater in the city of Quesnel area is at risk of nitrate contamination from leaking septic systems.[1]

Other impacts associated with urban development include encroachment on riparian areas and increased urban runoff.[1] In total there are 16 stormwater discharges to the Fraser River in the vicinity of the City of Quesnel, with 11 on the west bank and 5 on the east bank of the Fraser.[6]

Estimated loadings of various contaminants to the Fraser Basin from the City of Quesnel are presented in the Middle Fraser chapter (Table 4.3.1).[8] Non-point source urban runoff in the Quesnel HMA appears to be a significantly larger source of contaminants such as nutrients, and oil and grease than point sources. The estimated non-point source loadings cannot be compared directly with those from point sources, however, because waste management permits do not restrict some parameters even though they are present in effluent. For example, the pulp mills and STP at Quesnel all discharge phosphorus to the Fraser River, yet permits do not restrict phosphorus discharges because the Fraser River is not sensitive to phosphorus inputs.

8.3.2 Agriculture

Agricultural activities consist primarily of ranching, and include grazing, winter feeding, and forage production. There are large private land holdings throughout the HMA with seasonal grazing on adjoining Crown lands.[1] Both agricultural and rural developments are concentrated in valley bottoms adjacent to streams and lakes. A peak in agricultural activity occurred in the 1970s, and large areas of land were cleared during this time. There is now a trend toward smaller farm size.[1] Agriculture is also becoming more diversified; since the 1970s, dairy and poultry farms and forage production have increased. Three of 28 known salmon-bearing systems in the HMA were considered to be significantly impacted by agricultural development (Table 8.5.3).

Excessive water withdrawals create problems in only a few tributaries to the Quesnel River.[7] Concerns have been expressed about feedlots affecting water quality, especially in the Horsefly system. It was estimated that there are more ranches, cattle and feedlots in the Horsefly watershed than in other major systems such as the Lower Quesnel or the Cottonwood River.[1]

Crown range land is an important component of the land base supporting the beef industry in the Quesnel HMA and is utilized nearly to capacity.[1] Potential impacts from intensive use include stream bank erosion, fecal contamination of streams, and trampling of riparian vegetation.

Fertilizer use may have an impact on fish habitat and water quality. Although the amount of improved farm land has decreased in the Quesnel HMA, the amount of fertilized area increased over 400% between 1971 and 1986.[1] The increased quantity and extent of fertilizer application has increased the potential for nutrient loading to streams, and consequently, eutrophication.

8.3.3 Timber Harvesting

Logging began in this HMA in the 1950's, and intensified after 1965. Logging occurs extensively throughout the HMA and has increased on private lands, where requirements of the Forest Practices Code do not apply.[7] Most watersheds in the HMA are experiencing some amount of clearcut logging. Proposed logging during the period of 1990-1996 comprised one-third of all the logging in the previous 30 years.[1] The most impacted watersheds include the Cottonwood River and Edney and Hazeltine Creeks. The Cariboo and Horsefly rivers have also experienced significant impacts from logging. Nine of 28 known salmon-bearing systems in the HMA have been significantly impacted by logging (Table 8.5.3).

8.3.4 Mining

Placer mining is common in the Cottonwood, Cariboo, and Quesnel River watersheds, and most operations are located near salmon-bearing streams.[7] Sediment release, water withdrawals, and riparian destruction are frequent problems. Damage to fish habitat is considered to be likely.[7]

Historically, mercury was used in placer mining to help separate out gold, and this was once a common practice in the Quesnel HMA. The economic recovery of historic metallic mercury and elimination of an environmental hazard was the basis for a recent proposal to dredge 1 kilometer of stream in the Horsefly area.[9] Fish tissues have been sampled for mercury in areas of the HMA where mercury was suspected of being a problem. Mercury concentrations were low, indicating that methylation and uptake by biota is not occurring.

In addition to placer mining, there are several metal mines in the HMA, with gold being the focus of mining activity.

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8.4 General Water Quality Conditions

Water quality data are relatively sparse for this HMA. Only 3 stations have been sampled 20 times or more. Even for the Quesnel River, water quality sampling has been minimal in recent years, and few measurements of even basic parameters were available in the database. Older data indicate relatively high levels of dissolved solids, reflecting major ions such as Ca^{2+} and SO_4^{2-}, in Quesnel River water.[8] Stratified lavas, sandstones, and shales of the Central Plateau are believed to be the sources of these ions.[10]

Bedrock is predominantly volcanic or sedimentary in the HMA.[10] Most soils in the Quesnel HMA have moderate acid reduction potential.[10] About 11% of lakes for which data were available were considered to have high buffer capacity, 77% were considered to have moderate buffer capacity (4.1 - 40 $mmole \cdot L^{-1}$), and 11% were considered to have low buffer capacity.[10] Surface waters in some areas contain relatively high concentrations of metals such as copper in surface waters, reflecting the local geology.

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8.5 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Quesnel HMA.

Summary tables of:

- Surface water, sediment and fish tissue data (Table 8.5.1)
- land use areas, stream flow, and water demand information for each salmon stream (Table 8.5.2)
- identified impacts for each salmon stream (Table 8.5.3)

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 8.5.1.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals were based upon information provided in a hydrology report,[2] and/or SISS catalogues[3] unless otherwise indicated. Assessment criteria are explained in the Methods section of this report.

Fraser River at Quesnel

•Fish tissue samples were collected at 4 different locations above and below Quesnel and near pulp mill sites. The most intensively sampled site is located just downstream from Quesnel, where between 1988 and 1990, 32 samples were collected for analysis of T4CDD, and 12 samples were assayed for trichlorophenol and pentachlorophenol. Of these, 14 of 32 T4CDD values exceeded the guideline. In the Fraser River upstream of discharges from the Quesnel-area pulpmills, only 2 of 9 fish samples contained T4CDD in excess of guideline levels (Table 8.5.1).

★Tissues containing high contaminant levels were collected prior to implementation of stricter controls on pulp mill effluent quality.

Chlorophenol levels in fish tissues did not exceed guideline levels in any of the samples tested.

No other parameters are reported for the Fraser River within the Quesnel HMA, however, urban and industrial discharges from Prince George may negatively affect water quality in this reach (see discussions for Upper Fraser and Middle Fraser HMAs).

•16 stormwater outfalls from the City of Quesnel discharge directly into the Fraser River.

•**Other:** Domestic sewage from Quesnel River Pulp (P05803) is mixed with pulp effluent for treatment.

Evidence suggests that effluent from this pulp mill tracks the eastern shoreline for at least 600 m downstream from the point of discharge.[6] The mill is permitted to discharge up to 28,000 m^3 of effluent per day, at up to 38°C, to the Fraser River.[4,6]

Cariboo Pulp and Paper (P01152) is permitted to discharge up to 118,200 m^3 of effluent per day to the Fraser River, at up to 38°C.[4,6] This includes about 4,000 m^3 of sewage effluent from the City of Quesnel and the Red Bluff area, which is treated in the pulp mill effluent lagoons.[6] Effluent remains as a visible plume in the river until the first major bend in the river, which is about 2.5 km downstream from the mill.[6] An increase in water temperature of about 0.5°C was measurable 100 m downstream from the outfall.[6]

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Cottonwood River (00-5100)

•Agricultural activity includes 54.6 km^2 of improved farmland. Some impacts to riparian areas have been noted in lower reaches, downstream from the Lightning Creek confluence.[11]

•Extensive logging in upper tributaries is causing heavy siltation.[3] 19% of the total watershed was logged prior to 1989, and harvest of an additional 4.5% was proposed by 1996.[11] In upstream portions of the watershed riparian leave strips are commonly less than 10 m wide or non-existent.[11] Sedimentation from logging roads has been noted.[11]

•The naturalized summer 7-day mean low flow is 16% of the mean annual flow.[2]

•The potential August water demand for domestic, irrigation, waterworks and industrial uses is 2% of the naturalized summer 7-day mean low flow. Storage accounts for 52% of the total irrigation demand.[2]

•**Other:** Placer mining occurs throughout the watershed, including upper tributaries such as Lightning and John Boyd Creeks.[11] Overflowing settling ponds result in sedimentation of the river, and damage to riparian areas has been extensive, especially on tributaries.[11]

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Ahbau Creek (00-5100-100)

•Cattle ranching is the main agricultural activity,[11] but some cultivation also occurs.[1] About 7% of the watershed is cultivated.[2] Activities on private land have a significant potential to affect streams, while the threat from grazing use of crown range lands is low.[11]

•13% of the total watershed was logged by 1989, including 6% from recent activity.[2] Harvesting of another 3% was proposed by 1996.[1] Activities are concentrated north of Ahbau Lake.[10] In some areas all riparian vegetation has been removed.[11]

•The naturalized summer 7-day mean low flow is 13% of the mean annual flow.[2]

•The potential August water demand for domestic, irrigation and industrial uses is 18% of the naturalized summer 7-day mean low flow.[2] Storage accounts for 53% of the total irrigation demand.

•**Other:** Potential low flows and granting of more water licenses in the future is of concern.[3] High flows are attenuated by beaver dams, which may also impede upstream migration of fish. Ahbau Creek has been placer mined continuously since the 1860's, and some sediment input occurs.[11] A few placer mines still operate in the watershed and activity may increase if gold prices rise. Linear developments including highways, pipelines, powerlines, railways, and logging roads are collectively of concern.[1]

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Frye Creek

•One or 2 measurements are reported for pH, nonfilterable residue and dissolved ammonia at two sites. Only 1 dissolved ammonia value exceeded the 80th percentile level.

•20% of Frye Creek has been logged recently.[2]

•**Other:** A woodwaste landfill used by Cariboo Pulp and Paper from 1972 – '79 generates leachate which drains into Frye Creek.[1] Monitoring of leachate quality from 1974 – '98 showed no improvement in quality.[1] The leachate contains high concentrations of metals and phenols, both of which can be toxic to aquatic organisms.

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Lightning Creek (00-5100-400)

•Only 1 measurement for each of nonfilterable residue, total phosphorus, arsenic, copper, lead, and zinc in surface water is reported, and none exceeded the guideline or 80th percentile levels.

•3.64 km^2 of improved farmland is present.[1] The entire watershed has grazing capability.[11] The potential for impacts is considered low.[11]

•24% of the total watershed was logged prior to 1989, and 5% was planned for harvest prior to 1996.[2] Inadequate leave strips and steep terrain, especially in the Peters Creek tributary, have introduced sediment to Lightning Creek.[11] There are also concerns about the rate of cut in the watershed.[11]

•The naturalized summer 7-day mean low flow is 26% of the mean annual flow.[2]

•August water demand for domestic and industrial uses is <1% of the naturalized summer 7-day mean low flow.[2]

•**Other:** There are placer mining and logging roads throughout the watershed. Placer mining has been extensive in the system - almost every tributary has been mined at some time.[2] Impacts include siltation, altered flows and the removal of riparian vegetation.[3,11] The Wingdam mine on Lightning Creek is attempting to access prime placer gravels at depth adjacent to the creek by underground mining methods.[7] Historically, placer mining in the creek involved the use of mercury to recover gold. Rainbow trout tissues do not show evidence of mercury accumulation.[9]

Erosion and siltation have resulted from development of the Troll Ski Hill in the area.[3] There is a need for channel stabilization and restoration of riparian vegetation.[2]

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Victoria Creek (00-5100-500)

•1% of the total watershed has been logged recently, and a further 6% harvesting was proposed prior to 1996.[2] Intensive logging was proposed until 2001, resulting in a high level of concern regarding rate of cut.[11] Logging activity is concentrated in the first few kilometers from the mouth.[2]

•The naturalized summer 7-day mean low flow is 11% of the mean annual flow.[2]

•No licenses have been issued.[2]

•**Other:** Some areas of the basin are swampy.[11]

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Naver Creek (00-5400)

•The community of Hixon is located in the watershed. Bank stabilization projects such as rip rapping have been performed adjacent to the chinook spawning area.[3]

•Most of the arable land is developed and supports small ranches. Agriculture occupies about 8% of the watershed.[1] There was not enough information to assess the effect that it may have on water quality.

•Extensive logging has occurred in the upper watershed. 16% of the total watershed has been logged, including 9% from recent activity.[2] Logging of another 4% was proposed by 1996.[2] Many tributaries have been logged. The potential for cumulative impacts is considered high.[1]

•The naturalized summer 7-day mean low flow is 14% of the mean annual flow.[2] No low flow problems have been reported but Terry Creek may have possible water shortages and Laura and Van Buskirk Brooks are fully recorded by the WMB. DFO recommends that no future water withdrawals be permitted.[3]

•The potential August water demand for domestic, irrigation and industrial uses is 4% of the naturalized summer 7-day mean low flow.[2]

•**Other:** There is some low intensity placer mining activity in the watershed.[1,14] Minor problems on Meadowbank Creek are associated with local landowners and Dunkley Mills.[2]

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Hixon Creek (00-5400-050)

•17.54 km^2 of improved farmland is present. There was not enough information to assess the effect it may have on water quality. Agricultural land comprises about 7% of the land base.[1]

•5% of the total watershed has been logged recently, and another 1% was proposed for harvesting by 1996.[1] Large clear cuts are present in the upper watershed.[2]

•The naturalized summer 7-day mean low flow is 10% of the mean annual flow. Channel widening and gravel deposition caused by flooding in 1990 and spring ice jams in 1992 resulted in low flows in 1992 near the town of Hixon.[2] Grundell Creek, a tributary, also has potential low flow problems.

•The potential August water demand for domestic and industrial uses is 1% of the naturalized summer 7-day mean low flow.[2]

•**Other:** Rain falling on top of snow on George Mountain causes large floods, and large clearcuts in the upper watershed may add to flooding problems.[2] High intensity placer mining occurs upstream of the falls which limit salmon migration.[1] DFO is working with proponents on education and awareness, to address impacts on water quality and fish habitat.[14] An old hydraulic placer operation at the base of the falls causes sediment to enter the creek and contributes to its instability.[2] Severe flooding has destabilized lower creek reaches.[13] There is extensive rip rapping along the highways and gas pipelines.[13] A sanitary land fill is present.

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Lower Quesnel River (d/s from Beaver Creek) (06-0000-000-000-000-000-991)

•Nine measurements of T4CDD are reported, and 3 measurements each of tri- and penta-chlorophenol in fish tissue.

★Two of the T4CDD values exceeded the guideline, however, these samples were collected prior to 1992, when stricter controls on pulp mill effluent were established. None of the chlorophenol measurements exceeded guidelines.

•Stormwater runoff from Quesnel drains directly to the Quesnel River.[11] There has been some degradation of riparian areas and rip rapping adjacent to Quesnel and Likely.[11]

•Ranching is the dominant agricultural activity, however, dairy, poultry, and forage crop operations are also located in the watershed.[1] 155 km^2 of improved farmland are present.[1] High irrigation use has resulted in water shortages in several tributaries, which may limit off channel habitat, but flow in the main channel is not seriously affected.[2] Localized bank erosion is occurring.[11]

•Less than 1% of the watershed has been logged and no additional harvesting is proposed.[1] A log drive that originated on Cariboo River and went as far as the mills in Quesnel caused historic erosion.[11]

•The naturalized summer 7-day mean low flow is 50% of the mean annual flow.[2] Quesnel Lake stabilizes river flows.

•The potential August water demand is 1% of the naturalized summer 7-day mean low flow for domestic, irrigation, waterworks and industrial uses. Storage accounts for 23% of the total irrigation demand.[2]

•**Other:** While overall impacts to the lower watershed are low, there are significant localized cumulative impacts from agriculture, urban development, waste discharges, water withdrawal, and recreation near the river mouth.[11]

There is potential for increasing placer mining. Leachate from a log storage/sorting yard was observed entering the Quesnel River in the vicinity of Two Mile Flat. Black water entered the river via a drainage ditch just upstream of spawning pink salmon.[12]

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Dragon Lake

•Five sites have been sampled on the lake. The Middle Lake station is the most intensively sampled. Here, 69 pH values ranged from 7.7 to 8.9, 25 of 58 ammonia measurements exceeded the 80th percentile level (none were extremely high), and 90 of 92 phosphorus levels exceeded guidelines. In addition, all 5 copper measurements and 3 of 40 zinc levels exceeded guideline levels.

The lake is considered to be eutrophic as a result of nutrient inputs from animal wastes.[10]

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Landfill (Blacksand) Creek/Leachate (Black) Lake

•Three stations have been sampled, with a maximum of 4 samples collected at any station. At the lake outlet phosphorus levels were high, and pH was quite low (mean pH of 6.3), compared with sites further downstream (mean pH of 8.3).

•**Other:** The creek and lake are contaminated by leachate from a capped woodwaste landfill.[1] Leachate contains high levels of phenols, aluminum, arsenic, iron, magnesium, manganese, nickel, lead, and zinc. The lake acts as a treatment pond, and the lake water is toxic to fish.[1] The discharge water is very low in dissolved oxygen.

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Upper Quesnel River (u/s from Beaver Creek) (06-0000-000-000-000-000-992)

•Four sites were sampled, 2 upstream and 2 downstream from a fish hatchery. Immediately upstream of the hatchery, all 21 pH levels and all 20 phosphorus concentrations were within guideline or 80th percentile levels, and 3 of 21 ammonia measurements exceeded the 80th percentile level. Downstream from the hatchery, 1 of the 8 total phosphorus values (0.505 $mg \cdot L^{-1}$) was above the 80th percentile.

•Some riparian degradation and rip rapping have occurred in reaches adjacent to Likely. There is concern regarding domestic sewage seepage from Likely reaching the main chinook spawning area.[10]

•Agricultural activity includes 56.6 km^2 of improved farmland.[1] There is not enough information to assess the effect it may have on water quality.

•2% of the total watershed has been logged recently.[2] Logging around Quesnel Lake has increased since 1989.[2]

•The naturalized summer 7-day mean low flow is 47% of the mean annual flow.[2]

•The potential August water demand for domestic, irrigation and industrial uses is <1% of the naturalized summer 7-day mean low flow. Storage accounts for 18% of the total irrigation demand.[2]

•**Other:** Natural slumping of clay banks in numerous locations below Quesnel Forks causes siltation. Also, sediment discharged from the old Bullion Mine has built up in the reach between Morehead Creek and Quesnel Forks. This has altered the channel flow capacity and produced a cycle of aggradation followed by scour through the channel deposits.[2]

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Beaver Creek (06-2270)

•About 5% of the watershed consists of cultivated land, and 100% of the watershed has high grazing capability.[2] Most irrigation use is downstream of Beaver Lake. The potential for impacts from activity on private and crown lands is considered high.[2,11]

•9% of the total watershed has been logged, including 8% which has occurred recently. Logging was planned for an additional 2.5% of the watershed before 1996.[2]

•The naturalized summer 7-day mean low flow is 12% of the mean annual flow.[2]

•The potential August water demand for domestic, irrigation and industrial uses is 120% of the naturalized summer 7-day mean low flow. The stream is fully recorded.[2] Twenty tributaries are fully recorded or have potential water shortages.[3] Storage accounts for 24% of the total irrigation demand. There are many small storage facilities operated by individual ranchers.[11]

•**Other:** There is some placer mining on the lower creek reach, and also in the McDermot Creek tributary.[11] Strong concerns about low flows and high summer water temperatures have been noted.[11]

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Quesnel Lake

•There are 8 lodges on the lake. The area is a growing recreation destination.[12]

•Logging of tributaries is causing sedimentation of shoreline areas used by sockeye and coho salmon. Log dumps on the lake, bundling, storage, and towing procedures are of concern. Log storage and dump areas require assessment and monitoring.[12]

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6K Creek

•A maximum of 4 measurements were available for pH, nonfilterable residue, ammonia, phosphorous, and 5 metals. Both of 2 copper levels exceeded the guideline level but all other parameters were within guideline or 80th percentile levels.

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Morehead Creek

•Two sites have been sampled on the creek, including 1 at the outlet of Boot Jack Lake. Parameters measured included pH, nonfilterable residue, ammonia, phosphorus, and 5 metals. No parameter was measured more than 4 times at 1 site, and only 1 measurement is reported for each parameter at the lake outlet site. Ammonia and copper exceeded the 80th percentile or guideline level in all measurements. At the downstream site lead also exceeded the guideline.

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Boot Jack Lake

•Water quality parameters were measured a maximum of 11 times. Three of 8 ammonia and 2 of 8 phosphorus measurements exceeded 80th percentile levels. Eight of 9 copper, 1 of 5 mercury, and 1 of 11 zinc measurements exceeded guidelines.

In sediments, the single measurements of chromium, copper, and mercury exceeded guidelines, while lead and zinc were less than guideline levels.

•**Other:** The high metal concentrations likely reflect the geochemistry of the area. The Mt. Polley copper and gold mine is now in operation near Morehead Creek.[13]

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Maud Creek

•Three sites were sampled on Maud Creek and none of the sites were sampled more than twice. At the creek mouth only chromium and zinc exceeded guideline levels and the zinc concentration was very high (0.73 $mg \cdot L^{-1}$). At the two upper sites both of two copper measurements exceeded guideline levels. Ammonia, phosphorus, arsenic, and mercury never exceeded guideline levels.

A range of metals were measured in 3 sediment samples collected from two sites, and all exceeded guidelines at least once, except lead.

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Rudy Creek

•Rudy Creek was sampled at 2 locations with no more than 2 samples collected at each site. One measurement each of copper and zinc exceeded guideline levels.

A single sediment sample was collected from below a tailings area. Chromium and copper values both exceeded the guidelines, while mercury, lead, and zinc did not.

•**Other:** The high metal concentrations are likely a reflection of the geochemistry of the area. The mine near Maud Creek has been operating as QR gold since the early 1990's.[13]

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Cariboo River (06-3810)

•Less than 1% of the watershed is cultivated, and 47% has grazing capability.[11] The level of concern for fish is considered low.[11]

•11% of the total watershed has been logged, including 10% recently harvested.[2] Logging of another 3% was planned by 1996.[2] Harvesting has concentrated around Cariboo Lake, and is prohibited in the valley bottom upstream of Cariboo Lake, as this is a Protected Area.[11] Riparian buffers established along the Matthew River tributary and Cariboo are inadequate.[11]

•The naturalized summer 7-day mean low flow is 47% of the mean annual flow.[2] Headwater lakes and Cariboo Lake help to stabilize flows.

•The potential August water demand for domestic, irrigation and industrial uses is less than 1% of the naturalized summer 7-day mean low flow.[2]

•**Other:** The river carries a naturally high glacial silt load. Placer mining occurs in the mainstem and tributaries, including Harvey's, Keithley, Cunningham, Spanish, and Block Creeks. Gavex Gold, no longer in operation, has not been reclaimed and is causing sedimentation and riparian problems.[1] B.C. Hydro has an old power reserve on both Cariboo and Quesnel Lakes.[2] There are inactive log dumps adjacent to the river.[1] Logging and mining roads have been developed on both sides of the river.[11]

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Little River (06-3810-250)

•7% of the total watershed has been logged recently, and 3% was proposed for harvesting by 1996.[2] Activity has focussed in the lower 2 km of the watershed, and logging on steep slopes has increased the risk of erosion.[11]

•The naturalized summer 7-day mean low flow is 26% of the mean annual flow. Winter flows are very low.[2]

•No licenses have been issued.[2]

•**Other:** Placer mining is ongoing in this system. Peak flows are relatively severe.[2]

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Cunningham Creek (06-3810-400)

•8% of the total watershed has been logged recently, and 15% is proposed for harvesting. Severe over-harvesting has occurred in the lower reach. Logging on steep terrain and encroachment on creek banks have increased the potential for erosion and sedimentation.[11]

•The naturalized summer 7-day mean low flow is 26% of the mean annual flow. Winter flows are very low.[2]

•No licenses have been issued.[2]

•**Other:** Peak flows are relatively flashy. Placer mining activity is extensive in the upper reaches.[10]

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Hazeltine Creek (06-4810)

•Up to 5 measurements of pH, nonfilterable residue, dissolved ammonia, total phosphorus and metals in surface water were available in the database. Of these, 1 of 3 ammonia, 1 of 2 copper and 1 of 3 lead values exceeded the guidelines or 80th percentile.

•There are potential impacts from grazing on Crown range land, and from private farmland.[3]

•The stream is highly impacted by logging.[3] 42% of the total watershed has been logged, including 5% from recent activity.[2] The high percentage of cut has resulted in sedimentation and extreme water temperature fluctuations.[11]

•The naturalized summer 7-day mean low flow is 5% of the mean annual flow.[2] The creek is fed primarily by Polley Lake, but experiences extreme summer and winter low flows.

•No licenses have been issued.

•**Other:** The upper reaches of the creek and tributaries are now contained in a tailings pond.[13] There are potential impacts from the Mount Polley mine.[3]

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Edney Creek (06-4810-030)

•Between 1 and 4 measurements are reported for pH, nonfilterable residue, dissolved ammonia, total phosphorus and metals in a tributary to Edney Creek. Of these, 1 of 2 ammonia and 1 of 2 lead values exceeded the guideline or 80th percentile.

•Livestock grazing may cause some impacts to the watershed.[10]

•45% of the total watershed has been logged recently, and there are no plans for further harvesting (to 1996).[2]

•The naturalized summer 7-day mean low flow is 8% of the mean annual flow.

•No licenses have been issued.

•**Other:** Peak flows are relatively high.

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Boot Jack Creek

•Parameters measured included 5 metals, pH, nonfilterable residue, ammonia, and phosphorus. A single copper and 1 of 2 lead measurements exceeded guideline levels.

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Polley Lake

•Surface water quality was sampled at 2 stations.

At the north end of the lake, 4 of 9 ammonia, 6 of 9 phosphorus, 14 of 16 copper, 2 of 6 mercury, 4 of 19 lead and 1 of 18 zinc values in surface water exceeded the guidelines or 80th percentile. The single measurements of chromium, copper and mercury in sediments also exceeded the guidelines.

At the south site 2 of 7 ammonia, 5 of 7 phosphorus, 4 of 4 copper, and 1 of 4 mercury concentrations exceeded the guidelines.

•**Other:** The high metal concentrations may reflect the geochemistry of the area. The elevated mercury level may result from historical use of mercury in placer mining.

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Horsefly River (06-5460)

•The town of Horsefly is located in the watershed. Impacts from the small population (less than 500 in 1986) are not expected.[11]

•Agricultural activity is extensive downstream from the McKinley Creek confluence. Cattle grazing and watering have caused bank destabilization and degradation of the riparian zone. 44.8 km^2 of improved farmland are present.

•Logging is extensive in the upper watershed.[2] 9% of the total watershed has been logged (about 8% has been recently logged), and plans included logging another 3% of the watershed prior to 1996.[11] Logging has encroached on the McKusky Creek tributary.[11] Concerns have been expressed by DFO staff with regard to high rates of cut in some portions of the watershed, and impacts from sedimentation have been observed in some areas.[13]

•The naturalized summer 7-day mean low flow is 35% of the mean annual flow.[2]

•The potential August water demand for domestic, irrigation and industrial uses is 2% of the naturalized summer 7-day mean low flow. Storage accounts for 19% of the total irrigation demand.[2]

•**Other:** Placer mining occurred historically in the watershed, and is now ongoing in the Black Creek tributary. Re-development of the dormant Eureka Gold mine is possible, and could raise concerns about cyanide, copper sulphate, and sediment.[11] Linear development is extensive throughout the watershed.[11] Occasional high water temperatures have also been reported.[11]

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Little Horsefly River (06-5460-145)

•Four sites have been sampled on the Little Horsefly River, and 3 on Little Horsefly Lake. Ammonia, phosphorus, and pH were measured 12 times at 2 sites, 13 times at 1 site, and 7 times at the fourth site. Ammonia exceeded the 80th percentile in 3 samples, but levels were still low. Downstream from Horsefly Lake, the one temperature value exceeded the guideline. One or 2 measurements of pH, dissolved ammonia and total phosphorus are reported for Horsefly Lake for each of the 3 sites sampled. None of the parameters exceeded the guidelines or 80th percentiles.

•The community of Horsefly Lake (population < 500) is located adjacent to the river.[11]

•About 1% of the watershed is cultivated.[1] Grazing is noted to be a potential source of problems.[3]

•5% of the total watershed has been logged recently, and 2% was proposed for harvesting prior to 1996.[2] Riparian leave strips have been minimal in several tributaries.[11]

•The naturalized summer 7-day mean low flow is 57% of the mean annual flow.[2] Flows are moderated by Horsefly Lake.

•The potential August water demand for domestic, irrigation and industrial uses is 1% of the naturalized summer 7-day mean low flow. Storage accounts for 52% of the total irrigation demand.

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Moffat Creek (06-5460-190)

•About 1% of the watershed is cultivated farmland, and 89% has grazing capability.[1] Some encroachment on the riparian zone has been noted in lower reaches.[11] There has been extensive channelization by ranchers.[13]

•10% of the total watershed has been logged recently, and another 3% was proposed for harvesting prior to 1996.[2] In the longer term intensive harvesting has been proposed.[1]

•The naturalized summer 7-day mean low flow is 19% of the mean annual flow.[2]

•The potential August water demand for domestic, irrigation and industrial uses is 10% of the naturalized summer 7-day mean low flow.[2]

•**Other:** The creek is unstable on its fan, and major gravel deposition and movement occurs. Gravel and debris removal and channel works are required to maintain channel capacity and protect property.[2] The creek is a source of sediment to the Horsefly River, especially during flood events.[11]

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McKinley Creek (06-5460-480)

•About 3% of the watershed consists of improved farmland and 38% has grazing capability.[1] Localized impacts to the riparian zone have occurred.[11]

•13% of the total watershed has been logged recently, and another 5% was proposed for harvesting prior to 1996. High rates of cut are proposed for some tributaries such as Molybdenite Creek.[11] There are concerns regarding inadequate riparian vegetation and sediment release from unstable slopes.[2]

•The naturalized summer 7-day mean low flow is 23% of the mean annual flow.[2] The creek flows through a series of lakes, which help to moderate flows.

•The potential August water demand for domestic use is less than 1% of the naturalized summer 7-day mean low flow.[2]

•**Other:** A dam was built at the outlet of McKinley Lake in 1968 to enable release of cool water over downstream sockeye spawning grounds.[2] More logging may further aggravate high summer water temperature problems.

The Boss Mountain mine (not presently operating) is a source of sediment.[1]

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Unnamed (alias Wolftrack) Lake

•Both of 2 total phosphorus values exceeded the guideline. No other water quality data were reported.

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Melissa Lake

•Two measurements of total phosphorus in surface water were reported, one of which exceeded the guideline. One measurement each of 6 different metals were also reported; the cadmium, copper and mercury values exceeded their respective guidelines.

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Mitchell River (06-6960)

•1% of the total watershed has been logged recently, and another 2% was proposed for harvesting prior to 1996. Most logging has occurred upstream of Mitchell Lake.

•The naturalized summer 7-day mean low flow is 44% of the mean annual flow.[2]

•No licenses have been issued.[2]

•**Other:** There is an impassable cascade at the outlet of Mitchell Lake. A flow control weir was built at the outlet to improve incubation flows in the river.[3] A Class A Provincial Park was established in 1995, which encompasses all of the mainstem watershed, part of the Cameron Creek tributary, and a small area of the lower Penfold sub-basin.[11]

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Penfold (Mud) Creek (06-6960-020)

•2% of the watershed was proposed for harvest,[1] with activity to begin in 1996.[11] Terrain is steep, making impacts harder to avoid.[11]

•The naturalized summer 7-day mean low flow is 44% of the mean annual flow.[2]

•No licenses have been issued.

•**Other:** The lower 10 km are turbid.

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Cameron Creek (06-6960-180)

•3% of the total watershed has been logged recently, and 3% is proposed for harvesting.[2] In some tributaries timber has been harvested right up to the stream banks.

•The naturalized summer 7-day mean low flow is 43% of the mean annual flow.[2]

•No licenses have been issued.[2] Part of this watershed is captured by the Mitchell Lake/ Niagara Class A Provincial Park.[11]

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Watt Creek (06-6980)

•Logging of 0.5% of the watershed was proposed prior to 1996, and several blocks were proposed for harvest in the lower reaches in 1999.[11]

•The naturalized summer 7-day mean low flow is 43% of the mean annual flow.[2]

•No licenses have been issued.

•**Other:** Beaver dams and log jams on the creek have been reported. This watershed is considered to be pristine at present.[11]

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Roaring River (06-7020)

•3% of the total watershed has been logged recently, further harvesting is proposed to 1999.[11] Cutblocks are located in the lower reaches of the valley bottom, and leave strips may be inadequate or non-existant.[11]

•The naturalized summer 7-day mean low flow is 44% of the mean annual flow.[2] Winter flows are extremely low.[2]

•The potential August water demand for domestic use is less than 1% of the naturalized summer 7-day mean low flow.[2]

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Wasko Creek (06-7650)

•3% of the watershed was proposed for harvesting prior to 1996, with efforts focussed on the lower watershed.[1]

•The naturalized summer 7-day mean low flow is 26% of the mean annual flow.[2]

•The potential August water demand for domestic use is less than 1% of the naturalized summer 7-day mean low flow. The Barrett Creek tributary is almost fully allocated.[11]

•**Other:** Peak flows are relatively high. Most of the surrounding land in the lower reaches was burned in a large forest fire, but is now regenerating.[13]

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Lynx Creek (06-9050)

•No logging had occurred up to 1996, but logging has been proposed to address beetle infestations.[11] Difficult access may necessitate helicopter logging.

•The naturalized summer 7-day mean low flow is 26% of the mean annual flow. Peak flows are relatively high and winter flows are very low.[2]

•No licenses have been issued.

•**Other:** This is a pristine watershed.

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Bill Miner Creek (06-9249)

•There is some logging in upper reaches of the watershed.[13] No other information was available.

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Killdog Creek (06-9740)

•Logging began in 1991 and 15% of the watershed was proposed for harvesting by 1996.[2] Steep terrain results in a high potential for impacts from logging roads.[11]

•The naturalized summer 7-day mean low flow is 28% of the mean annual flow.[2] There are no lakes in the watershed to moderate flows.

•No licenses have been issued.[2]

•**Other:** Peak flows are relatively high and there are extreme winter low flows.

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Blue Lead Creek (06-9860)

•Logging began in 1991 and some mass wasting related to this activity was observed in 1994.[2,11] 4% of the watershed was proposed for harvesting by 1996.[2]

•The naturalized summer 7-day mean low flow is 45% of the mean annual flow.[2]

•No licenses have been issued.[2]

•**Other:** The creek floods in the spring and the channel is dynamic.[11] It is noted to carry a high sediment load.[11] Spawning occurs at gravel fans at the creek mouth. Coho utilizing the creek are at the upper limit of distribution in the Fraser Basin.[11]

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Summit Creek (06-9890)

•The naturalized summer 7-day mean low flow is 28% of the mean annual flow.[2] There is no significant moderation of flows by lakes, and winter flows are very low.

•No licenses have been issued.[2]

•**Other:** Peak flows are relatively high. The entire watershed except for the mouth is part of Mitchell Lake/Niagara Class A Provincial Park, as of July, 1995.[11]

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Table 8.2.1 Summary of Permitted Discharges to Surface Water in the Quesnel HMA.[1]

Record Id	Facility	Waste Type	Waste Number	Max. Flow ($m^3 \cdot d^{-1}$)	Receiving Water Body
P01152	Kraft Pulp Mill At Quesnel (Cariboo)[2]	Process	01	118,200	Fraser River
P01152	Kraft Pulp Mill At Quesnel (Cariboo)	Process	02	6,300	Quesnel River
P01720	Sawmill & Plywood Plant At Quesnel	STP	01	23	Fraser River
P01720	Sawmill & Plywood Plant At Quesnel	Process	02	41	Fraser River
P01720	Sawmill & Plywood Plant At Quesnel	Process	03	10,080	Fraser River
P05803	Quesnel River Pulp[2]	Process	01	28,000	Fraser River
P07204	Fish Hatchery At Likely, On Quesnel River	Process	01	24,600	Quesnel River
P07840	Fish Rearing Facility at Likely	Process	01	302	Quesnel River
P11088	Mine at Wingdam	Process	01	6,000	Lightning Creek

[1] Data were summarized from a 1994 version of the Environment Canada Effluent Point Source Inventory and Database for the Fraser River Basin (see reference 6).

[2] The temperature of this effluent at the point of discharge may be up to 38°C, which could potentially be harmful to fish.

Table 8.2.2a Summary of Permitted Daily Contaminant Loadings* to Surface Water in the Quesnel HMA ($kg \bullet d^{-1}$ except where noted)

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading	# of Facilities	Daily Loading
Bio. LC_{50}: Daph. Magna[1]	1	na	-	-	-	-	-	-	-	-
Bio. LC_{50}: Rainbow Tr[1]	2	na	-	-	-	-	-	-	-	-
Bioassay (Pass/fail)[1]	1	na	-	-	-	-	-	-	-	-
Bioassay LC_{50} (Salmon)[1]	1	na	-	-	-	-	-	-	-	-
Biochemical Oxygen Demand	2	14,852	-	-	-	-	1	1.0	-	-
Copper	1	30.0	-	-	-	-	-	-	-	-
Iron dissolved	1	1.8	-	-	-	-	-	-	-	-
Manganese	1	3.0	-	-	-	-	-	-	-	-
Nitrogen Amm. Total	1	0.1	-	-	-	-	-	-	-	-
Nitrogen NO_3 Total	1	0.3	-	-	-	-	-	-	-	-
Oxygen Dissolved[2]	2	58.8	-	-	-	-	-	-	-	-
pH[3]	2	na	-	-	-	-	-	-	-	-
Plywood & Veneer[4]	1	na	-	-	-	-	-	-	-	-
Residue Nonfilt.	5	37,455	-	-	-	-	1	1.4	-	-
Residue Total	1	302.4	-	-	-	-	-	-	-	-
Temperature[5]	2	na	-	-	-	-	-	-	-	-
Zinc	1	180.0	-	-	-	-	-	-	-	-

Table 8.2.2b Summary of Permitted Annual Contaminant Loadings* to Surface Water in the Quesnel HMA ($kg \bullet yr^{-1}$ except where noted)

	Processing		Cooling		Stormwater		Sewage Treatment		Leachate	
	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading	# of Facilities	Annual Loading
Bio. LC_{50}: Daph. Magna[1]	1	na	-	-	-	-	-	-	-	-
Bio. LC_{50}: Rainbow Tr[1]	2	na	-	-	-	-	-	-	-	-
Bioassay (Pass/fail)[1]	1	na	-	-	-	-	-	-	-	-
Bioassay LC_{50} (Salmon)[1]	1	na	-	-	-	-	-	-	-	-
Biochemical Oxygen Demand	2	5,420,980	-	-	-	-	1	378	-	-
Copper	1	10,950	-	-	-	-	-	-	-	-
Iron dissolved	1	657	-	-	-	-	-	-	-	-
Manganese	1	1,095	-	-	-	-	-	-	-	-
Nitrogen Amm. Total	1	33	-	-	-	-	-	-	-	-
Nitrogen NO_3 Total	1	110	-	-	-	-	-	-	-	-
Oxygen Dissolved[2]	2	21,462	-	-	-	-	-	-	-	-
pH[3]	2	na	-	-	-	-	-	-	-	-
Plywood & Veneer[4]	1	na	-	-	-	-	-	-	-	-
Residue Nonfilt.	5	13,671,075	-	-	-	-	1	504	-	-
Residue Total	1	110,376	-	-	-	-	-	-	-	-
Temperature[5]	2	na	-	-	-	-	-	-	-	-
Zinc	1	65,700	-	-	-	-	-	-	-	-

na = not applicable
[1] minimum requirement is 100% survival
[2] dissolved oxygen is to be a minimum of 2 $mg \bullet L^{-1}$
[3] requirement for pH is within the range of 6.5 to 8.5
[4] no requirement for effluent constituents, maximum volume of discharge is prescribed
[5] requirement for maximum temperature varies between 35°C and 38°C
* loadings are calculated from DOE's Fraser River Point Source Inventory and Database (see reference 6).

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
QUESNEL & CARIBOO PULP MILLS D/S							
Fish Tissue (1988)	2,3,7,8-T4CDD (pg/g)	4	1	0	2.9	137.0	43.3
BELOW QUESNEL							
Fish Tissue (1990)	2,3,7,8-T4CDD (pg/g)	32	14	15	0.4	410.0	63.7
	2,4,6-Trichlorophenol (ng/g)	12	0	12	1	1	1
	Pentachlorphenol (μg/g)	12	0	12	0.002	0.002	0.002
QUESNEL PULP MILLS U/S							
Fish Tissue (1988)	2,3,7,8-T4CDD (pg/g)	3	0	1	2.0	25.3	11.8
ABOVE QUESNEL							
Fish Tissue (1990)	2,3,7,8-T4CDD (pg/g)	6	2	0	1.3	53.0	21.1
	2,4,6-Trichlorophenol (ng/g)	3	0	3	1	1	1
	Pentachlorphenol (μg/g)	3	0	2	0.002	0.010	0.005
FRYE CR. TO NE OF CPP LANDFILL							
Surface Water	pH (pH units)	2	0	0	6.7	7.4	7.1
	Nonfilterable Residue (mg/L)	1	na	0	5	5	5
	Dissolved Ammonia Nitrogen (mg/L)	1	1	0	0.019	0.019	0.019
FRYE CR. ABOVE 15 MILE LAKE							
Surface Water	pH (pH units)	2	0	0	6.7	7.1	6.9
	Nonfilterable Residue (mg/L)	1	na	0	5	5	5
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Zinc (mg/L)	1	0	1	0.010	0.010	0.010
LIGHTNING CK 40 M U/S WINGDAM BRIDGE							
Surface Water	Nonfilterable Residue (mg/L)	1	na	0	34	34	34
	Total Phosphorus (mg/L)	1	0	0	0.033	0.033	0.033
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	0	0.001	0.001	0.001
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	0	0.006	0.006	0.006
QUESNEL RIVER							
Fish Tissue (1990)	2,3,7,8-T4CDD (pg/g)	9	2	6	0.1	83.0	18.2
	2,4,6-Trichlorophenol (ng/g)	3	0	3	1	1	1
	Pentachlorphenol (μg/g)	3	0	3	0.002	0.002	0.002
DRAGON CR AT LAKE OUTLET							
Surface Water	pH (pH units)	9	0	0	7.5	8.7	8.3
	Nonfilterable Residue (mg/L)	2	na	0	3	6	5
	Dissolved Ammonia Nitrogen (mg/L)	9	3	5	0.005	0.097	0.018
	Total Phosphorus (mg/L)	9	0	0	0.016	0.052	0.035
DRAGON LK. AT NORTH END							
Surface Water	pH (pH units)	10	0	0	8.0	8.9	8.5
	Dissolved Ammonia Nitrogen (mg/L)	9	6	1	0.005	0.131	0.051

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Phosphorus (mg/L)	9	9	0	0.022	0.113	0.050
	Total Zinc (mg/L)	3	0	2	0.010	0.010	0.010
DRAGON LK. AT MIDDLE							
Surface Water	pH (pH units)	69	0	0	7.7	8.9	8.4
	Dissolved Ammonia Nitrogen (mg/L)	58	25	14	0.005	0.271	0.029
	Total Phosphorus (mg/L)	92	90	0	0.010	0.080	0.029
	Total Chromium (mg/L)	1	1	0	0.010	0.010	0.010
	Total Copper (mg/L)	5	5	0	0.010	0.030	0.014
	Total Zinc (mg/L)	40	3	21	0.010	0.090	0.015
DRAGON LAKE AT SOUTH POINT							
Surface Water	pH (pH units)	17	0	0	8.3	8.9	8.5
	Dissolved Ammonia Nitrogen (mg/L)	16	7	6	0.005	0.095	0.018
	Total Phosphorus (mg/L)	16	13	0	0.013	0.065	0.027
	Total Zinc (mg/L)	2	0	1	0.010	0.010	0.010
DRAGON LK. AT SOUTH END							
Surface Water	pH (pH units)	9	0	0	8.4	8.8	8.5
	Dissolved Ammonia Nitrogen (mg/L)	8	3	3	0.005	0.103	0.022
	Total Phosphorus (mg/L)	8	8	0	0.017	0.099	0.043
LANDFILL (BLACKSAND) CR. ABOVE QUESNEL R.							
Surface Water	pH (pH units)	4	0	0	8.0	8.4	8.3
	Nonfilterable Residue (mg/L)	4	na	0	3	19	8
	Dissolved Ammonia Nitrogen (mg/L)	4	1	1	0.005	0.015	0.009
	Total Phosphorus (mg/L)	3	0	0	0.017	0.044	0.030
	Total Arsenic (mg/L)	2	0	2	0.001	0.040	0.021
	Total Chromium (mg/L)	1	1	0	0.010	0.010	0.010
	Total Copper (mg/L)	3	2	0	0.001	0.020	0.008
	Total Lead (mg/L)	2	1	1	0.001	0.002	0.002
	Total Zinc (mg/L)	5	1	3	0.005	0.040	0.017
LANDFILL CR. 1200 M. BELOW LEACHATE LK.							
Surface Water	pH (pH units)	2	0	0	7.3	7.7	7.5
	Nonfilterable Residue (mg/L)	2	na	0	6	14	10
	Dissolved Ammonia Nitrogen (mg/L)	2	2	0	0.015	0.270	0.143
	Total Phosphorus (mg/L)	2	1	0	0.041	0.103	0.072
	Total Copper (mg/L)	1	1	0	0.002	0.002	0.002
	Total Mercury (µg/L)	1	0	0	0.08	0.08	0.08
	Total Zinc (mg/L)	2	0	2	0.010	0.010	0.010
QUESNEL, (Leachate) LAKE OUTLET AT CP LFILL							
Surface Water	pH (pH units)	2	0	0	6.7	6.8	6.8
	Nonfilterable Residue (mg/L)	1	na	0	151	151	151
	Dissolved Ammonia Nitrogen (mg/L)	1	1	0	0.173	0.173	0.173
	Total Phosphorus (mg/L)	2	2	0	0.375	0.440	0.408
	Total Chromium (mg/L)	1	1	0	0.020	0.020	0.020

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
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n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Zinc (mg/L)	2	2	0	0.070	0.080	0.075
QUESNEL RIVER 300 M D/S LIKELY FISH CHANNELS							
Surface Water	pH (pH units)	1	0	0	7.9	7.9	7.9
	Nonfilterable Residue (mg/L)	1	na	0	1	1	1
	Dissolved Ammonia Nitrogen (mg/L)	1	0	0	0.008	0.008	0.008
	Total Phosphorus (mg/L)	1	0	1	0.003	0.003	0.003
QUESNEL RIVER 100 M. DOWNSTREAM FROM HATCHERY							
Surface Water	pH (pH units)	8	0	0	7.7	7.9	7.8
	Nonfilterable Residue (mg/L)	6	na	0	1	3	2
	Dissolved Ammonia Nitrogen (mg/L)	8	0	6	0.005	0.006	0.005
	Total Phosphorus (mg/L)	8	1	2	0.003	0.505	0.068
QUESNEL RIVER HATCHERY UPSTREAM							
Surface Water	pH (pH units)	21	0	0	6.9	8.0	7.7
	Dissolved Ammonia Nitrogen (mg/L)	21	3	18	0.005	0.100	0.046
	Total Phosphorus (mg/L)	20	0	16	0.005	0.007	0.005
QUESNEL R. AT LIKELY							
Surface Water	Dissolved Oxygen (mg/L)	1	0		13.4	13.4	13.4
	Temperature (°C)	1	0		5.5	5.5	5.5
	pH (pH units)	9	0	0	7.6	7.9	7.8
	Nonfilterable Residue (mg/L)	6	na	0	1	2	1
	Dissolved Ammonia Nitrogen (mg/L)	9	1	5	0.005	0.015	0.006
	Total Phosphorus (mg/L)	9	0	2	0.003	0.010	0.005
6K CR							
Surface Water	pH (pH units)	2	0	0	7.3	7.9	7.6
	Nonfilterable Residue (mg/L)	2	na	0	1	2	2
	Dissolved Ammonia Nitrogen (mg/L)	2	0	0	0.005	0.006	0.006
	Total Phosphorus (mg/L)	2	0	0	0.012	0.016	0.014
	Total Arsenic (mg/L)	4	0	3	0.001	0.040	0.021
	Total Chromium (mg/L)	1	0	1	0.002	0.002	0.002
	Total Copper (mg/L)	2	2	0	0.010	0.010	0.010
	Total Lead (mg/L)	1	0	0	0.001	0.001	0.001
	Total Zinc (mg/L)	3	0	2	0.002	0.010	0.006
MOREHEAD CR D/S BOOT JACK LK							
Surface Water	pH (pH units)	2	0	0	7.0	7.9	7.5
	Nonfilterable Residue (mg/L)	2	na	0	3	4	4
	Dissolved Ammonia Nitrogen (mg/L)	2	2	0	0.011	0.012	0.012
	Total Phosphorus (mg/L)	2	0	0	0.014	0.033	0.024
	Total Arsenic (mg/L)	4	0	4	0.001	0.040	0.021
	Total Chromium (mg/L)	1	0	1	0.002	0.002	0.002
	Total Copper (mg/L)	3	3	0	0.005	0.010	0.008
	Total Lead (mg/L)	1	1	0	0.002	0.002	0.002
	Total Zinc (mg/L)	3	0	1	0.005	0.010	0.008

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
MOREHEAD CR. AT BOOT JACK LK. OUTLET							
Surface Water	pH (pH units)	1	0	0	7.6	7.6	7.6
	Nonfilterable Residue (mg/L)	1	na	0	3	3	3
	Dissolved Ammonia Nitrogen (mg/L)	1	1	0	0.023	0.023	0.023
	Total Phosphorus (mg/L)	1	0	0	0.020	0.020	0.020
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	1	0	0.003	0.003	0.003
	Total Mercury (µg/L)	1	0	1	0.05	0.05	0.05
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	1	0	1	0.005	0.005	0.005
BOOT JACK LAKE @ NW BAY							
Surface Water	pH (pH units)	8	0	0	7.1	7.5	7.3
	Nonfilterable Residue (mg/L)	3	na	0	1	2	2
	Dissolved Ammonia Nitrogen (mg/L)	8	3	1	0.005	0.015	0.009
	Total Phosphorus (mg/L)	8	2	0	0.005	0.044	0.016
	Total Arsenic (mg/L)	8	0	8	0.001	0.040	0.016
	Total Copper (mg/L)	9	8	1	0.001	0.010	0.003
	Total Mercury (µg/L)	5	1	3	0.05	0.14	0.07
	Total Lead (mg/L)	11	0	9	0.001	0.001	0.001
	Total Zinc (mg/L)	11	1	5	0.005	0.030	0.011
Sediments	Total Chromium (µg/g)	1	1	0	38	38	38
	Total Copper (µg/g)	1	1	0	360	360	360
	Total Mercury (µg/g)	1	1	0	0.37	0.37	0.37
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	0	0	93	93	93
BOOT JACK CR. ABOVE HAZELTINE CR.							
Surface Water	pH (pH units)	2	0	0	7.1	8.1	7.6
	Nonfilterable Residue (mg/L)	2	na	0	1	2	2
	Dissolved Ammonia Nitrogen (mg/L)	2	0	0	0.005	0.006	0.006
	Total Phosphorus (mg/L)	2	0	0	0.018	0.018	0.018
	Total Arsenic (mg/L)	3	0	2	0.001	0.040	0.027
	Total Chromium (mg/L)	1	0	1	0.002	0.002	0.002
	Total Copper (mg/L)	1	1	0	0.010	0.010	0.010
	Total Lead (mg/L)	2	1	1	0.001	0.004	0.0025
	Total Zinc (mg/L)	1	0	1	0.002	0.002	0.002
MAUD CR. AT MOUTH							
Surface Water	pH (pH units)	1	0	0	8.5	8.5	8.5
	Nonfilterable Residue (mg/L)	1	na	0	1	1	1
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.003	0.003	0.003
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Chromium (mg/L)	1	1	0	0.050	0.050	0.050
	Total Copper (mg/L)	1	0	0	0.001	0.001	0.001

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Mercury (µg/L)	1	0	0	0.05	0.05	0.05
	Total Lead (mg/L)	1	0	0	0.001	0.001	0.001
	Total Zinc (mg/L)	1	1	0	0.730	0.730	0.730
Sediments	Total Arsenic (µg/g)	1	1	0	40	40	40
	Total Cadmium (µg/g)	1	1		13	13	13
	Total Chromium (µg/g)	1	1	0	101	101	101
	Total Copper (µg/g)	1	1	0	69	69	69
	Total Mercury (µg/g)	1	1	0	0.49	0.49	0.49
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	1	0	140	140	140
MAUD CK D/S RUDY							
Surface Water	pH (pH units)	1	0	0	8.2	8.2	8.2
	Nonfilterable Residue (mg/L)	1	na	0	11	11	11
	Dissolved Ammonia Nitrogen (mg/L)	1	0	0	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.018	0.018	0.018
	Total Arsenic (mg/L)	2	0	2	0.001	0.001	0.001
	Total Copper (mg/L)	2	2	0	0.002	0.003	0.003
	Total Mercury (µg/L)	2	0	1	0.05	0.05	0.05
	Total Lead (mg/L)	2	1	1	0.001	0.002	0.002
	Total Zinc (mg/L)	2	0	1	0.005	0.014	0.010
Sediments	Total Arsenic (µg/g)	2	2	0	35	37	36
	Total Chromium (µg/g)	2	2	0	91	96	93.5
	Total Copper (µg/g)	2	2	0	98	232	165
	Total Mercury (µg/g)	2	0	1	0.05	0.12	0.09
	Total Lead (µg/g)	2	0	2	10	10	10
	Total Zinc (µg/g)	2	0	0	115	118	117
MAUD CR U/S RUDY							
Surface Water	pH (pH units)	1	0	0	8.1	8.1	8.1
	Nonfilterable Residue (mg/L)	1	na	0	2	2	2
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.013	0.013	0.013
	Total Arsenic (mg/L)	2	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	2	2	0	0.002	0.003	0.003
	Total Mercury (µg/L)	2	0	2	0.05	0.05	0.05
	Total Lead (mg/L)	2	0	2	0.001	0.001	0.001
	Total Zinc (mg/L)	2	0	1	0.005	0.005	0.005
Fish Tissue (1990)	Mercury (µg/g)	1	0	0	0.08	0.08	0.08
RUDY CR U/S MAUD							
Surface Water	pH (pH units)	1	0	0	8.3	8.3	8.3
	Nonfilterable Residue (mg/L)	1	na	0	1	1	1
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.009	0.009	0.009
	Total Arsenic (mg/L)	2	0	1	0.001	0.001	0.001

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Total Copper (mg/L)	2	1	0	0.001	0.002	0.002
	Total Mercury (µg/L)	2	0	2	0.05	0.05	0.05
	Total Lead (mg/L)	2	0	2	0.001	0.001	0.001
	Total Zinc (mg/L)	2	0	2	0.005	0.005	0.005
<u>RUDY CR BELOW TAILING AREA</u>							
Surface Water	pH (pH units)	1	0	0	8.3	8.3	8.3
	Nonfilterable Residue (mg/L)	1	na	0	2	2	2
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.004	0.004	0.004
	Total Arsenic (mg/L)	1	0	1	0.001	0.001	0.001
	Total Copper (mg/L)	1	0	0	0.001	0.001	0.001
	Total Mercury (µg/L)	1	0	1	0.05	0.05	0.05
	Total Lead (mg/L)	1	0	1	0.001	0.001	0.001
	Total Zinc (mg/L)	1	1	0	0.030	0.030	0.030
Sediments	Total Chromium (µg/g)	1	1	0	80	80	80
	Total Copper (µg/g)	1	1	0	67	67	67
	Total Mercury (µg/g)	1	0	0	0.10	0.10	0.10
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	0	0	85	85	85
<u>EDNEY CR TRIB</u>							
Surface Water	pH (pH units)	2	0	0	7.3	8.5	7.9
	Nonfilterable Residue (mg/L)	2	na	0	1	2	2
	Dissolved Ammonia Nitrogen (mg/L)	2	1	1	0.005	0.013	0.009
	Total Phosphorus (mg/L)	3	0	0	0.009	0.060	0.034
	Total Arsenic (mg/L)	4	0	3	0.001	0.040	0.021
	Total Chromium (mg/L)	1	0	1	0.002	0.002	0.002
	Total Copper (mg/L)	1	0	1	0.001	0.001	0.001
	Total Lead (mg/L)	2	1	0	0.001	0.002	0.0015
	Total Zinc (mg/L)	2	0	2	0.002	0.005	0.004
<u>HAZELTINE CR. UPPER</u>							
Surface Water	pH (pH units)	3	0	0	7.4	8.0	7.7
	Nonfilterable Residue (mg/L)	3	na	0	1	8	3
	Dissolved Ammonia Nitrogen (mg/L)	3	1	0	0.006	0.029	0.014
	Total Phosphorus (mg/L)	4	0	0	0.019	0.050	0.030
	Total Arsenic (mg/L)	5	0	5	0.001	0.040	0.017
	Total Chromium (mg/L)	1	0	1	0.002	0.002	0.002
	Total Copper (mg/L)	2	1	1	0.001	0.004	0.003
	Total Mercury (µg/L)	1	0	1	0.05	0.05	0.05
	Total Lead (mg/L)	3	1	0	0.001	0.002	0.001
	Total Zinc (mg/L)	3	0	2	0.005	0.010	0.007
<u>POLLEY LAKE - SOUTH</u>							
Surface Water	pH (pH units)	7	0	0	7.5	7.9	7.7
	Nonfilterable Residue (mg/L)	4	na	0	1	2	1

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Dissolved Ammonia Nitrogen (mg/L)	7	2	0	0.005	0.018	0.010
	Total Phosphorus (mg/L)	7	5	0	0.013	0.020	0.016
	Total Arsenic (mg/L)	7	0	7	0.001	0.040	0.018
	Total Copper (mg/L)	4	4	0	0.002	0.006	0.004
	Total Mercury (µg/L)	4	1	2	0.05	0.26	0.11
	Total Lead (mg/L)	7	0	5	0.001	0.001	0.001
	Total Zinc (mg/L)	5	0	3	0.005	0.010	0.007
POLLEY LAKE - NORTH							
Surface Water	pH (pH units)	9	0	0	7.4	8.3	7.8
	Nonfilterable Residue (mg/L)	4	na	0	1	2	2
	Dissolved Ammonia Nitrogen (mg/L)	9	4	2	0.005	0.023	0.010
	Total Phosphorus (mg/L)	9	6	0	0.010	0.038	0.018
	Total Arsenic (mg/L)	8	0	8	0.001	0.040	0.016
	Total Copper (mg/L)	16	14	1	0.001	0.008	0.004
	Total Mercury (µg/L)	6	2	2	0.05	0.14	0.08
	Total Lead (mg/L)	19	4	10	0.001	0.006	0.001
	Total Zinc (mg/L)	18	1	12	0.005	0.030	0.007
Sediments	Total Chromium (µg/g)	1	1	0	59	59	59
	Total Copper (µg/g)	1	1	0	325	325	325
	Total Mercury (µg/g)	1	1	0	0.22	0.22	0.22
	Total Lead (µg/g)	1	0	1	10	10	10
	Total Zinc (µg/g)	1	0	0	102	102	102
NIQUIDET C. ABOVE GRUHS L.							
Surface Water	pH (pH units)	3	0	0	7.9	8.2	8.0
	Dissolved Ammonia Nitrogen (mg/L)	3	0	3	0.005	0.005	0.005
	Total Phosphorus (mg/L)	3	0	0	0.010	0.018	0.015
LITTLE HORSEFLY R. ABOVE GARDNER RD.							
Surface Water	pH (pH units)	12	0	0	7.7	8.2	7.9
	Dissolved Ammonia Nitrogen (mg/L)	12	1	8	0.005	0.011	0.006
	Total Phosphorus (mg/L)	12	0	0	0.004	0.014	0.009
LITTLE HORSEFLY R ABOVE NIQUIDET C							
Surface Water	pH (pH units)	12	0	0	7.5	8.2	8.0
	Dissolved Ammonia Nitrogen (mg/L)	12	2	7	0.005	0.011	0.006
	Total Phosphorus (mg/L)	12	0	0	0.005	0.012	0.008
LITTLE HORSEFLY R. BELOW LITTLE HORSEFLY L.							
Surface Water	Dissolved Oxygen (mg/L)	1	0	0	10	10	10
	Temperature (°C)	1	1	0	17.5	17.5	17.5
	pH (pH units)	7	0	0	7.1	8.1	7.9
	Dissolved Ammonia Nitrogen (mg/L)	7	0	5	0.005	0.007	0.005
	Total Phosphorus (mg/L)	7	0	0	0.005	0.012	0.008
LITTLE HORSEFLY R. AT HATCHERY RD.							
Surface Water	pH (pH units)	13	0	0	7.6	8.1	7.9

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Quesnel HMA

		n	# > Guideline*	# < MDL	Min	Max	Mean
	Dissolved Ammonia Nitrogen (mg/L)	13	0	12	0.005	0.006	0.005
	Total Phosphorus (mg/L)	13	0	0	0.004	0.009	0.006
LITTLE HORSEFLY L. AT OUTLET							
Surface Water	pH (pH units)	1	0	0	8.0	8.0	8.0
	Dissolved Ammonia Nitrogen (mg/L)	1	0	0	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.011	0.011	0.011
LITTLE HORSEFLY L. AT NORTH BAY							
Surface Water	pH (pH units)	2	0	0	7.8	8.0	7.9
	Dissolved Ammonia Nitrogen (mg/L)	2	0	2	0.005	0.005	0.005
	Total Phosphorus (mg/L)	2	0	0	0.009	0.009	0.009
LITTLE HORSEFLY L. AT CENTRE							
Surface Water	pH (pH units)	1	0	0	7.9	7.9	7.9
	Dissolved Ammonia Nitrogen (mg/L)	1	0	1	0.005	0.005	0.005
	Total Phosphorus (mg/L)	1	0	0	0.010	0.010	0.010
UNNAMED LAKE (ALIAS WOLFTRACK L)							
Surface Water	Total Phosphorus (mg/L)	2	2	0	0.018	0.023	0.021
MELISSA LAKE							
Surface Water	Total Phosphorus (mg/L)	2	1	0	0.010	0.120	0.065
Sediments	Total Cadmium (µg/g)	1	1		1	1	1
	Total Chromium (µg/g)	1	0	0	25	25	25
	Total Copper (µg/g)	1	1	0	70	70	70
	Total Mercury (µg/g)	1	1	0	0.21	0.21	0.21
	Total Lead (µg/g)	1	0	0	10	10	10
	Total Zinc (µg/g)	1	0	0	76	76	76

* Note that dissolved oxygen is # < guideline, and pH is # < or > guideline range.
MDL = method detection limit
na = no guideline was applicable

n = number of samples
d/s = downstream
u/s = upstream

Table 8.5.2 Summary of Land Areas, Stream Flows and Water Demand in the Quesnel HMA.[1]

			Landuse area (km sq.)			Naturalized Stream flow (L/s)			Potential August water demand (L/s)				
Stream	SISS code	Water-shed area (km sq.)	Improved farmland (1990)	Total logged	Recent/ proposed logging*	Summer 7-day mean low-flow	Winter 7-day mean low-flow	Mean annual flow	Domestic	Irrigation	Water-works	Industrial	Storage (ac-ft)
Cottonwood R.	00-5100	2,460	54.65	455.57	514.5	4,150	3,510	26,000	2.5	70	2.1	0.8	315
Ahbau Ck.	00-5100-100	505	36.33	65	46.7	390	570	3,000	0.05	67	0	1.7	310
Lightning Ck.	00-5100-400	243	3.64	59.4	30.87	1,320	670	5,000	0.05	0	0	0.21	0
Victoria Ck.	00-5100-500	305	0	3.41	21.99	190	310	1,700	0	0	0	0	0
Naver Ck.	00-5400	900	70.69	143.59	109.29	910	1,150	6,400	0.84	36.5	0	5.4	0
Hixon Ck.	00-5400-050	238	17.54	11.52	14.94	130	230	1,300	0.32	0	0	1	0
Lower Quesnel R.	06-0000-000-000-000-000-991	11,730	155.04	34	11.7	118,670	62,370	237,000	6.41	1137	92	17.4	2294
Upper Quesnel R.	06-0000-000-000-000-000-992	5,950	65.61	146.06	127.6	60,670	32,570	130,000	1.6	172	0	16.7	276
Beaver Ck.	06-2270	1,561	85.64	146.06	167.22	600	500	4,900	1.3	719	0	1.3	1518
Cariboo R.	06-3810	3,253	0.26	354.45	427.27	44,200	17,300	94,500	0.6	0.23	0	0.13	0
Little R.	06-3810-250	378	0	27.32	37.02	2,060	1,040	7,800	0	0	0	0	0
Cunningham Ck.	06-3810-400	168	0	11.54	32.59	910	460	3,500	0	0	0	0	0
Hazeltine Ck.	06-4810	124	0	52.39	48.79	10	30	200	0	0	0	0	0
Edney Ck.	06-4810-030	86	0	39	39	40	80	500	0	0	0	0	0
Horsefly R.	06-5460	2,860	44.82	246.64	320.57	11,520	6,880	33,200	0.76	171	0	5.3	286
Little Horsefly R.	06-5460-145	465	4.78	20.98	30.64	2,290	2,170	4,000	0.18	32.1	0	1.1	146
Moffat Ck.	06-5460-190	551	14.68	54.82	71.6	640	740	3,300	0.08	60.5	0	0.53	0
McKinley Ck.	06-5460-480	450	11.54	54.84	79.27	1,160	1,200	5,100	0.11	0	0	0	0
Mitchell Ck.	06-6960	574	0	3.77	14.7	8,090	2,920	18,500	0	0	0	0	0
Penfold Ck.	06-6960-020	199	0	0	4	2,060	680	4,700	0	0	0	0	0
Cameron Ck.	06-6960-180	71	0	1.81	3.94	730	240	1,700	0	0	0	0	0
Watt Ck.	06-6980	66	0	0	0	680	230	1,600	0	0	0	0	0
Roaring R.	06-7020	148	0	3.61	4.32	1,530	500	3,500	0.03	0	0	0	0
Wasko Ck.	06-7650	115	0	0	3.25	620	320	2,400	0.03	0	0	0	0
Lynx Ck.	06-9050	67	0	0	0	360	180	1,400	0	0	0	0	0
Killdog Ck.	06-9740	40	0	0	5.98	220	110	800	0	0	0	0	0
Blue Lead Ck.	06-9860	91	0	0	3.59	940	310	2,100	0	0	0	0	0
Summit Ck.	06-9890	40	0	0	0	220	110	800	0	0	0	0	0

* Proposed logging estimates were based on logging plans for 1990-1996.

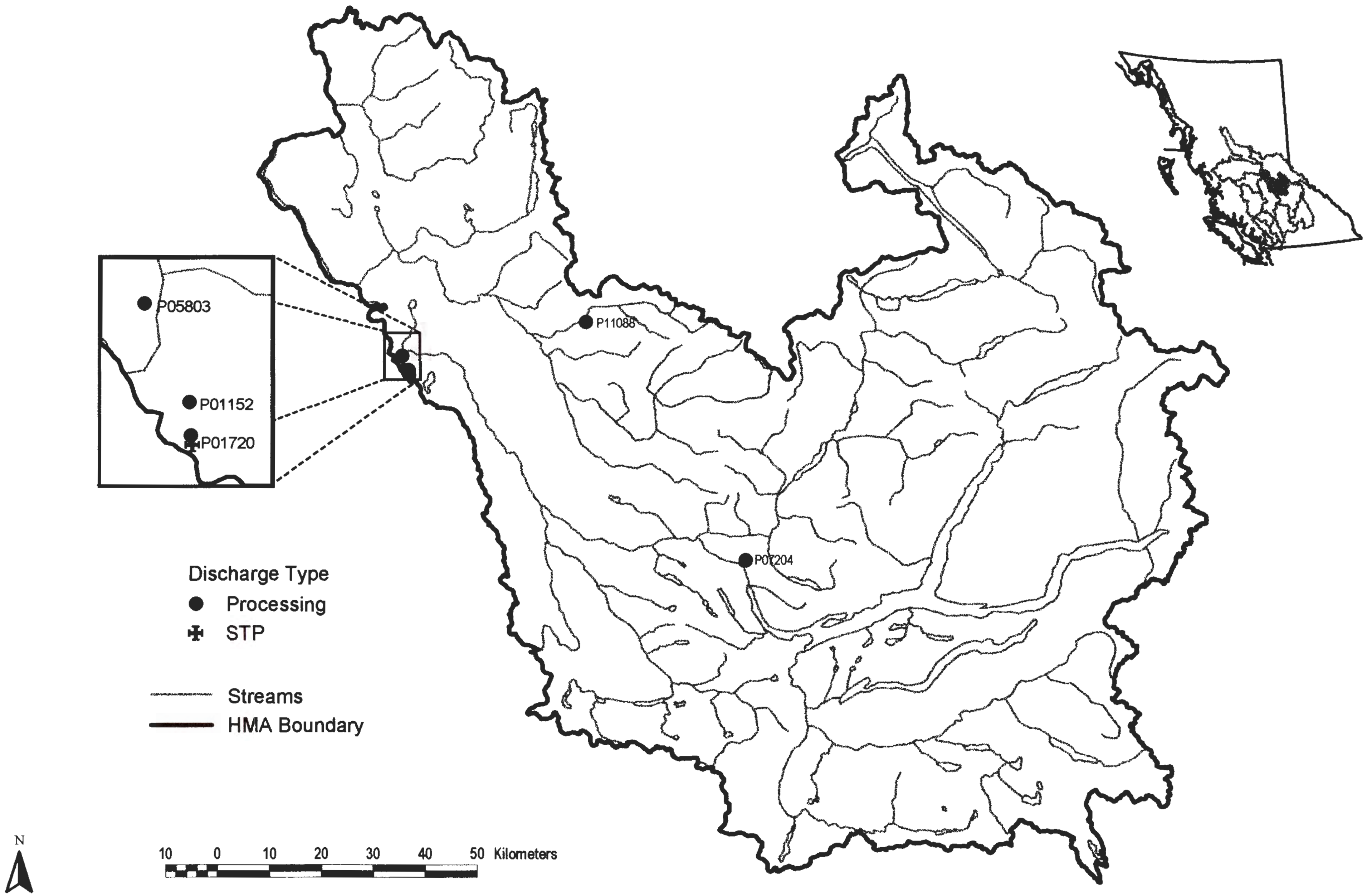
[1] Adapted from Rood and Hamilton, 1995 (see reference 2)

Table 8.5.3 Summary of Red-Coded[1] Indicators for Salmon-Bearing Streams in the Quesnel HMA. (Streams are ordered from downstream to upstream.)

Stream Name	Indicator				
	Urban	Agriculture	Logging	Stream Flow	Demand
Cottonwood River			*		
Ahbau Creek					*
Lightning Creek			*		
Victoria Creek					
Naver Creek			*		
Hixon Creek				*	
Lower Quesnel River	*				
Upper Quesnel River					
Beaver Creek		*			*
Cariboo River					
Little River					
Cunningham Creek			*		
Hazeltine Creek			*	*	
Edney Creek			*	*	
Horsefly River		*	*		
Little Horsefly River					
Moffat Creek		*			
McKinley Creek			*		
Mitchell River					
Penfold Creek					
Cameron Creek					
Watt Creek					
Roaring River					
Wasko Creek					
Lynx Creek					
Killdog Creek					
Blue Lead Creek			*		
Summit Creek					

[1] "Red-Coded" = likely to have water quality impacts associated with given land use, stream flow, or water demand conditions in the stream. See Chapter 3 for assessment methodology.

Figure 8.2.1 Location of Permitted Waste Discharges to Surface Water in the Quesnel HMA



Chapter 9 Key Issues and Recommended Actions

The issues and recommended actions outlined here address water quality issues identified in the Middle and northern Fraser Habitat Management Areas, in Chapters 4-8. Many of the issues and recommended actions are also relevant to other areas of the Fraser Basin, and the Province of B.C. as a whole. The agencies and/or levels of government which are well positioned to take a leadership role in implementing recommendations, based on existing jurisdictions, are usually identified. Issues are addressed in the same order as they are presented in Chapter 2.

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9.1 Urban Development

9.1.1 Land Clearing and Excavation: Preventing Impacts to Water Quality

The Issues:

A. Unless precautions are taken development inevitably results in erosion due to exposure of soils, and damage to stream banks and riparian vegetation. Increased suspended sediment levels in stream water result in sedimentation of the stream bottom, reduced photosynthesis, impaired ability of fish to feed, and numerous other impacts. The cities of Prince George and Quesnel are the largest urban/industrial centers in the HMAs considered here, and are experiencing about 2-4% population growth annually, resulting in land clearing for new housing and roads. Clearing of residential properties is noted to be a concern in Prince George, Quesnel, and Vanderhoof, along with the associated destruction of riparian vegetation on the Nechako, Quesnel, and Fraser Rivers.[6]

B. The province has jurisdiction over land use decisions, but does not have legislation to address common issues such as erosion control, riparian protection, etc. This absence of legislation creates an excessive workload for environmental agencies, who work with dozens of local governments and developers in attempts to pro-actively address these issues.

Recommended Actions:

1. Municipal governments should adopt the *Land Development Guidelines*[2] as minimum standards of environmental protection associated with land development. Municipalities have the jurisdiction of granting development permits and are therefore well positioned to require that developers comply with riparian leave strip guidelines, and sediment and erosion control approaches recommended in the *Land Development Guidelines.*[2]
2. Given the Province's stated interest in protecting fish and the fact that the *Land Development Guidelines*[2] is also a B.C. publication, it is a logical progression that B.C. should act on this recommendation. Adoption of *Land Development Guidelines*[2] in habitat protection legislation, as a minimum standard for protection of aquatic habitats during development, would be a significant step forward in environmental protection. It would also streamline agency efforts by reducing referral workloads, and reducing administrative costs.
3. Environmental agencies need to devote more effort to site visits before and during construction to ensure adequate protection of water quality (and habitat), and to undertake enforcement actions when necessary. Environmental protection is much less expensive and more effective than after-the-fact restoration programs, hence monitoring of development projects must be made a priority. Implementing recommendations 1 and 2 above would free up some staff time for site visits.
4. In that *Fisheries Act* enforcement is best suited to larger cases, DFO enforcement staff need access to a ticketing system to address the numerous less serious violations which are presently not enforced.
5. DFO and MELP must promote environmental education programs for construction workers and heavy equipment operators, who can only comply with guidelines and regulations if they are aware of and understand the guidelines. Heavy equipment companies and contractors must be encouraged to hold such courses.
6. The development community must take a stronger leadership role in improving development practices, from the planning and design stage through to the completion of construction. This would benefit fish, help developers avoid costly delays in obtaining necessary permits, and reduce the likelihood of charges under the *Fisheries Act*. It could also result in increased property values.

9.1.2 *Preventing Impacts to Stream Hydrology*

The Issues:

A. Replacement of vegetation with impermeable surfaces disrupts natural stream hydrology resulting in increased "flashiness" of stream flows. Increased high flows damage instream habitat and decreased low flows lead to higher summer water temperatures, and possibly other water quality impacts.

Recommended Actions:

1. Master drainage plans minimizing disruption of natural hydrology should be required by local governments in advance of development for all new development proposals. Plans would address the effects of development on both surface and groundwater regimes, and provide stormwater management approaches that ensure the reasonable maintenance of stream base flows. Plans would include some form of stormwater detention (e.g. artificial wetland, underground storage, etc.), with controlled release either to ground or surface waters, and tree retention. Master drainage plans should also address re-development and provide for retrofitting with Best Management Practices in these areas. Official Community Plans should address opportunities for retrofitting existing developed areas with stormwater detention (e.g. identify available land, etc.).
2. The provincial government, given their jurisdiction for managing land and water use, should provide leadership on stormwater management and detention issues, and establish minimum requirements that would protect healthy aquatic environments and hydrology. Objectives for providing adequate protection for stream hydrology should be developed by DFO and MELP. Establishing province-wide standards would provide an improved level of environmental protection and reduce demands on agency staff. Until an agreement is reached DFO and MELP should request stormwater detention for all new subdivisions, unless it is shown that runoff quality and quantity can be adequately addressed in other ways. Municipal governments should ensure that impermeable surfaces are minimized as a means of minimizing their stormwater management costs.
3. DFO must persevere with efforts to educate planners, developers, and municipal governments about the community, financial, and environmental benefits from improved stormwater management practices (e.g. *Land Development Guidelines,*[2] and *Stream Stewardship: A Guide for Urban Planners and Developers*[3]).
4. Where municipalities and/or developers do not provide adequate stormwater detention and treatment resulting in damage to streams, DFO and MELP should consider enforcement options.
5. Developers and municipalities must explore and implement ways of reducing stormwater runoff and increasing groundwater recharge, such as the use of permeable surfaces as alternatives to traditional impermeable materials. Other opportunities such as loose-fitting storm drain pipes to allow seepage into the ground, and using French Drains to keep groundwater out of the storm drain system and to replenish stream flows instead, need to be implemented where possible.
6. The system of local governance should consider addressing impervious surface area in property taxes as a means of discouraging property owners from increasing impervious surface area, and covering some of the cost of stormwater management. Municipal governments should also consider limiting the allowable percentage of impervious surface area on properties.

9.1.3 *Contaminants in Urban Stormwater Runoff*

The Issues:

A. Contaminants released from many routine human activities accumulate on street, parking lot, and lawn surfaces. They are washed into storm sewers and ultimately streams during precipitation and thaw events, often at harmful concentrations. There are numerous direct discharges of stormwater to the Quesnel and Fraser Rivers associated with urban centers.

B. Stormwater outfalls often discharge to sensitive environments, such as small streams and near-shore areas, that provide important fish habitat and are easily damaged.

Recommended Actions:

1. Implement recommendations which pertain to addressing hydrology concerns above, such as installation of artificial wetlands and stormwater detention ponds, as these actions would also lead to improved stormwater quality. DFO, DOE and MELP should encourage the installation of stormwater detention facilities which are

at least designed to capture the most highly contaminated "first flush" and to provide treatment, with all new developments.

2. Widespread adoption of development approaches recommended in *Land Development Guidelines*[2] and *Stream Stewardship: A Guide for Urban Planners and Developers*[3] is key to avoiding impacts from stormwater quantity and quality.
3. Guidelines for the design and construction of stormwater treatment methods such as artificial wetlands, bio-filtration swales, etc. need to be developed to address various needs.
4. DFO, DOE and MELP should work with local governments in the Middle and north Fraser HMAs to identify and modify or relocate the stormwater outfalls which discharge to environmentally sensitive areas, and to ensure that further stormwater impacts from new development are prevented.
5. Environmental agencies must continue to work pro-actively to raise public awareness about the impacts of stormwater on streams, and how individuals can minimize their contaminant contributions, e.g. by reducing use of automobiles, pesticides, fertilizers, etc.
6. Liquid waste management planning, which addresses stormwater runoff issues, should be made mandatory for all local governments.
7. Funds obtained through enforcement actions involving municipal governments should be placed in trust funds and used to support community groups working to benefit urban streams.

9.1.4 Municipal Sewage Discharges

The Issues:

A. Many STPs discharge acutely toxic effluents to the environment at various times.[5, 6] A compliance monitoring study done by DOE addressed about 10 STPs in the Fraser Basin including the Prince George STP. Rainbow trout LC_{50} bioassays were passed in 4 of the 7 samples tested (i.e. 50% or more of the test populations survived for 96 hours in 100% effluent concentration). Analytical results suggest that ammonia may have contributed to effluent toxicity. Seven effluent samples from the Williams Lake STP were tested for toxicity, and all samples proved toxic to rainbow trout.[5, 6]

B. To date, municipalities have not been required to plan for sewage discharges in anticipation of rapidly growing population, resulting in facilities being pushed beyond their intended capacity, and causing compromised effluent quality. There are numerous examples of STPs being out of compliance with their permits for years, while the population of the serviced area continued to grow rapidly.

C. Many of the permits for STP discharges restrict the release of only a few parameters such as BOD and TSS, yet effluents contain significant concentrations of numerous potentially harmful substances such as ammonia, residual chlorine, detergents, heavy metals, and other contaminants.

Recommended Action:

1. Continued efforts are required to ensure that sewage effluents are diligently managed in the Fraser Basin. The Prince George STP has been upgraded since the DOE tests were done, so toxicity problems associated with this STP may have been resolved. Toxicity problems at the Williams Lake STP need to be addressed. Numerous STPs in the middle and northern HMAs have not been assessed for toxicity, but should be.
2. Municipal governments must plan growth and development in a manner that recognizes limitations of existing infrastructure in place to protect environmental quality. Adequate infrastructure should precede rather than follow new development. This type of issue should be addressed in the future through growth management strategies under the *Municipal Act*, and liquid waste management plans under the *Waste Management Act*. British Columbia's planning system (as described in *Growth Strategies for the 1990s and Beyond*[8]) does not address these real growth issues and should be upgraded in consultation with environmental management agencies to adequately address environmental protection.
3. Regulatory agencies such as MELP, DOE, and DFO should continue working with municipal governments to achieve non-acutely lethal sewage discharges. Where cooperation is lacking, enforcement actions may be necessary.
4. Municipal governments need to recognize that they can best serve the long-term needs of their communities by protecting the environment through pro-active approaches such as source control. Continued efforts to

educate the public, municipal staff, and political representatives about the environmental and economic benefits of source control are needed.

5. Municipalities should be required to routinely monitor concentrations of ammonia, and other toxic substances which are expected to be present in a particular sewage discharge. Where effluents are chlorinated and de-chlorinated, monitoring of residual chlorine concentrations should also be required. Permitted discharge levels should be below concentrations known to be acutely toxic to aquatic organisms.

9.1.5 Septic Tanks

The Issues:

A. The Ministry of Health (MOH) permitting process for septic systems does not impose more stringent requirements for septic systems installed in highly permeable soils, which may allow contaminated seepage to reach nearby streams, or to contaminate unconfined aquifers. They in fact favour the installation of systems in these types of soils (i.e. soils must meet a minimum percolation rate but not a maximum percolation rate), resulting in the pollution of nearby surface and ground waters. Such problems are most likely to arise in urbanizing areas without STP service, where the combination of more septic tanks discharging to ground combine with disruption of natural hydrology to increase the chances of septic system failure.

B. Substandard construction of septic tank systems results in a significant percentage of failures.

C. The MOH permitting process for septic systems does not include any maintenance requirements. When septic systems are not maintained they will eventually fail, potentially resulting in effluents flowing virtually untreated through permeable soils into nearby streams. In general septic tanks should be pumped out at least once every 3 years. Many people are not aware that they are on a septic system and believe that they are connected to a municipal treatment facility.

D. New subdivisions are often located near existing houses which rely on septic systems for sewage disposal. Disruption of the natural hydrology of the area can cause septic systems to fail, increasing the probability that contaminants will reach streams.

Recommended Actions:

1. Environmental regulatory agencies must encourage the upgrading of permitting requirements for septic systems to ensure protection of surface water quality. Measures could include relating required setbacks from streams to the permeability of soils in the area - more permeable soils requiring wider setbacks.
2. The Ministry of Health needs to consider certification of contractors involved with construction and maintenance of septic systems. This is already happening in the Capital Regional District (Victoria) and is being considered by Fraser Valley health units.
3. Existence of a septic system should be indicated on property titles.
4. When reviewing development proposals regulatory agencies need to consider the presence of septic tanks, and either ensure that new development will not impair the function of existing septic systems, or connect the new and existing buildings to municipal sewage treatment systems.
5. The provincial government should establish a regulation requiring regular septic tank maintenance. This could be enforced by requiring property owners to submit proof of septic system maintenance every three years with their property taxes, with failure to do so resulting in the local government doing the maintenance work for a fee and a fine.
6. Consideration should be given to requiring new development to conform with the standards of the day, and not the standards in effect when the property is purchased, especially when development involves multiple units.

9.1.6 Domestic Water Supplies

The Issues:

A. Drinking water is treated to kill pathogens prior to entering the distribution system, and treatment chemicals persist in drinking water to ensure drinking water remains uncontaminated until it reaches the end user. Some substances such as chloramine are extremely toxic to aquatic biota and are also persistent. Salmon-bearing streams are at risk from chlorine or chloramine contamination from broken water mains and from water used in lawn watering or car washing reaching storm drains.

Recommended Action:

1. DFO and DOE should continue their efforts to educate the public and elected local government officials about the potential impacts of their domestic water supply reaching streams directly or via storm sewers. Water mains should be placed as far from fish-bearing streams as possible when new developments are underway.
2. The Province, through its Liquid Waste Management Plan process, needs to make it clear to communities that the risks of using chloramine in fisheries-sensitive areas may preclude its use for drinking water disinfection. Effective alternatives which present much less risk to the environment do exist.

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9.2 Addressing Permitted Waste Discharges

The Issues:

A. Permitted discharges to surface waters that may negatively affect surface water quality in the Middle and northern Fraser HMAs are identified in Tables 4.2.1, 7.2.1, and 8.2.1. In addition to water chemistry issues, discharge of large effluent volumes at high temperatures (up to 38°C) raises concerns.

B. The Waste Management Permit process has a strong engineering and pollution control emphasis (i.e. BACT). DFO's emphasis is based on a risk-averse strategy so as to prevent the discharge of toxic effluents, as fish will not necessarily avoid, and may even be attracted to harmful effluent plumes.

C. MELP does audit effluent discharges, however, in some areas it is their practice to notify the discharger ahead of time. This allows the discharger to prepare their facility for an inspection. Maintaining viable aquatic life requires facilities to always be diligent in maintaining effluent quality.

D. Permitted discharges of solid wastes to landfills can result in the generation of toxic leachates that impair surface water quality.

E. Larger facilites such as pulp mills submitt effluent quality data to MELP's Environmental Monitoring System (EMS), a central database. However, smaller facilities may submit data in paper form, which may or may not be entered into the EMS. Effluent quality data submitted to MELP by proponents is usually not readily accessible to other regulatory agencies.

Recommended Actions:

1. Requirements for toxicity-testing bioassays should be incorporated into most Waste Management Permits that address the discharge of an effluent to a fish-bearing surface water body.
2. Where toxicity is identified, proponents should be required to control toxic components of effluents within agreed-upon time frames. As well, persistent harmful substances should be removed from effluents.
3. Permits identified in Tables 4.2.1, 7.2.1, and 8.2.1 need to be revisited, and discharge conditions may need to be altered in order to adequately protect the environment.
4. MELP and DOE should continue to promote pollution prevention as a preferred method of pollution control.
5. Where Codes of Practice, Best Management Practices (BMPs) etc. have been developed, MELP and DOE should work with industry to ensure implementation and improve compliance. Biological assessments should be conducted to ensure BMPs are adequately protective of aquatic resources.
6. Waste Management inspectors should be empowered with full rights of trespass so that they may undertake audits without having to warn proponents ahead of time.
7. DFO needs to conduct audits of effluent quality from a biological perspective. Where problematic discharges are identified DFO should work with MELP and DOE to ensure that effluent quality is satisfactorily improved.
8. Effluent quality data submitted to MELP by proponents needs to be checked for Quality Assurance and Quality Control, and made electronically accessible to all resource management agencies within an established time frame after collection. Many commercial laboratories now provide direct electronic reporting.

9. Enforcement actions should be taken to address the significant amounts of wood waste that are inappropriately deposited by wood processing industries in and near sensitive fish habitats in the Middle and northern Fraser HMAs. In addition to the generation of toxic leachates, wood waste can also cause habitat impacts. Woodwaste problems result largely from poor management practices, and do not generally require complex solutions. Numerous wood waste and log storage sites in these HMAs require further inspection.[6]

10. The discharge of concrete truck washing effluents at construction sites and ready mix concrete plants has been identified as a concern in the lower Fraser, and similar problems are expected in the Middle and northern Fraser River HMAs, especially in growing urban and industrial centers. These truck wash effluents are usually very toxic to fish and are frequently discharged without compliance with permit specifications. The concrete delivery industry should provide drivers with disposal alternatives for wash water as facilities provided by the concrete purchaser are usually inadequate. Facilities to collect the wash water, and either recycle or neutralize and settle it need to be provided. DFO has been working with this industry in the Lower Fraser with considerable success. Similar efforts should be made in the north.

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9.3 Addressing Impacts from Agriculture

The Issues:

A. Spring runoff from livestock over-wintering areas is usually highly contaminated by manure and carries large amounts of nutrients, oxygen-demanding substances, and ammonia into fish-bearing streams. Many producers are working to improve practices, however, there are still numerous farms and ranches where problems persist. Small-scale "hobby" farms are increasingly becoming sources of impacts, as land owners often do not have much background on livestock management.

B. Improper disposal of farm wastes in addition to excess manure, such as animal carcasses, etc. can result in degraded water quality.

C. Exposed soils on fields erode, resulting in stream sedimentation and an increased need for ditch cleaning. This is noted as a problem in the Nechako, Middle Fraser, and Quesnel HMAs, where land is being cleared for ranching and hobby farming.[6]

D. Unrestricted livestock access to stream banks results in significant damage to riparian areas and degradation of water quality. This type of damage occurs to some extent in all of the HMAs addressed in this report.

E. There is an inadequate enforcement effort at both federal and provincial levels to address impacts from farming on water quality (and fish habitat).

Recommended Actions:

1. Agencies including DFO, DOE, MELP, and MAFF must continue working cooperatively to promote the use of Best Management Practices on farms. An education program complementary to the *Watershed Stewardship: A Guide for Agriculture* would be a logical approach. DFO should continue to support educational initiatives directed at producers.

2. Agencies should continue to work with producers, as cooperative efforts are bringing good results to date. In particular, the B.C. Cattlemen's Association has taken many positive steps to promote improved environmental practices among their members.

3. DFO needs to monitor the results of riparian habitat restoration, and to publicize results demonstrating the benefits of good riparian management for both fish and farmers.

4. DFO, MELP, and MAFF should increase stream bank restoration efforts on farm land with severe erosion problems, as this would address both habitat and water quality impacts, and improve relations with the farming community. DFO should also increase efforts to publicize successes of on-farm efforts, as this would promote interest in improved practices within the farming community.

5. Protection of aquatic life needs to be given a higher priority under the *Water Act*, and Water Managers need to be made responsible for ensuring that adequate flows for fish are always retained. Where streams are already over-subscribed, a watershed assessment should be completed, with the objective of determining how to meet the needs of stakeholders after water requirements for fish have been met.

6. Regulatory agencies should increase efforts at addressing impacts from agriculture via legal means, as appropriate, and should use a coordinated approach to ensure the best use of available resources.
7. Policies which promote detrimental (i.e. to fish) farming practices must be discouraged (e.g. higher taxes for unfarmed ALR land discourages establishment of leave strips). This will likely require high-level negotiations between environmental regulatory agencies and others such as the Agricultural Land Commission, as well as the public.

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9.4 Addressing Impacts from Forestry Activities on Water Quality

The Issues:

A. There are numerous salmon-bearing streams in the Middle and northern Fraser HMAs, which have been significantly impacted by logging already, and there is strong pressure for continued harvesting at a high rate of cut.

B. MOF policies limit the flexibility of MOF District Managers in implementing various provisions of the Forest Practices Code and result in inadequate protection of streams. Small streams (S4 – S6) are of particular concern, as the Code provisions for retaining riparian vegetation are minimal.

C. The B.C. Government led a process to develop a Land-Use Plan for the Cariboo-Chilcotin region. DFO participated in the planning process with the aim of pro-actively securing improved fish habitat protection in some key watersheds. Though the plan is currently being implemented, fish issues are not being addressed to the satisfaction of DFO. Very high rates of cut (approaching 30% Effective Clearcut Area) are occurring in some of the Fraser River's most productive sockeye-producing watersheds, including the Horsefly and Cottonwood Rivers. Sedimentation problems have already been noted in some of watersheds in the Quesnel HMA with only 15% ECA.

D. Log booming sites and practices in the Fraser River are resulting in impairment of fish habitat and may also be influencing water quality at several sites in Quesnel, Prince George, Takla Lake, Sheridan Creek, the Endako River, and the Fraser River near Boston Bar.[6]

Recommended Actions:

1. DFO must establish an auditing process to assess the adequacy of protection afforded to water quality and fish habitat in different areas of the basin (and the rest of B.C.) in association with forestry activities. This might best be accomplished through a partnership with MELP, and should be an ongoing activity. DFO must work with MOF to address their policies that result in conflicts with the *Fisheries Act*. Where forest harvesting leads to fish habitat and/or water quality impacts, DFO should pursue enforcement of the *Fisheries Act*.
2. DFO must work to prevent further disruptions to hydrology and sediment impacts from excessive or inappropriate logging in watersheds. This may require negotiations with senior provincial government staff, given that DFO's participation on the former Committee on Resources and the Environment (CORE) and LRMP planning processes in the Fraser Basin has not led to fish habitat and water quality concerns being adequately addressed.
3. DFO must consider the value of continued participation with provincially-led planning processes. The department should evaluate the benefits that have resulted from input to mid and upper basin CORE, LRMP, and LRUP processes. Efforts may be better directed at watershed-based planning and providing up-to-date fisheries resource information (as per FISS) to the planning processes, along with corresponding preferred management strategies.
4. Enforcement actions should be taken as necessary to address impacts to fish habitat and water quality resulting from log booming activities.

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9.5 Water Quality Issues Associated with Mining

The Issues:

A. Some placer mining occurs in areas of the Middle and northern Fraser HMAs. Ministry of Energy and Mines conducts annual flights to monitor and assess activities but DFO does not. Many placer mines are in relatively remote places, therefore air access is usually the best way reach a meaningful number of facilities.

B. Ministry of Energy and Mines, DFO, and MELP (Water Management Branch) all perform some compliance monitoring, however, this is usually done on an individual basis by respective agencies.

Recommended Actions:

1. Monitoring efforts (and the funds necessary to support monitoring) should be re-established to determine if fish-bearing streams in all placer mining areas are being adequately protected.
2. Ministry of Energy and Mines, DFO, and MELP should co-ordinate monitoring efforts to make the best use of resources available.
3. Agencies are working to provide education and raise awareness of environmental issues associated with placer mining. These efforts should continue.

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9.6 Contaminated Sites

The Issues:

A. Contaminated sites can be significant sources of persistent and harmful contaminants to surface waters. MELP is currently developing a geo-referenced contaminated sites database. Contaminated sites are not uncommon in older industrial areas, therefore it is possible that several may become issues in the Prince George and Quesnel industrial areas.

B. Overall, federal and provincial governments appear not to be adequately resourced to respond to many contaminated sites as they are identified.

C. In many cases the polluters are long gone, and present land owners do not have the funds to pay for extensive chemical testing and the removal and treatment of contaminated sediments or soils.

Recommended Actions:

1. Government agencies need to be adequately resourced to address the workloads associated with contaminated sites.
2. Resource management agencies should work cooperatively to prioritize clean-up efforts for contaminated sites. If DFO and DOE do not take a leadership role to address these sites they will likely remain permanently alienated habitat, and possibly long-term sources of contaminants into the Fraser River.
3. A clean-up fund needs to be established to address contaminated sites that are located on government-owned lands.
4. Realistic standards for the disposal of materials with low contaminant levels must be established. Presently some contaminated materials are left in sensitive environments because they are considered too contaminated to be removed and placed in a B.C. landfill, and the expense of disposing of the materials by other means is prohibitive. Contamination may amount to pockets of woodwaste containing wood preservatives - while structures containing the same wood preservatives are placed in the environment every day.

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9.7 Addressing Atmosphere-Sourced Impacts on Water Quality

The Issues:

A. Soils in the Nechako HMAs have predominately moderate-low potential to reduce acidity, suggesting that aquatic systems here are somewhat vulnerable to acid precipitation.[8] This suggests that surface waters in this area may be vulnerable to acidification.

B. Evidence suggests that the theory of global climate warming may be a reality. Global warming would likely result in increased stream temperatures during summer months, and could result in lower summer stream flows, higher summer temperatures, and increased demand for irrigation water.[9] This could be a serious problem given that summer water temperatures in some salmon-bearing streams of the Stuart-Takla system, and in the Nechako, frequently exceed levels preferred by salmonids.

Recommended Actions:

1. DFO should support and encourage monitoring of rainfall pH and pH of selected poorly buffered watercourses within the Nechako HMA, given the proximity of the area to Prince George. Such a monitoring

program would be inexpensive, and results could guide a variety of interim environmental management programs such as applying limestone to streams. Monitoring could be taken on by Streamkeeper groups where interest exists, if DFO was able to provide equipment and training. Funds for equipment could come from pollution prosecution fines.

2. Environment Canada should devote increased effort to studying air quality issues, and should liaise with DFO in establishing monitoring and research programs so that opportunities for collaboration are identified early on.
3. DFO and provincial agencies (MAFF, MELP, and MOF) should pursue the protection and restoration of riparian vegetation along all stream banks. This would help to address some of the sedimentation and erosion problems which negatively affect salmon-bearing streams. It would also lessen the summer temperature problems which already exist, and reduce the effects of future global warming on the salmon streams.

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9.8 Additional General Issues and Recommended Actions

The Issues:

A. Section 37(2) of the *Fisheries Act* enables the Minister of Fisheries and Oceans, with support of Cabinet, to shut down works which threaten to contravene the fish habitat and/or water quality protection provisions of the *Act*. This section of the *Act* is not often utilized because it requires a cabinet-level decision and has to compete with national priorities for space on the agenda.

B. Development is increasing rapidly in the Fraser Basin (and elsewhere in B.C.), while budgets for habitat management (and DFO in general) are decreasing. Staff do not have enough resources to address the full referral workload, especially when many development proposals require significant changes to attain adequate stream protection.

C. Existing legislative tools do not adequately protect streams and riparian areas from urban development and land uses such as agriculture.

Recommended Actions:

1. Seek an amendment to the *Fisheries Act* to delegate the use of Section 37(2) to the regional level. This would greatly facilitate the use of this section to prevent degradation of water quality and fish habitat, whereas Sections 35 and 36 enable DFO to address impacts once they have already occurred.
2. Programs need to be developed and implemented which would provide training for biological consultants and other professionals, with regard to standards acceptable to DFO. Professionals trained with regard to DFO standards would likely prepare development proposals that are more agreeable to DFO, and therefore require a reduced amount of staff time for review. This would benefit proponents, as they would likely receive quicker responses from DFO regarding their projects.
3. Taking the training idea above a step further, the concept of DFO developing a certification program for professionals needs to be further explored. Such an approach would have to offer clear benefits to both DFO and the professionals. Certification would have be revocable for certified professionals who fail to consistently achieve DFO standards. Project proposals from DFO-certified professionals would presumably require a lower level of effort from DFO than is currently often involved, and should free up more staff time for auditing of proposals, and field inspections. This should speed up the response time, resulting in a shorter waiting period for proponents.
4. In that *Fisheries Act* enforcement is best suited to larger cases, enforcement staff must have greater access to a universal ticketing system to address the numerous less serious violations which are presently not enforced.
5. Within the Middle and northern Fraser HMAs, government agencies must cooperatively develop and implement watershed-based plans for managing resources and restoring riparian vegetation to fish-bearing streams.

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9.9 References

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Figure 4.2.1 Assessment of Surface Water, Sediment and Fish Tissue Data for the Middle Fraser Habitat Management Area

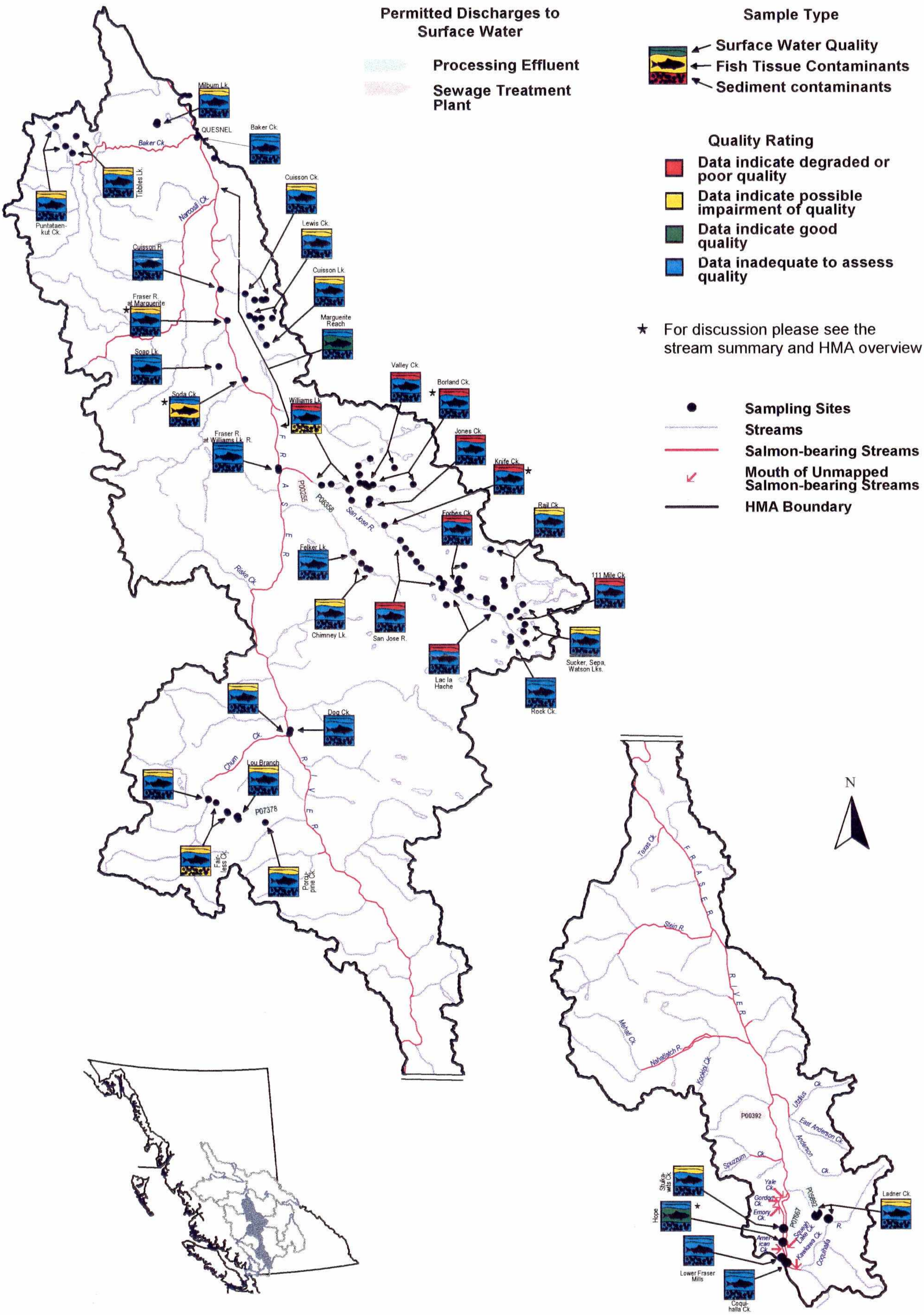

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Figure 5.5.1 Assessment of Surface Water, Sediment and Fish Tissue Data for the Nechako Habitat Management Area

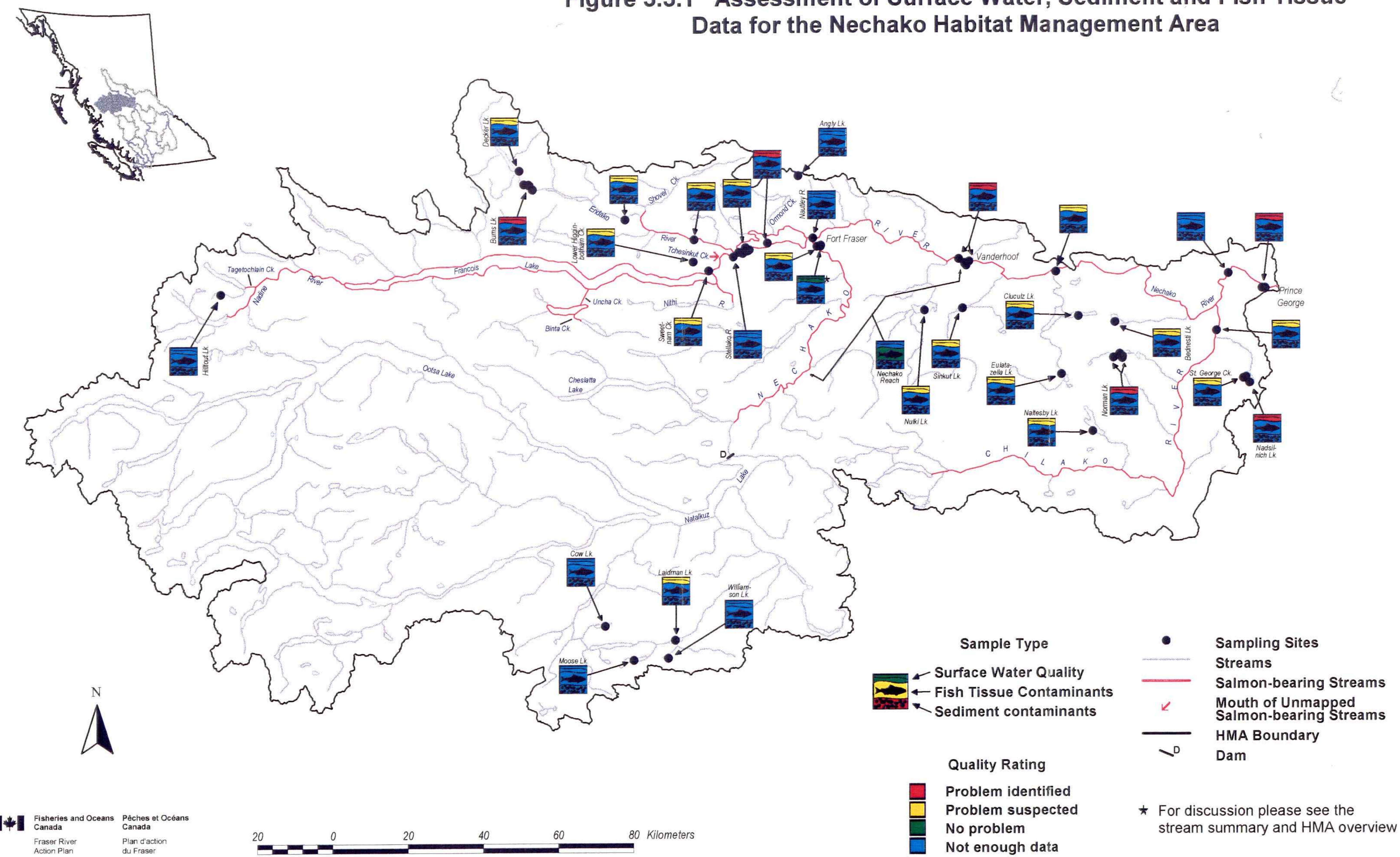

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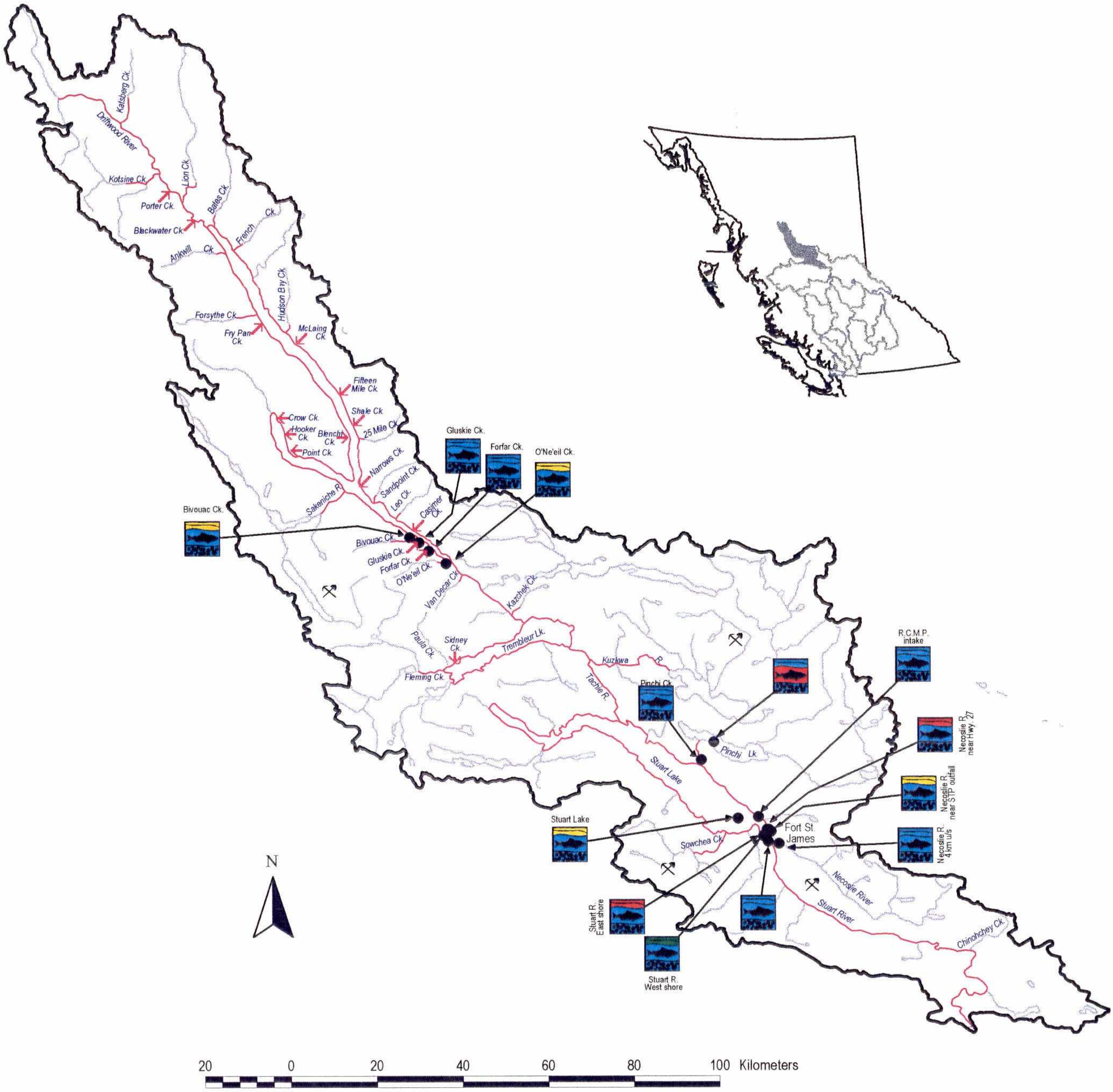
Figure 6.5.1 Assessment of Surface Water, Sediment and Fish Tissue Data for the Stuart-Takla Habitat Management Area



Sample Type

- Surface Water Quality
- Fish Tissue Contaminants
- Sediment contaminants

Quality Rating

- Data indicate degraded or poor quality
- Data indicate possible impairment of quality
- Data indicate good quality
- Data inadequate to assess quality

- Sampling Sites
- Streams
- Salmon-bearing Streams
- Mouth of Unmapped Salmon-bearing Streams
- HMA Boundary
- Designated Placer Mining Area

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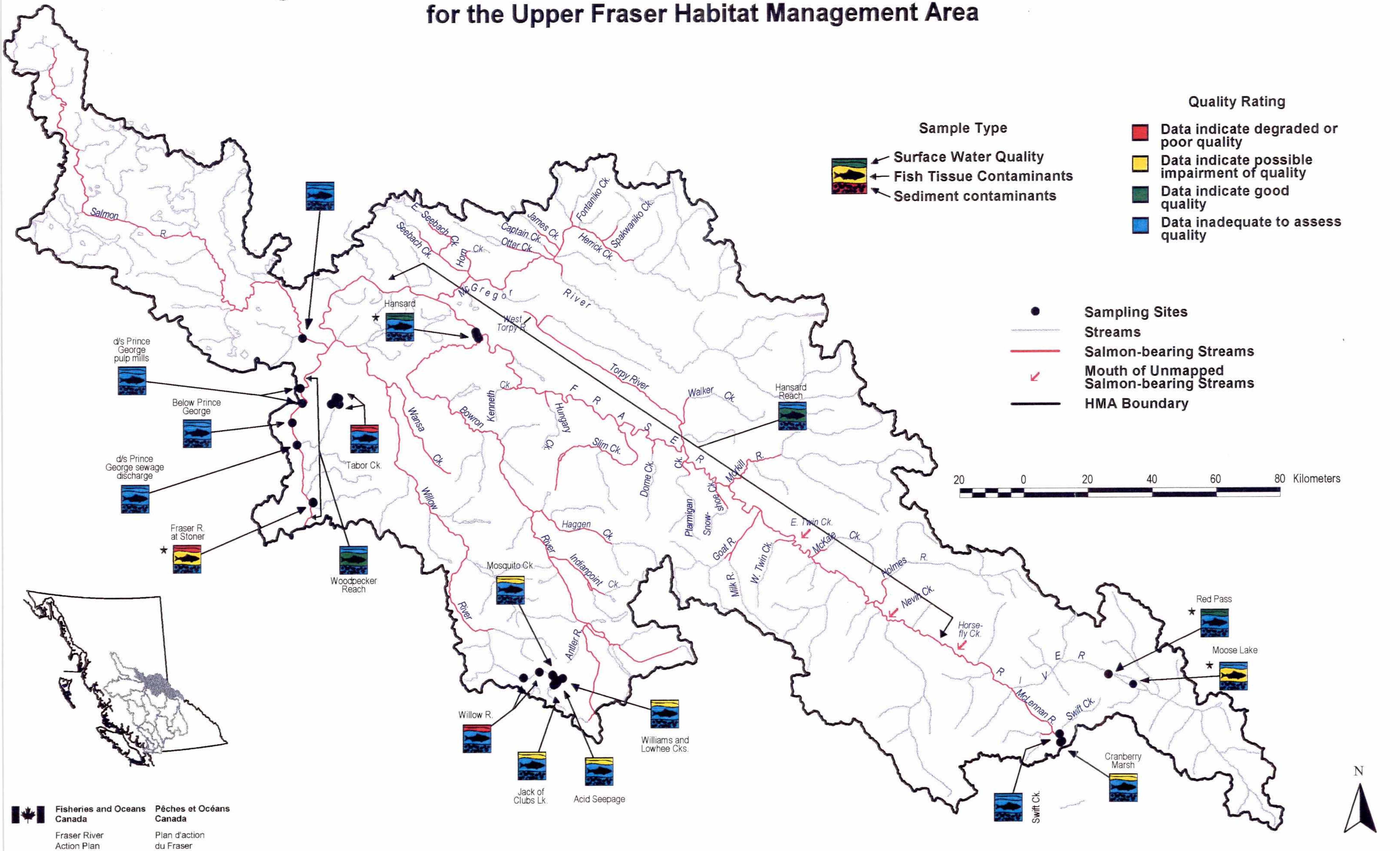
Figure 7.6.1 Assessment of Surface Water, Sediment and Fish Tissue Data for the Upper Fraser Habitat Management Area



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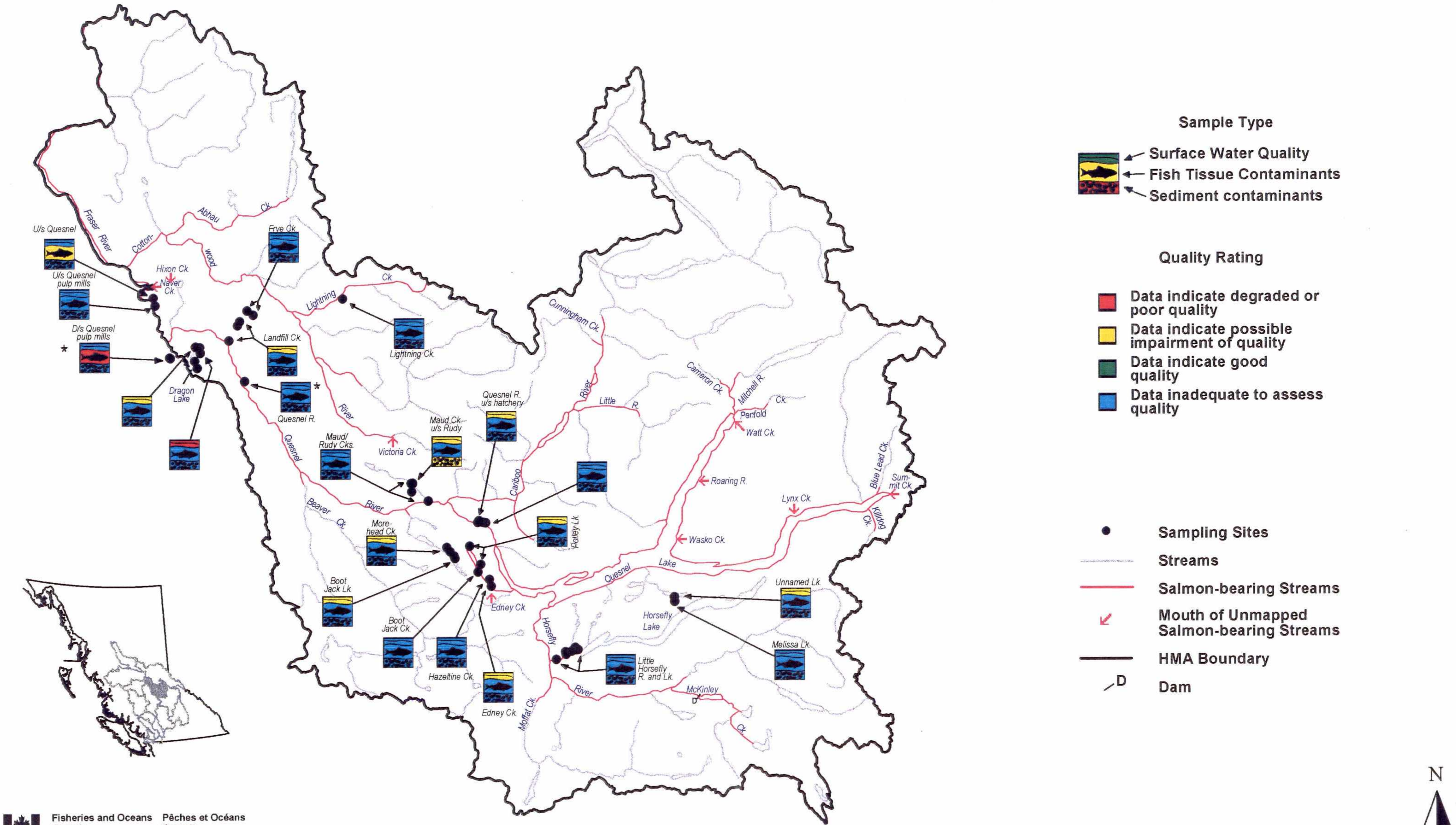
8.5.1

Figure 8.5.1 Assessment of Surface Water, Sediment and Fish Tissue Data for the Quesnel Habitat Management Area



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The Fraser River Action Plan (FRAP) was established in 1991 under the federal Green Plan to build partnerships, restore fish and wildlife productivity, and clean up pollution in the Fraser Basin. FRAP's urban planning group worked to find better ways to protect streams under pressure from urban development in the Lower Fraser Valley. This included building partnerships between senior and local governments to improve the planning and land development process and to ensure that aquatic and riparian resources are proactively protected in the urban environment.

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