

Fraser River Basin Strategic Water Quality Plan

Lower Fraser River:

Fraser Delta, Pitt-Stave, Chilliwack and Harrison-Lillooet
Habitat Management Areas

by

J.C. Nener¹ and B.G. Wernick¹

¹ Fraser River Action Plan
Habitat and Enhancement Branch
Fisheries and Oceans Canada
Suite 400-555 West Hastings Street
Vancouver, B.C. V6B 5G3

Canadian Cataloguing in Publication Data

Nener, Jennifer C. (Jennifer C.), 1961-

Fraser River Basin Strategic Water Quality Plan,
Lower Fraser Basin: Fraser Delta, Pitt-Stave,
Chilliwack and Harrison-Lillooet habitat management areas

(Fisheries and Oceans Canada - Fraser River
Action Plan Water Quality Series: 01)

Includes bibliographical references.

ISBN 0-662-25666-2

Cat. no. Fs22-2/1E

1. Water quality -- British Columbia -- Fraser River Watershed.
 2. Water quality bioassay -- British Columbia -- Fraser River Watershed.
 3. Salmon -- Effect of water quality on -- British Columbia -- Fraser River Watershed.
 4. Environmental monitoring -- British Columbia -- Fraser River Watershed.
- I. Wernick, B. G. (Barbara G.), 1969-
 - II. Fraser River Action Plan (Canada)
 - III. Title.
 - IV. Series

TD387.B7N46 1997 553.7'8'0971137 C97-980142-7

Acknowledgments

Many people made significant contributions to this document and their efforts served to greatly improve the final report. Advice on the methodology, the provision of up-to-date information, and thoughtful editorial input were greatly appreciated. The following people gave generously of their time:

- ◆ Brent Moore and Bev Locken from MELP, Surrey office;
- ◆ George Derksen, Lisa Walls, Phil Wong, and Rob McCandless from DOE's Pollution Abatement Branch;
- ◆ Taina Tuominen, Bev Raymond, Pat Shaw, and Mark Sekela from DOE's Environmental Quality Branch;
- ◆ Otto Langer, Lee Nikl, Karen Hutton, Steve Samis, Deborah Hughes, and Bruce Reid from DFO.

In addition, Bruce Galbraith of Environment Canada patiently responded to numerous requests related to the Fraser River Point Source Inventory database.

Steward Nimmo and Tom Pinkerton provided advice and guidance which contributed to the successful completion of GIS work for this project.

Peri Mehling prepared a status report on mining issues in the Fraser Basin, which served as the basis for the section on Mining in Chapter 2. Darlene Boyle prepared overview reports on Urbanization and Forestry, which

provided the foundations for respective sections of Chapter 2 in this report.

Linda Berg assisted with editing Chapter 2.

Raymond Bedard synthesized information from SISS catalogues and hydrology reports which was used in developing the stream summaries.

The following individuals are thanked for kindly contributing unpublished data:

- ◆ Karen Hutton, Lee Nikl, and Timber Whitehouse from DFO;
- ◆ Liz Freyman, Bev Locken, and Brent Moore from MELP, Surrey office;
- ◆ Taina Tuominen from DOE's Environmental Quality branch;
- ◆ Hans Schreier from UBC's Institute for Resources and Environment.

Many other people also contributed to the completion of this report. Their efforts are gratefully acknowledged.

The preparation and printing of this report was funded through the Fraser River Action Plan - Fisheries and Oceans Canada.

Table of Contents

ACKNOWLEDGEMENTS	iii	2.4 AGRICULTURE.....	2 - 13
TABLE OF CONTENTS.....	iv	2.4.1 <i>Introduction</i>	2 - 13
LIST OF TABLES.....	viii	2.4.2 <i>Impacts of Agriculture on Water Quality</i>	2 - 14
LIST OF FIGURES.....	ix	2.4.2.1 Ranching - northern and central areas of the Fraser Basin.....	2 - 14
LIST OF ACRONYMS	x	2.4.2.2 Fruit and Vegetable Production in Central Areas of the Fraser Basin	2 - 15
INDEX OF STREAMS	xi	2.4.2.3 Ginseng production in the Interior Fraser Basin.....	2 - 15
CHAPTER 1 INTRODUCTION TO THE FRASER BASIN STRATEGIC WATER QUALITY PLAN			
1.1 BACKGROUND	1 - 1	2.4.2.4 Animal and Vegetable Crop Production in the Lower Fraser.....	2 - 15
1.2 DEVELOPING THE PLAN	1 - 1	2.4.2.5 Hobby Farms	2 - 16
1.3 THE AUDIENCE	1 - 3	2.4.3 <i>Legislation</i>	2 - 17
1.4 REFERENCES	1 - 3	2.4.3.1 Federal Legislation	2 - 17
CHAPTER 2 POINT AND NON-POINT SOURCES OF POLLUTION IN THE FRASER BASIN			
2.1 INTRODUCTION	2 - 1	2.4.3.2 Provincial Legislation.....	2 - 17
2.2 MANUFACTURING AND PROCESSING INDUSTRIES	2 - 1	2.4.3.3 Industry Initiatives.....	2 - 18
2.2.1 <i>Introduction</i>	2 - 1	2.4.4 <i>DFO-FRAP Actions to Address Agricultural Issues</i>	2 - 18
2.2.2 <i>Management of Discharges to Surface Waters</i>	2 - 1	2.4.5 <i>Summary</i>	2 - 18
2.2.2.1 Federal Legislation.....	2 - 1	2.5 FORESTRY	2 - 18
2.2.2.2 Provincial Legislation.....	2 - 1	2.5.1 <i>Introduction</i>	2 - 18
2.2.2.3 Guidelines and Best Management Practices.....	2 - 2	2.5.2 <i>Timber Harvesting</i>	2 - 19
2.2.3 <i>Effluent Discharge Quality - Case Studies</i>	2 - 3	2.5.2.1 Effects of Road Building and Timber Harvesting on Water Quality	2 - 19
2.2.3.1 Effluent Characterization - A Study of Ten Industrial Facilities	2 - 3	2.5.3 <i>Silviculture</i>	2 - 19
2.2.3.2 Fish Processing Plant Effluent.....	2 - 3	2.5.3.1 Site Preparation Effects on Erosion and Stream Sedimentation	2 - 19
2.2.3.3 Wood Protection.....	2 - 5	2.5.3.2 Pesticides.....	2 - 19
2.2.3.4 Pulp & paper industry.....	2 - 5	2.5.3.3 Fertilization	2 - 20
2.2.4 <i>Evaluation of Processes and Tools for Managing Discharges to the Environment</i>	2 - 6	2.5.3.4 Forest Fire-Fighting.....	2 - 20
2.2.4.1 Waste Management Permit System.....	2 - 6	2.5.4 <i>Log handling, transportation and storage</i>	2 - 21
2.2.4.2 Guidelines as Effective Tools for Protecting Water Quality	2 - 6	2.5.5 <i>Woodwaste from forest product mills</i>	2 - 21
2.2.5 <i>Summary</i>	2 - 7	2.5.5.1 Leachate From Woodwaste Disposal Sites.....	2 - 21
2.3 URBANIZATION.....	2 - 7	2.5.6 <i>Regulation of Forest Practices in B.C.</i>	2 - 22
2.3.1 <i>Introduction</i>	2 - 7	2.5.7 <i>Summary</i>	2 - 22
2.3.2 <i>Impacts Resulting from Physical Alteration of the Land Base</i>	2 - 7	2.6 MINING OPERATIONS	2 - 22
2.3.3 <i>Water Quality Issues Associated with Land Development</i>	2 - 8	2.6.1 <i>Introduction</i>	2 - 22
2.3.3.1 Hydrological Impacts	2 - 8	2.6.1.1 Mining in the Fraser Basin	2 - 22
2.3.3.2 Contaminants in Urban Stormwater Runoff.....	2 - 8	2.6.2 <i>Water Quality Issues Associated With Mining</i>	2 - 22
2.3.4 <i>Water Quality Issues Associated with the Discharge of Sewage Effluent</i>	2 - 9	2.6.2.1 Exploration Activities.....	2 - 23
2.3.4.1 Sewage Disposal in Urban Areas	2 - 9	2.6.2.2 Road Access	2 - 23
2.3.4.2 Sewage Effluents.....	2 - 9	2.6.2.3 Base Metal Mines - Open Pit and Underground.....	2 - 23
2.3.4.3 Industrial Discharges to Sewage Systems	2 - 10	2.6.2.4 Gold Mill Operations.....	2 - 23
2.3.4.4 Combined Sewer Overflows.....	2 - 10	2.6.2.5 Placer Gold.....	2 - 24
2.3.4.5 Septic Tanks	2 - 10	2.6.2.6 Sand and Gravel	2 - 24
2.3.5 <i>Water Quality Issues Associated With Disposal of Municipal Solid Wastes</i>	2 - 11	2.6.2.7 Industrial Minerals, Quarries and 'Non - Mineral' Products	2 - 25
2.3.6 <i>Other Sources of Water Quality Impacts</i>	2 - 11	2.6.3 <i>Environmental Management Mechanisms And Review Processes</i>	2 - 25
2.3.7 <i>Regulation and Guidance of Land Development</i>	2 - 11	2.6.3.1 <i>B.C. Environmental Assessment Act</i>	2 - 25
2.3.8 <i>Summary</i>	2 - 11	2.6.3.2 <i>Canadian Environmental Assessment Act (1995)</i>	2 - 25
		2.6.4 <i>Provincial Legislation Pertaining to Water Quality</i>	2 - 25
		2.6.4.1 Mines Act.....	2 - 25
		2.6.4.2 Waste Management Act	2 - 25
		2.6.4.3 Water Act	2 - 25
		2.6.4.4 Contaminated Sites Regulation	2 - 25
		2.6.5 <i>Federal Legislation and Initiatives</i>	2 - 26
		2.6.5.1 Fisheries Act.....	2 - 26
		2.6.5.2 Metal Mining Liquid Effluent Regulations	2 - 26
		2.6.6 <i>General Compliance with Regulations</i>	2 - 26

2.6.7 Summary	2 - 27
2.7 "ATMOSPHERIC" EFFECTS.....	2 - 27
2.7.1 Introduction	2 - 27
2.7.2 Acid Precipitation	2 - 27
2.7.2.1 Effects on Biota.....	2 - 27
2.7.2.2 Chemistry of Acid Precipitation.....	2 - 27
2.7.2.2 Occurrence of Acid Precipitation in the Lower Fraser Basin.....	2 - 28
2.7.2.4 The Effect of Acid Precipitation on Salmon Streams.....	2 - 28
2.7.2.5 Summary of Acid Precipitation	2 - 29
2.7.3 Global Warming and Water Temperature	2 - 29
2.7.3.1 Effects of Global Warming on Hydrology and Biota of Freshwater Systems.....	2 - 29
2.7.3.2 Effects of Global Warming on Fish Populations.....	2 - 30
2.7.3.3 Prediction of Freshwater Habitat Changes for B.C.	2 - 30
2.7.3.4 Possible Implications of Global Warming for Fraser River Salmon	2 - 30
2.7.3.5 Existing Water Temperature Problems in the Fraser River Basin	2 - 31
2.7.5 Relevant Policies and Legislation.....	2 - 31
2.7.6 Summary	2 - 32
2.8 REFERENCES	2 - 32

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION	3 - 1
3.2 METHODOLOGY	3 - 1
3.2.1 Evaluation of Water Quality and Contaminant Data	3 - 1
3.2.1.1 Parameters.....	3 - 2
3.2.1.2 Data Evaluation.....	3 - 2
3.2.1.3 Evaluation Criteria applied to Water Quality Data: ..	3 - 4
3.2.2 Evaluation of Waste Management Permit Specifications.....	3 - 5
3.2.3 Evaluation of Land Uses and Hydrology Information	3 - 6
3.2.3.1 Urban development	3 - 6
3.2.3.2 Agriculture	3 - 6
3.2.3.3 Forestry	3 - 7
3.2.3.4 Summer 7-day mean low flow	3 - 8
3.2.3.5 Water demand	3 - 8
3.3 REFERENCES	3 - 9

CHAPTER 4 FRASER DELTA HABITAT MANAGEMENT AREA

4.1 BACKGROUND.....	4 - 1
4.1.1 Hydrology	4 - 1
4.1.2 Fish	4 - 1
4.1.3 Predominant Land Uses.....	4 - 1
4.2 POINT SOURCES OF CONTAMINANTS.....	4 - 1
4.2.1 Upstream Discharges.....	4 - 2
4.2.2 Urban/Industrial Point Source Discharges to Surface Waters.....	4 - 2
4.2.3 Discharges to Ground.....	4 - 3
4.3 FACTORS MODIFYING CONTAMINANT FATE AND EFFECTS	4 - 3

4.3.1 Fraser Mainstem	4 - 3
4.3.2 Sloughs	4 - 3
4.3.3 Tributary Streams.....	4 - 4
4.4 NON-POINT SOURCES OF CONTAMINANTS.....	4 - 4
4.4.1 Urban Stormwater Runoff.....	4 - 4
4.4.2 Agriculture	4 - 4
4.5 AN OVERVIEW OF WATER QUALITY CONDITIONS.....	4 - 5
4.5.1 General Water Quality Conditions in the Mainstem.....	4 - 5
4.5.1.1 FREMP Water Quality Data.....	4 - 5
4.5.2 General Water Quality Conditions in Tributaries.....	4 - 5
4.6 MEASURED WATER QUALITY CONDITIONS AND STREAM ASSESSMENTS.....	4 - 6
4.7 REFERENCES	4 - 16

CHAPTER 5 PITT-STAVE HABITAT MANAGEMENT AREA

5.1 BACKGROUND.....	5 - 1
5.1.1 Hydrology.....	5 - 1
5.1.2 Fish.....	5 - 1
5.1.3 Predominant Land Uses.....	5 - 1
5.2 SOURCES OF CONTAMINANTS.....	5 - 1
5.2.1 Urban/Industrial Point Source Discharges to Surface Waters.....	5 - 2
5.2.2 Permitted Discharges to Ground	5 - 2
5.3 NON-POINT SOURCES OF CONTAMINANTS	5 - 2
5.3.1 Urban Stormwater Runoff.....	5 - 2
5.3.2 Agriculture	5 - 2
5.3.3 Timber Harvesting.....	5 - 2
5.4 FACTORS MODIFYING CONTAMINANT FATE AND EFFECTS.....	5 - 2
5.4.1 Pitt River and Stave River Mainstems	5 - 2
5.5 AN OVERVIEW OF WATER QUALITY CONDITIONS.....	5 - 3
5.5.1 General Water Quality Conditions.....	5 - 3
5.5.2 Pitt River Watershed	5 - 3
5.5.3 Stave River Watershed.....	5 - 3
5.6 MEASURED WATER QUALITY CONDITIONS, AND STREAM ASSESSMENTS.....	5 - 3
5.7 REFERENCES	5 - 12

CHAPTER 6 CHILLIWACK HABITAT MANAGEMENT AREA

6.1 BACKGROUND.....	6 - 1
6.1.1 Hydrology.....	6 - 1
6.1.2 Fish.....	6 - 1
6.1.3 Predominant Land Uses.....	6 - 1
6.2 POINT SOURCES OF CONTAMINANTS	6 - 1
6.2.1 Urban/Industrial Point Source Discharges to Surface Water.....	6 - 1
6.2.2 Permitted Discharges to Ground	6 - 2
6.3 NON-POINT SOURCES OF CONTAMINANTS	6 - 2

6.3.1 Urban Development.....	6 - 2
6.3.2 Agriculture.....	6 - 2
6.3.3 Timber Harvesting.....	6 - 3
6.4 AN OVERVIEW OF WATER QUALITY CONDITIONS	6 - 3
6.4.1 General Mainstem Water Quality Conditions	6 - 3
6.4.2 General Water Quality Conditions in Tributaries.....	6 - 3
6.5 MEASURED WATER QUALITY CONDITIONS AND STREAM ASSESSMENTS	6 - 4
6.6 REFERENCES	6 - 14

**CHAPTER 7 HARRISON-LILLOOET HABITAT
MANAGEMENT AREA**

7.1 BACKGROUND	7 - 1
7.1.1 Hydrology.....	7 - 1
7.1.2 Fish.....	7 - 1
7.1.3 Predominant Land Uses	7 - 1
7.2 POINT SOURCES OF CONTAMINANTS.....	7 - 1
7.2.1 Urban/Industrial Point Source Discharges to Surface Water.....	7 - 1
7.2.2 Permitted Discharges to Ground.....	7 - 1
7.3 NON-POINT SOURCES OF CONTAMINANTS.....	7 - 1
7.3.1 Urban Development.....	7 - 2
7.3.2 Agriculture.....	7 - 2
7.3.3 Timber Harvesting.....	7 - 2
7.4 AN OVERVIEW OF WATER QUALITY CONDITIONS	7 - 2
7.5 MEASURED WATER QUALITY CONDITIONS AND STREAM ASSESSMENTS	7 - 3
7.6 REFERENCES	7 - 10

**CHAPTER 8 KEY ISSUES AND RECOMMENDED
ACTIONS**

8.1 ADDRESSING URBAN DEVELOPMENT ISSUES.....	8 - 1
8.1.1 Land Clearing and Excavation: Preventing Impacts to Water Quality.....	8 - 1
8.1.2 Preventing Impacts to Stream Hydrology.....	8 - 2
8.1.3 Contaminants in Urban Stormwater Runoff.....	8 - 2
8.1.4 Municipal Sewage Discharges.....	8 - 3
8.1.5 Septic Tanks.....	8 - 4

8.1.6 Combined Sewer Overflows	8 - 5
8.1.7 Domestic Water Supply.....	8 - 5
8.2 ADDRESSING PERMITTED WASTE DISCHARGES	8 - 5
8.3 ADDRESSING IMPACTS FROM AGRICULTURE.....	8 - 7
8.4 ADDRESSING IMPACTS FROM FORESTRY ACTIVITIES ON WATER QUALITY.....	8 - 7
8.5 WATER QUALITY ISSUES ASSOCIATED WITH MINING ..	8 - 8
8.6 CONTAMINATED SITES	8 - 9
8.7 ADDRESSING IMPACTS VIA ATMOSPHERE ON WATER QUALITY.....	8 - 9
8.8 ADDITIONAL GENERAL ISSUES AND RECOMMENDA- TIONS	8 - 10
8.9 REFERENCES	8 - 11

CHAPTER 9 OVERALL CONCLUSIONS

9.0 OVERALL CONCLUSIONS	9 - 1
-------------------------------	-------

**APPENDIX 1 GENERAL BACKGROUND
INFORMATION ABOUT WATER QUALITY**

1 SUSPENDED SEDIMENTS	A1 - 1
2 HARDNESS	A1 - 1
3 TEMPERATURE	A1 - 1
4 pH.....	A1 - 2
5 CONTAMINANTS.....	A1 - 2
5.1 Acute toxicity.....	A1 - 3
5.2 Non-genetic sublethal effects	A1 - 3
5.3 Genotoxicity	A1 - 3
5.4 Persistence in the environment	A1 - 3
5.5 Bioaccumulation	A1 - 3
6 REFERENCES	A1 - 3

List of Tables

Table 2.2.1	Total volumes of permitted discharges of various effluent types to surface waters in the Fraser Basin.	2 - 2	Table 4.4.5	Comparison of point source loading vs. non-point source loadings estimated for urban areas for selected contaminants in the Fraser Delta HMA	4 - 26
Table 2.2.2	Assessment of waste management permit compliance: A case study of ten industries.....	2 - 4	Table 4.5.1a	Summary of receiving environment data used to assess surface water, sediment and fish tissue quality in the Fraser Delta HMA.	4 - 27
Table 2.3.1	Contaminants typically found in urban stormwater runoff and potential sources of contamination.	2 - 8	Table 4.5.1b	Summary of contaminants measured in fish tissue collected by DOE-FRAP, 1994, for the Main Arm, North Arm, Barnston and Mission Reaches in the Fraser Delta HMA.....	4 - 41
Table 2.3.2	Sewage treatment statistics for the Lower Fraser region versus the Fraser interior, 1989.....	2 - 10	Table 4.6.1	Summary of land areas, stream flows and water demand in the Fraser Delta HMA.	4 - 42
Table 2.3.3	Municipal wastes generated, recycled and residuals disposed of in British Columbia in 1991, by regional district.....	2 - 12	Table 4.6.2	Summary of red-coded indicators for streams in the Fraser Delta HMA.....	4 - 44
Table 2.5.1	Silvicultural activities on crown land in 1992/93, measured in hectares, classified by Ministry of Forests region.	2 - 20	Table 5.2.1	Summary of facilities with permitted waste discharges to surface water in the Pitt-Stave HMA.....	5 - 13
Table 2.5.2	The production, utilization and disposal of mill residue in the Fraser River Basin.....	2 - 21	Table 5.2.2a	Summary of total permitted daily loadings to surface water in the Pitt-Stave HMA.	5 - 14
Table 2.6.1	Size of mining projects captured by CEAA and BCEAA	2 - 26	Table 5.2.2b	Summary of total permitted annual loadings to surface water in the Pitt-Stave HMA.	5 - 14
Table 2.7.1	Potential in Fraser Basin HMAs to reduce acidity from atmospheric deposits.....	2 - 28	Table 5.2.3	Comparison of point source loading vs. non-point source loadings estimated for urban areas for selected contaminants in the Pitt-Stave HMA.	5 - 15
Table 2.7.2	Possible freshwater fisheries consequences of climate change in B.C.	2 - 30	Table 5.5.1	Summary of receiving environment data used to assess surface water, sediment and fish tissue quality in the Pitt-Stave HMA.....	5 - 16
Table 3.2.1	Guidelines and 80th percentiles for parameters used in this study.....	3 - 2	Table 5.6.1	Summary of land areas, streams flows and water demand in the Pitt-Stave HMA.	5 - 20
Table 3.2.2	A comparison of B.C. MELP and CCME freshwater sediment guidelines.....	3 - 4	Table 5.6.2	Summary of red-coded indicators for streams in the Pitt-Stave HMA.....	5 - 22
Table 4.2.1	Summary of facilities with permitted waste discharges to surface water in the Fraser Delta HMA.	4 - 19	Table 6.2.1	Summary of facilities with permitted waste discharges to surface water in the Chilliwack Stave HMA.....	6 - 15
Table 4.2.2a	Summary of total permitted daily loadings to surface water in the Fraser Delta HMA.	4 - 22	Table 6.2.2a	Summary of total permitted daily loadings to surface water in the Chilliwack HMA.	6 - 16
Table 4.2.2b	Summary of total permitted annual loadings to surface water in the Fraser Delta HMA.	4 - 23			
Table 4.2.3	Summary of permit conditions that require revisiting in the Fraser Delta HMA.	4 - 24			
Table 4.2.4	Summary of permitted discharges of warm water to the Fraser Delta HMA.....	4 - 25			

Table 6.2.2b	Summary of total permitted annual loadings to surface water in the Chilliwack HMA.....	6 - 16	Table 7.2.1	Summary of permitted discharges to surface water in the Harrison-Lillooet HMA.	7 - 11
Table 6.2.3	Summary of permits that require revisiting in the Chilliwack HMA.	6 - 17	Table 7.2.2a	Summary of total permitted daily loadings to surface water in the Harrison-Lillooet HMA.	7 - 12
Table 6.3.1	Comparison of point source loading versus non-point source loadings estimated for urban areas for selected contaminants in the Chilliwack HMA.	6 - 18	Table 7.2.2b	Summary of total permitted annual loadings to surface water in the Harrison-Lillooet HMA.	7 - 12
Table 6.4.1a	Summary of receiving environment data used to assess surface water, sediment and fish tissue quality in the Chilliwack HMA.	6 - 19	Table 7.4.1	Summary of receiving environment data used to assess surface water, sediment and fish tissue quality in the Harrison-Lillooet HMA.	7 - 13
Table 6.4.1b	Summary of contaminants measured in fish tissue collected by DOE-FRAP, 1994, for the Agassiz Reach in the Chilliwack HMA.....	6 - 23	Table 7.5.1	Summary of land areas, stream flows and water demand in the Harrison-Lillooet HMA.	7 - 15
Table 6.5.1	Summary of land areas, stream flows and water demand in the Chilliwack HMA.....	6 - 24	Table 7.5.2	Summary of red-coded indicators for streams in the Harrison-Lillooet HMA.....	7 - 16
Table 6.5.2	Summary of red-coded indicators for streams in the Chilliwack HMA.....	6 - 26	Appendix 2	Guidelines for Organic Contaminants in Sediments and Fish Tissue	A2 - 1

List of Figures

Figure 1.1.1	Habitat Management Areas in the Fraser River Basin.	1 - 2	Figure 4.6.1	Assessment of Surface Water, Sediment, and Fish Tissue Data in the Fraser Delta HMA.....	pocket
Figure 2.4.1	Location of Agricultural Land Reserves in the Fraser River Basin.....	2 - 13	Figure 5.2.1	Location of permitted waste discharges to surface water in the Pitt-Stave HMA.	5 - 23
Figure 4.2.1A	Location of permitted waste discharges to surface water in the Fraser Delta HMA: processing effluent.....	4 - 45	Figure 5.5.1	Assessment of Surface Water, Sediment, and Fish Tissue Data in the Pitt-Stave HMA	pocket
Figure 4.2.1B	Location of permitted waste discharges to surface water in the Fraser Delta HMA: cooling effluent.....	4 - 46	Figure 6.2.1	Location of permitted waste discharges to surface water in the Chilliwack HMA.	6 - 27
Figure 4.2.1C	Location of permitted waste discharges to surface water in the Fraser Delta HMA: stormwater and leachate effluent.....	4 - 47	Figure 6.5.1	Assessment of Surface Water, Sediment, and Fish Tissue Data in the Chilliwack HMA.....	pocket
Figure 4.2.1D	Location of permitted waste discharges to surface water in the Fraser Delta HMA: STP effluent.	4 - 48	Figure 7.5.1	Assessment of Surface Water, Sediment, and Fish Tissue Data in the Harrison-Lillooet HMA	pocket

List of Acronyms

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

Index of Streams

A

Alouette River (00-0200-050)	5 - 4
Anderson Creek (90-0100-020)	4 - 16
Atchelitz Creek (00-0625-010)	6 - 10

B

Barnes Creek (00-0552-060)	5 - 10
Barrett Creek (00-0600-020-013)	6 - 7
Bear Creek (no SISS #)	7 - 5
Belcharton Creek (00-0500-060-010-010)	5 - 9
Big Silver Creek (01-1800)	7 - 6
Birkenhead River (01-4100)	7 - 7
Blaney Creek (00-0200-050-020-020)	5 - 5
Blue Creek (00-0200-800)	5 - 6
Boise Creek (00-0200-750)	5 - 6
Bonaccord Creek (00-0170)	4 - 10
Borden Creek (00-0600-020-120)	6 - 8
Bouchier Creek (00-0500-060-010)	5 - 9
Brousseau Creek (00-0552-028)	5 - 10
Brunette River (00-0100)	4 - 8
Byrne Creek (no SISS #)	4 - 7

C

Calkins Creek (00-0640-020-004)	6 - 11
Camp Slough (00-0640-010)	6 - 11
Campbell River (90-0080)	4 - 16
Cedar Creek (00-0200-060-001)	5 - 5
Centre Creek (00-0600-020-180)	6 - 9
Chehalis River (01-0400)	7 - 3
Chief Paul Creek (no SISS #)	7 - 7
Chilliwack Creek (00-0625)	6 - 9
Chilliwack River (downstream from Chilliwack Lake) (00-0600-020-000-000-000-991)	6 - 6
Chilliwack River (upstream from Chilliwack Lake) (00-0600-020-000-000-000-992)	6 - 6
Chilqua Creek (00-0500-020-020)	5 - 8
Chilqua Slough (00-0500-020)	5 - 8
Clayburn Creek (00-0460-010)	4 - 14
Cogburn Creek (01-1600)	7 - 5
Coghlan Creek (00-0300-200)	4 - 11
Coho Creek (00-0200-050-050)	5 - 5
Coho Creek (01-0400-080)	7 - 4
Coligny Creek (00-0438)	4 - 13
Coquitlam River (00-0180)	4 - 8
Cougar Canyon Creek (00-0160)	4 - 10

D

Deiner Creek (00-0200-080-010)	5 - 5
Depot Creek (00-0600-020-250)	6 - 9
Deroche Creek (00-0552-030)	5 - 10
Douglas Creek (01-2600)	7 - 6
Downes Creek (00-0440-020)	4 - 13
Draper Creek (00-0500-010)	5 - 8
Dunville Creek (00-0640-030)	6 - 12

E

East Creek (01-0500-015)	7 - 5
Elk Creek (00-0640-020)	6 - 11

F

Fifteen Mile Creek (00-0600-020-176)	6 - 9
Fish Hatchery Creek (00-0200-730)	5 - 6
Foley Creek (00-0600-020-160)	6 - 8
Ford Creek (00-0640-020-020)	6 - 11
Fourteen Mile Creek (00-0600-020-173)	6 - 9

G

Gifford Slough (00-0440)	4 - 13
Glen Lyon Creek (no SISS #)	4 - 7
Green River (01-4300)	7 - 8

H

Hanna Creek (00-0425)	4 - 12
Harrison River (01-0000-000-000-000-993)	7 - 3
Hatzic Slough (00-0500)	5 - 8
Hawkins Creek (00-0552-020-015)	5 - 10
Hicks Creek (00-0700-070)	6 - 12
Hope Slough (00-0640)	6 - 10
Hopedale Slough (00-0600-020-010-010)	6 - 7
Hoy Creek (00-0180-100-020)	4 - 9
Hunter Creek (00-0760)	6 - 13
Hyde Creek (00-0200-060)	5 - 5

I

Inches Creek (00-0552-020-005)	5 - 10
--------------------------------------	--------

J

Jones (Wahleach) Creek (00-0735)	6 - 12
--	--------

K

Kakila Creek (no SISS #)	7 - 7
Kanaka Creek (00-0290)	5 - 6
Kenworthy Creek (00-0500-050)	5 - 8
Kerstead Creek (no SISS #)	7 - 9
Kilgard Creek (00-0600-050-010)	6 - 6

L

Lagace Creek (00-0500-060)	5 - 8
Laurentian Creek (00-0150)	4 - 8
Lillooet River (between Harrison and Lillooet Lakes) (01-0000-000-000-000-000-991)	7 - 6
Lillooet River (upstream from Lillooet Lake) (01-0000-000-000-000-000-992)	7 - 7
Little Tamihi Creek (00-0600-020-070)	6 - 8
Liumchen Creek (00-0600-020-040)	6 - 7
Lonzo Creek (00-0600-050)	6 - 5
Lorenzetta Creek (00-0736)	6 - 13
Luckakuck Creek (00-0625-030)	6 - 10

M

MacIntyre Creek (00-0200-080)	5 - 5
MacKenzie Creek (01-4620)	7 - 9
Mahood Creek (00-0740)	6 - 13
Mahood Creek (90-0200-020)	4 - 15
Maple Creek (00-0180-110)	4 - 10
Marblehill Creek (00-0640-020-004-800)	6 - 11
Maria Slough (00-0700)	6 - 12
Matsqui Slough (00-0460)	4 - 13
McLennan Creek (00-0440-010)	4 - 13
Miami Creek (01-0600)	7 - 5

Miller Creek (01-4500)	7 - 8
Morris Creek (01-0500)	7 - 4
Mount Currie Slough (no SISS #)	7 - 8
Murray Creek (90-0100-030)	4 - 16
Musqueam Creek (00-0010)	4 - 7
Mystery Creek (01-1500)	7 - 5

N

N. Alouette River (00-0200-050-020)	5 - 4
Nathan Creek (00-0360)	4 - 12
Nesakwatch Creek (00-0600-020-170)	6 - 8
Nevin Creek (00-0640-030-005)	6 - 12
Nicomekl River (90-0100)	4 - 15
Nicomem Slough (00-0552)	5 - 9
Norrish Creek (00-0552-020)	5 - 9

O

Or Creek (00-0180-150)	4 - 10
------------------------------	--------

P

Paleface Creek (00-0600-020-240)	6 - 9
Peach Creek (00-0600-020-015)	6 - 7
Pemberton Creek (01-4400)	7 - 8
Pitt River (00-0200)	5 - 3
Poole Creek (01-4100-070)	7 - 8
Popeye Creek (00-0150-010)	4 - 8
Popkum Creek (00-0690)	6 - 12
Post Creek (00-0600-020-200)	6 - 9
Pretty Creek (01-0400-020)	7 - 4
Purcell Creek (01-2650)	7 - 6
Pye Creek (00-0552-050)	5 - 10

R

Railroad Creek (01-5000)	7 - 9
Railway Creek (00-0552-024)	5 - 10
Raven Creek (00-0200-190)	5 - 6
Ruby Creek (00-0750)	6 - 13
Ryan Creek (01-4600)	7 - 9
Ryder Creek (00-0600-020-050)	6 - 7

S

Saar Creek	6 - 5
Sakwi Creek (01-0500-010-010)	7 - 4
Salmon Creek (01-4820)	7 - 9
Salmon River (00-0300)	4 - 11
Salmon Slough (no SISS #)	7 - 9
Salwein Creek (00-0600-020-008)	6 - 6
Samson Creek (01-5050)	7 - 9

Schoolhouse Creek (00-0150-011)	4 - 8
Scorey Creek (00-0500-080)	5 - 9
Scott Creek - Coquitlam (00-0180-100)	4 - 9
Scott Creek - Surrey (no SISS #)	4 - 10
Semmihault Creek (no SISS #)	6 - 10
Serpentine River (90-0200)	4 - 15
Siddle Creek (00-0552-070)	5 - 11
Silverdale Creek (00-0435)	5 - 8
Silverhope Creek (00-0790)	6 - 13
Slesse Creek (00-0600-020-130)	6 - 8
Sloquet Creek (01-2700)	7 - 6
Smiling Creek (00-0200-060-010)	5 - 5
Snowcap Creek (no SISS #)	7 - 7
Squakum Creek (01-0100)	7 - 3
Statlu Creek (no SISS #)	7 - 4
Stave River (00-0400)	5 - 7
Steelhead Creek (01-0500-010-005)	7 - 4
Stokke Creek (01-2300)	7 - 6
Stoney Creek (00-0460-010-022)	4 - 14
Street Creek (00-0600-020-010)	6 - 6
Sumas River (00-0600)	6 - 4
Sussex Creek (no SISS #)	4 - 7
Sweltzer River (00-0600-020-020)	6 - 7

T

Tamihi Creek (00-0600-020-090)	6 - 8
Thurston Creek (00-0600-020-115)	6 - 8
Tipella Creek (01-2500)	7 - 6
Trout Lake Creek (01-0700)	7 - 5
Twenty Mile Creek (01-1700)	7 - 5

U

Unnamed Creek (00-0220)	4 - 10
Unnamed Creek (00-0230)	4 - 11
Unnamed Creek (00-0300-150)	4 - 12

W

Wades Creek (00-0550)	4 - 14
Wahleach Slough (00-0685)	6 - 12
Weaver Creek (01-0500-010)	7 - 4
West Creek (00-0330)	4 - 12
Whonnock Creek (00-0370)	5 - 7
Widgeon Creek (00-0200-150)	5 - 6
Willband Creek (00-0460-010-020)	4 - 14
Worth Creek (00-0552-020-010)	5 - 10

Y

Yorkson Creek (00-0260)	4 - 11
-------------------------------	--------

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 1990, 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 address pollution issues in the Fraser Basin, DFO undertook to develop 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 which lead 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 Basin: North Thompson, South Thompson, and Thompson-Nicola HMAs;
- Report 3: Chilcotin Region: Seton-Bridge, Chilcotin, and West Road HMAs; and
- Report 4: Cariboo-Upper Fraser: Quesnel, Middle Fraser, Nechako, Stuart-Takla, and Upper Fraser HMAs.



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 which 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 anthropo-

genic 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.

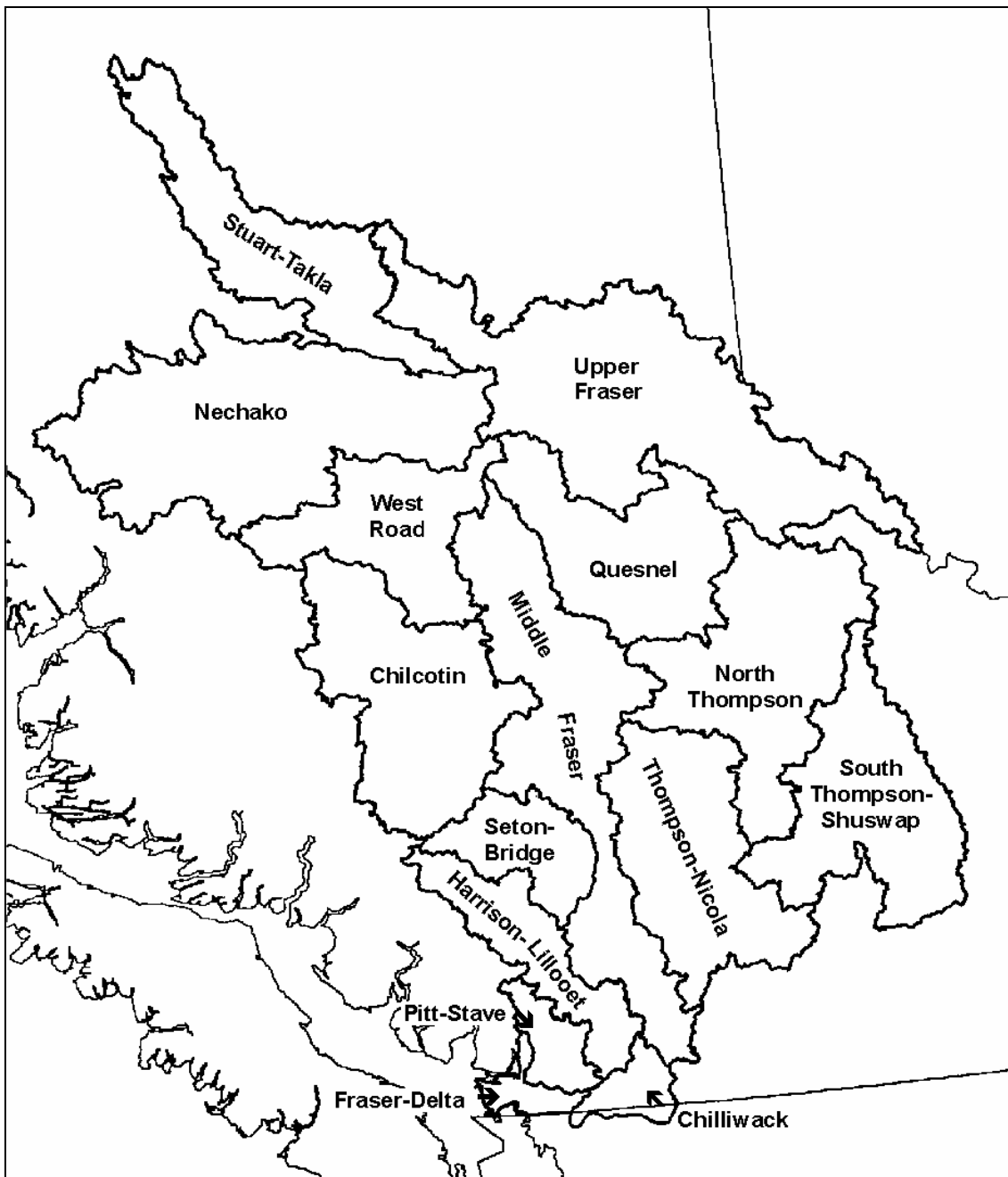
Because many contaminants can become concentrated in different components of the environment, all available data pertaining to contaminant concentrations in sediments and fish tissues were addressed in addition to data which characterize conditions in the water column.

Water quality data are not available for many salmon-bearing streams in the Fraser Basin. Information about ef-

fluent 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 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 water-

Figure 1.1.1 Fraser River Habitat Management Areas



shed 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, and would likely be an unproductive task since virtually all levels of government are currently down-sizing, re-structuring, and re-visiting how to best fulfill their mandates.

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*, and *Stream Stewardship: A Guide for Planners and Developers*). 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.



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 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.



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.

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 8. 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 relevant to the Fraser Basin, global warming and acid precipitation, and how they can influence water quality, is also provided.



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 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 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 relevant agencies. MELP circulates proposals 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. 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 Waste 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 to fish populations of such transient events may therefore be underestimated.

Requirements for monitoring usually apply only to the effluent and not the receiving environment, and may involve 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.

While there is a discharge auditing process, it is not

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 ·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.

uncommon for inspectors to phone ahead before visiting a facility, and 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 Polluter's List.

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 which exist 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.

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 which were 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 boatyards; 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 achieved. DOE then 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 and herbicide 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-FRAP⁴ 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. LC₅₀ rainbow trout bioassays showed eight of the ten effluents to be consistently non-lethal 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 their 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 (IC₂₅) 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 LC₅₀ 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 - <i>C. dubia</i>		
				<i>Daphnia magna</i>	Rainbow Trout	LC ₅₀ (%)	NOEC ¹ (%)	IC ₂₅ ² (%)
Lafarge Cement (1)	Non-contact cooling water & stormwater	No	Flow 3,106 m ³ ·d ⁻¹ (2,950 m ³ ·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·L ⁻¹ ¹ (<5 mg·L ⁻¹)	NA	NA	NA	NA	NA
MacMillan Bloedel (2)	Stormwater & kiln condensate	*No	Oil & grease 5 mg·L ⁻¹ ¹ (<5 mg·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
Hilinox 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·L ⁻¹ (TSS < 130 mg·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 IC₂₅ = 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 1991¹⁴³ 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 m³ of creosote 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 by DOE of five B.C. treatment facilities 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 pulp mill 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 a *Daphnia magna* LC₅₀ bio-assay. 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 acids¹⁶ 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

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.

MELP and DOE jointly establish Water Quality Objectives as a means of protecting existing and future water uses, including use by aquatic life, in surface waters of concern. DFO participates in developing Objectives by providing input through DOE. Agency policies on implementation of Water Quality Objectives further demonstrate 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 typically 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) 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 deterrent from polluting. This deterrent, 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 MELP's route to 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 cooperation, 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.



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 over 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 ex-

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 ammonia	♦Fertilization (golf courses, cemeteries, lawns) ♦Landfill leachate
Oxygen-demanding substances	♦Decaying vegetation ♦Animal wastes ♦Chemical wastes ♦Landfill and woodwaste leachate ♦Sewage seepage
Metals (dissolved & particulate)	♦Motor vehicle operation ♦Copper water pipes ♦Galvanized culverts ♦Landfill leachate ♦Pigments in paints ♦Road salt ♦Industrial discharges ♦Atmospheric deposition ♦Illicit dumping ♦Poor waste disposal practices
Oil & grease	♦Motor vehicle operation ♦Spills of oil and fuel
PAH & other hydrocarbons	♦Motor vehicle operation ♦Burning of fossil fuels, and fuel spills ♦Leaking underground fuel tanks ♦Creosoted structures ♦Asphalt particles ♦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 & naphthalene	♦Interaction between road salt, gasoline & asphalt

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

tremely 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 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 (BOD₅) is removed, and approximately 35-65% of suspended solids (sludge) settle in sedimentation tanks²⁴ 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 unserved 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 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 streams.

Installation of a septic tank system requires a permit from the Ministry of Health (MOH); to obtain a 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

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.

Level of treatment	% population served		% volume treated	
	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 .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)

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.

There are virtually no requirements to ensure the proper maintenance of septic systems, and in many cases people do not maintain their systems at all. In the long term, failure of the system 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 100 municipal waste landfill sites in the Fraser Basin (data from B.C. Landfill Site database²⁸).

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 Guidelines²³ 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 afford a significant level of protection to riparian zones, instream habitats, and water quality.

The DFO/MELP *Land Development Guidelines* 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

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

Regional District	Population	Households	<u>Waste disposed of</u>			<u>Waste recycled</u>			<u>Residual wastes</u>		
			Total waste (tonne)	Per capita (kg·yr ⁻¹)	Per household (kg·yr ⁻¹)	Total waste (tonne)	Per capita (kg·yr ⁻¹)	Per household (kg·yr ⁻¹)	Total waste (tonne)	Per capita (kg·yr ⁻¹)	Per household (kg·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.)

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*”, was jointly developed by DFO and MELP, and is complimentary to the *Land Development Guidelines*. It promotes the protection of fish and fish habitat during urban development through the use of local government bylaws to protect environmentally sensitive areas, and by promoting stewardship values.³³

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.



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.

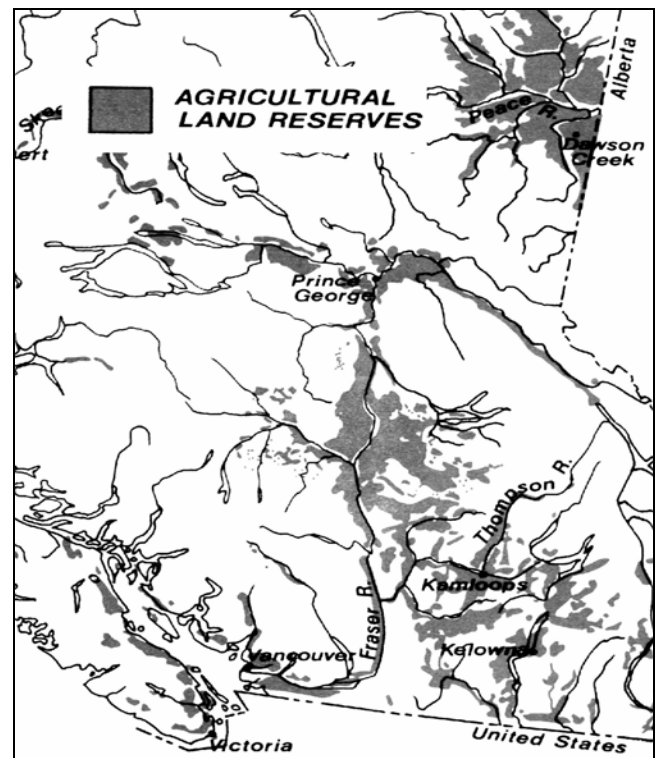
Dairy, beef, hog, and poultry production are all significant industries in the Lower Fraser Valley. Fruit and vegetable crops are also produced in this area, including cranberries, raspberries, strawberries, cole crops, corn, potatoes, mushrooms, and turf. In general, agricultural practices in the Lower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

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



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 $73.5 \text{ mg}\cdot\text{L}^{-1}$ 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 sus-

tained 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 led 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 average³⁸ 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 low-land Matsqui³⁹ and Sumas⁴⁰ 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 N·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, Fisheries and Food (MAFF) 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 $\mu\text{g}\cdot\text{L}^{-1}$ 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 hectareage 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 one of the most powerful tools for protecting water quality. Other pieces of legislation provide indirect protection to water quality. The federal *Fertilizer Act* specifies standards for composition, packaging, and labelling of fertilizers, and also prohibits the use of harmful ingredients. The *Canadian Environmental Protection 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 1996-97 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) have been supported as part of DOE-FRAP/MELP regional initiatives to address agricultural issues, however, it is unclear how MELP will address agriculture enforcement issues when the FRAP program is over.

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 MAFF, 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. It is unclear how these groups will continue to function when the Green Plan program is over (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, MAFF, 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 has been developed via an inter-agency committee led by DFO and including representatives from DOE, MELP, MAFF, 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.

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 MAFF need to expand upon existing cooperative efforts with producers if existing impacts on the environment and other resources are to be reversed and further impacts are to be prevented.



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 world's 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 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 Guidelines⁷⁸ 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 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 waterbodies 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 watersheds. The MOF Forest Fertilization Guidebook⁶⁹ recommends leaving a 10 m "no fertilizer application zone" around fisheries lakes, designated fishery 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}

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

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 (from B.C. Ministry of Forests⁶⁹):

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.

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 compounds⁸¹ from logs stored on land or in the water^{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 re-manufacturing 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. 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 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

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
<u>Vancouver Forest Region:</u>						
Chilliwack (Forest District 1)	892,200	450,300	441,900	2,392,500	1,535,800	856,700
<u>Kamloops Forest Region:</u>						
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
<u>Prince George Forest Region:</u>						
Prince George (Forest District 1)	375,000	9,200	365,800	843,200	142,500	700,700
<u>Cariboo Forest Region:</u>						
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)

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.



2.6 Mining Operations

This overview of mining issues in the Fraser Basin is based on an unpublished report¹⁴² prepared by Peri Mehling for DFO.

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 impound-

ment. The current mine proposal has been 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;
- ◆ 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 LC₅₀ 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, although no elevated mercury concentrations in biota have been reported in these areas.

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 wash-water 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* received first reading on May 5, 1994. 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 pre-requisite 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), and 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 regulates the deposit of prescribed substances into tailings impoundment areas. When triggered, CEAA requires a comprehensive environmental study. Generally, only the larger mining projects are captured by CEAA but moderate sized metal and gold mines may also be captured. 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 work-plans 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.

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*

Table 2.6.1 Size of mining projects captured by CEAA¹ and BCEAA.²

		CEAA	BCCEA
<i>Mineral Mines</i>	<i>see more specific definitions</i>		≥ 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
<i>Non-'Mineral' Mines:</i>	<i>see more specific definitions</i>		>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)

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. They are somewhat outdated, 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 ongoing 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.



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 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 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 $0\text{-}400 \text{ Teq}\cdot\text{L}^{-1}$, or $20 \text{ mg}\cdot\text{L}^{-1} \text{ CaCO}_3$ 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.

Wiens⁹⁷ 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

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.* (1993) 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

2.7.2.4 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 Henriksen¹⁰² 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·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 Dalley¹⁰⁴ 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.

2.7.2.5 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 trips per day per person is also increasing, and grew by 15.6% between 1985 and

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).

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 Moore¹¹⁵ 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 Ripley¹¹⁷ 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 Meisner¹²¹ 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 Levy¹¹³ 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 Northcote¹²³ 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, Northcote¹²³ 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.

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)

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 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 restriction 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 CO₂ 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. 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.



2.8 References

- 1 Westwater Research Centre. 1994. Effluent point source inventory and database for the Fraser River Basin. Prepared for Environment Canada, Environmental Protection, Fraser Pollution Abatement Office, North Vancouver, B.C. DOE-FRAP 1993-05. 14 p + appendices.
- 2 Mendoza, E. and J. Gee. 1994. Compliance status summary report: Fiscal year 1992-1993 - British Columbia. Environment Canada, Environmental Protection Branch, Enforcement & Emergencies Division, Inspection Section. North Vancouver, B.C. DOE Report 1994-02. 85 p.
- 3 Paquet, M. 1994. Compliance status summary report - British Columbia: Fiscal year 1993-1994. Prepared for Environment Canada, Environmental Protection Branch, Enforcement & Emergencies Division, Inspection Section. North Vancouver, B.C. DOE Report 1994-04. 110 p.
- 4 McDevitt, C.A., D.J. McLeay, and A. Brown. 1993. Effluent characterization study. Prepared for FREMP Water Quality/Waste Management Committee. DOE-FRAP 1993-13. 182 p.
- 5 NovaTec and EVS Consultants. 1993. Wastewater characterization of fish processing plant effluents. Prepared for FREMP, Water Quality/Waste Management Committee. DOE-FRAP Report 1993-39.

- 6 Konasewich, D.E. and F.A. Henning. 1988. Pentachlorophenol (PCP) wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/2. 90 p.
- 7 Davis, J.C. and R.A.W. Hoos. 1975. Use of sodium pentachlorophenate and dehydroabetic acid as reference toxicants for salmonid bioassays. *J. Fish. Res. Bd. Can.* 32:411.
- 8 S. Samis, Department of Fisheries and Oceans, Vancouver, B.C., personal communication.
- 9 EVS Consultants Ltd. 1994. Creosote evaluation project. Prepared for the Creosote Evaluation Project Steering Committee. Fraser River Estuary Management Program (FREMP) Technical Report No. WQWM-93-13. New Westminster, B.C. 49 p. + appendices.
- 10 Malins, D.C., M.M. Krahn, M.S. Myers, L.D. Rhodes, D.W. Brown, C.A. Krone, B.B. McCain and S. Chan. 1985. Toxic chemicals in sediments and biota from a creosote-polluted harbor: Relationships with hepatic neoplasms and other hepatic lesions in English sole (*Parophrys vetukus*). *Carcinogenesis* 6(10):1463-1469.
- 11 Vogelbein, W.K., J.W. Fournie, P.A. Van Veld and R.J. Huggett. 1990. Hepatic neoplasms in the mummichog *Fundulus heteroclitus* from a creosote-contaminated site. *Cancer Research* 50:5978-5986.
- 12 Konasewich, D.E. and F.A. Henning. 1988. Ammoniacal copper arsenate (ACA) wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/4. 88 p.
- 13 Konasewich, D.E. and F.A. Henning. 1988. Chromated copper arsenate (CCA) wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/3. 81 p.
- 14 Konasewich, D.E. and F.A. Henning. 1988. Creosote wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada. Report EPS 2/WP/1. 90 p.
- 15 Konasewich, D.E. and F.A. Henning. 1988. Pentachlorophenol (PCP) thermal wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/5. 88 p.
- 16 Sprague, J.B. and A.G. Colodey. 1989. Toxicity to aquatic organisms of organochlorine substances in kraft mill effluents. Unpublished background report for Environment Canada. IP-100. 53 p.
- 17 Environment Canada and Health and Welfare Canada. 1991. *Canadian Environmental Protection Act, Priority Substances List assessment report no. 2: Effluents from pulp mills using bleaching.* 60 p.
- 18 B.C. Water Management Branch. 1986. Principles for preparing Water Quality Objectives in British Columbia. Ministry of Environment and Parks, Province of B.C.
- 19 Stanley and Associates. 1993. Urban runoff quantification and contaminants loading in the Fraser River Basin and Burrard Inlet. DOE-FRAP 1993-19. Stanley Associates Engineering Ltd., Surrey, B.C.
- 20 Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.
- 21 Chillbeck, B., G. Chislett and G. Norris 1992. Land development guidelines for the protection of aquatic habitat. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks. 128 p.
- 22 MacKenzie, F.B. 1987. Urbanization and the hydrological regime, p. 277-293. *In: M.C. Healey and R.R. Wallace (ed.). 1987. Canadian aquatic resources. Can. Bull. Fish. Aquat. Sci.* 215: 533 p.
- 23 British Columbia Research Corporation. Waste Management Group. 1992. Urban runoff quality control guidelines for the Province of British Columbia. Prepared for BC Environment, Environmental Protection Division, Municipal Waste Reduction Branch. 132 p.
- 24 U.S. Congress. Office of Technology Assessment. 1987. Wastes in marine environments. OTA-O-334. 313 p.
- 25 Boeckh, I., V.S. Christie, A.H.J. Dorcey, and H.I. Reggeberg. 1991. Water use in the Fraser Basin. *In: Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288p*
- 26 UMA Engineering Ltd. 1993. Sewer use control for Fraser River basin and Burrard Inlet drainage basin. Prepared for Environment Canada, Conservation and Protection, Fraser Pollution Abatement Office,

- North Vancouver, B.C. Report No. DOE FRAP 1993-20. 83 p. + appendices.
- 27 B. Locken, Ministry of the Environment, Lands and Parks, Surrey, B.C., personal communication.
- 28 R. Dalrymple, Ministry of the Environment, Lands and Parks, Victoria, B.C., personal communication. *In: Boyle, D.E. 1995. The impacts of forestry and wood processing industries on water quality in the Fraser River Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.*
- 29 Atwater, J.W. 1980. Fraser River Estuary Study - water quality: Impact of landfills. Fraser River Estuary Study, Vancouver, B.C. 285 p.
- 30 Greater Vancouver Water District. 1993. Environmental impact assessment of proposed secondary disinfection of drinking water: Stage II.
- 31 L. Nikl, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.
- 32 Resource Integration Systems, CH2M HILL Engineering Ltd. and Peat Marwick Stevenson and Kellogg. 1993. Municipal reduction, reuse and recycling programs. GVRD solid waste management plan - stage 2: Technical memorandum 1. Prepared for the Greater Vancouver Regional District and the Ministry of Environment, Lands and Parks.
- 33 Lanarc Consultants Ltd. 1994. Stream stewardship: A guide for planners and developers. Stream Stewardship Series. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Municipal Affairs. 48 p.
- 34 Schreier, H., S.J. Brown and K.J. Hall. 1991. The land-water interface in the Fraser River Basin. *In: Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in Sustainable Development: Exploring Our Common Future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C.*
- 35 John, B., and M. Geier. 1994. Survey of agricultural practices in the Thompson Basin - 1994. Prepared for Ministry of the Environment, Lands and Parks, and Fraser Pollution Abatement Office, Environmental Protection. DOE-FRAP 1994-26. 52 p.
- 36 M. Fairbarns, Range Ecologist, Range Branch, Ministry of Forests, Victoria, B.C. personal communication.
- 37 Platts, W.S. 1981. Influence of forest and rangeland management on anadromous fish habitat in western North America. Effects of livestock grazing. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 25 p.
- 38 Statistics Canada. 1986. Agricultural census data for 1986. Statistics Canada, Ottawa.
- 39 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Matsqui River Watershed - summary report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada and Department of Fisheries and Oceans. DOE-FRAP 1994-22.
- 40 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Sumas River Watershed - summary report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada and Department of Fisheries and Oceans. DOE-FRAP 1994-21
- 41 Cook, K.E. 1994. An evaluation of water quality and land use in the Salmon River Watershed, Langley, B.C., using GIS techniques. M.Sc. Thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 252 p.
- 42 B.C. Ministry of Agriculture, Fisheries and Foods, B.C. Association of Cattle Feeders, B.C. Cattlemen's Association and B.C. Federation of Agriculture. 1992. Environmental guidelines for beef cattle producers in British Columbia. B.C. Ministry of Agriculture, Fisheries and Food, Soils and Engineering Branch, Abbotsford, B.C. 78 p.
- 43 Moore, B. 1989. Partner or Policeman: It's Your Choice. *In: South Coastal Dairy Education Association, 21st Annual Dairy Producers' Short Course, Proceedings, February 14 and 15, 1989. South coastal Dairy Education Association (Dairy Education Committee) and B.C. Ministry of Agriculture and Fisheries. p. 41-52.*
- 44 Brisbin, P.E. 1995. Agricultural nutrient management in the Lower Fraser Valley. Component project of management of livestock and poultry manures in the Lower Fraser Valley. Report 4. Prepared for B.C. MELP, Environment Canada-FRAP, B.C. MAFF, and Fisheries and Oceans-FRAP. DOE-FRAP 1995-27.
- 45 Runka, G. 1995. Livestock waste management practices and legislation outside British Columbia July 1995. DOE FRAP 1995 - 26.
- 46 R. Van Kleek, Ministry of Agriculture Fisheries and Food, Abbotsford, B.C., personal communication.
- 47 Swain, L.G. and D.G. Walton. 1991. (Fraser River Estuary Monitoring.) Report on the 1990 Lower Fraser River and Boundary Bay Sediment Chemistry and Toxicity Program.
- 48 Wan, M.T. 1989. Levels of selected pesticides in farm ditches leading to rivers in the Lower Mainland of British Columbia. *J. Environ. Sci. Health, 324(2):183-203.*

- 49 Sirois, G. 1995. Survey of agricultural pesticide application practices & recommendations for protecting Lower Mainland riparian habitat from off-target pesticide deposit: a view to the future. Prepared for Habitat Protection Branch, Ministry of the Environment, Lands and Parks, and Commercial Chemicals Division, Environmental Protection, Environment Canada. 53 p.
- 50 Wernick, B.G. 1996. Land use and water quality dynamics on the urban-rural fringe: A GIS analysis of the Salmon River Watershed, Langley, B.C. M.Sc. Thesis, Resource Management and Environmental Studies, University of British Columbia, Vancouver, B.C. 217 p.
- 51 Rood, K.M. and R.E. Hamilton. 1994. Hydrology and water use for salmon streams in the Fraser Delta Habitat Management Area, British Columbia. Manuscr. Rep. Fish. Aquat. Sci. 2238.
- 52 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilcotin Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2287.
- 53 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilliwack/Lower Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2288.
- 54 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Harrison Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2293.
- 55 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Middle Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2292.
- 56 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Nechako Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2299.
- 57 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2289.
- 58 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Quesnel Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2296.
- 59 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Seton/Bridge Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2298.
- 60 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Thompson Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2297.
- 61 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Upper Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2294.
- 62 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the West Road Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2295.
- 63 Brown, George W. 1991. Forestry and water quality, 2nd ed. Oregon State University, College of Forestry, Corvallis, OR. 142 p.
- 64 MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific northwest and Alaska. U.S. Environmental Protection Agency, Region 10, Seattle, WA; and University of Washington, College of Forestry and College of Ocean and Fishery Sciences, Center for Streamside Studies, Seattle, WA. Report No. EPA/910/9-91-001. 166 p.
- 65 Chamberlin, T.W., R.D. Harr and F.H. Everest. 1991. Timber harvesting, silviculture, and watershed processes. American Fisheries Society Special Publication 19:181-205.
- 66 Toews, D.A.A. and D.R. Gluns. 1986. Snow accumulation and ablation on adjacent forested and clearcut sites in southeastern British Columbia. *In: Proceedings, western snow conference 54th annual meeting, Spokane, Washington.* p.101-111.
- 67 Toews, D.A.A. and M.J. Brownlee. 1981. A handbook for fish habitat protection on forest lands in British Columbia. Department of Fisheries and Oceans, Field Services Branch, Habitat Protection Division, Land Use Unit. 166 p.
- 68 Scrivener, C. 1982. Logging impacts on the concentration pattern of dissolved ions in Carnation Creek, British Columbia. *In: G.F. Hartman (ed.). Proceedings of the Carnation creek workshop: A Ten-Year Review.* Malaspina College, Nanaimo, B.C. February 24-26, 1982.
- 69 B.C. Ministry of Forests and B.C. Environment. 1995. Forest Practices Code of British Columbia: Silviculture prescription guidebook. 72 p.
- 70 L. Anderson, Ministry of Agriculture, Fisheries and Food, Rosedale, B.C., personal communication. *In: Boyle, D.E. 1995. The impacts of forestry and wood processing industries on water quality in the Fraser River Basin.* Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.
- 71 Norris, L.A., H.W. Lorz and S.V. Gregory. 1991. Forest chemicals. American Fisheries Society Special Publication 19:207-296.
- 72 Servizi, J.A. 1989. Protecting Fraser River salmon (*Oncorhynchus spp.*) from wastewaters: An assessment. Can. Spec. Publ. Fish. Aquat. Sci. 105:136-153.

- 73 Chapman, P.M. 1989. Salmonid toxicity studies with Roundup. *In*: P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 257-262.
- 74 Kreutzweiser, D.P. and P.D. Kingsbury. 1989. Drift of aquatic invertebrates in a glyphosate contaminated watershed. *In*: P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 250-256.
- 75 Holtby, L.B. and S.J. Baillie. 1989. Effects of the herbicide ROUNDUP on coho salmon fingerlings in an oversprayed tributary of Carnation Creek, British Columbia. *In*: P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 273-285.
- 76 Reynolds, P.E., J.C. Scrivener, L.B. Holtby and P.D. Kingsbury. 1989. A summary of Carnation Creek herbicide study results. *In*: P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 322-334.
- 77 Samis, S.C., S. von Schuckmann, M.T. Wan, G.D. McKellar and M. Scott. 1992. Guidelines for the protection of fish and fish habitat during use of glyphosate and other selected forestry herbicides in coastal British Columbia. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 2176. 9 p.
- 78 B.C. Ministry of Forests; B.C. Ministry of Environment, Lands and Parks; Canada, Department of Fisheries and Oceans; and Council of Forest Industries. 1993. British Columbia coastal fisheries/forestry guidelines. Revised third edition (July 1993). 133 p.
- 79 L. Herring, Ministry of Forestry, Prince George, B.C., personal communication. *In*: Boyle, D.E. 1995. The Impacts of Forestry and Wood Processing Industries on Water Quality in the Fraser River Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.
- 80 H. Yano, Ministry of Forests, Kamloops, B.C., personal communication. *In*: Boyle, D.E. 1995. The impacts of forestry and wood processing industries on water quality in the Fraser River Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.
- 81 Sedell, J.R., F.N. Leone and W.S. Duval. 1991. Water transportation and storage of logs. *American Fisheries Society Special Publication* 19:325-368.
- 82 Fraser River Estuary Management Program (FREMP). 1991. Log management in the Fraser River estuary. Report of the Log Management Activity Working Group. 47 p.
- 83 Goudey J.S. and B.R. Taylor. 1992. Toxicity of aspen wood leachate to aquatic life. Part I: Laboratory studies. Prepared by Hydroqual Laboratories Ltd., Calgary, AB, for B.C. Ministry of Environment, Lands and Parks, Environmental Protection Branch, Northern Interior Region. 49 p. + appendices.
- 84 Taylor, B.R. 1994. Toxicity of aspen wood leachate to aquatic life, Part II: Field study. Prepared for B.C. Ministry of Environment, Northern Interior Branch, Environmental Protection Branch. 67 p.
- 85 Archibald, Craig. 1992. Woodwaste inventory 1992. B.C. Environment, Lower Mainland Region, Industrial Section. Surrey, B.C. 63 p. + appendices.
- 86 Stewart and Ewing Assoc. Ltd. (SEAFOR); F.B.M. Consulting Ent.; and J.F. McWilliams. 1990. British Columbia forest industry mill residues for calendar year 1989. Prepared for the B.C. Ministry of Forests Mill Residue Task Force.
- 87 Moore, K. 1992. Wood waste leachate characterization Study. Prepared for B.C. Environment, Lower Mainland Region, Industrial Section. 38 p. + appendices.
- 88 Liu, S.D., M.D. Nassichuk, and S.C. Samis. 1995. Guidelines on storage, use and disposal of wood residue for the protection of fish and fish habitat in British Columbia. DOE/DFO-FRAP 1995-18. 28 p.
- 89 Tripp, D., A. Nixon and R. Dunlop. 1992. The application and effectiveness of Coastal Fisheries Forestry Guidelines in selected cut blocks on Vancouver Island. Prepared by D. Tripp Biological Consultants Ltd. for B.C. MELP, Fish and Wildlife Division, Nanaimo, B.C. 25 p.
- 90 G. Ford, Ministry of the Environment, Lands and Parks, personal communication. *In*: Mehling, P. 1995. Review article for status of water quality issues pertaining to mining and gravel removal in the Fraser Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan. 33 p.
- 91 B. McDonald, Department of Fisheries and Oceans, Prince George office, personal communication.
- 92 Schofield, C. L. 1976. Acid precipitation: effects on fish. *Ambio* 5:228-230.
- 93 Rosseland, B.O. 1986. Ecological effects of acidification on tertiary consumers, fish population responses. *Water, Air and Soil Pollution*. 30:451-460.
- 94 W. Belzer, Environment Canada, Vancouver, B.C., personal communication.
- 95 Baker, J.P. 1982. Effects of metals associated with acidification. *In*: Acid Rain/Fisheries. Proc. International Symposium on Acidic Rain and Fishery Impacts in Northeastern North America. R.E. Johnson (ed.). Cornell University, New York. 357 p.
- 96 Clark, M.J.R. and N. Bonham. 1982. Potential sensitivity of the British Columbia aquatic environment to acid rain. B.C. Ministry of Environment, Victoria, B.C. 12 p. + figures.
- 97 Wiens, J. 1985. Sensitivity of British Columbia Soils and Geology to Acidic Inputs. *In*: Baldwin, J.W. (ed.).

- Acid Rain in the Pacific Northwest, Proceedings of the Acid Rain Symposium, Annual Conference of the Northwest Association for Environmental Studies, Univ. of Victoria, Victoria, B.C.
- 98 Hall, K.J., H. Schreier, and S.J. Brown. 1991. Water quality conditions in the Fraser River Basin. *In*: Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.
- 99 BC MELP and Environment Canada. 1992. State of the environment for the Lower Fraser River Basin. Ministry of Supply and Services Canada. SOE Report No. 92-1. 79 p.
- 100 Nikleva, S. 1985. Acid rain over southwestern British Columbia. In J.H. Baldwin (ed.) Proceedings of the Acid Rain Symposium. Annual Conference of the Northwest Association for Environmental Studies. University of Victoria. p. 15-29.
- 101 Whitfield, P.H., N. Rousseau and E. Michnowsky. 1993. Rainfall Induced changes in Chemistry of a British Columbia Coastal Stream. *Northwest Sci.* 67(1):1-6.
- 102 Henriksen, A. 1980. Acidification of freshwater - a large titration. *In*: D. Drablos and A. Tollan (eds.). Ecological impact of acid precipitation. Proc. Int. Conf. SNSF Proj. Rep. Norway. 383 p.
- 103 Sullivan, M.A. and S.C. Samis. 1988. Assessment of acidification potential of selected Lower Mainland and Vancouver Island, British Columbia streams. *Can. Tech. Rep. Fish. Aquat. Sci.* 1599: 113 p.
- 104 Whitfield, P.H. and N.E. Dalley. 1987. Rainfall driven pH depressions in a British Columbia coastal stream. Symposium on Monitoring, Modeling, and Mediating Water Quality. American Water Resources Association. p. 285-294.
- 105 Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines. Prepared by the Task Force on Water Quality Guidelines, Ottawa.
- 106 Bubenick, D.V. (ed.). 1984. Acid rain information book. 2nd edition. Noyes Publications, Park Ridge, New Jersey. 400 p.
- 107 Norton, S.A. 1982. The effects of acidification on the chemistry of ground and surface waters. *In*: R.E. Johnson (ed.). Acid Rain/Fisheries. Proc. International Symp. on Acidic Rain and Fishery Impacts in Northeastern North America. Cornell University, N.Y. 357 p.
- 108 Haines, T.A. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. *Trans. Am. Fish. Soc.* 110(6): 690-707.
- 109 Baker, J.P. and C.L. Schofield. 1982. Aluminum toxicity to fish in acidic waters. *Water, Air and Soil Pollution* 18:289-309.
- 110 Cleveland, L., E.E. Little, S.J. Hamilton, D.R. Buckler and J.B. Hunn. 1986. Interactive toxicity of aluminum and acidity to early life stages of brook trout. *Trans. Am. Fish. Soc.* 115: 610-620.
- 111 Greater Vancouver Regional District. 1992. Greater Vancouver travel survey. Report No. 6. Comparison of 1985 and 1992 Travel Characteristics. Greater Vancouver Regional District, Burnaby, B.C.
- 112 B. Thompson, Environment Canada, Vancouver, B.C., personal communication.
- 113 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.
- 114 Schneider, S.H. 1989. The changing climate. *Sci. Am.* 262:70-79.
- 115 Moore, R.D. 1991. Hydrology and water supply in the Fraser River basin. *In*: Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.
- 116 Pitman, A.J., A. Henderson-Sellars, and Z.L. Yang. 1990. Sensitivity of regional climates to localized precipitation in global models. *Nature* 346:734-737.
- 117 Ripley, E.A. 1987. Climatic change and the hydrological regime. *Can. Bull. Fish. Aquat. Sci.* 215:137-178.
- 118 Meisner, J.D., J.S. Rosenfeld, and H.A. Regier. 1988. The role of groundwater in the impact of climate warming on stream salmonines. *Fisheries* 13:2-8.
- 119 Walthers, L., and J.C. Nener. 1997. Continuous water temperature monitoring on the Nicola River, B.C., 1994: Implications of high measured temperatures for Pacific anadromous salmonids. *Can. Tech. Rep. Fish. and Aquat. Sci.* 2158:65.
- 120 Schindler, D.W., K.G. Beaty, E.J. Fee, D.R. Cruikshank, E.R. DeBruyn, D.L. Findlay, G.A. Linsey, J.A. Shearer, M.P. Stainton and M.A. Turner. 1990. Effects of climate warming on lakes of the central boreal forest. *Science* 250:967-970.
- 121 Meisner, J.D. 1990. Potential loss of thermal habitat for brook trout, due to climatic warming, in two Southern Ontario streams. *Trans. Am. Fish. Soc.* 119:282-291.
- 122 Moore, R.D. 1991. Hydrology and water supply in the Fraser River basin. *In*: Dorcey, A.H.J. and J.R. Griggs (eds.). Water in sustainable development: Exploring our common future in the Fraser River

- basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.
- 123 Northcote, T.G. 1992. Prediction and assessment of potential effects of global environment change on freshwater sport fish habitat in British Columbia. *GeoJournal* 28:39-49.
- 124 Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. *In*: T.G. Northcote (ed.). *Salmon and Trout in Streams*. H.R. MacMillan Lectures in Fisheries, U.B.C., Vancouver, B.C.
- 125 Holtby, L.B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). *Can. J. Fish. Aquat. Sci.* 45:502-515.
- 126 Slaney, P.A., T.G. Halsey, and H.A. Smith. 1977. Physical alterations to small stream channels associated with streamside logging practices in the Central Interior of British Columbia. Province of British Columbia, Ministry of Recreation and Conservation. Fisheries Management Report No. 31. 22 p.
- 127 Slaney, P.A., T.G. Halsey, and H.A. Smith. 1977. Some effects of forest harvesting on salmonid rearing habitat in two streams in the central interior of British Columbia. Province of British Columbia, Ministry of Recreation and Conservation. Fisheries Management Report No. 71. 26 p.
- 128 Brownlee, M.J., B.G. Shepherd, and D.R. Bustard. 1988. Some effects of forest harvesting on water quality in the Slim Creek Watershed in the central interior of British Columbia. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1613. 41 p.
- 129 Miles, M. 1995. Salmon river channel stability Analysis. *Can. Man. Rep. Fish. Aquat. Sci.* No. 2309. 121 p.
- 130 Miles, M. 1995. Deadman River channel stability analysis. *Can. Man. Rep. Fish. Aquat. Sci.* No. 2310. 145 p + maps.
- 131 Fisheries and Oceans Canada. In preparation. Strategic Review of Streams in the Lower Fraser Valley. Fraser River Action Plan - Fisheries and Oceans, Vancouver, B.C.
- 132 Fraser River Sockeye Public Review Board. 1994. Fraser River sockeye 1994: Problems & Discrepancies. Public Works and Government Services Canada, Ottawa, ON. 131 p.
- 133 Broersma, K., P. Webb, B. Roddan, and K. Wallach. 1995. Status report of projects in waste management in the livestock industry in the interior of British Columbia. Prepared for Fraser River Action Plan, Fraser Pollution Abatement Office, Environmental Protection, Environment Canada, Pacific and Yukon Region, North Vancouver, B.C. DOE-FRAP 1995-30. 135 p.
- 134 B.C. MAFF. 1996. Mark Aiyaddurai. Senior Data Analyst. M.C. Ministry of Agriculture, Fisheries and Food. Victoria, B.C.
- 135 The Management of Agricultural Wastes in the Lower Fraser Valley Program Steering Committee. In preparation. Management of agricultural wastes in the Lower Fraser Valley: Summary report - a working report.
- 136 Hartman, G.F. and M. Miles. 1997. Jones Creek spawning/rearing channel project: Post failure analysis. Prepared for Fraser River Action Plan, Fisheries and Oceans Canada, Vancouver, B.C.
- 137 B.C. Environment Backgrounder: "What is BACT?" Ministry of Environment, Lands, and Parks, 1992.
- 138 Scott, W.S. 1979. Road de-icing salts in an urban stream and flood control reservoir. *Water Res. Bull.* 15(6):1733-1742.
- 139 Helz, G.R., and A.C. Nweke. 1995. Incompleteness of dechlorination. *Environ. Sci. Technol.* 29:1018-1022.
- 140 Nikl, L. and D. Nikl. 1993. Environmental impacts associated with monochloramine-disinfected municipal potable water. *In*: W. Robertson, R. Tobin, and K. Kjartanson (eds.). *Disinfect dilemma: Microbiological control versus by-products*. American Water Works Association.
- 141 Gaikowski, M.P., S. J. Hamilton, K.J. Buhl, S.F. McDonald, and C.H. Summers. 1996. Acute toxicity of three fire-retardant and two fire suppressant foam formulations to the early life stages of rainbow trout (*Oncorhynchus mykiss*). *Environmental Toxicology and Chemistry* 15(8): 1365-1374.

- 142 Mehling, P. 1995. Review article for status of water quality issues pertaining to mining and gravel removal in the Fraser Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan. 33 p.
- 143 Norecol Environmental Consultants. 1993. A comprehensive survey of pesticide use in British Columbia:1991. DOE-FRAP 1993-35.
- 144 G. Kruzynski, Department of Fisheries and Oceans, West Vancouver Laboratory, personal communication.
- 145 Environment Canada, unpublished data, W. Belzer. Science Division. Environmental Conservation, Vancouver, B.C.

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-FRAP³⁻¹⁴ 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.

♦ 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. A black-and-white map indicating the locations of all discharges to surface waters addressed by MELP Waste Management Permits, and tables summarizing permit discharge information are also provided.



3.2 Methodology

3.2.1 Evaluation of Water Quality and Contaminant Data

A database compiled on behalf of DFO and DOE FRAP programs¹ 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 coordinates 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.

isons 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). For water quality parameters, data were compared with available CCREM (subsequently changed to CCME) guidelines³³ 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 Quality²⁷ were applied. Sediment metal data were compared with MELP Approved and Working Criteria for Water Quality²⁷ 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.

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	Aquatic life	DFO-FRAP
	Dissolved oxygen	0014	9.5 mg·L ⁻¹	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
Dioxins	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
	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 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

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 necessarily 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 ($15 \mu\text{g}\cdot\text{L}^{-1}$), 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 ($90 \mu\text{g}\cdot\text{L}^{-1}$) was used to evaluate concentrations of total phosphorous measured in streams and rivers.

C) Ammonia

The toxicity of ammonia increases as water temperature and pH increase, however, temperature and/or pH data often do not accompany ammonia measurements (same sampling date) in the database. 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.

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 natural 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.

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 bioavailability 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 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; and
- ◆ 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).

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 exceed 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 of good 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.

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

Metal	CCME ($\mu\text{g}\cdot\text{g}^{-1}$)		BC MELP ($\mu\text{g}\cdot\text{g}^{-1}$)
	TEL	PEL	
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

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

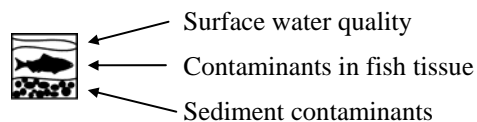
Green ♦ $n \geq 10$ and fewer than 20% of samples exceed the guideline for any parameters measured, or natural background levels for the watercourse as determined from the database;

OR $n \geq 10$ for 3 or more parameters, and none of the measured values exceed guidelines of 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 of good sediment or fish tissue quality (e.g. only pH measured), the icon colour would default to blue (see below).

Blue ♦ The above conditions are not 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.

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 catalogues¹⁵⁻²⁶ 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 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.

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

OR waterworks and industrial water licenses do exist for the stream according to hydrology reports, 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 (increased summer and decreased winter stream temperatures, and larger diurnal fluctuations) where extensive amounts of riparian vegetation have been removed, and can exacerbate natural low flow conditions. 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 Hamilton³⁻¹⁴ (this information usually dated back to the 1960s); plus
2. The percentage of the total watershed area proposed for logging in Ministry of Forests Five Year Plans (when available) was included in the 20% as most of this logging would have occurred by now (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.

♦The total and proposed cut is less than 3% of the watershed area or information indicates some logging activities with no impacts to water quality or fish habitat.

♦No information was available describing logging activity.

Blue *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 Hamilton³⁻¹⁴ 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 Hamilton³⁻¹⁴ 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 Hamilton³⁻¹⁴ 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:

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

Red

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. Tennant³¹ and Orth and Leonard³² 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 stream³⁻¹⁴ 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 intensive land use activities and 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

- 1 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.
- 2 Westwater Research Centre. 1994. 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, BC. DOE-FRAP 1993-05. 14 p. + appendices.
- 3 Rood, K.M. and R.E. Hamilton. 1994. Hydrology and water use for salmon streams in the Fraser Delta Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2238.
- 4 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilcotin Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2287.
- 5 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilliwack/Lower Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2288.
- 6 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Harrison Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2293.
- 7 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Middle Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2292.
- 8 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Nechako Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2299.
- 9 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2289.
- 10 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Quesnel Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2296.
- 11 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Seton/Bridge Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2298.
- 12 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Thompson Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2297.
- 13 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Upper Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2294.
- 14 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the West Road Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2295.
- 15 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 28A Vancouver. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 16 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 28B Squamish. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 17 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29B Surrey. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 18 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29C Coquitlam. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 19 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29D Mission. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 20 Department of Fisheries and Oceans. 1990. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29E Chilliwack. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 21 Department of Fisheries and Oceans. 1992. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29F Lillooet. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

- 22 Department of Fisheries and Oceans. 1991. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29G Williams Lake. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 23 Department of Fisheries and Oceans. 1990. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29H Quesnel. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 24 Department of Fisheries and Oceans. 1991. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29I Prince George. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 25 Department of Fisheries and Oceans. 1992. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29J Clearwater. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 26 Department of Fisheries and Oceans. 1990. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29K Salmon Arm. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 27 Nagpal, N.K., L.W. Pommen, and L.G. Swain. 1995. Approved and working criteria for water quality, 1995. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, BC. 45 p.
- 28 Smith, S.L, D.D. MacDonald, K.A. Keenleyside, and C.L. Gaudet. 1995. Development and implementation of Canadian sediment quality guidelines. *Ecovision World Monograph Series* (in press).
- 29 Haines, M.L., K. Brydges, M.J. MacDonald, S.L. Smith, and D.D. MacDonald. 1994. A review of environmental quality criteria and guidelines for priority substances in the Fraser River Basin, Supporting Documentation. Prepared by MacDonald Environmental Sciences Limited for Environment Canada-Fraser River Action Plan, DOE FRAP 1994-31. 222 p.
- 30 FREMP. 1996. Environmental quality of the Fraser River Estuary. Fraser River Estuary Management Program, Vancouver, B.C. 164 p.
- 31 Tennant, D.L. 1976. Instream flow regimens for fish, wildlife, recreation and related environmental resource. *Fisheries*. 1:6-10.
- 32 Orth, D.J. and P.M. Leonard. 1990. Comparison of discharge methods and habitat optimization for recommending instream flows to protect fish habitat. *Regulated Rivers*. 5:129-138.
- 33 Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian Water Quality Guidelines Chapter 3 (Freshwater Aquatic Life). p. 3.1 - 3.54.
- 34 M. Romaine, Fisheries and Oceans Canada, Vancouver, B.C., personal communication.
- 35 Fyles, T.M., B. King and P.R. West. 1993. Continental and Oceanographic Data Information System CODIS version 1.0. Protocols, software, compilation and appraisal of meta-data of organic contaminants in the Fraser River Basin. Prepared for Environment Canada, Environmental Conservation Directorate. DOE-FRAP 1993-24.

Chapter 4 Fraser Delta Habitat Management Area

4.1 Background

The Fraser Delta HMA encompasses 1,855 km², or less than 1% of the entire Fraser Basin. The mainstem Fraser River flows from east to west through the Fraser Lowlands and is joined by numerous small tributaries as well as several large tributaries, before it drains into the Strait of Georgia. The HMA includes the Fraser River estuary, tributaries on the south bank of the Fraser mainstem up to Matsqui, and on the north bank up to the Coquitlam River watershed.

4.1.1 Hydrology

Flows in the Fraser River mainstem are governed by snowmelt from the HMAs upstream. Peak flows normally occur during mid-summer, and low flows occur from December through to March, when most precipitation falls as snow.

The hydrology of tributary streams in the Fraser Delta HMA is strongly influenced by local precipitation. These tributaries experience peak flows during fall and winter months when precipitation is greatest. Low flows occur during summer months when there is little precipitation, and groundwater maintains base flows.

Based on criteria identified in the Methods section of this report, 31 of the 40 salmon-bearing streams assessed were coded red for having flow problems that would negatively affect fish populations - either very low summer flows, or the extreme fluctuations between high and low flows resulting from extensive impermeable surfaces.

4.1.2 Fish

The Fraser River mainstem is an important migration corridor for the five species of anadromous Pacific salmon which spawn in the basin. All Fraser River salmon surviving to reproduce pass through the Fraser delta twice in their life cycle: as juveniles migrating to the ocean, and again as adults returning to spawn in their natal streams. Depending on the species, juvenile salmon remain in the estuary from days to months, resting, feeding and acclimatizing to the marine environment. The duration of an adult salmon's stay in the estuary is apparently influenced by a number of factors including water temperature and water levels.¹

Forty tributary streams in the Fraser Delta HMA are known to provide important spawning and rearing habitat for Pacific salmon species.²⁻⁴ Approximately 65% of Fraser River coho and 85% of Fraser River chum spawn in tributaries downstream from Hope. A number of sockeye, chinook, and pink runs spawn in some tributaries, and large numbers of pink and chum salmon also utilized gravel bars in the mainstem for spawning.

Other migratory fish species using the Fraser River delta area for feeding and/or spawning include steelhead and cutthroat trout, eulachon, Pacific herring and white stur-

geon. Resident marine species include starry flounder, Pacific dogfish, and various types of sculpin and sole.⁵ Freshwater resident species inhabiting the tributaries and mainstem include rainbow trout, peamouth chub, mountain whitefish, leopard dace, and the endangered salish sucker, among others.

4.1.3 Predominant Land Uses

The Fraser Delta HMA was home to about 1.7 million people as of 1995.⁶ It is estimated that 40,000 to 50,000 people move to the Fraser Delta HMA each year⁴⁴ and by the year 2020 there could be as many as 3 million people living in the Vancouver Metropolitan Area.⁴⁵ This ongoing population growth has a large influence on land use dynamics in the Fraser Delta HMA and will have significant implications for water quality both in small streams and the Fraser mainstem.

A review of the history of land development and associated fish habitat losses in the Lower Fraser Valley is provided by Langer, *et al.*⁷ Urban and agricultural development are the two main land uses affecting water quality and fish habitat in the Fraser Delta HMA.

The metropolitan Vancouver area is highly urbanized, with pockets of industrial land adjacent to the Fraser River. The eastern areas consist of dense urban centers interspersed with residential sprawl, which has displaced much of the historical farming activity. The greatest amount of new development is occurring in the eastern municipalities.⁵ Densification of existing urban areas is likely to continue with some new development, and a significant amount of re-development taking place.

Parcels of agricultural land are located throughout the Fraser Delta HMA. The vast majority of these parcels are protected from non-agricultural development by the Agricultural Land Reserve (ALR), though increasing amounts of ALR land are supporting small "hobby farms" rather than commercial farms. Commercial agricultural operations, frequently intensive in nature, dominate the easternmost portion of the Fraser Delta HMA.

FREMP provides a detailed summary of land use and environmental quality issues in the Fraser Delta area.⁵ This level of detail will not be repeated here. Rather, the key water quality issues will be addressed.



4.2 Point Sources of Contaminants

Water quality in the mainstem may be affected by contaminant inputs from upstream anthropogenic sources, as well as point and non-point source discharges within the HMA.

4.2.1 Upstream Discharges

There is always the potential for upstream contaminant discharges to affect water quality at downstream areas, including in the Fraser Delta HMA, particularly if persis-

tent contaminants are released to the river. It should be noted that there is presently no evidence of contaminants from upstream sources negatively affecting water quality in the Fraser Delta HMA.

Six pulp and paper mills at Kamloops, Quesnel and Prince George collectively contribute 75% of the volume of permitted discharges to surface waters upstream from Hope. These mills contributed to levels of chlorinated dioxins, furans, and adsorbable organic halides, along with mills in the Fraser Delta, which were affecting bird and fish species in the estuary. Actions by government and industry have greatly reduced loadings of harmful contaminants from pulp mill discharges, and the affected fish and wildlife populations are recovering.⁴⁶ For example, average LC₅₀ tests of the effluent improved from 70% fish survival in 1990 to 96% in 1994, and in 1994 the consumption advisory for whitefish in the upper Fraser was lifted.⁴⁶

4.2.2 Urban/Industrial Point Source Discharges to Surface Waters

Permitted waste discharges in the Fraser Delta HMA are numerous (99 in total) and there are many clusters, where a number of discharges are located very close together (Figures 4.2.1 A - D). Tidal influences in the estuary may reduce mixing, and multiple effluent streams which track the shoreline or wash into sloughs may result. Nearshore areas provide the most important habitats in the estuary for juvenile salmonids. Data indicate that some sloughs have low dissolved oxygen concentrations at depth, though to some extent this may be a natural conditions for the sloughs.⁴⁷ The Middle and North Arms of the Fraser River have particularly high densities of discharges. Existing water quality measurements may not reflect the conditions which fish are exposed to in the delta, as sampling efforts are often focused on fully mixed mid-channel areas, while fish are often close to shore.

A summary of permitted waste discharges to surface waters is provided in Table 4.2.1. Permitted discharges to surface water include processing (30), cooling (28), stormwater (13), STP (24) and leachate (4) effluents. Most discharges (65) are to some part of the Fraser River itself (i.e. North Arm, sloughs, etc.), 22 are to ditches draining to the Fraser River, 5 are to tributaries, and 7 are to ditches draining into tributaries of the Fraser.

STPs are major contributors of many contaminants (Table 4.2.2). The total permitted discharge volume of effluents into surface waters in the Fraser Delta HMA amounts to 924,800 m³·d⁻¹. About 75% of this volume comes from two wastewater treatment facilities: the Annacis and Lulu STPs. Both of these facilities discharge into the Main Arm of the Fraser.

Some of the numerous industries located along the banks of the Fraser River discharge their effluents to the municipal STPs, however, many discharge liquid wastes to the Fraser River. Industrial contaminants such as oil and grease, BOD, nutrients, trace metals and a variety

of organics are discharged into the river through outfall pipes or indirectly through a municipal sewerage system. Runoff from industrial sites is another avenue by which contaminants reach the Fraser mainstem and its tributaries.

Some of the permits governing discharges into ditches, sloughs, and the Fraser River need to be re-assessed for compatibility with the receiving environment. Discharges that are potentially problematic because of the concentration and/or loading of some parameters, relative to the nature of the receiving water body, are identified in Table 4.2.3. Many of the chlorinated effluent discharges may be problematic because permitted concentrations of chlorine in effluent are high enough to be toxic to aquatic life. To address this concern, MELP is currently considering lowering the maximum permitted chlorine concentrations to 0.05 mg·L⁻¹.

The GVRD will soon be increasing the concentration of chlorine in its potable water distribution system. Some industries utilize the municipal water supply as a source of cooling water, and it may become necessary for them to dechlorinate this cooling water prior to discharge to prevent toxicity to aquatic life.

A large volume of warm effluent and cooling water is discharged to the Fraser Delta HMA each day (Table 4.2.4). The small warm discharges to the Fraser mainstem are not likely to cause water quality concerns, however, there are some relatively large discharges of very warm water to ditches, small streams, sloughs and the tidally reversing estuary, which should be re-assessed. In the context of Fraser River flows (~12,000 m³·s⁻¹ at Mission during summer months) the warm discharges are relatively small, however, tidal influences on dispersion could result in warm water influencing water temperatures in habitats preferred by migrating fish. Also, during several summers in the past decade water temperature in the Lower Fraser has exceeded the threshold for inducing mortality in salmonids.⁴⁹ It is unknown whether these larger warm water discharges to the Fraser River have an effect on fish when water temperatures are already high.

Specific problems with a number of industrial discharges are reviewed by FREMP.^{8,9} Effluent characterization studies determined that a number of effluents contained potentially harmful substances which were not addressed in Waste Management Permits, and some effluents were found to be acutely toxic in rainbow trout and *Daphnia magna* bioassays. At present, the discharges from Annacis and Lulu STPs are often acutely toxic in 96-hr rainbow trout bioassays. These STPs are the largest point sources of biological oxygen demand, fecal coliforms, oil and grease, ammonia and copper to the Fraser River estuary.⁵ Following a directive from DFO's Minister, the GVRD is proceeding with upgrading the Annacis and Lulu STPs, both of which discharge primary treated effluent into the Main Arm of the Fraser River. Secondary treatment is to be operational by the end of 1998. Loading from a third major GVRD STP, Iona, is not addressed here because the primary treatment

facility discharges into the Georgia Strait via an 8 km long pipe.

Combined sewer overflows (CSO) in New Westminster and Vancouver discharge a mixture of stormwater and raw sewage into the Fraser River during periods of high rainfall. CSOs are sources of oil and grease, BOD, nutrients, bacterial contamination, trace metals and a variety of organic contaminants. There are a large number of CSO outfalls in the North Arm of the Fraser River. CSOs are to be examined in Stage 2 of the GVRD's Liquid Waste Management Planning process, which is presently underway. The GVRD has made changes to the way in which it manages CSO infrastructure, which has greatly reduced the number of direct discharges to Burrard inlet in recent years, but CSOs draining into the Fraser River mainstem have not yet been addressed.

4.2.3 Discharges to Ground

Thirty-seven discharges to ground are addressed via MELP's Waste Management Permits: 18 for processing, 5 for cooling, 4 for stormwater and 10 for STP effluents. Discharges to ground are a concern where contaminants can leach into either ground or surface waters.

Increasing numbers of small septic systems (discharge volume < 22.7 m³·d⁻¹), permitted through the B.C. Ministry of Health, are also of concern in some areas of the Fraser Delta HMA. Urbanization of rural areas is occurring at a faster rate than the expansion of municipal sewerage services. On-site waste disposal is therefore relied upon in many areas including densely populated parts of Richmond, which has a very high water table, and other areas such as parts of Surrey and Langley. There is no mechanism for ensuring that septic tanks are properly maintained once installed, and consequently many of them fail over time. There are numerous reports of septic tank seepage reaching streams in the Lower Fraser HMA.¹¹ Septic tanks are a source of nitrate contamination of groundwater in unconfined aquifers in the Langley area,¹² and increased nitrate concentrations have been measured in the Salmon River groundwater enters the river.²³



4.3 Factors Modifying Contaminant Fate and Effects

Numerous physical features of rivers and streams affect the way contaminants behave in the receiving environment and therefore influence the effect of contaminants on the receiving environment. The primary physical features influencing the Fraser mainstem and tributaries in the Fraser Delta HMA are outlined below.

4.3.1 Fraser Mainstem

During flood tide and low river flow conditions, water accumulates upstream of the delta, and at times the direction of river flow may actually be reversed. At ebb tide the stored water is released and the velocity of the water increases. The influence of the tide can be observed as far upstream as Mission. The tidal effects on river

flow in the Lower Fraser River are due to a wedge of dense sea water which alternately advances and retreats beneath the river water in the delta. This salt water wedge, observed as far up stream as Annacis Island, affects flow velocities, reduces the vertical mixing of effluents⁵ and may increase the bioavailability of metals.¹³ The changing velocity and direction of flow results in varying dilution and residence times of contaminants discharged into the river.¹³ As well, some sites may experience "multiple dosing" as the same contaminated water passes a given site more than once, likely accumulating more contaminants from continuous sources with each pass.

Tidal influences on many tributary streams in the lower Fraser are controlled by flood gates which were installed many decades ago. These flood gates slow the flow of water in lower reaches of tributary streams, leading to warming of the water, and decreased dissolved oxygen concentrations.

4.3.2 Sloughs

Sloughs are regions of slow moving water removed from the main channel, and along with side channels are heavily utilized by fish, particularly juveniles. Shallow shoreline areas, where currents are slow relative to mid-channel, also provide valuable fish habitat. Because of limited mixing, water quality in sloughs is more susceptible to degradation in comparison with mid-channel areas. For example, Fraser delta sloughs are subject to low dissolved oxygen conditions at depth because oxygen is consumed (at least in part due to BOD inputs) more rapidly than it is replenished by photosynthesis or mixing.¹³

Due to the reduced mixing action in sloughs, fine sediment particles tend to settle out in these areas. Sediment quality in sloughs is often affected by trace metals and organic compounds, which are bound to the settling sediments.⁵

4.3.3 Tributary Streams

Small tributary streams are more susceptible to impacts from surrounding land uses and non-point sources of pollution in comparison with the mainstem. Most of these streams have relatively low flows, particularly during summer months, making them vulnerable to contaminant inputs and elevated water temperatures.



4.4 Non-point Sources of Contaminants

The types of land uses prevalent in the Fraser Delta HMA make non-point sources of pollution significant.

4.4.1 Urban Stormwater Runoff

A study conducted by Stanley and Associates estimated loading of various contaminants into the Fraser Basin from urban stormwater runoff.¹⁴ Collectively, these non-point sources of contaminants are often comparable with loading from permitted discharges (Table 4.4.5).

Stormwater runoff introduces trace metals, bacteria, and organic contaminants such as PAHs into the Fraser mainstem and tributary streams. Extensive impervious surfaces and notoriously heavy rainfalls make stormwater runoff a significant source of contaminants in the Fraser Delta HMA. As part of the Liquid Waste Management Plan (LWMP), the GVRD is characterizing stormwater runoff in the Serpentine River in Surrey, and in Still Creek, a tributary to the Brunette River.

A total of 20 salmon-bearing tributaries in the HMA were considered to have degraded water quality and habitat conditions as a result of urban development (Section 4.6). Streams affected by urban development where salmon are no longer found are not included in this number.

4.4.2 Agriculture

Agriculture in the Fraser Delta HMA includes a great diversity of crops, ranging from berry and vegetable production to intensive livestock and poultry operations. Small hobby farms are common in the ALR, especially in the western portion of the HMA, while larger commercial enterprises are more common in the eastern municipalities.

Effects from agricultural activities are concentrated in the southern delta area, the Boundary Bay tributaries and the Fraser River tributaries upstream of Fort Langley. The water quality conditions in a total of 13 streams in the Fraser Delta HMA were considered to be degraded by surrounding agricultural activities (Section 4.6), based on criteria identified in the Methodology section of this report. Water quality in localized near-shore areas of the Main and North Arms of the Fraser River may also be negatively affected by runoff from agricultural lands in the municipalities of Delta and Richmond.

Runoff is the primary source of water quality degradation associated with agriculture. Non-point source nutrient runoff from agriculture results from excessive applications of manure and chemical fertilizers. While average fertilizer application rates for Canada are in the range of 125 - 415 kg/ha/yr, the highest average application rate was 625 kg/ha/yr, in southwestern B.C.¹⁵ Furthermore, despite the relatively small area defined as the Lower Fraser Basin, 52% of all fertilizers used in the entire Fraser Basin are applied in the Lower Fraser area. Results of a recent study indicated that producers in the Lower Fraser could collectively save about \$12 million per year in fertilizer expenses if the use of manure as a nutrient source was optimized.¹⁶ This would also help reduce the pollution problems resulting from excess nutrients reaching tributary streams and near-shore areas.

Depletion of dissolved oxygen resulting from BOD inputs and eutrophication is a problem in numerous Lower Fraser tributaries draining agricultural land. Agricultural runoff can also be a significant source of fecal coliforms, pesticide residues, potentially toxic concentrations of ammonia, and sediments.

A broad range of herbicides, insecticides and fungicides are applied to agricultural land in the Lower Fraser Valley, including the Fraser Delta HMA. Pesticides may reach surface waters in runoff water and from spray drift. Because pesticides are expensive to analyze very few studies have documented the amounts reaching surface waters from agricultural applications. Pesticide residues may remain in ditch water for up to a year after spraying, and concentrations of endosulfan exceeding the LC₅₀ for rainbow trout by a factor of 1,100 were measured in ditch water approximately 30 minutes after spraying.¹⁸ Endosulfan is one of the more persistent insecticides used in the Lower Fraser Valley.

The use of Integrated Pest Management (IPM) approaches is increasing, however, it is unknown whether pesticide use has actually declined significantly in the Lower Fraser Valley as a result.

Other effects noted in the HMA result from removal of riparian vegetation around ditches and streams, and excessive irrigation withdrawals. The lack of riparian vegetation results in high summer water temperatures, which are often accompanied by low dissolved oxygen concentrations. Tributaries in the Fraser Lowland experience low flows during the period when irrigation demands are often highest, which can affect fish habitat directly and contribute to high water temperatures. Withdrawals from groundwater aquifers may also affect stream flow and reduce inputs of cool water because groundwater maintains summer base flows in many Lower Fraser streams.



4.5 Overview of Water Quality Conditions

4.5.1 General Water Quality Conditions in the Mainstem

The large volume of water in the mainstem helps to stabilize both physical and chemical properties of the water quality. The Fraser mainstem is near-neutral, with a pH generally in the range of 7 to 8. Drinnan and Clark report that the mainstem water is poorly buffered against alkaline discharges.¹⁹

Suspended sediment loads are naturally high, giving the water a muddy appearance. Mainstem temperatures are usually in the range preferred by salmonids, although in several recent hot summers high water temperatures are believed to have greatly reduced the number of fish successfully reaching spawning grounds in other parts of the Basin.²⁰

Monitoring programs have targeted well-mixed waters in the middle of the river. Near-shore areas and sloughs, which provide critical fish habitat, have been sampled much less often despite the fact that they are more likely to be affected by degraded water quality.

Generally, criteria for the protection of aquatic life are met most of the time, with some notable exceptions for temperature in recent summers. Water quality degradation is most evident in the North Arm, which carries

about 15% of the Fraser River flow. Relatively low flow coupled with large numbers of stormwater discharges, combined sewer overflows and minor industrial discharges, has reportedly resulted in some degradation of water quality in the North Arm relative to other parts of the mainstem.¹³

4.5.1.1 FREMP Water Quality Data

Water quality sampling in the Fraser Delta HMA has been more intensive than in other HMAs. As part of the FREMP Water Quality Monitoring Program, three sites were sampled every 2 weeks for 15 months: Mission, Tilbury Island, and Oak Street Bridge. Six sloughs were sampled less frequently, both at the surface and at depth. Resulting data enabled identification of some seasonal water quality trends, and also provided the opportunity for some comparisons between sites. This data set also made it possible to establish correlations between parameters, for example between metals and suspended sediments.

A detailed review of this data set is provided by Drinnan and Humphrey.²¹ Key findings include the following:

- ◆ a decrease of one order of magnitude in the total chlorophenol concentration in water from pre-1987 to 1993-94, reflecting federal de-registration of chlorophenates for antispasmin use.
- ◆ seasonal patterns in dissolved oxygen and water temperature in the estuary are inversely related and follow expected seasonal cycles;
- ◆ high concentrations of metals including aluminum, arsenic, copper, chromium, iron, nickel, and zinc appear to mirror levels of suspended solids.
- ◆ pH at the Oak Street Bridge site was significantly lower than at other sites. Acidic industrial discharges or storm drains are possible sources of hydrogen ions.
- ◆ high fecal coliform counts at the Oak Street Bridge corresponded to heavy rainfall events prior to or during sampling.
- ◆ all six sloughs sampled had fecal coliform counts exceeding the guideline of 200 CFU·100 mL⁻¹.
- ◆ Gunderson Slough had higher PAH levels than the other 5 sloughs.
- ◆ with the exception of some lower dissolved oxygen concentrations measured approximately 1 m above the bottom in one slough, water quality in sloughs is generally good.

4.5.2 General Water Quality Conditions in Tributaries

In tributary streams of the Fraser Delta HMA, water quality normally reflects a combination of the water chemistry of precipitation during rainy seasons, and the local geology during dry summer months when groundwater is the predominant water source. Tributary streams which are not affected by human land uses generally lack the high suspended sediment loads of the mainstem.

Water quality conditions in Lower Fraser tributaries vary widely depending primarily upon predominant land uses in the surrounding watershed. Many tributaries are affected significantly by runoff from urban and agricultural activities. Trace metals and organic contaminants are the primary pollutants in the metropolitan areas, while nutrients and BOD affect many rural streams. Site-specific water quality assessments, and influencing factors and supporting data (Table 4.5.1 a-b) are provided in Section 4.6 on a stream-by-stream basis.

Two tributaries to the Fraser River in the Fraser Delta HMA have been researched extensively and serve as case studies for the effects of various land uses on water quality:

1. The Brunette River Watershed in Burnaby is highly urbanized and also hosts several industries. The primary water quality issues here include heavy metal contamination of sediments, oil and grease, and high fecal coliform levels related to storm runoff from streets in the watershed. Although coliform bacteria are not expected to affect fish, they are often associated with nutrients from human and animal wastes, which can contribute to eutrophication. Sediment cores taken from lakes in the Brunette system show increasing concentrations of some metals related to human activities.²²
2. The Salmon River Watershed in Langley was the second case study, and provided an example of how mixed land uses in an urban-rural fringe setting can affect water quality. Commercial agriculture, hobby farms and septic systems are all sources of the nitrate contamination in the Hopington Aquifer. The aquifer, in turn, contributes a large proportion of summer base flows in the Salmon River resulting in elevated nitrate concentrations in the stream water.²³ Concentrations as high as 7.5 mg·L⁻¹ have been measured during the summer low flow period. Results of a temperature monitoring program showed that summer water temperatures can reach 26°C,²³ exceeding the upper lethal temperature limit for Pacific salmonids. This river supports an important coho run.



4.6 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 Fraser Delta HMA. Summary tables of:

- ◆ surface water, sediment and fish tissue data (Tables 4.5.1a and b);
- ◆ land use areas, stream flow, and water demand information, for each salmon stream (Table 4.6.1);

- ◆ red-coded indicators for each salmon stream (Table 4.6.2).

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 4.6.1.

Water quality conditions were assessed based on a database compiled by DFO and DOE and the data were categorized according to the criteria outlined in the Methodology section. Additional information was included in stream summaries where available, but it did not influence the outcome of the category rating.

Assessments of potential effects of urban development, agriculture, forestry, low stream flows, and water demand on water quality were based on information provided in a series of hydrology reports prepared by Rood and Hamilton, and/or SISS catalogues, unless otherwise indicated. Assessment criteria are described in the Methodology section of this report.



Fraser River Mainstem

Fraser River Middle and North Arms



◆10 of the 22 fecal coliform counts from the Middle Arm and 10 of 24 from the North Arm exceeded the guideline. High fecal coliform levels are not a direct threat to fish, but indicate sewage discharges and/or stormwater inputs. 20 of 21 dissolved ammonia concentrations in the Fraser River at Oak Street were above the 80th percentile but none exceeded the 30-day criteria for total ammonia.

Total copper consistently exceeded the guideline (12 of 15 in the Middle, and 12 of 14 in the North Arm), while total lead and chromium sometimes exceeded the guidelines (2 of 3 chromium and 4 of 15 lead in the Middle, and 1 of 1 chromium and 7 of 20 lead in the North Arm). Total metal concentrations are associated with suspended sediment levels and largely reflect natural conditions, as concentrations of these metals in the estuary are similar to those upstream from Prince George.

Elevated levels of several metals and one PAH (phenanthrene) were measured in sediments at Belkin Slough (also known as Tree Island or Blind Slough). Metal levels may result from nearby industrial activity. Tree Island Industries (P03190) discharges processing effluent to infiltration lagoons which have historically had seepage problems, resulting in effluent reaching the Fraser River.

The North Arm contains a relatively large number of permitted discharges (Figures 4.2.1 A-D) and CSO outfalls. Existing water quality data usually result from mid-channel sampling and may not reflect what fish are exposed to as they reside in or migrate through the Arm. The near-shore areas which are more heavily utilized by fish may have higher contaminant concentrations due to

stormwater runoff and the location of many discharge pipes.

The Middle, North and Main Arms of the Fraser River are major shipping corridors and there have been numerous small fuel spills.²⁶



◆None of the parameters measured (1994) in fish muscle (dioxin, furan, PCB, toxaphene and p,p'-DDE) exceeded the federal consumption guidelines established to protect human health. The long-term effects of low levels of contaminant mixtures on aquatic organisms are unknown.



Fraser River Main Arm



◆Ammonia, fecal coliform counts and some metals exceeded the guidelines in the vicinity of the Lulu STP and Annacis STP outfalls, as well as near the Pattullo Bridge. For example, 19 of 21 dissolved ammonia, 16 of 29 fecal coliform, and 12 of 19 copper measurements upstream from the Annacis STP outfall exceeded the 80th percentile or guidelines. As in the North and Middle Arms of the Fraser River, high metal concentrations are likely natural.



◆None of the parameters measured (1994) in fish muscle (dioxin, furan, PCB, toxaphene and p,p'-DDE) exceeded the federal consumption guidelines established to protect human health. The long-term effects of low levels of contaminant mixtures on aquatic organisms are unknown.



Ladner Slough



◆2 of 4 fecal coliform counts and 3 of 4 copper levels in surface water exceeded the guidelines. Total copper may reflect natural levels associated with the suspended sediment load of the Fraser. 3 of 4 dissolved ammonia concentrations were above the 80th percentile, but none exceeded the 30-day criteria for total ammonia.

5 of 5 copper and chromium and 4 of 5 zinc values in sediment exceeded the guidelines.

◆**Other water quality data:** A study of sediment pore water showed elevated levels of ammonia and metals, even at the "control" sites in the slough.²⁴

◆**Other:** Areas adjacent to the slough are increasingly being urbanized.



Fraser River Mainstem



◆None of the parameters measured (1994) in fish muscle (dioxin, furan, PCB, toxaphene and p,p'-DDE) collected from the Barnston or Mission reaches exceeded the federal consumption guidelines established to protect human health. The long-term effects of low levels of contaminant mixtures on aquatic organisms are unknown.



◆Upstream from the Aldergrove STP outfall, 12 of 14 dissolved ammonia and 10 of 15 fecal coliform values exceeded the 80th percentile or guideline. Downstream from the outfall, 5 of 9 fecal coliform values exceeded the guideline. Samples have also been collected upstream from the James STP outfall. At this site, 7 of 14 dissolved ammonia and 5 of 14 fecal coliform values exceeded the 80th percentile or guideline. Downstream from the STP, only 6 of 14 dissolved ammonia and 2 of 15 fecal coliform values exceeded the critical values.



Fraser River North Shore Tributaries

Musqueam Creek (00-0010)



◆12% EIA. Removal of riparian vegetation, erosion of channel banks, and chemical runoff from a golf course have been reported.²⁵ Storm runoff from the surrounding urban area may also affect water quality.



◆The naturalized summer 7-day mean low flow is 9% of the mean annual flow. Low flow problems have been reported.²



◆No water licenses have been issued.

◆**Other:** There is a proposal to drill a well to pump water into the creek and develop storage to alleviate extreme low flow problems. Several fugitive discharges causing adverse effects have been noted, especially where Marine Drive crosses the creek.²⁶



Glen Lyon Creek (no SISS #)



◆23% EIA. An old landfill and woodwaste deposition site located near the creek may generate leachate.²⁶



◆The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



◆No water licenses have been issued.

◆**Other:** While no details were provided, the hydrology report stated that maintenance of adequate water quality was concern.²⁵



Sussex Creek (no SISS #)



◆7% EIA indicates moderate urban development.



◆Runoff from vegetable farming near the stream may affect water quality.²⁶



◆The naturalized summer 7-day mean low flow is 10% of the mean annual flow.



◆No water licenses have been issued.

◆**Other:** Annual dredging threatens the most productive section of the stream. A new golf course has been developed on the south side of the creek.²⁶



Byrne Creek (no SISS #)



◆27% EIA indicates extensive development, and the natural hydrologic regime has been disrupted. Concerns about the quality and quantity of stormwater draining into the creek have been identified.²⁵



◆The naturalized summer 7-day mean low flow is 6.5% of the mean annual flow.



◆No water licenses have been issued.

◆**Other:** Juvenile coho and cutthroat trout are observed each year.

The lower section was relocated and channelized to accommodate a golf course.

There have been several episodic spills and fish kills associated with a culvert in a park near Edmonds.²⁶ There are several connections to storm sewer lines draining into Byrne Creek which are not identified in City of Burnaby documentation.²⁶ Hollis Creek, a tributary to Byrne Creek, was re-routed through a historical woodwaste landfill site, which generates toxic leachate. A liner separates the creek from the landfill. Other impediments to fish on Hollis Creek include low flow problems.²⁶



Brunette River (00-0100)



◆14 of 15 dissolved ammonia, 9 of 14 fecal coliform and 3 of 10 total phosphorus values exceeded the guideline or 80th percentiles in Burnaby Lake. A maximum fecal coliform count of 90,000 was reported for Still Creek. Copper, lead, and zinc levels consistently exceeded guidelines (n=12), while chromium and zinc sometimes exceeded guidelines, in both surface water and sediment samples from Burnaby Lake and Still Creek. Copper concentrations in Still Creek sediments were up to twenty times the guideline for the protection of aquatic organisms.

◆**Other water quality data:** Average water hardness in the Brunette system ranges from 40 - 60 mg·L⁻¹, indicating moderately soft water. Alkalinity values indicate moderate to low sensitivity to acidic inputs (usually about 20 mg·L⁻¹ or more).²⁷ Elevated fecal coliform counts, phosphorus and ammonia are believed to result from stormwater outfalls, urban runoff, and possibly water fowl and cross-connected sewage lines.²⁶



◆27% EIA. Urban development has occurred along 22% of the stream length, and there are parks along 16%. Urban development is encroaching on the tributaries and has affected water quality in Stoney Creek.⁴



♦The naturalized summer 7-day mean low flow is 6% of the mean annual flow.



♦No water licenses have been issued by the WMB.

♦**Other:** Industrial processing occurs along 47% of the stream length, and industrial effluent affects water quality in Eagle and Still Creeks.⁴ Waste discharges to these creeks include permits P06945, P03138 and P03840, all of which are petroleum storage and handling facilities. Chlorine spills, mainly from private swimming pools, and jet fuel spills from Trans-Mountain Pipe Lines have occurred in the Stoney Creek tributary. An industrial park with increasing small industry borders the stream. There have been several fish kills in the last five years.²⁶

The lower river is channelized and dyked on both sides. High water temperatures and low dissolved oxygen levels have been reported downstream of the Burnaby Lake dam.²⁵

The watershed has been studied extensively since the 1970s and the stormwater issues are well documented.^{22,28-30} A community program with wide participation from agencies at all levels is underway, in an attempt to address water quality and habitat issues.



Laurentian Creek (00-0150)



♦9.8% EIA indicates extensive urban development, primarily in headwaters. The creek flows through an industrial area with a history of pollution problems.⁴



♦The naturalized summer 7-day mean low flow is 3% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** A reach was relocated in 1978, and a bypass now reroutes flood waters to Popeye Creek.³¹ The creek receives treated landfill leachate as a permitted discharge (P04745).



Popeye Creek (00-0150-010)



♦9.9% EIA indicates extensive urban development. Warehousing and a trailer court are located along the creek.



♦The naturalized summer 7-day mean low flow is 2% of the mean annual flow. Low flow problems in the lower of creek have been reported.⁴



♦No water licenses have been issued.



Schoolhouse Creek (00-0150-011)

♦32% EIA indicates extensive urban development.

♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. Summer low flows have been reported.

♦No water licenses have been issued.



♦**Other:** Woodwaste leachate has affected water quality in the past.⁴ The leachate is now treated. Lack of riparian vegetation has resulted in high water temperatures near the Lougheed Hwy.²⁵



Coquitlam River (00-0180)

♦The Coquitlam River drains one of three lakes which provide the Greater Vancouver Water District (GVWD)



municipal water supply. Several stations have been sampled in the Coquitlam River and two tributaries. At the mouth, 16 of 24 dissolved ammonia concentrations exceeded the 80th percentile. Nonfilterable residues levels are similar to those measured the Fraser mainstem at the Pattullo Bridge site. Fecal coliforms, dissolved ammonia and nonfilterable residue increase from headwaters to the mouth.

♦**Other water quality data:** The Coquitlam River is susceptible to acidic inputs from rainfall. During the mid-1970's pH measured downstream from Coquitlam Lake ranged from 5.8 to 6.3. Weekly average pH values measured at the GVWD water intake near the Coquitlam Lake dam for a 25 year time period, starting in 1959, decreased by 0.28 units.²⁷

♦Urban development occurs along 18% of the stream length, and 8% is bordered by park land. Storm runoff



and encroachment on the stream banks are increasing problems. Development of the Westwood Plateau is contributing significant sediment loads, resulting in high levels of nonfilterable residues.²⁵

♦Agricultural activity occurs along 23% of stream length near the mouth.⁴ The ALR land is largely



unused and shrubs are growing in the pasture land. The future of agricultural activity here is uncertain.²⁶

♦The naturalized summer 7-day mean low flow is 12% of the mean annual flow. Flows are largely



regulated by the dam at the mouth of Coquitlam Lake. Flow from the dam ranges from 8 to 30 CFS. Fluctuating flows have been noted to cause scouring.

♦The potential August and September water demand for waterworks and industrial uses is 73% of the naturalized summer 7-day mean low flow.



♦**Other:** Extensive logging has occurred around Coquitlam Lake under the jurisdiction of the GVWD. A moratorium on further logging is in place at least until a review of logging in the 3 GVWD watersheds is complete.

The floodplain has been dyked to protect agricultural and urban lands.

Three large gravel pit operations in the middle reaches of the Coquitlam River cause chronic sedimentation problems as a result of inadequate settling ponds.³² Year-round gravel removal in and around the river, which began in the 1950's, has seriously damaged the river and contributed to the demise of Coquitlam River fish stocks. The stream water is reportedly clear upstream of the gravel pits and muddy downstream from the pits.⁴⁸

Pink salmon were last reported in 1957 and steelhead trout in 1967.²⁷



Scott Creek - Coquitlam (00-0180-100)



◆ 5 of 5 dissolved ammonia values were above the 80th percentile, but did not exceed the 30-day criteria for total ammonia. 4 of 5 fecal coliform counts were significantly higher than the guideline.



◆ 23.7% EIA indicates extensive urban development. Development has caused heavy siltation and the lower 5 kilometers have changed considerably due to residential and industrial development.⁴



◆ The naturalized summer 7-day mean low flow is 2% of the mean annual flow.



◆ The potential August and September water demand for industrial use is 28% of the naturalized summer 7-day mean low flow.

◆ **Other:** The Eagle Ridge development was predicted to increase peak flow so the lower creek was straightened, cleared and enlarged.³¹ Some riparian habitat remains downstream of the Lougheed Highway. Future stormwater diversions are planned and will reduce peak flows. A green belt and trails have been established from the Barnet Hwy. to the upper watershed.⁴

There is one permitted waste discharge (P08917) of processing effluent from a gas compressor station. Other light industry includes chicken processing.²⁶



Hoy Creek (00-0180-100-020)



◆ 20.8% EIA reflects the heavy residential development which is underway.²⁶ The Westwood Plateau developers plan to include stormwater detention and creek setbacks, but stormwater will be transferred to the Coquitlam River from the Hoy and Scott Creek watersheds, ultimately reducing flows in Hoy Creek.³¹



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



◆ The potential August and September water demand for industrial use exceeds the naturalized summer 7-day mean low flow.

◆ **Other:** A riparian buffer along the lower creek protects spawning areas, and a green belt from the Barnet Hwy. to the upper watershed is proposed.⁴ Aggradation and sedimentation occurs in the lower reaches.³¹ A golf course in the upper watershed has used large quantities of hogfuel on its property. While the site is far upstream from areas used by salmon, leachate could potentially affect fish habitat. Numerous spills of oil and latex associated with construction have been reported and a fish kill occurred in 1996 due to concrete wash water entering the stream.²⁶

The Hoy Creek Streamkeepers group is active in the watershed and has posted water quality data on an internet web page.²⁶



Maple Creek (00-0180-110)



◆ 26.9% EIA indicates extensive urban development. There is some industrial development adjacent to the creek and more is proposed near the mouth. Major problems with residential encroachment have been noted.⁴



◆ The naturalized summer 7-day mean low flow is 2% of the mean annual flow. Low flows were previously maintained by groundwater inflow.

The stream bed was dry near CP Rail tracks in 1986 and there are ongoing problems with stream flow.⁴



◆ No water licenses have been issued.

◆ **Other:** 400 L·s⁻¹ of groundwater and stormwater runoff is diverted through storm sewers to the Coquitlam River near Ozadi Ave.^{4,31} Two upstream diversions in tributaries were proposed, however, it is uncertain if they were constructed. A settling basin was built in the creek to prevent downstream sedimentation.

Occasional spills of concrete from delivery trucks, truck washout and detergent have been reported. A fish kill occurred in the upper watershed in 1995, however, the cause is unknown.²⁶



Or Creek (00-0180-150)



◆ The limited data available suggest that water quality in Or Creek is good. Only 1 of 9 dissolved oxygen values was below the minimum guideline.



◆ 14% of the total watershed has been logged, including 2% from recent or proposed activity. Elevated suspended sediment loads were reported in the 1970's from poor logging practices but the stream appears clear now.²⁶ Heavy gravel movement resulting from logging was also reported.³¹



◆ The naturalized summer 7-day mean low flow is 11% of the mean annual flow. Until recently Or Creek provided almost all of the Coquitlam River

flows since the Coquitlam Lake dam was constructed. During the winter Or Creek is still a large contributor to Coquitlam River flows.



♦The potential August and September water demand for waterworks use is 10% of the naturalized summer 7-day mean low flow.

♦**Other:** The stream has a flashy hydrologic regime. The GVRD applied to divert Or Creek into Coquitlam Reservoir; however, it is not considered an ideal drinking water source due to high suspended sediment load.³¹ The Water Investigations Branch (1978) recommended stabilization of natural slide areas along Or Creek and Coquitlam River but it is unknown if work was done. Erosion now appears to be a much smaller problem than it used to be.



Fraser River South Shore Tributaries

Cougar Canyon Creek (00-0160)



♦21% EIA indicates extensive urbanization. A storm drain in the upper reaches discharges to the creek.



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The creek bank is eroding, causing sedimentation. The lower reach, used by salmon, parallels two sewer trunk lines and a railroad. Proposed upgrading of sewer lines could seriously affect the creek.



Scott Creek - Surrey (no SISS #)



♦38% EIA indicates extensive urban development.



♦The naturalized summer 7-day mean low flow is 6% of the mean annual flow.



♦No water licenses have been issued.



Bonaccord Creek (00-0170)



♦23% EIA indicates extensive urban development. A storm drain in the upper reach discharges to the creek.



♦The naturalized summer 7-day mean low flow is 6% of the mean annual flow. Flows are relatively stable considering the degree of urbanization.



♦No water licenses have been issued.

♦**Other:** The creek flows through a municipal park which provides some protection to the channel. A landfill is located near the mouth, to the east of the Port

Mann bridge, and is scheduled to close in Nov. '97. Landfill leachate is collected and treated.



Unnamed Creek (00-0220)



♦3% EIA indicates moderate urban development.



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The creek flows through a CN Rail intermodal yard.



Unnamed Creek (00-0230)



♦3% EIA indicates moderate urban development.



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The creek flows through a CN Rail intermodal yard.



Yorkson Creek (00-0260)



♦10% EIA indicates extensive urban development, which is mostly located south of 96th Ave. in the Walnut Grove area of the Township of Langley. Inadequate stormwater detention causes increased flood discharges. Encroachment along parts of the creek is causing increased sedimentation. The riparian zone is generally in good condition and some wetlands are present.



♦Agricultural land occupies the lower reaches of the creek north of 96th Ave., in the Township of Langley. Cranberry farms use hogfuel to build dykes, which may generate leachate. There is some cattle access to the stream.



♦The naturalized summer 7-day mean low flow is 13% of the mean annual flow. Extreme low flows are reported in the upper tributaries, Munday and East Munday Creeks.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 2% of the naturalized summer 7-day mean low flow. Storage accounts for 32% of the total irrigation demand.

♦**Other:** The flood control facility near the mouth has a "fish-friendly" pump. High summer water temperatures have been reported.³ Industrial development near the creek mouth is encroaching on the floodplain.



Salmon River (00-0300)



◆Nutrients (3 of 4 dissolved ammonia; 15 of 15 total nitrite-nitrate-N; and, 15 of 15 total phosphorus) and fecal coliform counts (4 of 4) were above the guideline or 80th percentile in the lower reaches of the river.

◆**Other water quality data:** Continuous monitoring data indicate that stream water temperatures can reach 26°C near the mouth and 22°C in the headwaters.³³ The average summer temperature is about 20°C. Groundwater contributions from the Hopington Aquifer help moderate stream temperatures in middle and lower reaches.³³



◆2% EIA. 12% of the stream length south of 56 Ave. is developed. Stormwater runoff is resulting in scouring of gravel, and development is causing some sedimentation. There is one permitted discharge of sewage effluent (P01554).



◆Farming occurs along 55% of the river length, and generates agricultural runoff which reaches the river.



◆The naturalized summer 7-day mean low flow is 14% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial uses is 23% of the naturalized summer 7-day mean low flow. No further licensing is being granted by the WMB. Storage accounts for 16% of the total irrigation demand.

◆**Other:** Farmland and one of two golf courses encroach on the floodplain. The river responds rapidly to rainfall, partly because of field drainage channels and stormwater networks.

The Vancouver Zoological Centre is located in the upper reach of the Salmon River. Animals have unrestricted access to the river in places, and are directly (trampling) and indirectly (sedimentation) damaging some of the last known habitat of the salish sucker in B.C.³⁴

The Township of Langley Council placed restrictions on the residential subdivision of land in the Hopington Aquifer area in order to protect groundwater quality, which will ultimately benefit fish in the Salmon River. The Township of Langley and various community groups are actively involved in restoring stream banks and planting riparian vegetation. The watershed has been the subject of comprehensive studies since the early 1970s.^{23,35-37}



Coghlan Creek (00-0300-200)

◆**Other water quality data:** The maximum temperature measured in a continuous monitoring program is about 17°C. Nitrate-N levels in the stream approach 7 mg·L⁻¹ in Williams Park, due to high nitrate-N levels in groundwater inputs.³⁸



◆2% EIA indicates a low level of urban development.

◆Berry farming is prevalent, resulting in large irrigation withdrawals; 48% of the naturalized summer 7-day low flow may be withdrawn for agricultural use.

◆The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial use is 50% of the naturalized summer 7-day mean low flow. No further licensing is being granted by the WMB. Storage accounts for 59% of the total irrigation demand.

◆**Other:** Coghlan Creek is largely fed by groundwater from the Hopington Aquifer. As a result, the lowest summer stream temperatures in the Salmon River watershed are measured here.³³



Unnamed Creek (00-0300-150)



◆6% EIA indicates moderate urban development.



◆The naturalized summer 7-day mean low flow is 10% of the mean annual flow.



◆No water licenses have been issued.



West Creek (00-0330)



◆1% EIA indicates a low level of urban development.



◆There has been infilling of the floodplain and encroachment on the streambank near the mouth associated with agricultural activities.²⁵

Unauthorized stream channelization has occurred between 80 Ave and 84 Ave in the Township of Langley.³



◆The naturalized summer 7-day mean low flow is 21% of the mean annual flow. Low flows limit fish usage of the upper reaches. Heavy rains cause flash floods.



◆The potential August and September water demand for domestic, irrigation and industrial uses is 79% of the naturalized summer 7-day mean low flow.

◆**Other:** A gravel pit operates in the lower reach and the upper watershed is being developed as an industrial park.



Nathan Creek (00-0360)



◆16 of 30 total phosphorus concentrations exceeded the 80th percentile. 21 of 30 ammonia concentrations were above the 80th percentile and some exceeded the 30-day criteria for total ammonia, depending on pH and temperature. The range of pH measurements is extreme (6.4-10.0), possibly due to

eutrophication, and the extreme values were beyond guideline levels.



♦Less than 1% EIA indicates a low level of urban development.



♦Farming occurs along 45% of the stream length, mostly the lower 3.5 km. Farms are encroaching on the stream banks, causing water quality problems and removal of riparian vegetation. Cattle have uncontrolled access to the stream.²⁵



♦The naturalized summer 7-day mean low flow is 10% of the mean annual flow. Summer low flows in the upper reaches are very low.

Groundwater inputs help to maintain flows and alleviate high water temperatures.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 33% of the naturalized summer 7-day mean low flow.

♦**Other:** High summer water temperatures in lower reaches have been reported.²⁵ The lower 2 km are straightened and channelized, and gravel is regularly removed to maintain the channel and reduce flooding.

There is one permitted discharge (P04648) of processing effluent to Nathan Creek



Nathan Slough and Benson Canal



♦30 of 30 ammonia values exceeded the 80th percentile, 22 of 29 fecal coliform counts were above the 80th percentile, and 22 of 24 dissolved oxygen levels were below the minimum guideline. Several ammonia concentrations exceeded the 30-day MELP criteria, given the range of temperatures and pH reported. The very high nutrient concentrations and low DO indicate that eutrophication is a problem.



♦Benson Canal, a former creek channel, is now an agricultural drainage ditch and the riparian zone is about 95% denuded of vegetation. Agricultural runoff is likely the source of the nutrients and microbes.



Hanna Creek (00-0425)



♦15 of 30 total phosphorus concentrations and 21 of 30 dissolved ammonia concentrations exceeded the 80th percentile levels. Some extremely high fecal coliform counts (77,000) were measured.



♦1% EIA indicates a low level of urban development.



♦Agriculture is the probable source of the contaminants measured in the stream water.



♦The naturalized summer 7-day mean low flow is 7% of the mean annual flow.



♦The potential August and September water demand for domestic and industrial uses is 1%

of the naturalized summer 7-day mean low flow.



Coligny Creek (00-0438)



♦Less than 1% EIA indicates a low level of urban development.



♦No information was available to assess agricultural activity in the watershed.



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. The upper reaches may go dry naturally.



♦The potential August water demand for industrial use is less than 1% of the naturalized summer 7-day mean low flow.

♦**Other:** The local Native Band has cleaned the channel, improved fish access to the creek and is building a hatchery.



Gifford Slough (00-0440)



♦Two stations were sampled 5 times each. Dissolved oxygen concentrations were below the guideline in 9 of 10 measurements and values as low as 1.25 mg-L⁻¹ were measured. Three of 10 temperature measurements exceeded the guideline level.



♦3% EIA indicates moderate urban development.



♦Extensive agricultural activity is causing poor water quality. Improper manure management on one farm caused a fish kill in the fall of 1987.³⁹



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 18% of the naturalized summer 7-day mean low flow.

♦**Other:** The slough has been straightened and channelized in its lower reaches and riparian vegetation has been removed. The former Matsqui District Municipality wanted to annually dredge the slough to improve drainage. An Agriculture and Rural Development Subsidiary Agreement (ARDSA) community irrigation project was completed in the early 1990s. It involved expanding the network of ditches and pumps along the slough to distribute water pumped from the Fraser River, to improve irrigation.²⁵



McLennan Creek (00-0440-010)



♦24 of 31 total phosphorus concentrations and 21 of 30 fecal coliform counts exceeded the guidelines while 29 of 31 dissolved ammonia concentrations were above the 80th percentile. 14 of 25 dissolved oxygen measurements were below the guideline level.



◆2% EIA indicates a low level of urban development.



◆Intensive agricultural activity is present. Runoff is likely affecting water quality.



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



◆The potential August and September water demand for domestic, irrigation and industrial uses is 16% of the naturalized summer 7-day mean low flow.



Downes Creek (00-0440-020)



◆6% EIA indicates moderate urban development, which is located mainly upstream of Downes Road.



◆Agricultural runoff is likely affecting the stream.⁴⁰



◆The naturalized summer 7-day mean low flow is 9% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial use is 2% of the naturalized summer 7-day mean low flow.



Matsqui Slough (00-0460-010)



◆All sites in the Slough, an unnamed tributary, and Page Creek had low dissolved oxygen and high nutrient concentrations. Near the mouth of the slough, 23 of 35 dissolved oxygen values were below the guideline (min. = 3.8 mg·L⁻¹). 15 of 31 fecal coliform, 40 of 41 dissolved ammonia and 7 of 31 total phosphorus values exceeded the guideline or 80th percentiles. Low dissolved oxygen likely results from algal die-off and BOD inputs from manure runoff. Extremely low dissolved oxygen concentrations at the mouth of the slough in fall form an environmental barrier to returning adult salmonids and may prevent them from reaching their spawning grounds.



◆6% EIA indicates moderate urban development, most of which is located along Willband Creek in the upper watershed.



◆Agriculture is intensive and occupies much of the watershed. Most riparian vegetation has been removed.



◆The naturalized summer 7-day mean low flow is 6% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial uses is 123% of the naturalized summer 7-day mean low flow. Storage accounts for less than 1% of the total irrigation demand.

◆**Other:** The slough has been straightened and channelized in its lower reaches and riparian vegetation removed. There is a proposal to annually dredge the

slough to improve drainage. An ARDSA community irrigation project to expand the network of ditches along the slough and pump water from the Fraser River to improve irrigation was completed in the early 1990s.



Clayburn Creek (00-0460-010)



◆While both Clayburn sites are rated as having water quality concerns, the upstream “control” site, located in a relatively undeveloped area, has significantly lower nutrient and coliform levels, as well as higher dissolved oxygen concentrations. 9 of 42 dissolved ammonia values (max. = 0.034 mg·L⁻¹) at the control site exceeded the 80th percentile, while 40 of 42 were high (max. = 0.564 mg·L⁻¹) at the downstream site. Some of the dissolved ammonia values at the downstream site may have exceeded the 30-day criteria for total ammonia, depending on pH and temperature. Patterns in the data and land use provide strong evidence that the water quality problem is mostly related to urban and agricultural runoff.



◆9% EIA indicates moderate urban development.



◆Dykes have been constructed along the lower reaches with no streamside cover. Farming occurs up to the stream bank.



◆The naturalized summer 7-day mean low flow is 6% of the mean annual flow. Upper reaches are affected by extremely low flows.



◆The potential August and September water demand for domestic, irrigation and industrial uses is 182% of the naturalized summer 7-day mean low flow. Storage accounts for less than 1% of the total irrigation demand.

◆**Other:** An ARDSA community irrigation project to expand the network of ditches along the creek and pump water from the Fraser River to improve irrigation was completed in the early 1990s.²⁶



Willband Creek (00-0460-010-020)



◆30 of 42 dissolved ammonia values are above the 80th percentile, 23 of 36 dissolved oxygen measurements are below the minimum guideline, and some phosphorous concentrations exceed guidelines.

◆**Other water quality data:** An old sewage lagoon was used as a landfill and subsequently capped without a leachate collection system being installed. MELP staff indicate that ammonia and coliform levels were elevated in Willband Creek downstream from the site, as compared to upstream sampling stations. MELP data indicate that the influence of this site on Willband Creek has declined.⁴¹



◆26% EIA indicates extensive urban development.



◆Numerous farms line the lower reaches of the creek and irrigation withdrawals exceed the naturalized summer 7-day low flow. However, there was not enough information to assess the effect agriculture may have on water quality.



◆The naturalized summer 7-day mean low flow is 9% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial uses is 108% of the naturalized summer 7-day mean low flow.

◆**Other:** There is one permitted discharge (P08927) of stormwater effluent from a bulk petroleum storage facility and a sewer line crosses the creek.



Stoney Creek (00-0460-010-022)



◆8% EIA indicates a high level of urban development. Flood peaks have increased, likely due to little or ineffective stormwater detention. Development has also caused extensive erosion and damaged spawning and rearing habitat. Chronic siltation is a problem.



◆Irrigation licenses indicate agricultural activity, but there was not enough information to assess the effect agriculture may have on water quality.



◆The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial use is 53% of the naturalized summer 7-day mean low flow.

◆**Other:** A pipeline and service road have encroached upon the creek. Removal of riparian vegetation appears to have increased summer water temperatures.



Wades Creek (00-0550)



◆Irrigation withdrawals consume as much as 35% of the naturalized summer 7-day low flow.



◆The naturalized summer 7-day mean low flow is 23% of the mean annual flow.



◆The potential August water demand for domestic, irrigation, and waterworks uses is 35% of the naturalized summer 7-day mean low.



Boundary Bay Tributaries

Serpentine River (90-0200)



◆One measurement each of metals, PAHs and organochlorine pesticides in sediments is reported. One arsenic, chromium, copper and lead value exceeded the guidelines, as did one fluoranthene, fluorene and indeno(1,2,3-cd)pyrene value. Five to six measurements of dissolved oxygen, temp-

erature and pH were recently collected from ten different sites in the river. Near the mouth, all six ammonia values exceeded the 80th percentile, and all six dissolved oxygen values were below the minimum guideline (min. = 3.94 mg·L⁻¹). In the upper watershed, five of six temperature values exceeded the guideline, while all six dissolved oxygen values were above the minimum guideline.

◆**Other water quality data:** Fish kills were reported in October, 1980 and October, 1984 due to low oxygen levels.⁴² Algal blooms are readily visible during the summer months.



◆EIA is 13% and land clearing has destabilized flow patterns, resulting in low summer flows, bank erosion, scouring and silting. Urban encroachment on the stream has been reported.



◆Agricultural activity is located primarily on the lower mainstem floodplain and scattered throughout the upland tributaries. Leachate from corn silage and fall runoff of manure from fields contribute high BOD loading, resulting in low dissolved oxygen in stream water. Fish kills have occurred following fall rains.³



◆The naturalized summer 7-day mean low flow is 13% of the mean annual flow.



◆The potential August and September water demand for domestic, irrigation and industrial uses is 50% of the naturalized summer 7-day mean low flow. No further licensing is being permitted by WMB.

◆**Other:** The lower river is dyked, riparian vegetation has been removed and velocities are slow, resulting in high summer water temperatures (> 23°C). Agricultural drainage, high temperatures and low dissolved oxygen have limited the habitat available for fish in Latimer Creek, a tributary. Hyland Creek's main channel has almost no flow in the summer.



Mahood Creek (Bear Creek) (90-0200-020)



◆20 of 29 dissolved ammonia measurements in surface water were above the 80th percentile, and 16 of 25 fecal coliform counts were above the guideline level.



◆23% EIA. Urban encroachment on the stream has occurred. The creek is a flashy system due to stormwater runoff. The upper half of the stream is dominated by urban development and a few golf courses.



◆Agricultural activity dominates the lower half of the watershed, but no further information was available.



◆The naturalized summer 7-day mean low flow is 5% of the mean annual flow. Low-flow problems have been reported during the summer, and flooding and erosion in the winter.



♦The potential August and September water demand for irrigation and industrial uses is 1% of the naturalized summer 7-day mean low flow.

♦**Other:** Industrial processing, including one plastics manufacturing operation, has degraded water quality and resulted in several fish kills.³ Flooding and erosion problems occur during the winter.



Nicomekl River (90-0100)



♦Almost all of the 31 dissolved oxygen values and 12 of 43 temperature measurements at 40 Ave. did not meet guidelines for the protection of aquatic life. All of the 11 dissolved ammonia and five phosphorus values exceeded the 80th percentiles.

♦**Other water quality data:** Results from a water quality study in 1987 indicate that low dissolved oxygen levels at the downstream sites occur in relation to tidal cycles; at high tide, the flood gates are closed and streamwater backs up as far as 184 St. in Surrey and stagnates.³⁹ Extreme eutrophication is evidenced by excessive algal growth.



♦6% EIA. Urban development has destabilized runoff patterns causing reduced minimum flows, erosion and scouring of banks at high flows. Storm runoff is affecting water quality.



♦Agricultural activity is located primarily along the mainstem. Livestock access and clearing of riparian vegetation have affected the river. Agricultural ditches drain into the river via flap gates. At periods of low flow, the oxygen-poor, nutrient-rich ditch water can enter the river and cause problems.³⁹ Low dissolved oxygen and agricultural runoff in the fall have caused numerous fish kills.³



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. Some tributaries are groundwater fed and have good summer base flows. The lower reach is stagnant during the summer.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 12% of the naturalized summer 7-day mean low flow. No further licensing is being granted by the WMB during low flows.

♦**Other:** The lower river is dyked, riparian vegetation has been removed and velocities are slow, resulting in high summer water temperatures.



Anderson Creek (90-0100-020)



♦One station in the creek, at 208 St., has consistently high dissolved ammonia (11 of 12 were above the 80th percentile) and fecal coliform counts (7 of 12 exceeded the guideline but were unlikely to exceed the 30-day criteria for total ammonia) in surface water.

♦**Other water quality data:** Dissolved oxygen can drop below lethal levels (min.=3.2 mg·L⁻¹ at 224 St.) in the remnant pools during low flow periods.³⁹



♦4% EIA. Stream channelization has occurred downstream of 36 Ave. to 200th Street in the Brookwood community of the Township of Langley.



♦Erosion problems have occurred due to bank clearing and access by grazing livestock.



♦The naturalized summer 7-day mean low flow is 24% of the mean annual flow, and the middle reaches go dry during periods of low flow.

Summer base flows are maintained by groundwater inflow.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 1% of the naturalized summer 7-day mean low flow. Storage accounts for 100% of the total irrigation demand.

♦**Other:** There is a lack of riparian vegetation.



Murray Creek (90-0100-030)



♦One station (at 232 St.) showed high dissolved ammonia and fecal coliform counts in surface water. 20 of 20 ammonia and 11 of 18 coliform values exceeded the 80th percentile or guideline. Some dissolved ammonia measurements exceeded the 30-day criteria for total ammonia for all pH and temperature combinations reported for this site. Not enough data were available at the other sites to assess water quality.



♦2% EIA. Low density development is present.



♦Agriculture is the main land use. Stream bank clearance and livestock access have affected water quality and habitat.



♦The naturalized summer 7-day mean low flow is 2% of the mean annual flow. Low flows are reported to be a problem.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 84% of the naturalized summer 7-day mean low flow.

♦**Other:** A golf course is causing erosion.²⁵



Campbell River (90-0080)



♦9 to 28 measurements are reported for pH, nonfilterable residue, fecal coliforms and dissolved ammonia at each of two sites. 13 of 24 coliform counts and 24 of 28 ammonia values exceeded the 80th percentile or guideline at the downstream site.

♦**Other water quality data:** Some fish kills in the river have been attributed to low dissolved oxygen. Copper



is measured in sediments from a site in the river very high.⁴³



♦4% EIA. Urban development has occurred mostly around the upper reaches. Some residents near the mouth of the river rely on private septic systems for domestic waste disposal, and may contribute some nutrients through groundwater seepage.⁴³



♦Intensive agricultural activity is present. Nutrient loading from farms in the watershed is significant.⁴³

♦The naturalized summer 7-day mean low flow is 4% of the mean annual flow. Some sections of the stream dry up in the summer due to losses to groundwater and agricultural withdrawals.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 70% of the naturalized summer 7-day mean low flow. Storage accounts for 9% of the total irrigation demand. It is recommended that no further withdrawals be permitted.



4.7 References

- Groot, C. and L. Margolis (eds.). 1991. Pacific salmon life histories. UBC Press, Vancouver, B.C. 564 p.
- Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 28A Vancouver. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29B Surrey. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- Department of Fisheries and Oceans. 1988. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29C Coquitlam. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- FREMP. 1996. Environmental quality of the Fraser River Estuary. Fraser River Estuary Management Program, Vancouver, B.C. 164 p.
- BC Stats. 1995. BC Stats Population Section, Release: November, Issue: 95-2.
- Langer, O.E., F. Hietkamp and M. Farrell. 1996. Human population growth and the sustainability of urban salmonid streams in the Lower Fraser Valley. Presented at: Sustainable Fisheries Conference, American Fisheries Society, April 26-30, 1996, Victoria, B.C.
- FREMP. 1993. Contaminant loading to the Fraser River Estuary. Prepared by Karen Moore for FREMP. Technical Report WQWM 93-04. 92 p.
- FREMP. 1994. Wastewater characterization of fish processing plant effluents. Prepared by NovaTec Consultants Inc., and EVS Environmental Consultants for FREMP. Technical Report Series FREMP WQWM 93-10; DOE FRAP 1993-39
- P. Wong, Environment Canada, North Vancouver, B.C., personal communication.
- B. Locken, B.C. Ministry of Environment, Lands and Parks, Surrey, B.C., personal communication.
- Schreier, H., P. Scales, K. Hall, B. Wernick, W. Tamagi, A. Kenney, W. Thompson, S. Brown, and L.M. Lavkulich. 1996. A groundwater quality assessment in the Hopington Aquifer. Prepared for the Township of Langley and the Fraser River Action Plan (Environment Canada and Department of Fisheries and Oceans). 56 p.
- FREMP. 1991. Water Quality Plan - 1991. Monitoring and objectives. Prepared by the Standing Committee on the Fraser River Estuary Water Quality Plan. 133 p.
- Stanley and Associates. 1993. Urban runoff quantification and contaminants loading in the Fraser River Basin and Burrard Inlet. DOE-FRAP 1993-19. Stanley Associates Engineering Ltd., Surrey, B.C.
- Bird and Rapport. 1986. cited in Schreier, H., S.J. Brown and K.J. Hall. 1991. The land-water interface in the Fraser River Basin. *In: Water in sustainable development: Exploring our common future in the Fraser River Basin.* A.H.J. Dorsey and J.R. Griggs (eds.). Westwater Research Centre, University of British Columbia, Vancouver, B.C. 288 p.
- Brisbin, P.E. 1995. Agricultural nutrient management in the Lower Fraser Valley. Prepared for Environment Canada-Fraser River Action Plan, Department of Fisheries and Oceans-Fraser River Action Plan, Ministry of Environment, Lands and Parks, and Ministry of Agriculture, Fisheries and Food. DOE-FRAP 1995-27.
- Schreier, H., S.J. Brown and K.J. Hall. 1991. The land-water interface in the Fraser River Basin. *In: Water in sustainable development: Exploring our common future in the Fraser River Basin.* A.H.J. Dorsey and J.R. Griggs (eds.). Westwater Research Centre, University of British Columbia, Vancouver, B.C. 288 p.
- Wan, M.T. 1989. Levels of selected pesticides in farm ditches leading to rivers in the lower mainland of British Columbia. *J. Environ. Sci. Health*, 324(2), 183-203.
- Drinnan, R.W. and M.J.R. Clark. 1980. Fraser River Estuary study: Water quality. Government of Canada and British Columbia, Victoria, B.C., 160 p.
- Foreman, M.G.G., C.B. James, M.C. Quick, P. Hollemans and E. Wiebe. 1997. Flow and

- temperature models for the Fraser and Thompson Rivers. Atmosphere-Ocean (in press).
- 21 Drinnan, R.W. and B. Humphrey. (In preparation). Water quality in the Fraser River Estuary January, 1993 to March, 1994. Prepared for the Fraser River Estuary Management Program Water Quality Waste management Committee. FREMP-WQWM 94-01. DOE-FRAP 1994 - 18.
 - 22 McCallum, D.W. 1995. An examination of trace metal contamination and land use in an urban watershed. M.Sc. Thesis, Department of Civil Engineering, University of British Columbia, Vancouver, B.C. 217 p.
 - 23 Wernick, B.G. 1996. Land use and water quality dynamics on the urban-rural Fringe: A GIS evaluation of the Salmon River Watershed, Langley, B.C. M.Sc. Thesis, Resource Management and Environmental Studies, University of British Columbia, Vancouver, B.C., 217 p.
 - 24 Department of Fisheries and Oceans, unpublished data, L. Nikl, New Westminster, B.C.
 - 25 Rood, K.M. and R.E. Hamilton. 1994. Hydrology and water use for salmon streams in the Fraser Delta Habitat Management Area, British Columbia. Manuscr. Rep. Fish. Aquat. Sci. 2238.
 - 26 L. Nikl, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.
 - 27 Swain, L.G. 1989. Coquitlam-Pitt River area, Tributaries to the Lower Fraser River along the north shore, water quality assessment and Objectives Technical appendix. BC Environment, Water Management Division. 140 p.
 - 28 City of Burnaby. 1993. The state of the environment report (SOER) for Burnaby. Environment and Waste Committee, City of Burnaby.
 - 29 Lawson, E.M., G.B. Mitchell, and D.G. Walton. 1985. Stormwater monitoring in an industrial catchment basin located in Burnaby, British Columbia. Waste Management, Ministry of Environment, Province of British Columbia.
 - 30 Hall, K.J., I. Yesake, and J. Chan. 1976. Trace metals and chlorinated hydrocarbons in the sediments of a metropolitan watershed. Westwater Research Centre, University of British Columbia, Technical Report No. 10.
 - 31 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Manuscr. Rep. Fish. Aquat. Sci. 2289.
 - 32 Ionson, B. 1995. Habitat Enforcement Report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.
 - 33 Schreier, H. 1996. Analysis of temperature data for the Salmon River. Prepared for Department of Fisheries and Oceans-Fraser River Action Plan. Unpublished report.
 - 34 Envirowest Consultants. 1995. Salmon River impact assessment and biophysical, Vancouver Game Farm, Aldergrove. Prepared for the Department of Fisheries and Oceans. Unpublished report.
 - 35 Beale, R.L. 1976. Analysis of the effect of land use and soils on water quality of the Salmon River Watershed in Langley, B.C. M.Sc. Thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 243 p.
 - 36 Watts, R.D. 1993. A GIS evaluation of land use and fish habitat in the Salmon River Watershed - Langley, B.C. M.Sc. Thesis, Resource Management and Environmental Studies, University of British Columbia, Vancouver, B.C. 156 p.
 - 37 Cook, K.E. 1994. An evaluation of water quality and land use in the Salmon River Watershed, Langley, B.C., Using GIS Techniques. M.Sc. Thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 252 p.
 - 38 Brown, S., B.G. Wernick, W.A. Thompson, A. Kenney, W. Tamagi, K. Hall, and H. Schreier. 1996. Watershed modeling using a GIS/hyper-media framework: A case study of land use-water quality interactions in the Salmon River Watershed in Langley, B.C. *In: Watercourses: Getting on stream with current thinking.* Conference Proceedings, Vancouver B.C., October, 22-25, 1996. 274 p.
 - 39 Hutton, K. 1987. Lower Fraser Valley agricultural waste management survey. Prepared for the Ministry of Environment, Lands, and Parks. 46 p. + appendices.
 - 40 K. Hutton, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.
 - 41 L. Freyman, B.C. Ministry of Environment, Lands and Parks, Surrey, B.C., personal communication.
 - 42 Moore, B. 1989. Partner or policeman: It's your choice. *In: South Coastal Dairy Education Association, 21st Annual Dairy Producers' Short Course, Proceedings, February 14 and 15, 1989.* South coastal Dairy Education Association (Dairy Education Committee) and B.C. Ministry of Agriculture and Fisheries. p. 41-52.
 - 43 Swain, L.G., and G.B. Holms 1988. Water quality assessment and objectives, Fraser-Delta Area, Boundary Bay and its tributaries. Technical Appendix. Ministry of Environment, Lands and Parks, Water Management Branch. 168 p.
 - 44 Greater Vancouver Regional District. 1992. Population, household, labour force, and employment projections for the Metropolitan Vancouver Region: 1991 to 2021. Development Services Department, Greater Vancouver Regional District, Burnaby, B.C.
 - 45 Greater Vancouver Regional District. 1993. Managing Greater Vancouver's growth: The Livable Region Strategic Plan, creating our future...Steps to a

- more livable region. Strategic Planning Department, Greater Vancouver Regional District, Burnaby, B.C.
- 46 Ministry of Environment, Lands and Parks. 1995. B.C.'s Pulp Mills: Effluent status report. 1994 Update. Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, B.C. 10 p.
- 47 B.C. Environment. 1992. Water Quality in British Columbia, Objectives Attainment in 1992. Water Quality Branch, Water Management Division, Ministry of Environment, Lands and Parks, Victoria, B.C. 228 p.
- 48 O. Langer, Department of Fisheries and Oceans, Vancouver, B.C., personal communication.
- 49 Fraser River Sockeye Public Review Board. 1995. Fraser River sockeye 1994: Problems & discrepancies. Canada Communication Group - Publishing, Ottawa, ON. 131 p.

Table 4.6.2 Summary of Red-coded Indicators for Streams in the Fraser Delta HMA
(streams are ordered by SISS code)

Stream Name	Indicator				
	Urban	Agriculture	Logging	Stream Flow	Demand
Musqueam Creek	*			*	
Glen Lyon Creek	*			*	
Sussex Creek				*	
Byrne Creek	*			*	
Brunette River	*			*	
Laurentian Creek	*			*	
Popeye Creek	*			*	
Schoolhouse Creek	*			*	
Coquitlam River	*				*
Scott Creek (Coquitlam)	*			*	*
Hoy Creek	*			*	*
Maple Creek	*			*	
Or Creek					
Cougar Canyon Creek	*			*	
Scott Creek (Surrey)	*			*	
Bonaccord Creek	*			*	
Unnamed Creek (00-0220)				*	
Unnamed Creek (00-0230)				*	
Yorkson Creek	*				
Salmon River		*			
Coghlan Creek				*	*
Unnamed Creek (00-0300-150)					
West Creek		*			*
Nathan Creek		*			*
Hanna Creek				*	
Coligny Creek				*	
Gifford Slough		*		*	*
McLennan Creek		*		*	*
Downes Creek		*		*	*
Matsqui Slough		*		*	*
Clayburn Creek		*		*	*
Willband Creek	*			*	*
Stoney Creek	*			*	*
Wades Creek					*
Serpentine River	*	*			*
Mahood Creek	*			*	*
Nicomekl River	*	*		*	*
Anderson Creek		*		*	
Murray Creek		*		*	*
Campbell River		*		*	*

Chapter 5 Pitt-Stave Habitat Management Area

5.1 Background

The Pitt-Stave HMA consists of two large watersheds, the Pitt and Stave Rivers, which drain the Coastal Fjord Ranges to the north. Several smaller watersheds drain the Fraser Lowland area in the south. The Alouette River originally drained entirely to the lower Pitt River, however, B.C. Hydro now diverts much of the water from Alouette Lake into the Stave system.

In general, there is much less pressure on salmon streams from anthropogenic activities in this HMA compared with the Fraser Delta HMA. Of the 39 salmon-bearing streams in the Pitt-Stave, 12 have not been affected by human activities (i.e. not red-coded according to criteria identified in the Methodology).

5.1.1 Hydrology

The hydrology of the Pitt River is governed by the glaciers and accumulation of snow pack in the mountains of the Fjord Range. Flows in the smaller tributaries of the Fraser Lowland are, in contrast, largely governed by local precipitation. Their high flow period coincides with the heavy rains of the winter and during summer months groundwater is the primary source for base flows.

Flows in the Alouette River are controlled by a dam at the outlet of Alouette Lake. The hydrology of the Stave River is also partially controlled by two dams operated by B.C. Hydro. One dam is located at Stave Falls and regulates outflow from Stave Lake. Another is further downstream and controls the outflow from Hayward Lake. These three dams are barriers to upstream fish migration.

5.1.2 Fish

There are thirty-nine known salmon-bearing streams in the Pitt-Stave HMA. The Pitt and Stave systems support runs of coho, pink, chinook, chum salmon, and steelhead trout. The Pitt also supports a large sockeye run.

Tributaries to the Pitt and Stave systems, both upstream and downstream from the dams, provide habitat for a wide variety of non-anadromous fishes including cutthroat trout, dolly varden char, and mountain whitefish. The lower Pitt River is habitat for the endangered pygmy longfin smelt and white sturgeon.

5.1.3 Predominant Land Uses

The major land uses in the HMA include forestry, agriculture, and urban development.

The population of the Pitt-Stave HMA was estimated in 1995 to be about 107,000 people,¹ with most living in one of three municipal districts bordering on the Fraser River: Pitt Meadows, Maple Ridge, and Mission. There

is some accompanying industrial development in the lower reaches of the Stave River. The three districts vary in the degree to which fish habitat and water quality are protected by municipal bylaws and other measures implemented by local governments.²

It is estimated that the population of the Vancouver Metropolitan Area (which extends from West Vancouver to Chilliwack) will increase by about 70% to three million people by the year 2021.³ The Districts of Pitt Meadows, Maple Ridge and Mission are expected to experience population growth rates of 39%, 34% and 19%, respectively, over the next 5 years alone.²

The flat lowland areas in the southern HMA provide high quality agricultural land. In the 1940's much of the slough area between the Pitt and Alouette Rivers was reclaimed via dyking. The most arable lowland area is protected by the ALR but there is increasing pressure to exclude some of these lands from the ALR, to accommodate more urban development.

Forest harvesting in the Pitt-Stave watersheds began in the early part of the twentieth century. Railroads were used to haul timber out of the Stave, Alouette and Pitt watersheds from about 1915 to 1930. The benchlands along the river were harvested at that time. There is still some logging ongoing in the HMA, mostly on the upper slopes. Logging of Boise Creek, a tributary to the Pitt River which supports sockeye salmon, caused a recent controversy.

The northern portion of the HMA remains largely as an undeveloped wilderness area with high recreational values. The headwaters of the Pitt and Stave Rivers are in Garibaldi Provincial Park to the north and Golden Ears Provincial Park to the east. The new Pinecone Burke Provincial Park extends along the western shore of the Pitt River from Widgeon Creek north to Garibaldi Provincial Park. The southern portion of the HMA along the Fraser River is subject to increasing pressures from urban development.



5.2 Sources of Contaminants

The northern bank of the Fraser River is the southern boundary of the HMA, so the water quality of the Fraser mainstem is not considered here. Two discharges to the Fraser mainstem originate from this HMA and are discussed in this chapter.

Water quality is affected by logging in the upper watersheds, and by point and non-point pollution sources associated with urban development and limited industrial development in the lower watersheds. Agricultural runoff also contributes contaminants to streams in the lower watersheds.

5.2.1 *Urban/Industrial Point Source Discharges to Surface Waters*

There are eight permitted discharges to surface waters in the Pitt-Stave HMA: five for industrial processing effluents and three for treated sewage effluents (Figure 5.2.1). A summary of the discharges is provided in Table 5.2.1. Two of these facilities discharge directly to the Fraser River while the remainder discharge to Kanaka Creek, Alouette Lake, Gilbert Brook, Silverdale Creek, Cascade Creek, or the Pitt River.

A summary of permitted contaminant loading by waste type is provided in Table 5.2.2.

The Miracle Valley sewage treatment facility is the largest discharge in the Pitt-Stave HMA. According to permit specifications, up to 33,215 kg-yr⁻¹ of nonfilterable residues and 14,947 kg-yr⁻¹ of biochemical oxygen demand may be discharged by the STP to Cascade Creek. The maximum permitted discharge concentration of non-filterable residue is 100 mg-L⁻¹, however, there are no discharge criteria specified for ammonia or coliforms, nor are there any chlorination/ dechlorination requirements. Cascade Creek drains into the shallow southeast corner of Stave Lake. No data were available to determine whether or not the discharge affects Cascade Creek or Stave Lake.

5.2.2 *Permitted Discharges to Ground*

Permitted discharges to ground include five for processing and nine for sewage treatment effluents. As well, a large number of rural residents rely on on-site sewage disposal. Staining of the river bed suggests that a landfill operated by J.S. Holdings Ltd. is generating leachate which reaches the east bank of the Pitt River.⁴



5.3 *Non-Point Sources of Contaminants*

5.3.1 *Urban Stormwater Runoff*

A total of six streams in the HMA have experienced significant impacts from urban development according to criteria outlined in the Methodology section. Urban development in another six salmon-bearing watersheds has resulted in some negative effects on streams. With the high anticipated growth rate in the HMA, the extent of these impacts will likely increase in the near future.

The three municipal governments (Pitt Meadows, Maple Ridge, and Mission), all have provisions for stormwater management requirements to accompany new development,² however, these provisions are not always implemented.⁵ A study conducted by Stanley and Associates estimated loading of various contaminants to the Fraser Basin from urban runoff.⁶ In the Pitt-Stave

HMA, non-point urban runoff is a much larger source of contaminant loading to streams than the permitted discharges (Table 5.2.3).

5.3.2 *Agriculture*

Seven streams in the HMA have documented significant negative effects on water quality from agriculture, according to assessment criteria documented in the Methodology section (red-coded). Another seventeen streams in the HMA support agriculture, but information suggested a lower level of intensity and relatively localized effects on water quality (yellow-coded). Livestock, nursery products, and a range of fruit and vegetable crops are produced in the agricultural area of this HMA.

Water withdrawals for irrigation are creating low flow problems in some streams, particularly in the Pitt Polder area and the Stave River watershed.⁷

The lower reaches of the Pitt and Stave Rivers have been damaged by removal of riparian vegetation, stream bank degradation, poor manure storage facilities, the spreading of manure near water, and the heavy use of pesticides and chemical fertilizers.⁸

5.3.3 *Timber Harvesting*

Five streams in the HMA are severely affected by forestry activities, according to the criteria outlined in Chapter 3. Four of those streams are in the Pitt River watershed. Forest harvesting is thought to have affected the hydrology of the upper Pitt system. The channel in the lower reaches is braided and channel shifting occurs often with large floods that transport gravel and debris.⁹

There have been complaints against logging companies for poor road construction in the Boise Creek area.⁸ In 1993/94, a section of road was causing erosion and sedimentation problems, however, the road was deactivated when the Pinecone Burke Provincial Park was established.

Logging on the Stave system occurs primarily above the dams,⁸ which are not passable by anadromous salmonids.



5.4 *Factors Modifying Contaminant Fate and Effects*

5.4.1 *Pitt River and Stave River Mainstems*

Outflow from the Pitt River is influenced by tidal effects from the Fraser mainstem. High tides cause flow reversal and have contributed to the development of a reverse-delta in the south end of Pitt Lake where Fraser River sediments have deposited.

The active ice fields in the upper Pitt and Stave Rivers influence the hydrologies of these systems and are also significant sources of natural sediments. Pitt and Stave Lakes act, to some extent, as settling ponds. Hence water downstream from lake outlets can be expected to have lower suspended sediment levels compared with the upstream end of the lake.



5.5 An Overview of Water Quality Conditions

5.5.1 General Water Quality Conditions

In general, there is little water quality data available for the HMA, both in terms of the number of samples collected at various stations, and the range of parameters measured. The most basic data (e.g. pH, temperature, dissolved oxygen) are lacking. Ten stations were sampled in 1986-87, and no more recent data were available.

Site-specific water quality assessments, and influencing factors and supporting data (Table 5.5.1) are provided in Section 5.6 on a stream-by-stream basis.

5.5.2 Pitt River Watershed

Limited data show widely variable levels of non-filterable residue, with very high maximum levels ($172 \text{ mg}\cdot\text{L}^{-1}$). The wide variations may reflect contributions of glacial flour during the summer via meltwater, and lower levels during winter months. Sediment loads resulting from erosion will also influence NFR levels. Downstream from the lake, which acts as a settling basin, NFR levels are lower (max. $78 \text{ mg}\cdot\text{L}^{-1}$).

Tributaries to the Pitt in the upper watershed, for which data are available, also have very high maximum NFR levels, again likely reflecting glacial origins. The few pH values reported for headwater tributaries suggest that the water is slightly acidic with most values between 6 and 7. One or two samples from several sites in the headwater tributaries were analyzed for a few metals. Mercury exceeded criteria for the protection of aquatic life in 11 of 12 samples. Further sampling should be done to confirm these findings.

The limited data available downstream from Pitt Lake do not indicate any obvious water quality problems.

The Alouette River is the largest tributary to the lower Pitt River. From the limited data available there is some indication that water quality deteriorates in the lower watershed compared with upstream stations.

5.5.3 Stave River Watershed

There is not enough information to make any statements regarding water quality in the Stave River.



5.6 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 Pitt-Stave HMA. Summary tables of:

- ◆ surface water, sediment and fish tissue data (Table 5.5.1);
- ◆ land use areas, stream flow, and water demand information for each salmon stream (Table 5.6.1), and
- ◆ red-coded indicators for each salmon stream (Table 5.6.2)

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 5.6.1.

Water quality conditions were assessed using a database compiled by DFO and DOE and the data were categorized according to the criteria outlined in the Methodology section. Additional information was included where available, but it did not influence the outcome of the category rating.

Assessments of potential water quality problems resulting from urban development, agriculture, forestry, low stream flows, and water demand were based upon information provided in a series of hydrology reports by Rood and Hamilton,⁷ and/or SISS catalogues,^{10,11} unless otherwise indicated. Assessment criteria are described in the Methodology section of this report.



Pitt River (00-0200)



◆Very little water quality data is available for the Pitt River upstream from Pitt Lake. Existing data show that nonfilterable residues are relatively high. Fifteen samples have been collected downstream at the Lougheed Hwy., with a maximum of five parameters measured. Only one of five zinc measurements exceeded the guideline, possibly due to high suspended sediment levels. None of the pentachlorophenol concentrations measured in 10 fish tissue samples exceeded the guideline for protection of aquatic life. The pH of the river downstream from Pitt Lake is slightly alkaline (7.2 - 8.0). Only one measurement is reported upstream from the lake, and was slightly acidic (6.6).

◆**Other water quality data:** The Pitt River is classified as soft (hardness value $< 75 \text{ mg}\cdot\text{L}^{-1}$). Pitt Lake is even softer (hardness value $< 10 \text{ mg}\cdot\text{L}^{-1}$).⁴ MELP states that the river can be slightly acidic, reflecting the poor buffering capacity of soils in the watershed and acidity of rain in the area.⁴



◆Residential development is occurring near Haney and Pitt Meadows and there is minor industry in the lower watershed. Population growth is rapid in Pitt Meadows (19.6% from 1991 to 1996, based on BC Stats data).¹



◆Dairy, poultry and greenhouses are located in the lower watershed. 94 km^2 of the watershed is in the Agricultural Land Reserve,⁴ however, not all of it is actively farmed.¹² The river has been dyked in the agricultural areas.



◆10% of the total watershed has been logged, including 5% from recent/proposed activity. Logging is the main activity in the upper watershed and is reported to have affected the hydrology and channel stability.⁷



◆The naturalized summer 7-day mean low flow is 18% of the mean annual flow.



◆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.

◆**Other:** The upper watershed is part of Garibaldi Provincial Park. The lower reaches are braided and large floods transport gravel and debris.⁷ Log storage areas are located along the lower river.⁴ Pleasure boats and houseboats may discharge untreated domestic sewage in to the system. A golf course discharges STP effluent to the Pitt River (P10721).



Alouette River (00-0200-050)



◆Water quality at the south lake station appears to be relatively good, while fecal coliform counts, dissolved ammonia concentrations and nonfilterable residues increase between the lake outlet and 232 St. At this downstream station 14 of 15 dissolved ammonia concentrations exceeded the 80th percentile, compared with 6 of 15 at the upstream site. None of the ammonia concentrations would likely have exceeded the 30-day total ammonia criteria for protection of aquatic life.

◆**Other water quality data:** The Alouette River is classified as soft (hardness value < 75 mg·L⁻¹). Alouette Lake is even softer (hardness value < 10 mg·L⁻¹).⁴ The pH of the river can be slightly acidic, possibly reflecting the acidic nature of rain in the area and the poor buffering capacity of soils in the watershed.⁴



◆Urban development is present along 22% of the river length. Houses and dykes are close to the river and riparian vegetation has been removed by homeowners.⁶



◆Agricultural activity occurs along 47% of stream length. Riparian vegetation has been removed in the farming area.⁷ Woodwaste use on hobby farms may generate leachate which negatively affects the river.¹²



◆17% of the total watershed has been logged, including 9% from recent or proposed harvesting.



◆The naturalized summer 7-day mean low flow is 17% of the mean annual flow. Temperature and low flow problems have been reported.¹²



◆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.

◆**Other:** A water diversion at the north end of Alouette Lake carries water to Stave Lake. For about the past 15 years, B.C. Hydro has maintained a minimum release of 0.7 m³·s⁻¹ from the south end of Alouette Lake. B.C. Hydro's water license has required a minimum release of 0.06 m³·s⁻¹ from the dam and minimum flows of 0.7 m³·s⁻¹ in the Alouette River at 232 St. A recently revised Water Use Plan recommends full pipe release (2.7 - 3.1 m³·s⁻¹) from the dam. This Plan has been sent to the Water Controller for approval.

Pleasure boats and some float homes create the potential for domestic sewage to be discharged untreated, especially near the mouth of the river. In order to prevent bank erosion, a new bylaw has been established prohibiting the use of power boats in the lower river reaches. Flooding, erosion and aggradation problems occur in lower reaches.⁷ A progressive community group is actively involved in resource conservation efforts in this watershed.



North Alouette River (00-0200-050-020)



◆Dissolved ammonia values tended to increase between the upstream site at 233 St. and the downstream 208 St. station. At the downstream station half of the 15 dissolved ammonia concentrations exceeded the 80th percentile, while none did at the upstream site. None of the measurements would likely have exceeded the 30-day criteria for total ammonia concentration.

◆**Other water quality data:** The North Alouette River is classified as soft (hardness < 75 mg·L⁻¹).⁴ The pH of the river can be slightly acidic, reflecting the acidic nature of rain in the area and the poor buffering capacity of soils in the watershed.⁴



◆Houses and dykes encroach on the river and riparian vegetation has been removed by homeowners.⁷



◆Farms line the lower reach, and much of the riparian vegetation has been removed.⁷ Woodwaste use on hobby farms may generate leachate which negatively affects the river.¹²



◆41% of the total watershed has been logged, including 29% from recent or proposed harvesting.



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



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



Blaney Creek (00-0200-050-020-020)



◆ Not enough information was available to assess the effects of urban development.



◆ Berry, cattle and horse farms are located in the lower reaches. Irrigation withdrawals account for up to 40% of the summer 7-day low flow. Parts of the creek have been chanelized.⁷



◆ 4% of the watershed was recently logged, and there is no proposed harvesting before 1998.



◆ The naturalized summer 7-day mean low flow is 3% of the mean annual flow.



◆ The potential August and September water demand for domestic, irrigation and industrial uses is 66% of the naturalized summer 7-day mean low flow.



Coho Creek (00-0200-050-050)



◆ The lower reaches have been diverted and the channel widened to prevent flooding.⁷ Potential problems with stormwater runoff and siltation have been identified.¹⁰ Covenants to protect the creek have been negotiated for some new developments.



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



◆ No water licenses have been issued.



Hyde Creek (00-0200-060)



◆ 10.6% EIA indicates extensive urban development. Channelization and encroachment have affected fish habitat.¹⁰



◆ The naturalized summer 7-day mean low flow is 2% of the mean annual flow. The stream dewatered above Smiling Creek in dry years.¹⁰



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

◆ **Other:** The stream has a flashy hydrologic regime with aggradation in lower reaches. Ravine failures in upper reaches are due to both natural conditions and stormwater diversion.⁷ Port Coquitlam plans a settling pond in the lower reach to reduce gravel removal costs.



Cedar Creek (00-0200-060-001)



◆ 2.2% EIA is low because the upper area is subdivided into one and two acre lots.¹⁰ Development has resulted in encroachment on the stream.



◆ The naturalized summer 7-day mean low flow is 3% of the mean annual flow.

◆ No water licenses have been issued.

◆ **Other:** The creek has been diverted into a roadside ditch for a portion of its length.



Smiling Creek (00-0200-060-010)



◆ 5.5% EIA indicates moderate urban development, primarily in the lower reach.



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



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



MacIntyre Creek (00-0200-080)



◆ The naturalized summer 7-day mean low flow is 13% of the mean annual flow. The upper reaches can go dry during the summer.¹⁰



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

◆ **Other:** The headwaters of MacIntyre and Munroe Creeks are slated for urban development. A gravel and rock quarry formerly operated in a headwater tributary. Another quarry which would affect the whole system has been proposed. The central watershed has a stable second growth forest.¹⁰ The lower portion of MacIntyre Creek is a conservation area.



Deiner Creek (00-0200-080-010)



◆ The naturalized summer 7-day mean low flow is 11% of the mean annual flow. The creek is reported to often go dry.⁷



◆ The potential August and September water demand for waterworks use is 3% of the naturalized summer 7-day mean low flow.

◆ **Other:** The stream is reported to have mobile bed material. Riprapping and channelization have affected salmon habitat.¹⁰



Widgeon Creek (00-0200-150)



◆ 2.3% of the total watershed has been logged, and only a small area was harvested recently. A dryland sort was formerly located on the east side of the river.¹⁰ A forest service recreation site is located in the lower reach of the creek.¹²



◆ The naturalized summer 7-day mean low flow is 13% of the mean annual flow. There are large fluctuations in flow.¹⁰



◆ No water licenses have been issued.

♦**Other:** The watershed has been included in the Pinecone Burke Provincial Park (1996). Good water quality is expected in Widgeon Creek because there are no apparent sources of contamination.



Raven Creek (00-0200-190)



♦16% of the total watershed has been logged, including 10% from recent harvesting.



♦The naturalized summer 7-day mean low flow is 13% of the mean annual flow.



♦No water licenses have been issued.



Red Slough



♦Two of two mercury measurements in surface water exceeded the guideline for protection of aquatic life. High mercury concentrations in this stream as well as the adjacent Fish Hatchery and Corbold Creeks may reflect the natural geology of the area; there is no obvious anthropogenic source of mercury. Further sampling should be done to confirm earlier results.



Fish Hatchery Creek (00-0200-730)



♦Data from a small tributary, Alvin Creek, showed elevated mercury and lead values in the one sample collected. See discussion of Red Slough data.



♦14% of the watershed is proposed for harvesting.



♦The naturalized summer 7-day mean low flow is 13% of the mean annual flow.



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



Corbold Creek



♦Mercury values measured at the fish hatchery were elevated in 2 of 2 samples and copper values in 3 of 4 samples. See discussion of Red Slough data.

♦**Other:** There is a DFO hatchery located on the creek. The influence of hatchery discharge on the creek is unknown.



Boise Creek (00-0200-750)



♦One temperature measurement out of 4 marginally exceeded the 15°C guideline. Copper (1 sample) and mercury (2 of 2 samples) in surface

water were elevated. See discussion of Red Slough data.



♦5% of the total watershed has been logged, including 1% from recent harvesting. Stream stability in lower reach has been affected by logging.⁷



♦The naturalized summer 7-day mean low flow is 13% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** Fish and Wildlife has requested a hydrologic study from Ministry of Forests. The upper half of the watershed has been included in the new Pinecone Burke Provincial Park (1996). Salmon use only the lower watershed.



Blue Creek (00-0200-800)



♦7% of the total watershed has been logged, including 1% from recent activity. An additional 22% of the watershed is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 13% of the mean annual flow.



♦No water licenses have been issued.



Kanaka Creek (00-0290)



♦2 of 2 chromium and 5 of 5 zinc values from each of 2 stations exceeded the guidelines, but the downstream levels tended to be higher. Seven of fifteen dissolved ammonia values were above the 80th percentile at the downstream site compared with 2 of 15 at the upstream site. None exceeded the 30-day criteria for total ammonia.

♦**Other water quality data:** Water in Kanaka Creek is considered to be very soft (hardness < 40 mg-L⁻¹), especially in the headwaters.⁴ The toxicity of metals is higher in softer water. The acidity of rainfall can affect Kanaka Creek and depressions of pH greater than 1.0 unit commonly result.¹³ A pH of as low as 4.8 has been measured on this creek.⁴



♦Urban development has occurred along 34% of the stream length. Most of the mainstem and mouth are in a regional park which now protects riparian vegetation. The Municipality of Maple Ridge plans careful development on tributaries. There are an estimated 900 septic systems in the watershed.⁴



♦Agricultural activity occurs along 8% of stream length and includes both hobby and commercial farms. Fur and poultry farms are located throughout the watershed. Removal of riparian vegetation has resulted in bank destabilization.⁷ A tributary, Donovan Creek, also flows through agricultural lands.



♦3% of the total watershed has been logged, including 1% from recent harvesting.



♦The naturalized summer 7-day mean low flow is 5% of the mean annual flow. Low flow problems, especially in tributaries, are due to the low groundwater storage capacity of soils.



♦The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 21% of the naturalized summer 7-day mean low flow. Shallow wells may intercept groundwater flow to the creek.⁷

♦**Other:** Erosion from an abandoned gravel pit is causing sedimentation.⁷ Two active gravel pits use settling ponds along the creek. One golf course is located in the watershed. A fish hatchery is located on the east branch of the creek.



Whonnock Creek (00-0370)



♦The upper part of the creek is being urbanized without adequate stormwater detention.⁷



♦Irrigation licenses indicate some agricultural activity. There has been little disturbance to the watershed from the small amount of mixed commercial and hobby farming.¹¹



♦The naturalized summer 7-day mean low flow is 3% of the mean annual flow.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 35% of the naturalized summer 7-day mean low flow. Storage accounts for 7% of the irrigation water demand. Shallow wells may intercept groundwater flows to the creek.⁷

♦**Other:** Erosion from a slide has occurred near 112th St. in Whonnock.⁷



Stave River (00-0400)



♦The few samples taken from Stave Lake were analyzed for total phosphorus, none of which exceeded the 80th percentile. One sediment sample was collected from Hayward Lake. Only lead exceeded the guideline for the protection of aquatic life.



♦Industry on the lower east bank has removed some riparian vegetation.⁷ There is some urban development on the east bank and proposals for more on the west bank.



♦Irrigation licenses indicate agricultural activity. There was not enough information to assess the effect agriculture may have on water quality.



♦16% of the total watershed has been logged, including 5% from recent or proposed harvesting.



♦No information was available regarding stream flow, however, it is regulated by dams.

♦There is water demand for domestic, irrigation, waterworks and industrial uses.

♦**Other:** Three B.C. Hydro storage and diversion dams result in uneven flows because the power plants run only at peak demand.⁷ A recent agreement calls for a minimum release of $38 \text{ m}^3 \cdot \text{s}^{-1}$ during salmon egg incubation periods, and 76 to $152 \text{ m}^3 \cdot \text{s}^{-1}$ during chum spawning, with negotiations on a minimum flow volume.⁷

Leachates from numerous woodwaste dumps may seep into the Stave River.¹²



Jacobs Lake



♦All of the cadmium (11) and chromium (14) samples exceeded the guidelines, as did 16 of 39 of the copper and 26 of 41 lead concentrations. Two of ten dissolved ammonia concentrations were above the 80th percentile but none exceeded the 30-day criteria for total ammonia. Some pH measurements were below the minimum guideline.

♦**Other:** This lake, which drains into the North Alouette River, is located in the U.B.C. Research Forest and has been the subject of various studies, including pesticide experiments.



Silverdale Creek (00-0435)



♦Urbanization is ongoing in the upper reach, and is noted to have caused deterioration of water quality.¹¹



♦The lower 1.3 km supports agricultural activities.¹¹ There was not enough information to assess the effect that agriculture may have on water quality.



♦The District of Mission has logged a limited area in the headwaters of the creek in recent years.⁷



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 32% of the naturalized summer 7-day mean low flow.

♦**Other:** Peak flows are predicted to increase due to urbanization.⁷ Most of the creek is in a wooded valley except at the lower end where there are a number of mills. DFO has proposed wide buffer zones to preserve the floodplain. The lower reach is subject to siltation.¹¹ There is an active woodwaste dump located on the creek bank.¹²



Hatzic Slough (00-0500)



♦Hatzic Lake has been sampled for fecal coliforms only. The one reported result did not exceed the guideline.



♦Small farms are located in the watershed. Problems with ditching of streams and subsequent clearing and maintenance, removal of riparian vegetation and the use of herbicides and pesticides to the stream edge, have been noted.⁷



♦7% of the total watershed has been logged, including 4% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



♦The potential August water demand for domestic, irrigation and industrial uses is 43% of the naturalized summer 7-day mean low flow.



Draper Creek (00-0500-010)



♦The upper and urbanizing reaches are in Mission, where there are no requirements for on-site stormwater detention.⁷ The pump station at the mouth has a major effect on downstream migrating fish.¹¹



♦The naturalized summer 7-day mean low flow is 19% of the mean annual flow.



♦The potential August water demand for domestic use is <1% of the naturalized summer 7-day mean low flow.



Chilqua Slough (00-0500-020)



♦No information was available regarding agricultural activity.



♦60% of the total watershed has been logged, including 26% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



♦The potential August water demand flow for irrigation use is 32% of the naturalized summer 7-day mean low.



Chilqua Creek (00-0500-020-020)



♦Much of the drainage area is farmland. The north branch of the creek has been ditched for most of its 1.5 km length.⁷



♦4% of the total watershed has been logged, and 9% is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow. Although the creek is groundwater fed, it is reported to have high summer water temperatures.¹¹

♦The potential August water demand for irrigation use is 110% of the naturalized summer 7-day mean low flow.



Kenworthy Creek (00-0500-050)



♦Agricultural activity occurs in the lower reach. There was not enough information to assess any effects on water quality.



♦There has not been any logging to date. 6% of the watershed is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



♦The potential August water demand for domestic use is 1% of the naturalized summer 7-day mean low flow.

♦Other: A debris flow occurred in the early 1980s.



Lagace Creek (00-0500-060)



♦Licensed irrigation withdrawals account for as much as 16% of the summer 7-day low flow. There was not enough information to assess effects of agriculture on water quality.



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



♦The potential August water demand for domestic, irrigation and industrial uses is 76% of the naturalized summer 7-day mean low flow.

♦Other: Debris torrents in a tributary, Patterson Creek, have deposited large amounts of sediment in Lagace Creek.⁷ This has led to channel aggradation and widening and subsequent loss of low flows into substrate.



Bouchier Creek (00-0500-060-010)



♦Hog farms are located in the watershed. There was not enough information to assess the effect they may have on water quality.



♦The naturalized summer 7-day mean low flow is 25% of the mean annual flow.



♦The potential August water demand for domestic use is 1% of the naturalized summer 7-day mean low flow.

♦Other: Diversions and ditching have altered the stream course. A debris flow has been recorded.⁶



Belcharton Creek (00-0500-060-010-010)



♦Licensed irrigation withdrawals are large relative to the summer 7-day low flow. Discharges from a hog farm may affect water quality.¹¹



♦The actual summer and winter 7-day mean low flow is 22% of the mean annual flow.



♦The potential August water demand for domestic, irrigation, and industrial use is 243% of the naturalized summer 7-day mean low flow.

♦**Other:** A rock quarry began operating adjacent to the stream in 1994. Erosion of unprotected soil and debris from blasting have affected fish habitat and stream water quality. Potential petrochemical spills pose a threat.



Scorey Creek. (00-0500-080)



♦Urban development is present. However, there are no indications of whether or not it is causing problems.



♦Farm development has negatively affected the stream, however, no details are given.¹¹



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



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

♦**Other:** Heavy stream flows have negative effects on the stream.¹¹



Nicomen Slough (00-0552)



♦Some residential development is present, including the Town of Dewdney, but there is no indication of effects on water quality. There is some recreational use of the slough (water skiing).¹⁴



♦Approximately 50% of the watershed is used for agriculture.¹¹ Dairy farming and cattle access have caused water quality problems.¹⁴



♦2% of the total watershed has been logged, and 3% is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 15% of the mean annual flow. Low flows have reportedly degraded rearing habitat.



♦The potential August water demand for domestic, irrigation, waterworks and industrial uses is 21% of the naturalized summer 7-day mean low flow. Storage accounts for much more than irrigation water demand.

♦**Other:** Heavy siltation and aquatic plant growth have degraded salmon rearing habitat.¹⁰



Norrish Creek (00-0552-020)



♦Some agricultural activity is noted in the area,¹¹ however, there was not enough information to assess the effects on water quality.



♦4% of the total watershed has been logged, and another 4% is proposed for harvest.⁷



♦The naturalized summer 7-day mean low flow is 14% of the mean annual flow. Portions of the

creek bed go dry during low flows because of losses to sub-gravel flow and due to a dam on system.¹¹



♦The potential August water demand for waterworks is 26% of the naturalized summer 7-day mean low flow. Storage accounts for much more than irrigation water demand. Withdrawals have resulted in low flows that caused fish kills in the past.¹²

♦**Other:** Gravel accumulation and bed instability on the fan of Norrish Creek has been a problem for many years. The Dewdney-Alouette Regional District operates an intake on the creek and the Dickson Lake reservoir is operated to maintain instream flows below the intake. Major slide activity and turbidity problems have been noted. Placer mining is noted in one area of the creek. Fish hatchery discharges may affect water quality.¹¹



Inches Creek (00-0552-020-005)



♦No information was available regarding agricultural activities.



♦The naturalized summer 7-day mean low flow is <1% of the mean annual flow.



♦No licenses have been issued.

♦**Other:** Flows are maintained in the lower creek for the Inches Creek hatchery by groundwater pumped from wells.⁷ Prior to 1965 lower Inches Creek was naturally groundwater-fed.



Worth Creek (00-0552-020-010)



♦No information was available regarding agricultural activities.



♦The naturalized summer 7-day mean low flow is 15% of the mean annual flow. Worth Creek was once a channel of Norrish Creek but is now groundwater-fed.



♦No licenses have been issued.



Hawkins Creek (00-0552-020-015)



♦The creek is reported to be turning into a farm drainage ditch (1975).



♦The naturalized summer 7-day mean low flow is <10% of the mean annual flow. The stream often goes dry.¹¹



♦No licenses have been issued.



Railway Creek (00-0552-024)



◆No information was available regarding agricultural activity.



◆The naturalized summer 7-day mean low flow is 20% of the mean annual flow.



◆No licenses have been issued.

◆**Other:** The creek is primarily supplied by groundwater with surface water contributions during heavy rainfall.⁷



Brousseau Creek (00-0552-028)



◆Licensed irrigation withdrawals account for as much 53% of the summer 7-day low flow. There was not enough information to assess effects of agriculture on water quality.



◆The naturalized summer 7-day mean low flow is 14% of the mean annual flow.



◆The potential August water demand for domestic, irrigation, waterworks and industrial uses is 56% of the naturalized summer 7-day mean low flow.



Deroche Creek (00-0552-030)



◆Irrigation licenses indicate some agricultural activity in the watershed but there was not enough information to assess effects on water quality.



◆The naturalized summer 7-day mean low flow is 14% of the mean annual flow.



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

◆**Other:** The creek transports large quantities of gravel onto its fan and is reported to have a flashy hydrologic regime.⁷



Pye Creek (00-0552-050)



◆Irrigation licenses indicate some agricultural activity but there is not enough information to assess implications for water quality.



◆The naturalized summer 7-day mean low flow is 14% of the mean annual flow. The creek downstream of the CP Rail bridge is reported to often go dry, although there may be sub-gravel flow.⁷



◆The potential August water demand for domestic and irrigation uses is 2% of the naturalized summer 7-day mean low flow.

◆**Other:** The creek has a flashy hydrologic regime and moves large quantities of coarse gravel.



Barnes Creek (00-0552-060)

◆Urban development is proceeding in the upper watershed but there was not enough information to assess any effects it may have on water quality. Most lots are large and leave strips have been incorporated to protect the creek.⁷



◆Irrigation licenses indicate that there is agricultural activity in the watershed. There was not enough information available to assess the effect that agriculture may have on water quality.



◆The naturalized summer 7-day mean low flow is 15% of the mean annual flow. The lower reach is reported to often go dry in late summer.⁷



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

◆**Other:** The creek channel is stable and does not have the sediment problems found in adjacent watersheds.⁷



Siddle Creek (00-0552-070)



◆Residential development is scattered in the upper watershed but there was not enough information to assess any effects on water quality.¹¹



◆Agricultural activity predominates in the lower watershed,¹¹ however, there was not enough information to assess effects on water quality.



◆Sedimentation problems are reported to be caused by logging in the headwaters¹¹ although the hydrology report states that no logging has occurred in the watershed.⁷



◆The naturalized summer 7-day mean low flow is 14% of the mean annual flow.



◆The potential August water demand for domestic use is <1% of the naturalized summer 7-day mean low flow.

◆**Other:** The stream bed is unstable and subjected to both scouring and sedimentation.⁷



5.7 References

- 1 BC Stats. 1995. BC Stats Population Section, Release: November, Issue: 95-2.
- 2 Quadra Planning Consultants, Ltd. 1995. Protection of Aquatic and Riparian Habitat by Local Governments: Measures Adopted in the Lower Fraser Valley. Prepared for Fraser River Action Plan, Department of Fisheries and Oceans and Environment Canada.
- 3 Greater Vancouver Regional District. 1993. Managing Greater Vancouver's Growth: The Livable Region Strategic Plan, Creating Our Future...Steps to a More Livable Region. Strategic Planning Department, Greater Vancouver Regional District, Burnaby, B.C.
- 4 Swain, L.G. 1989. Coquitlam-Pitt River Area, Tributaries to the Lower Fraser River Along the North Shore, Water Quality Assessment and Objectives, Technical Appendix. Water Management Branch, B.C. Ministry of Environment. 140 p.
- 5 M. Farrell, Fraser River Action Plan, Department of Fisheries and Oceans, Vancouver, B.C., personal communication.
- 6 Stanley and Associates. 1993. Urban Runoff Quantification and Contaminants Loading in the Fraser River Basin and Burrard Inlet. DOE-FRAP 1993-19. Stanley Associates Engineering Ltd., Surrey, B.C.
- 7 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2289.
- 8 Ionson, B. 1995. Habitat Enforcement Report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.
- 9 Schubert, N.D. 1977. Cited in: Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2289.
- 10 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 29C Coquitlam. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 11 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 29D Mission. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 12 L. Nikl, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.
- 13 Whitfield, P.H. and N.E. Dalley. 1987. Rainfall driven pH depressions in a British Columbia coastal stream. Symposium on monitoring, modeling, and mediating water quality. American Water Resources Association. p. 285-294.
- 14 B. Locken, Ministry of Environment, Lands, and Parks, Surrey, B.C., personal communication.

Table 5.2.1 Summary of Facilities with Permitted Waste Discharges to Surface Water in the Pitt/Stave HMA

Record Id	Facility	Waste Type	Waste Num	Flow Max (m ³ ·d ⁻¹)	Receiving Water Body
P02569	Gravel Washing Plant at Albion	Proc.	1	320	Ditch to Kanaka Creek
P02756	Hammond Cedar Div. Sawmill at Hammond	Proc.	1	50	Fraser River
P02756	Hammond Cedar Div. Sawmill at Hammond	Cool.	2	2500	Fraser River
P02756	Hammond Cedar Div. Sawmill at Hammond	Proc.	3	40	Fraser River
P02988	Alouette Lake Day Area, Golden Ears Park	STP	1	40.8	Alouette Lake
P05422	Fish Farm at Mission	Proc.	1	0.9	Gilbert Brook
P05422	Fish Farm at Mission	Proc.	2	450	Silverdale Creek
P05422	Fish Farm at Mission	Proc.	3	130	Silverdale Creek
P05987	Miracle Valley Treatment Centre at Mission	STP	1	910	Cascade Creek
P06657	Mobile Home Park at Ruskin	STP	1	176	Fraser River
P06832	Interfor, Bay Lumber at Pitt Meadows	Proc.	1	40	Fraser River
P06832	Interfor, Bay Lumber at Pitt Meadows	Cool.	2	600	Fraser River
P10721	Golf Course at Rennie Road, Pitt Meadows	STP	1	410	Pitt River

Chapter 6 Chilliwack Habitat Management Area

6.1 Background

The Chilliwack HMA includes streams draining to the Fraser River between Mission and Hope on the north side, and between the Sumas River sub-basin and Hope on the south side. This area consists partly of the extensive floodplains of the lower Fraser, and of the surrounding mountainous areas.

6.1.1 Hydrology

Most of the Fraser River tributaries in this HMA are fed by precipitation and groundwater, hence their hydrologies are largely determined by local weather conditions. In contrast, the hydrology of the Fraser mainstem is governed by weather conditions in the upper watershed; peak flows usually occur in June in response to the melting of the snow pack in the upper Fraser Basin.

6.1.2 Fish

Forty-eight streams in the Chilliwack HMA are known to be salmon-bearing. The Fraser mainstem serves as a migration corridor for coho, chum, chinook, pink, and sockeye salmon, and also provides some spawning habitat for pink and chum salmon. All five species utilize tributaries in the Lower Fraser for spawning, however, these small systems are particularly important to coho and chum salmon. Approximately 65% of Fraser River coho and 85% of Fraser River chum spawn in tributaries to the Fraser mainstem located downstream from Hope. The Chilliwack River itself supports a very large coho population (>10,000 spawners). A broad range of resident fishes are present, including sturgeon, cutthroat trout, kokanee salmon, suckers, whitefish, dolly varden char, and others.

6.1.3 Predominant Land Uses

Current trends indicate that the population of the Lower Fraser Valley, including Greater Vancouver (which extends from West Vancouver eastward), will increase from 2 million people in 1995 to 3.5 million by the year 2031 assuming only a moderate growth rate.¹⁸ The Chilliwack HMA is already absorbing a significant portion of this growth as people seek more affordable housing and a more rural setting than can be found in the Vancouver area. It has been estimated that most of the municipalities in the Chilliwack HMA will grow by about 20% to 32% over the next five years.¹ The town of Hope is the only exception, with an anticipated growth rate of 3% over the next five years.

The rich soils of the Fraser River flood plain support intensive agricultural activities in the Chilliwack HMA. A range of berry and vegetable crops are produced in addition to livestock and poultry. Some farm land is being converted from intensive commercial operations to smaller parcels of land supporting hobby farms.

Almost all of the farm land of the Fraser floodplain is part of the Agricultural Land Reserve (ALR) and is largely protected from non-agricultural development. Consequently, pressure for increasing urbanization results in numerous new developments in the hills lining the Fraser River floodplain, and the expansion and densification of existing urban centres such as Chilliwack.

Hillside developments will create drainage problems for downstream farm land unless accompanied by adequate stormwater detention facilities. Urban stormwater runoff and increased drainage problems on farm land will lead to further deterioration of water quality in streams. Studies on the Matsqui Slough system in the Fraser Delta HMA¹⁹ indicate that stream reaches at the base of the hillsides in the Lower Fraser Valley provide valuable rearing habitat for juvenile coho salmon. Degradation of water quality and habitat in these areas by urban development may mean the end of numerous Fraser coho populations.

Some logging occurs in the HMA, mostly in tributaries to the Chilliwack River. The nature of terrain and soils in some parts of the HMA result in a significant potential for erosion, slumping, and debris torrents unless adequate precautions are taken.



6.2 Point Sources of Contaminants

Water quality in the Fraser mainstem can be affected by waste discharges upstream of the HMA, however, there is no evidence indicating that this is presently an issue.

Point source discharges in the HMA may affect water quality in the Fraser mainstem. Point and non-point sources of pollution both affect water quality in tributaries to the Fraser in the Chilliwack HMA.

6.2.1 Urban/Industrial Point Source Discharges to Surface Water

Waste Permits have been issued for eleven discharges to surface water including two for processing, four for cooling, three for storm and four for STP effluents (Table 6.2.1). All of the STPs discharge directly to the Fraser mainstem, while the other effluents are discharged to ditches and tributaries on the south side of the Fraser (Figure 6.2.1). Permitted daily and annual loading to the HMA is summarized in Table 6.2.2a & 6.2.2b.

The Chilliwack STP is the largest permitted discharge in the HMA, and can release effluent containing up to 2,025 kg-d⁻¹ of BOD and 2,700 kg-d⁻¹ of nonfilterable residues from the secondary treatment facility. In 1993, the STP outfall was extended further into the river to enhance effluent mixing and the treatment system was upgraded. The Fraser River downstream from the outfall is currently being assessed to determine if changes at the STP are reducing effects on water quality.²

Effluent from the secondary treatment plant at Hope was acutely lethal in 3 of 7 rainbow trout LC₅₀ bioassays conducted by DOE.³ An assessment of the improvements necessary to meet current and future permit requirements for this plant was recently completed.³ The current permit stipulates 5-day biochemical oxygen demand (BOD₅) and nonfilterable residue criteria of 100 mg·L⁻¹ each. Both criteria were exceeded in 1993. MELP has advised the District that the permit may be changed to meet the existing B.C. criteria for Best Available Control Technology, 45 mg·L⁻¹ for BOD₅ and 60 mg·L⁻¹ for total suspended solids (TSS).

Several permitted discharges to streams in the HMA may be affecting water quality in the receiving environment due to large effluent volumes and high loading of some parameters. These discharges and issues of concern are summarized in Table 6.2.3.

6.2.2 Permitted Discharges to Ground

There are twenty-eight discharges to the ground addressed by Provincial Waste Management Permits, including eleven for processing, one for cooling and 16 for STP effluents. No information was found to indicate that any of these discharges are resulting in detrimental effects to water quality.

Many houses in rural areas of the HMA are not connected to a municipal sewage treatment system and discharge to onsite septic systems. These systems are often not properly maintained and MELP field staff sometimes encounter raw sewage discharges entering streams from failed septic systems.¹⁴



6.3 Non-Point Sources of Contaminants

The types of land uses prevalent in the Chilliwack HMA make non-point sources of pollution significant contaminant sources compared with point source discharges.

6.3.1 Urban Development

Contaminant loading estimates from urban stormwater runoff indicate that this is a significant contaminant source compared with permitted point source discharges (Table 6.3.1). One of the primary concerns with urban development in the Chilliwack HMA is the lack of stormwater detention/retention for new developments. New housing developments in the hills surrounding Fraser Valley agricultural land will have increasing negative effects on the hydrology and water quality of local streams. Stream reaches between the low-lying agricultural land and relatively steep hillsides often provide refugia for fish from the degraded habitat found in intensively farmed downstream areas. Urban development poses a significant threat to these refuge areas, and hence to the remaining fish populations which depend on the relatively clean water and natural habitat features of upstream reaches.

In the Fraser River floodplain near Chilliwack, increasing urban and commercial/industrial activity is affecting the streams in the area. Luckakuck Creek now has an

Effective Impervious Area (EIA) of 21%, the highest of any watershed in the HMA. Both urban and industrial developments are encroaching on the stream channel and some of the riparian vegetation has been removed in the residential areas.⁴ In the Hope Slough area, residential properties are large. However, because they often extend into the slough, there is a problem with property owners removing riparian vegetation for aesthetic reasons.⁴

Local streams such as Elk and Nevin Creeks were formerly used as a domestic water supply. The large withdrawals of water from these streams resulted in low flow problems and some fish kills.²⁰

Two of the forty-eight salmon-bearing streams in the Chilliwack HMA are considered to be negatively affected by urban activities, as determined by the criteria in the Methodology section.

6.3.2 Agriculture

A large proportion of the Chilliwack HMA is included in the provincial Agricultural Land Reserve (ALR). The entire Sumas Prairie, the watersheds in the lower Chilliwack River basin and the Fraser River floodplain near the town of Chilliwack are used for dairy, pig, and poultry operations and some vegetable and berry growing. Many of the streams in these areas experience similar water quality impacts:

- ◆ erosion and siltation due to removal of riparian vegetation and livestock access to stream banks;
- ◆ high nutrient and microbial concentrations from agricultural runoff;
- ◆ high streamwater temperatures due to lack of riparian vegetation,⁴⁻⁶ and
- ◆ low dissolved oxygen concentrations due to eutrophication and inputs of BOD from agricultural runoff.

Fourteen of the forty-eight salmon-bearing streams in the HMA are considered to be negatively affected by agricultural activity, as determined by the criteria in the Methodology chapter.

The Sumas Prairie is one of the most intensively farmed areas in Canada. In the early 1920's Sumas Lake and the surrounding wetland was drained for farmland. Since that time, drainage ditches and dykes have been built to protect the area from periodic flooding. Because of the extensive ditching of the Sumas River and its tributaries, the water is slow moving and water temperatures are high during summer months.⁵

The relationships between agriculture and surface water quality were the focus of a detailed study in the Sumas River.⁷ Study findings included a statistically significant positive correlation (p<0.05) between the amount of surplus nitrogen applied per farmed hectare and ammonia-N concentrations in surface waters during the wet season. Conversely, there was a significant negative correlation between surplus nitrogen applied per farmed hectare and dissolved oxygen concentrations in surface waters during both wet and dry seasons. Dissolved oxygen concen-

trations are lowest during the fall months, when the effects from oxygen demand associated with manure runoff are compounded by the die-off of large amounts of algae in eutrophic streams. This period of lowest DO concentrations often coincides with the timing of spawning migrations of Lower Fraser coho.

In a 1988 study, several small streams in the Chilliwack HMA were evaluated to locate specific areas where live-stock have adversely affected stream banks and riparian vegetation.⁸ Sites on Lonzo Creek in the Sumas Basin, Salwein, Street and Railway Creeks in the Chilliwack Basin, and Atchelitz and Nevin Creeks in the Hope Slough area were identified as candidates for restoration efforts, because of impacts which have occurred there.

6.3.3 Timber Harvesting

Logging has caused significant deleterious effects on streams in the Chilliwack HMA, resulting in erosion, sedimentation, and disruption of hydrology. Of the forty-eight salmon-bearing streams, eight are considered to have been negatively affected by timber harvesting, as determined by the criteria in the Methodology chapter. Logging activity has focused in the upper tributaries of the Chilliwack River and some of the smaller Fraser River tributaries near Hope.

One of the more extreme examples of how a logging may affect streams is provided by Jones (Wahleach) Creek. Logging began in the 1930's and increased through the 1950's and '60's. The greatest damage to the stream has been the result of road building and extensive clearcutting on the steep, unstable slopes of the Three Mile Creek tributary. Heavy storms in 1993 and 1995 caused the thin layer of unprotected soil to slip off the bedrock of the mountain. Debris torrents scoured the stream bed and filled the channel with large rocks and debris. The Jones Creek pink salmon run is now considered to be virtually extinct.²¹



6.4 An Overview of Water Quality Conditions

6.4.1 General Mainstem Water Quality Conditions

Data pertaining to the Fraser mainstem in this HMA are limited. Most data are from a long-term monitoring site at

Hope. Site-specific water quality assessments, and influencing factors and supporting data (Table 6.4.1 a-b) are provided in Section 6.5 on a stream-by-stream basis. In general pH is near-neutral, ranging from 6.8 to 8.2 at Hope, and 6.5 to 8.2 at Chilliwack. Alkalinity, a measure of buffer capacity, is moderate and hardness was also classified as moderate.⁹

Total concentrations of some metals exceeded CCME guidelines for the protection of aquatic life. However, metals are likely associated with suspended sediments and therefore not bioavailable. Except for copper and lead, measured metal concentrations are comparable to concentrations measured in the Fraser mainstem upstream of anthropogenic inputs.

Average concentrations of total copper, lead, and zinc are slightly higher in the Fraser mainstem in the Chilliwack HMA than in the Fraser Delta HMA. Like metals, mean NFR is higher at Hope compared to downstream mainstem sites. Below Hope the Fraser becomes wider and the velocity decreases, allowing some settling of suspended sediments and associated metals.

Approximately one third of the 165 nitrate+nitrite-N and the 168 total phosphorus concentrations exceeded 80th percentile levels at Hope. The nitrate+nitrite-N concentrations were comparable, if not lower, than concentrations measured at Hansard, upstream of significant anthropogenic inputs. Mean total phosphorus concentrations were slightly higher at Hope (0.082 mg·L⁻¹; n = 168) compared to Hansard (0.056 mg·L⁻¹; n = 304) while mean NFR levels were similar for the two sites.

6.4.2 General Water Quality Conditions in Tributaries

Water quality in the tributaries largely reflects characteristics of precipitation during the rainy season and groundwater sources during dry summer months in areas where groundwater is the major water source to streams. Tributary streams in their natural state generally have lower suspended sediment levels than those characteristically found in the mainstem.

Tributary streams are sensitive to the effects of surrounding land uses including those resulting from forestry activities, agriculture, and urban development in different parts of the HMA.




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 Chilliwack HMA. Summary tables of:

- ◆ surface water, sediment and fish tissue data (Tables 6.4.1a and b).

- ◆ land use areas, stream flow, and water demand information, for each salmon stream (Table 6.5.1); and,
- ◆ red-coded indicators for each salmon stream (Table 6.5.2).

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 6.5.1.


 r quality conditions were assessed using a base compiled by DFO and DOE and the data were categorized according to the criteria outlined in the Methodology section. Additional information was included where available, but it did not influence the outcome of the category rating.

Assessments of potential water quality problems resulting from urban development, agriculture, forestry, low stream flows, and water demand were based upon information provided in a series of hydrology reports by Rood and Hamilton, and/or SISS catalogues, unless otherwise indicated. Assessment criteria are described in the Methodology section of this report.



Fraser River Mainstem


Chilliwack STP Site

 ◆Nutrient and fecal coliform levels exceeded guidelines or 80th percentiles upstream and downstream from the Chilliwack STP. 23 of 23 ammonia (max. = 2.08 mg·L⁻¹) and 5 of 6 coliform (max. = 24,000 CFU) values exceeded the guideline or 80th percentile 300 m downstream from the Chilliwack STP. Dissolved ammonia levels may exceed the 30-day criteria for total ammonia depending on pH and temperature downstream from the STP. Upstream from the STP, 25 of 36 dissolved ammonia values exceeded the 80th percentile (max. = 0.136).

◆**Other:** The Chilliwack STP outfall has been moved closer to the middle of the Fraser to enhance mixing, and the treatment system was upgraded in 1993. The Fraser River downstream from the outfall is currently being assessed to determine if the changes at the STP are leading to any improvement in water quality.




Kent STP site

 ◆Downstream from the Kent STP outfall, 3 of 8 fecal coliforms (max. = 4,200 CFU) and dissolved ammonia (max. = 0.15 mg·L⁻¹) values exceeded the 80th percentile. Upstream from the outfall, 5 of 14 coliform (max. = 1,260 CFU) and ammonia (max. = 0.023 mg·L⁻¹) values exceeded the 80th percentile or guideline.



Agassiz Reach

 ◆None of the PCB or pesticide concentrations measured in fish muscle (1994), exceeded the consumption guidelines established to protect human health. The long-term effects of low levels of contaminant mixtures on aquatic organisms are unknown.




Greyell Slough and Wahleach Channel

◆One 2,3,7,8-T4CDD concentration in fish tissue is reported (from 1992), and is below guidelines.



Fraser Mainstem at Hope


 ◆36% of the 168 total phosphorus measurements and more than 10% of 100 cadmium, copper, chromium and lead samples at Hope exceeded the CCME guidelines for the protection of aquatic life.

★The high concentrations of these parameters are likely associated with the naturally high suspended sediment loads of the Fraser River. All metals measured at Hope were at concentrations similar to those measured upstream of Prince George. Copper and lead were the exceptions. Concentrations of both metals are about twice as high at Hope compared with the upstream Hansard site (about 100 measurements from each site). About 50% more copper and lead measurements exceeded guideline levels at Hansard than did at Hope, however, maximum concentrations were higher at Hope. Copper and lead concentrations at Hope could reflect natural background conditions, or anthropogenic inputs.



Fraser River Tributaries

Sumas River (00-0600)

 ◆At the international border 25 of 125 temperature measurements exceeded the guideline for protection of cold water biota. Almost all of 407 total phosphorous concentrations and 372 total nitrate+nitrite-N measurements were above the 80th percentiles. Of the metals sampled in surface water, half of the cadmium and chromium, two-thirds of the copper and one-fifth of the zinc concentrations exceeded guidelines.

◆**Other water quality data:** Low dissolved oxygen and high ammonia nitrogen concentrations were measured at two sites downstream from the border.¹⁰ The inflow of low-dissolved oxygen water from Saar Creek may affect the Sumas River.¹¹ Chromium and nickel are naturally elevated due to a deposit of serpentinitic materials exposed by a landslide in the headwaters of Swift Creek in the U.S., a tributary to the Sumas River.¹² This slide results in some of the highest naturally occurring water-borne asbestos levels in Canadian freshwaters.⁹



◆Urban development is present in upper watershed in the U.S. and on the lower slopes of Sumas Mountain in Canada.



◆Farms along 91% of river length are noted to cause heavy siltation. Fish kills have been attributed to pesticides and agricultural runoff in the system.⁵ The Sumas River originates in an agricultural area of the United States. There are high nutrient and microbial levels in the stream from animal wastes and sewage discharge as it crosses the Canada/U.S. border, and additional phosphorus, nitrogen and fecal coliforms come from Canadian agricultural sources.^{7, 9}



◆1% of the total watershed has been logged, and less than 1% is proposed for harvest.



◆The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



◆The potential August water demand for domestic, irrigation, waterworks and industrial is 35% of the naturalized summer 7-day mean low flow.

◆**Other:** The Sumas is a slow-moving river with very little shade, high temperatures and low dissolved oxygen concentrations. Narrow dykes contain the river and riparian vegetation is removed as part of dyke maintenance. Many of the tributaries have been ditched and the timing of cleaning and maintenance is a major concern.⁴



Lonzo (Marshall) Creek (00-0600-050)



◆Dissolved oxygen, temperature, pH, dissolved ammonia and total phosphorus data are reported for two sites. A maximum of six measurements was reported for any parameter at a given site. 5 of 6 dissolved oxygen values were below the minimum guideline, and 2 of 6 temperature values exceeded the guideline at Sumas Road.

◆**Other water quality data:** IRC reports low dissolved oxygen and high dissolved ammonia concentrations near the confluence of Lonzo Creek with the Sumas River.¹⁰ Low dissolved oxygen ($3.5 \text{ mg}\cdot\text{L}^{-1}$) was also measured by Hutton.¹¹ In the past, a fertilizer plant may have contributed to water quality problems in the creek.¹³ High nitrate-N concentrations measured in the headwaters of Lonzo Creek are likely due to inputs of groundwater from the Abbotsford Aquifer, which is contaminated with nitrate-N.⁷



◆6.0% EIA indicates moderate urban development. Further development may significantly alter the hydrologic regime.⁴



◆Agriculture occurs throughout the watershed. Siltation and pollution from farming are reported.⁵ Agricultural activity is thought to contribute high copper and zinc concentrations and may also contribute to eutrophication.



◆The naturalized summer 7-day mean low flow is 41% of the mean annual flow. The stream is groundwater-fed by the Abbotsford Aquifer.



◆The potential August water demand for domestic, irrigation, and industrial uses is 27% of the naturalized summer 7-day mean low flow.

◆**Other:** Well withdrawals from this part of the Abbotsford Aquifer reduce the recharge of Lonzo Creek. Land-filling and encroachment on the floodplain have narrowed the stream.

Discharges from industry may be affecting water quality. Permitted discharges to Lonzo Creek include effluent from a fish hatchery (P01726), containing high BOD and phosphorus which may be detrimental to this low-flow

system. Eutrophication problems have been reported in Lonzo Creek. The permitted discharge volume ($15,000 \text{ m}^3\cdot\text{d}^{-1}$) could reach about 36% of the August stream flow.

The discharge of cooling water from an evaporated milk plant (P04608) to a tributary of Lonzo Creek may cause temperature problems in this low-flow system. There is also a stormwater discharge from a bulk petroleum storage facility (P08618).



Saar Creek



◆All five total phosphorus and dissolved ammonia nitrogen concentrations exceeded the 80th percentiles, and four of five coliform levels exceeded guidelines.

◆**Other water quality data:** IRC measured extremely low dissolved oxygen and high dissolved ammonia concentrations at a site upstream of the Lamson Road site reported above.¹⁰ Saar Creek has low dissolved oxygen levels during fall months,¹¹ resulting from inputs of BOD and the decomposition of large amounts of algae, present due to eutrophic conditions.



◆Cattle have direct access to the stream.¹³



Arnold Slough



◆8 of 8 dissolved oxygen measurements were below the minimum guideline for the protection of aquatic life, and 4 of 4 dissolved ammonia values exceeded the 80th percentile at the border station. Several of the ammonia values also exceeded the 30-day criteria for total ammonia.

◆**Other water quality data:** Extremely low dissolved oxygen ($< 1 \text{ mg}\cdot\text{L}^{-1}$) and high dissolved ammonia ($> 4 \text{ mg}\cdot\text{L}^{-1}$) concentrations have been reported for several other stations in the slough.^{10,11}



◆Agriculture is the only significant land use in the watershed. Cattle have direct access to the slough.¹³ The slough straddles the Canada/U.S. border; it is likely that intensive agricultural activity in Washington state is also contributing to the poor water quality.¹¹



Kilgard Creek (00-0600-050-010)



◆2.9% EIA indicates moderate urban development. Urban developments on Sumas mountain lack stormwater management facilities, and have affected some tributaries including Kilgard Creek.⁴



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



◆No water licenses have been issued.

♦**Other:** Siltation along lower reaches is a concern. Riparian restoration works have been undertaken.



Lower Chilliwack River/Vedder River d/s Chilliwack Lake (00-0600-020-000-000-000-991)



♦ 1 of 3 total phosphorus values from Cultus Lake, and 1 of 14 fecal coliform values from the Vedder Canal exceeded the guideline or 80th percentile.

♦**Other water quality data:** Data from the 1970s indicate a moderate buffering capacity (alkalinity 30 mg-L⁻¹) just upstream of the Vedder River confluence with the Fraser.⁹



♦ Urban development has occurred along several roads near the river. However, there is no indication whether it is causing problems.



♦ Irrigation licenses indicate agricultural activity in the watershed. There was not enough information available to assess the effect that agriculture may have on water quality.



♦ 5% of the total watershed has been logged, including 1% from recent or proposed harvesting. Logging is extensive in the upper watershed.



♦ The naturalized summer 7-day mean low flow is 27% of the mean annual flow.



♦ The potential August water demand for domestic, irrigation, waterworks and industrial uses is 1% of the naturalized summer 7-day mean low flow. Storage accounts for less than 1% of the total irrigation demand.

♦**Other:** Setback dykes, river training works and bank revetments have blocked secondary channels.⁴ Large organic debris along the channel has been removed. Since 1989/90 there has been increased turbidity and sediment input from naturally occurring clay slides on the Chilliwack mainstem. A hatchery is located near the confluence of Slesse Creek with the Chilliwack River.⁵



Upper Chilliwack River u/s Chilliwack Lake (00-0600-020-000-000-000-992)

♦**Other water quality data:** Chilliwack Lake is reported to be very poorly buffered and extremely vulnerable to acid inputs, based on data from the 1970's.⁹



♦ 29% of the total watershed has been logged, including 1% from recent or proposed harvesting. Logging also occurs on the U.S. side.⁵



♦ The naturalized summer 7-day mean low flow is 27% of the mean annual flow.



♦ The potential August demand for domestic, irrigation, waterworks and industrial uses is less

than 1% of the naturalized summer 7-day mean low flow.



Salwein Creek (00-0600-020-008)



♦ Agriculture has contributed to siltation and degraded spawning gravels in the east branch of creek.⁴ Livestock trampling of riparian areas has been reported. DFO has stopped allowing maintenance dredging until fencing is installed to prevent livestock access to the stream channel.⁵



♦ The naturalized summer 7-day mean low flow is 20% of the mean annual flow.



♦ No water licenses have been issued.

♦**Other:** The creek has been ditched through farmland in its upper 3 km.



Street Creek (00-0600-020-010)



♦ 0.6% EIA indicates minimal urban development.



♦ Agricultural activity occurs throughout the watershed.⁵ 50% of the stream's summer 7-day low flow is allotted for irrigation withdrawals.



♦ The naturalized summer 7-day mean low flow is 23% of the mean annual flow.



♦ The potential August water demand for domestic and irrigation uses is 41% of the naturalized summer 7-day mean low flow. Storage accounts for 8% of the total irrigation demand.

♦**Other:** This is a stable, spring-fed, low gradient stream.⁵



Hopedale Slough (00-0600-020-010-010)



♦ 1.2% EIA indicates minimal urban development present.



♦ Agricultural activity is minimal.¹⁴



♦ To date, the watershed has not been logged. 10% is proposed for harvest.



♦ The naturalized summer 7-day mean low flow is 20% of the mean annual flow.



♦ No licenses have been issued.

♦**Other:** The slough is cut off from the Vedder River by a dyke.



Barrett Creek (00-0600-020-013)



♦ 2.4% EIA indicates some urban development is present.



◆ Potential water quality problems from agriculture have been noted.⁵ Irrigation withdrawals may consume as much as 18% of the summer 7-day low flow.



◆ The naturalized summer 7-day mean low flow is 15% of the mean annual flow. The creek is spring-fed. Low flows have been reported to impede salmon migration.⁵



◆ The potential August water demand for domestic and irrigation use is 21% of the naturalized summer 7-day mean low flow.



Peach Creek (00-0600-020-015)



◆ 1.4% EIA indicates minimal urban development.



◆ Minimal agricultural activity takes place in the watershed.^{5, 14}



◆ The naturalized summer 7-day mean low flow is 20% of the mean annual flow. The stream channel goes dry and freezes to the stream bed during cold winters.⁵



◆ No water licenses have been issued.

◆ **Other:** The creek was formerly a seepage ditch with no cover, and heavy silting occurred below a culvert.⁴



Sweltzer River (00-0600-020-020)



◆ The extent of agriculture is minimal.¹⁴



◆ The naturalized summer 7-day mean low flow is 28% of the mean annual flow.



◆ The potential August demand for domestic, irrigation, waterworks and industrial uses is 4% of the naturalized summer 7-day mean low flow.

◆ **Other:** High summer water temperatures are reported.⁵ Summer flows out of Cultus Lake are reduced to maintain water levels suitable for recreation.



Liumchen Creek (00-0600-020-040)



◆ 1% of the total watershed has been logged, and 1% is proposed for harvest. Logging is causing turbidity.



◆ The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



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

◆ **Other:** The District of Chilliwack has applied for waterworks licenses on Liumchen and Foley Creeks as a

short term solution for water supply and plans for both creeks as a long term supply.⁴ Stream banks have been stripped of riparian vegetation.



Ryder Creek (00-0600-020-050)



◆ 0.2% EIA indicates minimal urban development present, however, extensive development is planned. There are currently no requirements for stormwater detention or retention and stormwater from further development will likely impact the creek.⁴



◆ Irrigation licenses indicate that agricultural activity is present in the watershed. Hobby farms are common throughout the watershed, and may be affecting water quality.¹⁴



◆ The naturalized summer 7-day mean low flow is 21% of the mean annual flow. Low and unstable flows have been reported.⁵



◆ The potential August water demand for domestic, irrigation and industrial use is 6% of the naturalized summer 7-day mean low flow. DFO recommends no further water withdrawals to ensure adequate flows for fish.⁵

◆ **Other:** Flood flows erode banks and scour gravel, and sedimentation is occurring.



Little Tamihi Creek (00-0600-020-070)



◆ 48% of the total watershed has been logged (pre-1963), and there is no proposed additional harvesting.



◆ The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



◆ No water licenses have been issued.



Tamihi Creek (00-0600-020-090)



◆ Irrigation licenses indicate that agricultural activity is present in the watershed but no other information was available.



◆ 11% of the total watershed has been logged, and 1% is proposed for harvest. Logging occurs primarily in the upper reaches.



◆ The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



◆ The potential August demand for domestic, irrigation, waterworks and industrial uses is 3% of the naturalized summer 7-day mean low flow.

◆ **Other:** The creek is glacier-fed and maintains high summer flows.



Thurston Creek (00-0600-020-115)



♦The naturalized summer 7-day mean low flow is 31% of the mean annual flow. The creek is groundwater-fed which helps maintain flows.



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



Borden Creek (00-0600-020-120)



♦Irrigation licenses indicate that agricultural activity is present in the watershed. No other information was available.



♦31% of the total watershed has been logged, and 2% is proposed for harvest. SISS describes logging activity as heavy in the upper watershed.⁵



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow. The creek has a flashy hydrologic regime.⁵



♦The potential August water demand for irrigation use is <1% of the naturalized summer 7-day mean low flow.

♦**Other:** The creek is described as having usually clear water, although scouring problems have been noted. The stream is vulnerable to freshets and can freeze over.



Slesse Creek (00-0600-020-130)



♦Logging activity has been occurring since the 1960s.⁵ 3% of the total watershed has been logged, and less than 1% is proposed for harvest. Road construction and clearcutting have caused large failures which contributed gravel and silt to the river.⁴ A moratorium has been placed on further logging.



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The creek is unstable and active, and is a major gravel source to the upper Chilliwack River.⁴



Foley Creek (00-0600-020-160)



♦16% of the total watershed has been logged (mostly pre-1972), including 2% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow. Extreme fluctuations in discharge have been observed.⁵



♦No water licenses have been issued.

♦**Other:** The District of Chilliwack has applied for waterworks licenses on Foley Creek as a short term solution

for water supply and plans to use the creek as a long term supply.⁴



Nesakwatch Creek (00-0600-020-170)



♦18% of the total watershed has been logged, and 2% is proposed for harvest. Stream bank instability and heavy erosion are reported.⁵



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



♦No water licenses have been issued.



Fourteen Mile Creek (00-0600-020-173)



♦While B.C. Ministry of Forests records do not indicate any activity,⁴ SISS reports that the lower end of the watershed has been logged.



♦The naturalized summer 7-day mean low flow is 20% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The creek flows in a former side channel of Chilliwack River and is groundwater-fed.⁵



Fifteen Mile Creek (00-0600-020-176)



♦The naturalized summer 7-day mean low flow is 18% of the mean annual flow. The creek is spring-fed.



♦No water licenses have been issued.

♦**Other:** Lack of flow and siltation are reported as constraints in this system.⁵



Center Creek (00-0600-020-180)



♦18% of the total watershed has been logged (mostly pre-1972), including 2% from recent activity. Logging is located in the upper watershed.



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow. Notable flow fluctuations have been reported.⁵



♦No water licenses have been issued.



Post Creek (00-0600-020-200)



♦Summer cottages are located at the mouth. There is no indication of any adverse effects.



◆1% of the total watershed has been logged, and no recent or proposed harvesting is reported.



◆The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



◆No water licenses have been issued.

◆**Other:** Chilliwack Provincial Park is located in the watershed.



Paleface Creek (00-0600-020-240)



◆34% of the total watershed has been logged, including 1% from recent or proposed harvesting. Extensive logging is reported to have altered flow and made the creek unstable.⁵



◆The naturalized summer 7-day mean low flow is 22% of the mean annual flow. Low flows are reported to restrict fish passage.⁵



◆No water licenses have been issued.

◆**Other:** A Forest Service Camp is located near the mouth.



Depot Creek (00-0600-020-250)



◆11% of the total watershed has been logged, and there is no proposed harvesting.



◆The naturalized summer 7-day mean low flow is 22% of the mean annual flow. Extreme fluctuations in water level have been reported.⁵



◆No water licenses have been issued.

◆**Other:** The creek may freeze up. A forestry park and campgrounds are located at mouth.



Chilliwack Creek (00-0625)



◆14 of 14 dissolved ammonia values exceeded the 80th percentile value indicating an ammonia source to the creek. 1 of 14 fecal coliform counts exceeded the guideline.

◆**Other water quality data:** Old data (1973) indicate moderately soft water with moderately high buffering capacity.⁹ Low dissolved oxygen concentrations have also been measured.¹⁵



◆2.9% EIA indicates some urban development. Storm drains discharge directly into the stream.¹⁶



◆Agricultural water use is noted to significantly reduce summer flows.⁴ There was not enough information to assess the implications for water quality.



◆The naturalized summer 7-day mean low flow is 22% of the mean annual flow. Chilliwack

Creek is an old channel of the Chilliwack/Vedder River and receives groundwater inflow.



◆The potential August water demand for domestic, irrigation and industrial uses is 65% of the naturalized summer 7-day mean low flow.

◆**Other:** Chilliwack Creek receives stormwater from a bulk petroleum storage facility (P07853) and cooling effluent from a food processing plant (P07703). The food processing plant may discharge up to 810 m³·d⁻¹ warm water (max. 22°C) to Chilliwack Creek, which has summer low flows of about 40,600 m³·d⁻¹.



Atchelitz Creek (00-0625-010)

◆**Other water quality data:** Low dissolved oxygen concentrations have been measured.¹⁵ Old data (1973) indicate the creek water has moderately high buffering capacity, with near-neutral pH, and is moderately soft.⁹ A high phosphorous concentration (max. = 1.45 mg·L⁻¹) was reported, and very low dissolved oxygen concentrations were measured (min. = 2.2 mg·L⁻¹), with a mean of only 6 mg·L⁻¹.



◆3.2% EIA indicates some urban development. Storm drains discharge into the stream.¹⁶



◆Heavy siltation of the entire stream from farmland erosion is reported.⁵



◆The naturalized summer 7-day mean low flow is 23% of the mean annual flow. Low flow problems have been reported.



◆The potential August water demand for irrigation and industrial uses is 34% of the naturalized summer 7-day mean low flow. DFO opposes further withdrawals.

◆**Other:** Industrial activities include a canning factory, food processing plant and saw mill. More industrial development is occurring in the lower watershed. Atchelitz Creek receives stormwater from two bulk petroleum cardlock facilities (P07998 and P08034) and cooling effluent from a food processing plant (P01684). The food processing plant may discharge 2,000 m³·d⁻¹ of warm water (max. 24°C) to Atchelitz Creek, equivalent to about 27% of the stream flow volume during August low flows, and likely contributes to thermal stress of aquatic biota in the stream.



Luckakuck Creek (00-0625-030)



◆15 of 15 fecal coliform counts exceeded the 80th percentile. 14 of 15 dissolved ammonia concentrations were above the 80th percentile (max. = 0.438 mg·L⁻¹).

◆**Other water quality data:** Low dissolved oxygen concentrations have been measured.¹⁵



◆21.4% EIA indicates extensive urban development. Both industrial and residential developments encroach on the creek and riparian vege-

tation has been removed in most residential areas.⁴ Domestic sewage problems are noted⁵ and storm drains discharge into the stream.¹⁶



♦Animal wastes are noted to cause water quality problems.⁵



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow. The creek is an old channel of the Chilliwack/Vedder River and receives groundwater inflow.



♦The potential August water demand for domestic, irrigation and industrial uses is 307% of the naturalized summer 7-day mean low flow.



Semmihault Creek (no SISS #)



♦2.1% EIA indicates some urban development.



♦Irrigation withdrawals consume 100% of the naturalized summer 7-day mean low flow. Intensive dairy operations are common.¹⁴



♦The naturalized summer 7-day mean low flow is 22% of the mean annual flow.



♦The potential August water demand for domestic, irrigation and industrial use is 69% of the naturalized summer 7-day mean low flow.



Hope Slough (00-0640)



♦All 14 dissolved ammonia values are above the 80th percentile, indicating a source of contamination in the watershed. High fecal coliforms were measured in one of 13 samples.

♦**Other water quality data:** Based on 1978-82 data, water quality conditions in Hope Slough are similar to those described for Elk Creek, although maximum concentrations of the measured nutrients are lower.⁹ In a 1987 water quality study, dissolved oxygen dropped to 1.25 mg·L⁻¹ at one station and below 5 mg·L⁻¹ at several others.¹¹



♦2.4% EIA indicates moderate urban development. Extensive development nearer to Chilliwack and industrial processing are also noted.⁵ Landowners removed riparian vegetation to the edge of the slough.⁴



♦Agricultural activity occurs along 79% of the stream length.⁵ One side of the stream is completely agricultural.¹³ Agricultural runoff is the suspected source of elevated nutrient concentrations.



♦The naturalized summer 7-day mean low flow is 26% of the mean annual flow.



♦The potential August water demand for domestic, irrigation, waterworks and industrial

use is 86% of the naturalized summer 7-day mean low flow. Storage accounts for less than 1% of the total irrigation demand.

♦**Other:** Extensive silting is noted throughout, and there is a milfoil weed control program in the Slough.⁵ Hope Slough receives discharges from a fish farm (P07886). During August low flows effluent from the Cheam View Trout Farm may comprise about 18% of the flow in Hope Slough. Effluent data show that concentrations of BOD, suspended solids, ammonia and phosphorus have all exceeded permit specifications by significant amounts. While the trout farm is not the only nutrient source to Hope Slough, its contribution may be significant.



Camp Slough (00-0640-010)



♦0.8% EIA indicates a minor amount of development.



♦Agriculture is the dominant activity in the slough.⁵ Clearing and dyking have degraded fish habitat.



♦The naturalized summer 7-day mean low flow is 9% of the mean annual flow.



♦The potential August water demand for domestic and irrigation use is 114% of the naturalized summer 7-day mean low flow.



Elk Creek (00-0640-020)



♦All 5 total phosphorus concentrations exceed the 80th percentile by a wide margin (max. = 4.8 mg·L⁻¹). 14 of 14 dissolved ammonia concentrations likely exceed the 30-day criteria for total ammonia (max. = 25.7 mg·L⁻¹, mean = 3.68 mg·L⁻¹, temperature data not provided).

♦**Other water quality data:** 1970's data show widely fluctuating dissolved oxygen percent saturation values, high ortho-phosphate concentrations (up to 0.195 mg·L⁻¹) and high nitrite concentrations (0.29 mg·L⁻¹).⁹



♦0.2% EIA indicates minimal urban development to date. A major development is being planned.



♦The stream channel is surrounded by farms. Most of the lower 4 km are ditched and riparian vegetation has been removed. Fencing is needed to control cattle access.⁵ Agricultural runoff is the suspected source of the elevated nutrient concentrations measured in the stream. A new watercress farming operation was noted in the slough.¹⁷



♦Ministry of Forests is preparing a Watershed Resource Plan for the upper creek.



♦The naturalized summer 7-day mean low flow is 31% of the mean annual flow. Extreme summer low flows due to excessive water withdrawals have resulted in major fish kills.⁵



♦The potential August water demand for waterworks and industrial use is 46% of the naturalized summer 7-day mean low flow. A low flow bypass is used to maintain $0.2 \text{ m}^3 \text{ s}^{-1}$ during salmon spawning and $0.11 \text{ m}^3 \text{ s}^{-1}$ for rearing. Flows in upper Elk Creek are often only half of the licensed volume during droughts. DFO opposes any new water licenses.

♦**Other:** The cleaning of a debris basin causes siltation in downstream reaches. Impacts to this creek have been ongoing for decades without being adequately addressed by regulatory agencies.



Calkins Creek (00-0640-020-004)



♦0.4% EIA indicates little urban development.



♦Irrigation licenses indicate agricultural activity in the watershed but no further information was available.



♦The naturalized summer 7-day mean low flow is 25% of the mean annual flow. Low flow problems have been reported.⁵



♦The potential August water demand for domestic and irrigation uses is 18% of the naturalized summer 7-day mean low flow. DFO opposes any further withdrawals.⁵



Marblehill Creek (00-0640-020-004-800)



♦0.5% EIA indicates little urban development.



♦Agricultural activity occurs in the lower reach⁵ and licensed irrigation withdrawals consume a significant proportion of summer low flows.

There was not enough information to assess implications for water quality.



♦The naturalized summer 7-day mean low flow is 14% of the mean annual flow. Low flow problems have been reported.⁵



♦The potential August water demand for domestic, irrigation and industrial uses is 70% of the naturalized summer 7-day mean low flow. DFO opposes any further withdrawals.



Ford Creek (00-0640-020-010)



♦A golf course is being developed on the flats and an entire hillside is the site of new urban developments.



♦Farming is noted throughout most of the watershed. Not enough information was available to assess the effect it may have on water quality.



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.

♦The potential August water demand for domestic, irrigation and industrial uses is 20% of the naturalized summer 7-day mean low flow.



Dunville Creek (00-0640-030)



♦0.2% EIA indicates minimal development.



♦The lower section is channelized through agricultural lands and the riparian vegetation has been removed.⁴



♦SISS reports some logging activity.⁵ There was not enough information to assess the effect forest harvesting may have on water quality.



♦The naturalized summer 7-day mean low flow is 20% of the mean low flow. Low flow problems have been reported.⁵



♦The potential August water demand for domestic, irrigation, waterworks and industrial uses is 113% of the naturalized summer 7-day mean low flow. DFO opposes any further withdrawals.⁵ The District of Chilliwack uses Dunville Creek as a water supply.

♦**Other:** A debris trap in the upper creek sometimes overflows during floods and sediment is carried downstream.⁴ Heavy silting is occurring in the lower watershed.



Nevin Creek (00-0640-030-005)



♦0.2% EIA indicates minimal development.



♦Extensive agriculture occurs on the flats. Uncontrolled livestock access has caused stream degradation.⁵



♦The naturalized summer 7-day mean low flow is 21% of the mean low flow.



♦The potential August water demand for domestic, irrigation and waterworks uses is 190% of the naturalized summer 7-day mean low flow. DFO recommends no further water withdrawals.



Wahleach Slough (00-0685)



♦Agricultural activity may be affecting water quality.¹⁴



♦Scott Paper has a woodlot license on the island between the slough and the Fraser River; cottonwood is harvested on a rotational basis.

There appears to be some encroachment on the river bank.



♦The naturalized summer 7-day mean low flow is 21% of the mean annual flow.



♦No water licenses have been issued.



Popkum Creek (00-0690)



♦A golf course and urban development along the lower reaches exist but a 30 meter riparian corridor has been left.⁴



♦ Large dairy operations near the mouth of the creek may be affecting water quality.



♦Anderson Creek, a tributary, is affected by logging and the channel often goes dry due to sub-gravel flows.⁴



♦The naturalized summer 7-day mean low flow is less than 23% of the mean annual flow.



♦The potential August water demand flow for domestic, irrigation and industrial uses is 95% of the naturalized summer 7-day mean low.

♦**Other:** The steam bed is coated with marl from marl mining.⁵



Maria Slough (00-0700)



♦Intensive agricultural activity is occurring in the watershed.⁶



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦The potential August and September water demand for domestic, irrigation and industrial uses is 34% of the naturalized summer 7-day mean low flow.

♦**Other:** Riparian vegetation has been removed along the road and powerline adjacent to the slough.¹⁷ The local Native band has shown an interest in building bridge and pipeline crossings at several narrow points.



Hicks Creek (00-0700-070)



♦While there are no irrigation licenses for this creek SISS reports problems with irrigation water removal, suggesting some agricultural activity is present.⁶



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. Low flows hinder rearing and migration.⁶



♦See agriculture.

♦**Other:** The creek is subject to scouring in the upper reach.



Jones (Wahleach) Creek (00-0735)

♦5% of the total watershed has been logged, and no recent or proposed harvesting is reported. Despite the minimal cut shown by

Ministry of Forests records, there have been catastrophic effects on fish habitat and water quality (see **Other**).



♦The naturalized summer 7-day mean low flow is 12% of the mean annual flow.



♦The potential August water demand for domestic and waterworks uses is <1% of the naturalized summer 7-day mean low flow.

♦**Other:** Roads and logging have destabilized slopes in the watershed, causing debris torrents in the creek and destruction of a spawning channel.^{4,21} BC Hydro operates a dam at the outlet of Wahleach Lake. The run of pink salmon spawning in this system is now considered to be virtually extinct.²¹



Lorenzetta Creek (00-0736)



♦Farming (dairy) is predominant in the lower reach, and farmers along the lower 2 km have removed riparian vegetation.⁴



♦5% of the total watershed has been logged, and no additional harvesting is proposed.



♦The naturalized summer 7-day mean low flow is 23% of the mean annual flow. The creek often goes dry during droughts when flows are sub-gravel.⁴



♦The potential August water demand for domestic and industrial uses is <1% of the naturalized summer 7-day mean low flow. DFO opposes any further withdrawals.⁵

♦**Other:** The creek has a very flashy hydrologic regime. Channel instability and flooding have resulted from sediment accumulation on the fan.⁴ Gravel is removed by the Province even though the area is used for spawning.



Mahood Creek (00-0740)



♦There are no records for logging on Crown land but there is private harvesting in the watershed.⁶



♦The naturalized summer 7-day mean low flow is 32% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** Flooding and erosion are the main problems. Heavy siltation occurs downstream in Johnson Slough.¹⁷



Ruby Creek (00-0750)



◆2% of the total watershed has been logged recently, and 5% is proposed for harvest. Previous logging contributed to scouring of gravels during freshets.¹⁷



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



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

◆**Other:** The stream is prone to flash floods and extreme peak flows.¹⁷ The Ruby Creek fan is expanding into the Fraser River and provides excellent spawning gravel. Interest has been expressed in gravel removal.¹⁷



Hunter Creek (00-0760)



◆Agricultural activity is minimal.¹⁴



◆16% of the total watershed has been logged, and 3% is proposed for harvest.



◆The naturalized summer 7-day mean low flow is 23% of the mean annual flow.



◆The potential August water demand for domestic and waterworks use is <1% of the

naturalized summer 7-day mean low flow.

◆**Other:** Erosion, silting and scouring are reported problems.⁵



Silverhope Creek (00-0790)



◆The Municipality of Silver Creek is present but not enough information was available to assess the effect it may have on water quality.



◆Irrigation licenses indicate that agricultural activity is present in the watershed. The extent of agriculture is minimal.¹⁴



◆5% of the total watershed has been logged, and 1% is proposed for harvest.



◆The naturalized summer 7-day mean low flow is 23% of the mean annual flow.



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

◆**Other:** The creek streambed is very mobile, and has accumulated about 1 meter of gravel near the bridges crossing the creek since the 1960's.⁴ Stream bank erosion also occurs.



6.6 References

- 1 Quadra Planning Consultants, Ltd. 1995. Protection of aquatic and riparian habitat by local governments: Measures adopted in the Lower Fraser Valley. Prepared for Fraser River Action Plan, Department of Fisheries and Oceans and Environment Canada. 37 p. + appendices.
- 2 Phil Wong, Fraser Pollution Abatement Office, Environment Canada, Vancouver, B.C., personal communication.
- 3 Dayton & Knight Ltd. 1994. District of Hope sewage treatment study. DOE-FRAP 1994-12.
- 4 Rood, K.M. and Hamilton. 1995. Hydrology and water use for salmon streams in the Chilliwack/Lower Fraser Habitat Management Area, British Columbia. Manuscript Rep. Fish. Aquat. Sci. 2288:236 p.
- 5 Department of Fisheries and Oceans. 1990. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 29E Chilliwack. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 6 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 29D Mission. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 7 Berka, C.S. 1996. Relationships between agricultural land use and surface water quality using a GIS: Sumas River Watershed, Abbotsford, B.C. M.Sc. Thesis, Resource Management and Environmental Studies, The University of British Columbia, Vancouver, B.C. 174 p.
- 8 Whyte, I.W. 1988. An evaluation of livestock-related impacts in Lower Fraser Valley streams. Prepared for Habitat Section, fish and Wildlife Branch, B.C. Ministry of Environment and Parks.
- 9 Swain, L.G. and G.B. Holms. 1985. Fraser-Delta Area. Fraser River sub-basin from Hope to Kanaka Creek water quality assessment and objectives. Technical Appendix. Water Management Branch, Ministry of the Environment, Province of British Columbia. 193 p.
- 10 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Sumas River Watershed - Summary report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada and Department of Fisheries and Oceans.

- 11 Hutton, K. 1987. Lower Fraser Valley agricultural waste management survey. Prepared for the Ministry of Environment and Parks. 46 p. + appendices.
- 12 Schreier, H. 1987. Asbestos fibres introduce trace metals into streamwater and sediments. *Environmental Pollution*. 43:229-249.
- 13 L. Nikl, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.
- 14 B. Locken, Agricultural Impact Officer, Ministry of Environment, Lands, and Parks, Surrey, B.C., personal communication.
- 15 Department of Fisheries and Oceans, unpublished data.
- 16 K. Hutton, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.
- 17 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Harrison Habitat Management Area, British Columbia. Manuscript Rep. Fish. Aquat. Sci. 2293:184 p.
- 18 Elliot, B. and N. Guppy. In press. On the edge: Demographic change in the Lower Fraser Basin. Working paper, Lower Fraser Basin Eco-Research Project, University of British Columbia, 1995. Forthcoming in: M. Healey (ed.). Sustainability and human choices in the Lower Fraser Basin: Resolving the dissonance. Vancouver: UBC Press.
- 19 IRC Integrated Resource Consultants Ltd. 1994. Agricultural land use survey in the Matsqui Slough watershed. Summary Report. DOE-FRAP 1994-22.
- 20 O. Langer, Department of Fisheries and Oceans, Vancouver, B.C., personal communication.
- 21 Hartman, G.F. and M. Miles. 1997. Jones Creek spawning/rearing channel project: Post failure analysis. Prepared for Fraser River Action Plan, Fisheries and Oceans Canada, Vancouver, B.C.

Table 6.2.3 Summary of Permit Conditions That Need to be Revisited in the Chilliwack HMA.

Permit #	Facility	Waste Type	Receiving Water Body	Parameter	Daily Load	Maximum Discharge	Maximum Flow	Comments
P04608	Evaporated Milk Plant at Abbotsford	2	Trib. of Marshall Crk.	Temperature		23 °C	2,300 m ³ .d ⁻¹	Warm discharge to low-flow stream
P00039	Chilliwack, BC STP	4	Fraser River	Resid. Chlorine Ammonia		0.1 - 1.0 mg·L ⁻¹ *27.8 mg·L ⁻¹	45,000 m ³ .d ⁻¹ 45,000 m ³ .d ⁻¹	Chlorine concentration should not exceed 0.05 mg·L ⁻¹ Ammonia concentrations may be toxic to fish.
P00137	STP at Agassiz	4	Fraser River	Ammonia Coliforms Chlorine		* 31.0 mg·L ⁻¹ *240,000 MPN·100mL ⁻¹ 0.5-1.0 mg·L ⁻¹	3,300 m ³ .d ⁻¹ 3,300 m ³ .d ⁻¹ 3,300 m ³ .d ⁻¹	High concentration of chlorine
P02234	Compressor Station at Rosedale	2	Fraser River; Ferry Slough	Temperature		27 °C	4,000 m ³ .d ⁻¹	Although measured temperature never exceeded 18°C discharge volume is typically 10 times the permitted limit. This is a large volume of warm water to discharge to a slough, and may be contaminated with other substances.
P04125	STP AT Silverhope Creek	4	Fraser River	Residue Nonfilt. BOD	681.9 kg·d ⁻¹ 681.9 kg·d ⁻¹	100 mg·L ⁻¹ 100 mg·L ⁻¹	6,819 m ³ .d ⁻¹ 6,819 m ³ .d ⁻¹	Permitted concentrations of BOD and NFR are high.
P07886	Cheam View Trout Farm - Chilliwack	1	Ditch - Hope Slough/Elm Creek	BOD	54.5 kg·d ⁻¹	10 mg·L ⁻¹	5,450 m ³ .d ⁻¹	High BOD loading to a low-flow system. Effluent data show that concentrations of BOD, suspended solids, ammonia, and phosphorous have all exceeded permit specifications by significant amounts.
P01726	Fish Hatchery at Abbotsford	1	Lonzo Creek	BOD Phosphate-Soluble	150 kg·d ⁻¹ 7.5 kg·d ⁻¹	10 mg·L ⁻¹ 0.5 mg·L ⁻¹	15,000 m ³ .d ⁻¹ 15,000 m ³ .d ⁻¹	High BOD loading to a low-flow system. High phosphorous system to a low-flow system
P01684	Fraser Valley Foods, Processing Plant at Sardis	2	Atchelitz Creek	Temperature		24 °C	1,930 m ³ .d ⁻¹	Large volume of warm water to a low-flow system (discharge could be as much as 25% of flow volume in summer)

* measured values; restrictions for these parameters are not included in the waste discharge permits.

NOTE: Effluent data referred to here are reported in Reference #9, of Chapter 6

Chapter 7 Harrison-Lillooet Habitat Management Area

7.1 Background

The Harrison-Lillooet HMA is 8,400 km² in area and lies primarily in the Coast Mountains. A small area at the southern tip of the HMA adjacent to the Fraser River lies within the Fraser Lowland. The area is sparsely populated; less than 3,000 people reside in the HMA.

7.1.1 Hydrology

Annual precipitation ranges from 1,100 to 2,000 mm, much of which falls during the winter as snow or rain. The hydrology of the HMA is dominated by two different climate regimes:

1. Melting snowpack and glaciers result in peak flows during May and June and relatively high flows for the remainder of the summer in most tributaries upstream from Lillooet Lake.¹ Low flows occur in February when glaciers are not melting and precipitation falls mostly as snow. This pattern is also observed in the Lillooet River downstream from Lillooet Lake, although Lillooet Lake has a moderating influence.

2. For streams draining the southern half of the HMA, peak flows generally occur in late fall in response to the heavy rains.¹ Low flows typically occur in the late summer, particularly in the smaller watersheds.

The Lillooet River was significantly modified following a major flood in 1940; a program of dyking and river straightening was undertaken upstream from the confluence of the Ryan River tributary. As a result the Lillooet was shortened by about 17 km.¹ The river is now constrained by dykes along much of its length between Pemberton Meadows and Pemberton.

7.1.2 Fish

There are thirty-nine documented salmon-bearing streams in the Harrison-Lillooet HMA providing spawning and/or rearing habitat for all five species of anadromous Pacific salmon that return to the Fraser Basin.¹ The Harrison River supports the largest chinook, chum, coho runs and the third largest pink stock in the Fraser Basin.²⁻⁶ Chinook,⁷ chum and pink begin their seaward migration virtually immediately after emergence, while coho and sockeye remain in the lakes and small side channels from several months to two years, with considerable variation among stocks.

7.1.3 Predominant Land Uses

There are two main urbanizing areas in the HMA. They are located at the south end of Harrison Lake in the Harrison Mills/Hot Springs area and at the north end of Lillooet Lake in the Pemberton/Mount Currie area. Both areas support populations of approximately 1,000 each.⁸ The Resort Municipality of Whistler drains mostly to the Squamish River system, however, a portion of Whistler

North drains to the Harrison-Lillooet HMA via the Green River.

Timber harvesting and agriculture are the main land uses in the HMA. Other industry is limited and mostly related to logging. A pumice mine recently began operation near the Meager Creek area, however, it is relatively small. There has been some relatively recent mining exploration work in the Lower Lillooet River, most notably in the area by Billygoat Creek and at the north end of Harrison Lake in the Douglas Creek area.¹⁷

As a whole, the HMA supports high recreational values, and is a popular destination for hiking and back-country skiing. Garibaldi Park and the Whistler resort draw many people to the Pemberton area. Hot springs in the Meager Creek area have also attracted many visitors. Harrison Hot Springs is a well-established resort area and has an important tourism industry.



7.2 Point Sources of Contaminants

7.2.1 Urban/Industrial Point Source Discharges to Surface Water

There are four permitted discharges of treated sewage effluent within the Harrison-Lillooet HMA (Table 7.2.1). Two are located at the south end of Harrison Lake (Figure 7.2.1). The Harrison Hot Springs STP discharges to Harrison Lake and the Hemlock Valley Resort STP discharges to Disposal Creek, a tributary of Maisal Creek in the Chehalis watershed. The other two STPs are just north of Lillooet Lake and service the towns of Pemberton and Mount Currie. The BOD and nonfilterable residue loading from these facilities is relatively small (Table 7.2.2).

There are no permitted discharges of industrial effluents to surface waters in the HMA.

7.2.2 Permitted Discharges to Ground

There is only one permitted discharge to the ground in the Harrison-Lillooet HMA. STP effluent is discharged by a campground near Harrison Bay.



7.3 Non-Point Sources of Contaminants

Diffuse, non-point sources of contaminants put water quality at risk in some of the salmon-bearing streams of the Harrison-Lillooet HMA.

7.3.1 Urban Development

The majority of the less than 3,000 people who live in the HMA are concentrated in Harrison Mills at the south end of Harrison Lake and in the Pemberton/Mount Currie area at the north end of Lillooet Lake. The Pemberton/ Mount Currie area is rapidly growing with spill-over from the Whistler area. Urban development

has already resulted in the loss of some riparian vegetation and encroachment on the flood plain and in several areas walls built for flood protection encroach on streams.¹ There are also reports of septic tanks leaching into nearby streams in the Pemberton area.¹

New development will result in sedimentation of streams, disruption of natural hydrology, and increased urban stormwater runoff and sewage discharges. A housing development near Whistler is seeking permission to dispose of domestic sewage into the Green River. If this occurs it will open another avenue for development in the Whistler area, and further potential for degradation of tributaries to the Lillooet system. Growth of Whistler is currently constrained by the capacity of the existing sewage treatment plant.

There are two golf courses bordering on the Green River near the north end of Lillooet Lake, which service the local population and attract tourists. One recently requested a permit to discharge sewage effluent to surface waters, but the request was denied.

7.3.2 Agriculture

Agriculture, including vegetable crop production and livestock operations have led to dyking, removal of riparian vegetation, and streambank erosion on the Birkenhead River, Pemberton, Ryan, Arndt and Miller Creeks and Salmon Slough.⁹ DFO staff have observed generally poor stewardship practices around ditches in the Pemberton Meadows area.¹⁷ Cattle have been observed wandering among spawning sockeye in the lower Birkenhead River. Runoff from cattle holding areas is likely having localized effects on water quality in the Lillooet River and tributaries between Pemberton Meadows and the north end of Lillooet Lake. Pesticide use may be of concern where fields used for crop production encroach on streams, and ditches drain runoff water from fields to fish-bearing streams. In the southern portion of the HMA, agricultural inputs are causing nutrient enrichment and eutrophication of Miami Creek.¹

7.3.3 Timber Harvesting

Most of the valuable timber in the Lillooet watershed is below 1,200 m in elevation, and only 20 to 30% of the watershed contains timber suitable for harvest.¹ Logging is extensive, however, and some forest harvesting has occurred in most of the side valleys. With the exception of the valleys encompassed by Garibaldi Provincial

Park, only three unlogged valleys of significant size remain:

1. Douglas Creek, at the north-east tip of Harrison Lake;
2. Sockeye Creek, which flows into Birkenhead Lake; and,

3. The Upper Lillooet, including the headwaters of the Upper Lillooet and Elaho Rivers.

Most logging occurs upstream of the limit of salmon migration, however, downstream effects on water quality and fish habitat are not uncommon.⁹ Poor road construction in the Upper Lillooet has resulted in blocked culverts which impede fish migration. In other areas logging debris and gravel from destabilized banks have resulted in unstable flows.¹⁰ The construction and maintenance of logging roads has caused siltation in some streams.¹

MELP has been working pro-actively with the communities of Pemberton and Mount Currie on watershed restoration projects using Forest Renewal funds. Projects focus on restabilizing stream banks disrupted by past forestry activities. Candidate streams were evaluated based on their potential to benefit fish populations, and prioritized accordingly for restoration work. Restoration efforts begin in the summer of 1997.



7.4 An Overview of Water Quality Conditions

The two main natural factors influencing water quality in the Harrison-Lillooet HMA are geological formations and the glaciers in the headwaters of the Lillooet River and many tributaries.

The Lillooet River mainstem is a division between two different geological formations.¹¹ The influence of the bedrock geology on water quality is evident; northeast of the Lillooet River stream pH values are usually basic, while on the southwest side of the mainstem many streams are slightly acidic.

The Lillooet River originates from the Lillooet Glacier, and is consequently laden with glacial silt. It is most turbid during the summer months (51-54 NTU) when it carries large volumes of glacial meltwater. The Lillooet River downstream from Lillooet Lake is much less turbid in comparison (12 NTU), indicating that much of the glacial flour is settling out in the lake.

The Green River is generally clear during the summer because Green Lake settles out much of the glacial flour contributed by Fitzsimmons Creek. Turbidity increases in winter months; this has been attributed to land disturbance in the watershed (primarily urban development in the Whistler area), that would contribute to elevated turbidity during storm events.¹¹

The Birkenhead River is extremely clear with NTU usually in the range of 2. It does not receive any glacial inputs.

Site-specific water quality assessments, and influencing factors and supporting data (Table 7.4.1) are provided in Section 7.5 on a stream-by-stream basis.



7.5 Measured Water Quality Conditions and Stream Assessments

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 Harrison-Lillooet HMA is provided here. Summary tables of:

- ◆ land use areas, stream flow, and water demand information for each salmon stream (Table 7.5.1)
- ◆ red-coded indicators for each salmon stream (Table 7.5.2)
- ◆ surface water and sediment data (Table 7.4.1)

are provided for quick reference. The assessment of surface water, sediment and fish tissue quality is also summarized in Figure 7.5.1.

Water quality conditions were assessed using a database compiled through DFO and DOE and the data were categorized according to the criteria outlined in the Methodology section. Additional information was included where available, but it did not influence the outcome of the category rating.

Assessments of potential effects on water quality from urban development, agriculture, forestry, low stream flows, and water demand were based upon information provided in a series of hydrology reports by Rood and Hamilton, and/or SISS catalogues, unless otherwise indicated. Assessment criteria are described in the Methodology section of this report.



Harrison River (01-0000-000-000-000-993)

◆**Other water quality data:** Continuous temperature monitoring near the mouth of the river (at the south end of Harrison Bay) from 1988 to 1993 show that maximum July and August stream water temperatures often exceed 20°C.¹²



◆Urban development is located mostly in the area of Harrison Mills. There is no indication of whether it is affecting water quality of nearby streams or Harrison Lake.



◆Some agricultural activity is present, mostly in the lower reaches between the southern end of Harrison Lake and the Fraser River.



◆7% of the total watershed has been logged, including 4% from recent or proposed harvesting.



◆The naturalized summer 7-day mean low flow is 44% of the mean annual flow. Large lakes upstream help to stabilize flows.



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

◆**Other:** The river downstream of Harrison Lake is gravel bedded, straight and confined by bedrock up-

stream of Chehalis Village. The lower portion of river has been dredged to maintain a navigation channel.¹



Squakum Creek (01-0100)



◆Sewage discharges and septic fields from homes and cottages around Errock Lake affect water quality in the lake and in Squakum Creek, which drains the lake to Harrison Bay.¹



◆The naturalized summer 7-day mean low flow is 9% of the mean annual flow. Low flows occur during spawning.¹³



◆No water licenses have been issued.

◆**Other:** The upper tributaries to Errock Lake move large quantities of sediment and debris. The lower portions downstream are channelized to prevent flooding. Mosquito spraying may affect water quality.¹³



Chehalis River (01-0400)



◆The only sampling station in this watershed was on Disposal Creek. Data for between 3 and 7 measurements of nutrient, coliform, and basic physical parameters were available. No parameters exceeded guidelines/80th percentile levels except one temperature measurement, which was 15°C.



◆32% of the total watershed has been logged including 9% from recent or proposed harvesting. Logging is extensive in the upper watershed.



◆The naturalized summer 7-day mean low flow is 14% of the mean annual flow.



◆The potential August and September water demand for industrial use is less than 1% of the naturalized summer 7-day mean low flow.

◆**Other:** The river is laterally and vertically unstable with previous channel changes on its fan. The slow aggradation of the channel bed results in sub-surface flows during dry periods and necessitates gravel removal to maintain surface flow.¹ Dykes have been built to protect areas from flooding.



Pretty Creek (01-0400-020)



◆5% of the total watershed has been logged recently, and 5% is proposed for harvest.



◆The naturalized summer 7-day mean low flow is 7% of the mean annual flow. The stream has a flashy hydrologic regime.¹³



◆The potential August and September water demand for industrial use is 2% of the naturalized summer 7-day mean low flow.





Creek (01-0400-080)

♦3% of the total watershed has been logged recently, and 4% is proposed for harvest. Some siltation results from logging roads.¹³



♦The naturalized summer 7-day mean low flow is 7% of the mean annual flow. Summer flows are considered stable because it is ground-water-fed, however, occasional low flows have been reported.¹³



♦No water licenses have been issued.

♦**Other:** A forestry camp site is located near the creek mouth. SEP constructed a groundwater-fed spawning channel in the upper reaches of the creek.



Statlu Creek (no SISS #)



♦40% of the total watershed has been logged, including 12% from recent or proposed harvesting.



♦No information was available to assess stream flow.



♦No information was available to assess water demand.



Morris Creek (01-0500)



♦Water licenses indicate some development, however, there was not enough information to assess any effects on water quality.



♦1% of the total watershed has been logged recently and there is no proposed harvesting (to 1998).



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦The potential August and September water demand for domestic, waterworks and industrial uses is 8% of the naturalized summer 7-day mean low flow. There is a large volume of water storage and no irrigation demand.

♦**Other:** The creek is more like a slough, and has been used as a log dump.¹



Weaver Creek (01-0500-010)



♦Water licenses indicate that some development is present, however, there was not enough information to assess the effect on water quality.



♦1% of the total watershed has been logged, and there is no further proposed harvesting (to 1998). Logging has caused heavy input of gravel and logging debris into the creek, and has resulted in unstable flows.¹³

♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. Low flows are at times augmented when the spawning channel at Weaver is open but a low flow problem still exists.¹



♦The potential August and September water demand for domestic, waterworks and industrial uses is 6% of the naturalized summer 7-day mean low flow. There is a large volume of water storage and no irrigation demand.

♦**Other:** Development of the Hemlock Valley Ski Resort at the head of the Sakwi Creek tributary has resulted in heavy inputs of gravel and logging debris into the creek. The creek has been dredged annually for a number of years below Hudon Bridge to maintain access to the Weaver Creek Spawning Channel.¹ The spawning channel was developed to offset damage caused from sediment loads.



Steelhead Creek (01-0500-010-005)



♦The naturalized summer 7-day mean low flow is 5% of the mean annual flow. The stream has a flashy hydrologic regime.¹³



♦No water licenses have been issued.



Sakwi Creek (01-0500-010-010)



♦Licensed irrigation withdrawals suggest the presence of some agricultural land use, however, there was not enough information to assess the implications for water quality.



♦3% of the total watershed has been logged, and there is no proposed harvesting (to 1998). Operations have caused a heavy input of gravel and logging debris into Sakwi and Weaver Creeks.¹ The north part of the creek was logged prior to 1963 and caused extensive erosion.



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. Some of the flow is diverted for the Weaver Creek spawning channel.¹



♦The potential August water demand for irrigation and waterworks uses is 24% of the naturalized summer 7-day mean low flow.

♦**Other:** Development of the Hemlock Valley Ski Resort has caused heavy input of gravel and logging debris into this major tributary of Weaver Creek.¹



East Creek (01-0500-015)



♦The naturalized summer 7-day mean low flow is 7% of the mean annual flow. The creek has a flashy hydrologic regime.



♦No water licenses have been issued.



Miami Creek (01-0600)



♦The Village of Harrison Mills is located in the watershed. There is a lack of riparian vegetation along the creek in the lower reaches.¹



♦Nutrients from agricultural activity cause eutrophication and chronic weed growth.¹ Excessive growth is cut back and removed. The upper reaches have been ditched and are treated as a field drainage system.



♦The naturalized summer 7-day mean low flow is 11% of the mean annual flow.



♦The potential August water demand for domestic and irrigation uses is <1% of the naturalized summer 7-day mean low flow.

♦**Other:** There is a sluice gate and a pumphouse at the mouth.



Trout Lake Creek (01-0700)



♦A subdivision adjacent to the lower reach has insufficient setbacks and walls have been built along the creek to prevent flooding of residential properties.¹



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow.



♦The potential August and September water demand for domestic and industrial use is 44% of the naturalized summer 7-day mean low flow.

♦**Other:** The creek moves a large bedload and the channel is aggrading and delta building.¹ MoTH regularly removes gravel from beneath their bridge. One upper tributary is prone to debris flows.



Bear Creek (no SISS #)



♦30% of the total watershed has been logged, 14% recently logged. There is no proposed harvesting.



♦No information was available to assess stream flow.



♦No water licenses have been issued.



Mystery Creek (01-1500)



♦53% of the total watershed has been logged, including 46% from recent activity. 29% is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 8% of the mean annual flow. The creek is

prone to flash flooding.



♦No water licenses have been issued.



Cogburn Creek (01-1600)



♦8% of the total watershed has been logged, including 7% from recent activity. 4% is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 33% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** Aerial spraying of herbicide on forestry land occurred in 1986.¹³



Twenty Mile Creek (01-0700)



♦10% of the total watershed has been logged recently, and 1% is proposed for harvest.



♦The naturalized summer 7-day mean low flow is 7% of the mean annual flow. The stream dries up in the summer.¹³



♦No water licenses have been issued.

♦**Other:** Aggradation is occurring. A large quantity of coarse sediment is transported onto the creek fan. MoTH regularly cleans debris from under their bridge.¹



Big Silver Creek (01-6800)



♦24% of the total watershed has been logged, including 15% from recent or proposed harvesting. Forest companies want to begin logging the lower watershed but plans are opposed by DFO.¹



♦The naturalized summer 7-day mean low flow is 33% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The main flow was diverted from the east to the west channel to take advantage of good spawning gravel.¹



Stokke Creek (01-2300)



♦16% of the total watershed has been logged, including 8% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 33% of the mean annual flow.



♦No water licenses have been issued.





La Creek (01-2500)

♦A logging camp is located at the mouth, and implications for water quality are unknown.



♦3% of the total watershed has been logged recently, and there is no proposed harvesting (to 1998).



♦The naturalized summer 7-day mean low flow is 25% of the mean annual flow.



♦No water licenses have been issued.



Douglas Creek (01-2600)



♦1% of the total watershed has been logged recently, and 1% is proposed for harvest. Skidder activity has caused severe slumping and logging in the 1960's left the stream unstable for several years.¹³



♦The naturalized summer 7-day mean low flow is 33% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** The lower section has been channelized. This unstable system is prone to flash floods.¹



Purcell Creek (01-2650)



♦There was a large logging camp located by the creek in 1987 and implications for water quality are unknown.



♦The naturalized summer 7-day mean low flow is 32% of the mean annual flow.



♦No water licenses have been issued.



Lower Lillooet River (01-0000-000-000-000-000-991)

(from Lillooet Lake to Harrison Lake.)



♦Three of seven dissolved oxygen values were below the guideline. There were not enough data at the lake station to assess sediment quality.



♦Water licenses indicate that some development is present, but implications for water quality are unknown.



♦4% of the total watershed has been logged, including 2% from recent or proposed harvesting. There is logging throughout the watershed but little along the mainstem.



♦The naturalized summer 7-day mean low flow is 38% of the mean annual flow.

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



Sloquet Creek (01-2700)

♦3% of the total watershed has been logged, including 1% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 25% of the mean annual flow.



♦No water licenses have been issued.



♦**Other:** Placer mining is present. The stream is unstable and subject to heavy scouring.¹³ Anglers have suggested that increased logging and streambank instability during freshets may be contributing to the decline of steelhead trout populations.¹⁴



Snowcap Creek (no SISS #)

♦**Other water quality data:** Dissolved oxygen values ranged between 9 and 11 mg-L⁻¹.¹⁵

♦The watershed has been clearcut logged on the valley walls on both sides of the creek. Stream flow has been affected, riparian vegetation has been removed and there are sediment inputs to the stream.¹⁵ Regrowth on the western side of the valley may have mitigated some of the effects of the clear-cutting.



♦Forest harvesting has affected stream flows.



♦No water withdrawal licenses have been issued.



♦**Other:** Low densities of coho fry were observed near the mouth.¹⁶



Chief Paul Creek (no SISS #)

♦**Other:** Moderate densities of coho fry were observed near the mouth.¹⁶ No information was available to assess land use or water quality.



Unnamed tributary to Little Lillooet Lake (no SISS #)

♦**Other:** High densities of coho fry were observed near the mouth.¹⁶ No information was available to assess land use or water quality.



Kakila Creek (no SISS #)



◆ There has been significant logging in the watershed, and riparian vegetation has been removed in several locations.¹⁵



◆ No information was available to assess summer flows.



◆ No water licenses have been issued.

◆ **Other:** A few coho fry were observed near the mouth.¹⁶



Upper Lillooet River (01-0000-000-000-000-992)

(from glacier origins to the north end of Lillooet Lake)



◆ 2 of 7 dissolved oxygen values were below the guideline just upstream of the Green River confluence and 2 of 19 dissolved ammonia values exceeded the 80th percentile at the upstream station near Railroad Creek.



◆ Just upstream from Lillooet Lake, the river flows by the towns of Pemberton and Mount Currie. This area is experiencing rapid urban growth due to spill-over from the resort town of Whistler. There may be localized effects on water quality from leaking septic systems, and some riparian vegetation has been lost.¹



◆ Agricultural activity including ranching and crop production occurs throughout the 40 km upstream from Lillooet Lake. There has been extensive dyking for flood control in this area. Some concerns over agricultural runoff have been noted.



◆ 4% of the total watershed has been logged, including 3% from recent or proposed harvesting.



◆ The naturalized summer 7-day mean low flow is 38% of the mean annual flow. The glacial origins provide cool and naturally turbid water through the summer months.



◆ 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.

◆ **Other:** Gravel accumulation occurs in the main river and tributaries, and there is pressure from industry for gravel removal. The main channel has been straightened, dyked, and moved to the west side of the valley upstream of the Ryan River confluence. This straightening shortened the river by about 17 km.¹



Birkenhead River (01-4100)



◆ Four of seven dissolved oxygen values were below the guideline, two temperature measurements exceeded the guideline and three of nineteen ammonia measurements exceeded the 80th percentile. Not enough data were available at the

Birkenhead Lake station to assess water quality. The Birkenhead has generally clear water.

◆ **Other water quality data:** Continuous temperature data near the mouth from 1986 to 1991 show that maximum stream water temperatures can exceed 15°C from June to August.¹² In general, upstream of the agricultural area water quality is expected to be good.



◆ There is some residential development in the lower reaches but no indication of implications for water quality. The Duffy Lake Road encroaches on the river in the lower reaches.



◆ Agriculture is likely affecting water quality in the lower reaches of the Birkenhead. Cattle have been observed wandering into the creek while salmon are spawning, and are causing significant stream bank erosion. Riparian vegetation has been removed from much of the agricultural area.



◆ 2% of the total watershed has been logged, including 2% from recent or proposed harvesting.



◆ The naturalized summer 7-day mean low flow is 37% of the mean annual flow.



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

◆ **Other:** Mining exploration was occurring in the 1980's¹⁰ but there are no producing mines in the watershed. Birkenhead Lake is located in a provincial park.



Mount Currie Slough and Ditch near Mount Currie (no SISS #)



◆ Urban runoff may affect water quality.



◆ Agricultural runoff may affect water quality.

◆ **Other:** Coho were observed in both the Slough and a nearby ditch.¹⁴ No stream flow or water demand information was available.



Poole Creek (01-4100-070)



◆ Licensed irrigation withdrawals indicate some agricultural development is present, however, there was not enough information to assess implications for water quality.



◆ 1% of the total watershed has been logged recently, and 1% is proposed for harvest.



◆ The naturalized summer 7-day mean low flow is 37% of the mean annual flow. Flow problems in the upper watershed have been reported.



◆ The potential August water demand for domestic and irrigation uses is 1% of the

naturalized summer 7-day mean low flow.



Green River (01-4300)



♦2 of 19 pH measurements were below the guideline at both stations. Three of nineteen dissolved ammonia values exceeded the 80th percentile but not the 30-day criteria for total ammonia.

♦**Other water quality data:** Water quality data show that TSS and conductivity increase in the winter. This may be due to urban stormwater runoff contributed by Fitzsimmons Creek, which drains the Whistler North area.¹¹



♦The Whistler-Blackcomb ski complex is located in the headwaters. It mostly drains to the Squamish watershed, however, the Whistler-North area drains to the Green River. Whistler has proposed a sewage effluent discharge to the Green River.¹



♦4% of the total watershed has been logged, including 3% from recent or proposed harvest.



♦The naturalized summer 7-day mean low flow is 36% of the mean annual flow.



♦The potential August and September water demand for domestic, waterworks and industrial uses is 2% of the naturalized summer 7-day mean low flow. Some demand for industrial use is from license applications not yet approved.

♦**Other:** A golf course has recently been developed just upstream from the confluence with the Lillooet River. Industrial and housing developments could also affect the river.



Pemberton Creek (01-4400)



♦Nine of twelve pH measurements were below the guideline. ★These results likely reflect the influence of the surficial geology. Ammonia concentrations were low at the two sites sampled.



♦Pemberton Village is located near the mouth. The creek has been dyked in the lower reaches. There is a new townhouse development next to the creek at Hwy. 99.



♦There is some agricultural development in the lower reaches. Not enough information was available to assess its effect on water quality.



♦2% of the total watershed has been logged recently, and there is no proposed harvesting (to 1998).



♦The naturalized summer 7-day mean low flow

is 33% of the mean annual flow.



♦The potential August and September water demand for waterworks and industrial uses is 11% of the naturalized summer 7-day mean low flow.

♦**Other:** The creek is a flashy system with cold temperatures. There is a conflict between landowners and DFO concerning flood control and erosion protection.



Miller Creek (01-4500)



♦Agricultural development is located in the lower reaches. Extensive dyking is present.¹⁰



♦2% of the total watershed has been logged, including 1% from recent activity. There is no proposed harvesting (to 1998).



♦The naturalized summer 7-day mean low flow is 32% of the mean annual flow.



♦The potential August water demand for domestic, irrigation and industrial uses is 2% of the naturalized summer 7-day mean low flow.

♦**Other:** The substrate in the creek includes lots of fine sediments.¹ Coho production appears to have declined.



Ryan River (01-4600)



♦One of five dissolved oxygen values was below the minimum guideline.



♦Agricultural development is present in the lower reaches where the river flows parallel to the Lillooet River. Dyking has stabilized the stream. Not enough information was available to assess the effect of these activities on water quality.



♦7% of total watershed has been logged, including 3% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 32% of the mean annual flow.



♦The potential August water demand for domestic and irrigation uses is <1% of the naturalized summer 7-day mean low flow.

♦**Other:** Aggradation has resulted in a small fan where the river enters the Pemberton valley. Two small creeks entering downstream of the fan are subject to debris torrents.¹



McKenzie Creek (01-4620)



♦Logging occurred between 1975 - 1989. No recent information is available.

♦**Other:** Pesticides were applied to forested land prior to 1989;¹⁰ no more recent information is available.



Ditch through Pemberton Meadows (no SISS #)

♦**Other:** Salmon fry were observed in 1994.¹⁴ No information was available to assess water quality or land use, although agriculture is predominant in this area.



Salmon Slough and Kerstead Creek (no SISS #)

♦**Other:** Kerstead Creek, which flows through Salmon Slough, supports populations of coho and chinook.¹⁴ Salmon Slough provides excellent spawning habitat for coho. No information was available to assess land uses in the watershed.



Salmon Creek (01-4820)

♦**Other:** No information was available to assess land use or water quality.



Sloughs to North and South of South Creek (no SISS #)

♦**Other:** The sloughs provide excellent coho and chinook habitat.¹⁴ No information was available to assess land use or water quality.



Railroad Creek (01-5000)



♦40% of the total watershed has been logged, including 4% from recent or proposed harvesting. Logging began in 1969.



♦The naturalized summer 7-day mean low flow is 37% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** Regeneration from older logging cuts may mitigate some effects of logging on flows. Crossing construction has caused material to slide into the creek.¹⁰



Samson Creek (01-5050)



♦7% of the total watershed has been logged, including 6% from recent or proposed harvesting.



♦The naturalized summer 7-day mean low flow is 36% of the mean annual flow.



♦No water licenses have been issued.

♦**Other:** Shifting of the Lillooet River has caused Samson Creek to become a tributary of Railroad Creek.



7.6 References

- 1 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Harrison Habitat Management Area, British Columbia. Can. Manusc. Rep. Fish. Aquat. Sci. 2293.
- 2 Department of Fisheries and Oceans. 1995. Fraser River chinook salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 24 p.
- 3 Department of Fisheries and Oceans. 1996. Fraser River chum salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 22 p.
- 4 Department of Fisheries and Oceans. 1996. Fraser River coho salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 20 p.
- 5 Department of Fisheries and Oceans. 1995. Fraser River pink salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 19 p.
- 6 Department of Fisheries and Oceans. 1995. Fraser River sockeye salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 55 p.
- 7 Healey, M. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). In: C.Groot and L. Margolis (eds.). Pacific Salmon Life Histories. UBC Press, Vancouver, B.C. p. 313-393.
- 8 BC Stats. 1995. BC Stats Population Section, Release: November, Issue: 95-2.
- 9 Ionson, B. 1995. Habitat enforcement report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.
- 10 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 28B Squamish. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

- 11 Moore, B. and L. Freyman. In preparation. Lillooet River Water Quality Report 1994-1996. Can. Manuscr. Rep. Fish. Aquat. Sci.
- 12 Department of Fisheries and Oceans, unpublished data. T. Whitehouse, Vancouver, B.C.
- 13 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 29D Mission. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.
- 14 Tobe, E.B. 1996. Stream Data Compilation and Update for the Harrison Habitat Management Area (Lillooet River Watershed). Prepared for the Department of Fisheries and Oceans. Unpublished report.
- 15 Ministry of Environment, Lands and Parks. In preparation. Assessment of the Lillooet River Watershed. Unpublished report. L. Freyman, Ministry of Environment, Lands and Parks, Surrey, B.C.
- 16 Ministry of Environment, Lands and Parks. 1993. Stream Survey Summaries for the Lillooet River Watershed. Surrey, B.C. Unpublished data.
- 17 D. Hughes, Department of Fisheries and Oceans, Squamish, personal communication.

Table 7.4.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Harrison-Lillooet HMA (see *Chapter 3 Methodology* for guidelines)

		n	# > Guide- line*	# < MDL	Min	Max	Mean
<u>Disposal Cr 400M U/S Maisal Cr</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	3	0	0	10.3	12.7	11.6
	Temperature (°C)	5	1	0	1.5	15	8.12
	pH (pH units)	7	nd	0	6.4	7.5	7.1
	Nonfilterable Residue (mg/L)	5	nd	0	1	19	5.6
	Fecal Coliforms (MPN/100 mL)	6	0	3	1	20	5
	Dissolved Ammonia-Nitrogen (mg/L)	5	0	3	0.005	0.006	0.005
	Total Phosphorus (mg/L)	7	0	1	0.005	0.026	0.009
<u>Lillooet River d/s Lake</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	7	3	0	4.6	10.5	9.2
	pH	17	2	0	5.9	7.4	7.0
	Temperature (°C)	12	1	0	4	15.5	10.5
	Dissolved Ammonia-N (mg/L)	17	0	13	0.005	0.007	0.007
<u>Lillooet Lake</u>							
<i>Sediments</i>	Total Chromium (µg/g)	1	1	0	26	26	26
	Total Copper (µg/g)	1	1	0	63	63	63
	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	98	98	98
<u>Lillooet R. u/s Green R. (Reference 11)</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	7	2	0	7.2	12.6	10.3
	pH	7	0	0	6.9	7.4	7.2
	Temperature (°C)	7	0	0	9	10	9.6
	Dissolved Ammonia-N (mg/L)	7	1	6	0.020	0.020	0.020
<u>Upper Lillooet R. (Reference 11)</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	7	1	0	7	11.3	10.2
	pH	19	0	0	6.5	7.4	7.1
	Temperature (°C)	12	0	0	0	12	6.8
	Dissolved Ammonia-N (mg/L)	19	2	16	0.006	0.029	0.015
<u>Birkenhead River near Mouth (Reference 11)</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	7	4	0	7.2	10	8.7
	pH	19	0	0	6.5	7.3	7.0
	Temperature (°C)	14	2	0	1	16	10.1
	Dissolved Ammonia-N (mg/L)	19	3	13	0.005	0.047	0.015
<u>Birkenhead Lake, Centre</u>							
<i>Surface Water</i>	pH (pH units)	1	nd	0	6.5	6.5	6.5
	Nonfilterable Residue (mg/L)	1	nd	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	0.006	0.006	0.006
<u>Green River at Wedge (Reference 11)</u>							

* Note that dissolved oxygen is # < guideline
MDL = method detection limit
nd = not determined

Table 7.4.1 Summary of Receiving Environment Data Used to Assess Surface Water, Sediment and Fish Tissue Quality in the Harrison-Lillooet HMA (see *Chapter 3 Methodology* for guidelines)

		n	# > Guide- line*	# < MDL	Min	Max	Mean
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	6	0	0	9.6	11.1	10.2
	pH	19	2	0	6.2	7.6	7.1
	Temperature (°C)	13	0	0	0	14.5	8.6
	Dissolved Ammonia-N (mg/L)	19	3	12	0.005	0.280	0.054
<u>Green River near Mouth (Reference 11)</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	7	0	0	9.8	12	10.7
	pH	19	2	0	6.3	7.3	6.9
	Temperature (°C)	14	0	0	0	13.5	7.7
	Dissolved Ammonia-N (mg/L)	19	2	14	0.005	0.370	0.099
<u>Pemberton Creek (d/s) (Reference 11)</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	6	0	0	10	11.4	10.6
	pH	7	0	0	6.6	7.1	6.8
	Temperature (°C)	7	0	0	11	13	12.0
	Dissolved Ammonia-N (mg/L)	7	1	3	0.005	0.013	0.009
<u>Pemberton Creek (u/s) (Reference 11)</u>							
<i>Surface Water</i>	pH	12	9	0	5.5	7.1	6.4
	Temperature (°C)	7	0	0	-2	9	3.1
	Dissolved Ammonia-N (mg/L)	12	0	10	0.006	0.007	0.007
<u>Ryan R. (Reference 11)</u>							
<i>Surface Water</i>	Dissolved Oxygen (mg/L)	5	1	0	5	11.6	8.9
	pH	7	0	0	6.7	7.2	7.0
	Temperature (°C)	7	0	0	9	11	10.2
	Dissolved Ammonia-N (mg/L)	7	1	1	0.011	0.011	0.011

* Note that dissolved oxygen is # < guideline
MDL = method detection limit
nd = not determined

Chapter 8 Key Issues and Recommended Actions

The issues and recommended actions outlined here address water quality issues identified in the four Lower Fraser Habitat Management Areas, in Chapters 4-7. 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.



8.1 Addressing Urban Development Issues

8.1.1 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 results in sedimentation of the stream bottom.

Only 7 of the 27 Lower Fraser local governments have substantial policies and regulatory measures in place to address erosion and sediment control, and another 7 have partial measures in place.¹ Of these, some rely on senior environmental agencies for monitoring and enforcement. Six rely on referrals to senior government agencies to address erosion and sediment control issues with new developments. Coquitlam has implemented a sediment control bylaw, and the cities of Port Moody, Burnaby, Maple Ridge, Abbotsford, and Vancouver are reviewing sediment and erosion control bylaws.

- 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 sediment control approaches recommended in the *Land Development Guidelines*.²
2. Presently, there is a significant duplication of effort as DFO and MELP lobby dozens of municipal governments throughout the Fraser Basin (and the rest of B.C.) to establish sediment control bylaws. 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 reduce 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. Habitat protection is much less expensive and more effective than after-the-fact habitat restoration programs, hence monitoring of development projects must be made a priority. Implementing recommendations 1 & 2 above should free up some staff time for site visits.
4. In that *Fisheries Act* enforcement is best suited to larger cases, enforcement staff must have 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, as people can only comply with environmental guidelines if they are aware of and understand the guidelines. Heavy equipment companies 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*.

8.1.2 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. A recent report concludes that most municipalities in the Lower Fraser lack substantial policies, plans, and programs to address stormwater quantity issues.¹

Recommended Actions:

1. Watershed-based master drainage plans should be required 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, can best provide leadership on stormwater management and detention issues by establishing 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 require stormwater detention for all new subdivisions, unless it is shown that runoff 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. as per *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 legal alternatives.
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 our traditional impermeable surface materials. Other opportunities such as loose-fitting storm drain pipes to allow seepage into the groundwater, and the use of French drains to keep groundwater out of the storm drain system, 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.

8.1.3 Contaminants in Urban Stormwater Runoff

The Issues:

- A. Contaminants are released as a result of many routine human activities, and accumulate on street, parking lot, and lawn surfaces. Contaminants are washed into storm sewers and ultimately streams during precipitation events, often at harmful concentrations. This will be an increasing problem as contaminant loadings and impermeable surfaces increase with population. A recent report concludes that most municipalities in the Lower Fraser lack substantial policies, plans, and programs to address stormwater quality issues.¹
- B. Stormwater outfalls are often located in sensitive areas. A recent study of 252 stormwater outfalls located in the Fraser Estuary (downstream from Kanaka Creek) used five criteria to rank the sensitivity of the receiving environment: flushing characteristics of the receiving water, discharge flow, habitat sensitivity, drainage area and land uses, and public use. Forty outfalls were considered to discharge into highly sensitive areas and 96 others were considered to present moderate environmental risk.⁴

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 storm water quality. DFO, DOE and MELP should encourage the installation of stormwater collection and detention facilities which should at least be 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 a selection of stormwater treatment methods such as artificial wetlands, bio-filtration swales, etc. need to be developed to suit particular needs.
4. DFO, DOE and MELP should work with local governments in the Fraser Delta HMA to modify or relocate the 40 stormwater outfalls identified which discharge to highly sensitive areas. This task could be coordinated by the FREMP Water Quality Management Committee.
5. Municipalities should utilize the authorities for stormwater management granted them under the *Municipal Act* to approach re-development as an opportunity to retrofit for stormwater detention. This would help alleviate pressure on municipal combined sewer infrastructure. Municipalities elsewhere have successfully implemented bylaws requiring retrofitting of stormwater detention facilities with re-development. One example is provided by Maryland, USA, where retrofits are required if:
 - b) a re-development project exceeding 2,500 ft.² replaces one that lacked stormwater management even if existing impervious area is merely being replaced;
 - c) a project will double impervious area; or
 - d) a project disturbs 50% or more of the existing site.
6. 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.
7. Liquid waste management planning, which addresses stormwater runoff issues, should be made mandatory.
8. 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.

8.1.4 Municipal Sewage Discharges

The Issues:

- A. Many STPs discharge acutely toxic effluents to the environment at various times.^{5, 6} 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.
- B. Many of the permits for STP discharges only restrict the discharge of a few parameters such as BOD and TSS, yet effluents likely contain significant concentrations of numerous potentially harmful substances such as ammonia, residual chlorine, detergents, heavy metals, and other contaminants.

Recommended Action:

1. 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 may 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.
2. Regulatory agencies such as MELP, DOE, and DFO should continue working with municipal governments in the Fraser Basin to achieve non-acutely lethal sewage discharges. (Only 4 of 10 STPs achieved 50% or better survival in 3 or 4 of 4 rainbow trout bioassays per facility in 92/93. Similar results were obtained for different STPs in 93/94). Where cooperation is lacking, enforcement actions may be necessary.

3. 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.
4. 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, maximum concentrations of residual chlorine should be specified in permits. Permitted discharge concentrations should be below concentrations known to be acutely toxic to aquatic organisms.

8.1.5 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. 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.
- B. Sub-standard 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.
- D. New subdivisions are often located near existing houses which are on septic systems. Disruption of the natural hydrology in the area can cause septic systems to fail, increasing the probability that contaminants will reach streams. This type of problem has occurred in several areas of the Lower Fraser Valley.
- E. There are no requirements for property owners to maintain septic systems (in general they should be pumped out at least once every 3 years). Often people are not aware that they are on a septic system and believe that they are connected to a municipal treatment facility.

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 municipal government doing the maintenance work for a fee and a fine.

8.1.6 Combined Sewer Overflows

The Issues:

- A. Combined sewer overflows contribute large volumes of contaminants and toxic effluents to the Lower Fraser and some tributaries many times each year. Most of the Greater Vancouver area which is serviced by CSOs (most of the cities of New Westminster and Vancouver, and parts of Burnaby, amounting to about 16% of the sewered area in the GVRD) was developed in the early 1900's, and is currently experiencing significant redevelopment. This redevelopment typically results in increased impervious surface area and population density. Stormwater volumes and contaminant loadings to CSO infrastructure can therefore be expected to increase. The GVRD has altered its management of combined sewer systems and greatly reduced the incidence of overflow events to Burrard Inlet, but this has yet to happen in the Fraser Estuary. Due to slow-paced sewer separation programs sewer separation will not be complete until about the year 2060.⁹

Recommended Actions:

1. The GVRD should explore and act upon opportunities to reduce the incidence of CSO discharges to the Fraser Estuary. The GVRD and member municipalities have a prime responsibility in this area. Implementation should be through a prioritized planning process which involves DFO.
2. The City of Vancouver should place a much higher priority on their sewer separation program for CSOs. The City should either expedite separation or provide detention and/or treatment facilities.

8.1.7 Domestic Water Supplies

The Issues:

- A. Drinking water is treated to kill pathogens prior to entering the distribution system, and treatment chemicals are intended to persist in drinking water to ensure it remains uncontaminated until it reaches the end user. About 3 years ago Mission and Abbotsford (now part of the Fraser Valley Regional District [FVRD]) began treating their domestic water supply with chloramine, which is more persistent than chlorine and extremely toxic to aquatic organisms. This chloramine use will pose a significantly greater threat to fish populations throughout the water distribution area, compared with chlorine. Salmon-bearing streams are at risk from 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 officials in the FVRD about the potential impacts of their domestic water supply reaching streams directly or via storm sewers.
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 lower-impact alternatives do exist.



8.2 Addressing Permitted Waste Discharges

The Issues:

- A. In numerous cases it appears that Waste Management Permit specifications for effluents discharged to surface waters do not adequately protect the receiving environment (i.e. permits allow the discharge of potentially harmful levels/concentrations/loadings of some parameters to receiving waters, or do not limit the discharge of potentially harmful substances at all).
- 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. Aquatic organisms do not understand the concept of an Initial Dilution Zone!
- C. MELP does audit effluent discharges, however, 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 which impair surface water quality.
- E. Effluent quality data submitted to MELP by proponents will soon be incorporated into the new provincial Environmental Monitoring System database, however, it will not be directly accessible to other agencies.

Recommended Actions:

1. Requirements for toxicity-testing bioassays should be incorporated into most Waste Management Permits which address the discharge of an effluent to a sensitive surface water body.
2. Where toxicity is identified, proponents should be required to control toxic components of effluent within agreed-upon time frames. Where persistent harmful substances are found in an effluent, the facility releasing these substances should be placed on a compliance schedule to remove the substances.
3. Permits identified in Tables 4.2.3 and 6.2.3 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 need 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 woodwaste which are inappropriately deposited by wood processing industries in and near sensitive fish habitats in the Lower Fraser where they impact habitat and/or generate toxic leachates. Specific problems are noted by Ionson⁷ in the Fraser Delta, Pitt-Stave, and Chilliwack HMAs. Woodwaste problems result largely from poor management practices, not problems requiring complex solutions. DFO should work with other agencies as appropriate to address these problems in the immediate future.
10. Current gaps in provincial legislation enable the use of vast volumes of woodwaste as fill in development projects, while disposal under the same environmental conditions would not be permitted. The environmental consequences are the same, however, and leachate generation is usually inevitable, based on abundant examples. Agencies need to make land owners more aware of the liabilities associated with creating a woodwaste leachate problem.
11. The discharge of truck washing effluents at construction sites and ready mix concrete plants has been identified as a concern, especially on the Fraser River North Arm.⁷ These effluents, which are usually very toxic to fish, are reportedly discharged without compliance with permit specifications.
12. 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.
13. Private landfills in Delta and Richmond cause leachate problems.⁷ Delta has recently hired staff to address these problems. DFO and DOE should monitor the progress made, and if timely improvements are not achieved, explore enforcement actions against landfill owners.
14. Fish processors discharging into the Fraser estuary need to be audited and compliance actions taken as necessary to bring effluent discharge quality into line with contemporary effluent discharge requirements.



8.3 Addressing Impacts from Agriculture

The Issues:

- A. Nutrient inputs from chemical fertilizers cause pollution (eutrophication) of streams, and inputs of nutrients, BOD, and ammonia from manure runoff severely impact the water quality of Lower Fraser tributary streams.
- B. Exposed soils on fields erode, resulting in stream sedimentation and an increased need for ditch cleaning.
- C. Riparian zones in agricultural areas are often heavily damaged by livestock and intentional removal of natural vegetation by producers who wish to maximize the use of their land base.
- D. Improper disposal of farm wastes other than manure, such as animal carcasses, can result in degraded water quality.
- E. There is an inadequate enforcement effort at both federal and provincial levels to address impacts from farming on water quality (and fish habitat).
- F. Pesticides are heavily used in the Lower Fraser Valley. Little information is available about the amounts and concentrations of pesticides which may reach streams and ditches under normal application conditions in the Lower Fraser Valley.

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 *Water Stewardship: A Guide for Agriculture*¹¹ would be a logical approach. DFO should continue to support educational initiatives

directed at producers - to date FRAP staff have taken a lead in this area, and efforts need to continue beyond the end of the FRAP program.

2. Recommendations developed jointly by MELP, MAFF, DOE, and DFO regarding agricultural waste management in the Lower Fraser Valley need to be acted upon as a starting point in addressing pollution problems associated with intensive agriculture in the Lower Fraser Valley.¹⁰
3. 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.
4. MELP should increase the number of staff who address enforcement of the Agricultural Waste Control Regulation. DFO and DOE should pursue legal actions under the *Fisheries Act* when the Agricultural Waste Control Regulation fails to adequately protect fish habitat and water quality.
5. Policies which promote farming practices that are detrimental to fish 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.
6. Studies should be done to determine the concentrations and persistence of pesticides which reach/accumulate in streams and ditches (including sediments) in the Lower Fraser Valley under normal application conditions. This information should be used to further refine appropriate management practices as necessary to protect fish populations.



8.4 Addressing Impacts from Forestry Activities on Water Quality

The Issues:

- A. There are numerous salmon-bearing streams in the Lower Fraser HMAs, particularly the Chilliwack and Harrison-Lillooet HMAs, which have been significantly impacted by logging.
- B. There is significant pressure to harvest remaining timber, particularly in Lower Fraser HMAs, because of the proximity to mills and major transportation links.
- C. The Forest Practices Code leaves most decisions relating to stream protection on crown forest land to the discretion of the District Manager, resulting in some inconsistencies in the level of protection which is afforded to streams.
- D. Numerous planning processes such as Land Resource Management Plans (LRMPs), and Local Resource Use Plans (LRUPs) have been led by the Ministry of Forests in the Fraser Basin outside of the Lower Fraser HMAs. DFO-FRAP actively participated in some of these processes, however, the interests of the Department were often not adequately reflected in the resulting plans and/or their implementation.
- E. Overall, DFO has reduced involvement with forestry issues due to a re-allocation of staff. There is now one habitat technician in Squamish to deal with referrals for the entire Squamish and Lillooet River drainages.

Recommended Actions:

1. DFO must establish an auditing process to assess the adequacy of protection afforded to fish habitat and water quality in different areas of the basin (province) in association with forestry activities. This might best be accomplished through a partnership with MELP, and should be an ongoing activity. 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 from excessive logging in watersheds in the Lower Fraser HMAs. This may require negotiations with senior provincial government staff.
3. DFO should continue to participate in the Lillooet Watershed Management Plan, an initiative being led by MELP's Environmental Protection Branch in Surrey and involving strong participation from local residents. The Lillooet and Birkenhead Rivers upstream of Lillooet Lake support very productive fish habitat and are under heavy pressure from urban, agricultural, and logging development. Participation in the watershed management planning process has provided DFO with a valuable forum for liaising with the community, forestry companies, and MOF.
4. DFO must consider the value of involvement with MOF-led planning processes in the Lower Fraser Basin and elsewhere. The department should evaluate the benefits which have resulted from participation in mid and upper basin CORE, LRMP, and LRUP processes. It may be best to direct most efforts at reviewing 5-year

timber harvest plans and providing up-to-date fisheries resource information (as per FISS) to the planning processes, along with corresponding preferred management strategies, and devote the balance of efforts to auditing, and where necessary, enforcement.



8.5 Water Quality Issues Associated with Mining

The Issues:

- A. Ionson⁷ identified a number of enforcement concerns associated with mining in the Lower Fraser Basin HMAs, and pertaining to water quality:
 - a) *Fraser Delta*: Gravel removal is described as a major problem, with chronic problems resulting from three large gravel quarries on the Coquitlam River. Settling ponds are insufficient to contain and settle runoff from pits, resulting in excessive sediment flow into the river. The companies involved have had over a decade to come into compliance with DFO requirements and have failed to do so. Gravel quarries are also noted to degrade streams in the Abbotsford area.
 - b) *Pitt-Stave*: Gravel removal operations along tributaries to Kanaka Creek are noted to release high volumes of silt, causing significant downstream impacts. Hard rock and placer mining operations are described as insignificant for this area due to little activity. Gravel removal from the Alouette River to create dykes often disrupts spawning habitat.
 - c) *Chilliwack*: In general mining has not been considered a priority in this area. Minto Landing gravel removal operation has had problems complying with the *Fisheries Act*, but is now considered to be in compliance. Some gravel is removed from the Chilliwack River as necessary for flood hazard protection.
 - d) *Harrison-Lillooet*: There are some small placer operations in the Lower Lillooet River/Harrison Lake area, and construction of access roads in the past has resulted in sedimentation problems.

Recommended Actions:

1. Resolution of the long standing non-compliance problems on the Coquitlam River and other affected streams should be acted upon as a high priority. This river was formerly a significant producer of salmonids. Considerable efforts have been made by the public and by DFO to keep populations of coho, chum, cutthroat, and steelhead from declining further and these efforts should continue in concert with abatement of gravel mine pollution.
2. The remaining issues in the Chilliwack and Harrison-Lillooet HMAs should be monitored, as maintaining a presence often encourages compliance with environmental regulations.



8.6 Contaminated Sites

The Issues:

- A. Contaminated sites can be significant sources of persistent and harmful contaminants to surface waters. For example, wood preservative chemicals are presently leaching into the Fraser River from the Stella-Jones wood preservative plant (the contaminant problem began with a previous operator - Domtar) in Coquitlam, and another site at 9250 Oak Street is believed to be leaching persistent and toxic chemicals into the Fraser River. It is likely that many more contaminated sites which are affecting water quality/fish habitat will be identified over the next decade, particularly in the Lower Fraser which has a long history of industrial activity.
- B. 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. One of the most significant question which DFO staff need to address is "How much clean-up is enough?" There is little available in terms of useful guidelines to address this question, particularly when more than one contaminant is involved.

Recommended Actions:

1. More work needs to be done to define an approach or protocol which should be used to ascertain the clean-up end-point, especially when a contaminated site is affected by numerous chemicals which may have synergistic effects. A biologically defensible approach must be taken.
2. A clean-up fund needs to be established to address contaminated sites, and resource management agencies must work cooperatively to prioritize clean-up efforts to address such sites, otherwise they may remain permanently alienated habitat, and possibly long-term sources of contaminants to the Fraser River.

3. 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.



8.7 Addressing Atmosphere-Sourced Impacts on Water Quality

The Issues:

- A. There is evidence that relatively poorly buffered surface waters in the Lower Fraser area are slowly becoming more acidic, and that rainfall events are causing potentially harmful short-term declines in pH.
- 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 affect stream hydrology, fish migration, and other functions.

Recommended Actions:

1. DFO should support and encourage monitoring of rainfall pH and pH of selected poorly buffered tributaries to the Lower Fraser. 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 and the GVRD should devote increased effort to studying air quality issues, and DFO should liaise with these agencies so that opportunities for collaboration on research and monitoring programs are identified early on.
3. Contributions of acid-generating contaminants from the United States should be investigated and quantified. If warranted, Canada should begin negotiating with the U.S. to reduce emissions of acid-generating contaminants in Washington State.
4. The potential for increased water temperatures from global warming is of concern for all salmon streams in B.C., including those located in the Lower Fraser Valley. This should provide further motivation for DFO and the province (MAFF, MELP, and MOF) to pursue the protection and restoration of riparian vegetation along all stream banks.



8.8 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 simply 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.
- D. Many streams in the Lower Fraser Valley receive a significant portion of their summer flows from groundwater sources. Unconfined aquifers such as the Abbotsford and Hopington aquifers are becoming contaminated with nitrates and other substances, and in turn become a source of contaminants to streams.

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. Presumably DFO-trained professionals would likely develop approaches to development, etc., which are more agreeable to DFO, and therefore require a reduced amount of staff time for review. This would also 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 to 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 to response time, resulting in a shorter waiting period for proponents.
4. DFO should encourage MELP to develop legislation directed at protecting groundwater quality and quantity.



8.9 References

- 1 Quadra Planning Consultants, Ltd. 1995. Protection of Aquatic and Riparian Habitat by Local Governments: Measures Adopted in the Lower Fraser Valley. Prepared for Fraser River Action Plan, Department of Fisheries and Oceans and Environment Canada.
- 2 Chilibeck, B., G. Chislett and G. Norris 1992. Land development guidelines for the protection of aquatic habitat. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks. 128 p.
- 3 Lanarc Consultants Ltd. 1994. Stream stewardship: A guide for planners and developers. Stream Stewardship Series. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Municipal Affairs. 48 p.
- 4 UMA Engineering Ltd. 1994. Inventory of Municipal Stormwater Discharges Within the Fraser River Estuary. Prepared for Environment Canada, Conservation and Protection, Fraser Pollution Abatement Office.
- 5 Mendoza, E. and J. Gee. 1994. Compliance status summary report: Fiscal year 1992-1993 - British Columbia. Environment Canada, Environmental Protection Branch, Enforcement & Emergencies Division, Inspection Section. North Vancouver, B.C. DOE Report 1994-02. 85 p.
- 6 Paquet, M. 1994. Compliance status summary report - British Columbia: Fiscal year 1993-1994. Prepared for Environment Canada, Environmental Protection Branch, Enforcement & Emergencies Division, Inspection Section. North Vancouver, B.C. DOE Report 1994-04. 110 p.
- 7 Ionson, B. 1995. Habitat Enforcement Report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.
- 8 B.C. Ministry of Municipal Affairs. 1994. Growth strategies for the 1990s and beyond. Updating British Columbia's planning system. Interactive Inclusive Flexible. 22 pp + Appendices.
- 9 GVRD, 1989. Liquid Waste Management Plan - Stage 1. Greater Vancouver Regional District. 130 pp. + Appendices.
- 10 MELP, MAFF, DOE, and DFO. 1996. Management of Agricultural wastes in the Lower Fraser Valley. Summary report - A working document. Report 9. DOE FRAP 1996-30.
- 11 Nener, J., *et al* 1997. Watershed stewardship: A guide for agriculture. Department of Fisheries and Oceans and the Province of British Columbia. 60 p.

Chapter 9 Overall Conclusions

Protecting water quality in the Lower Fraser River, its tributaries, and the estuary is key to the future of all Fraser River salmon stocks. Each anadromous salmon that survives to spawn must successfully pass through the lower mainstem twice, once as a juvenile and once as an adult. All juvenile salmon actively or passively feed and rear in this part of the river for varying periods of time on their way to the ocean. Tributaries to the Lower Fraser provide critical habitat to Fraser coho and chum species with 65% and 85% respectively of Fraser stocks spawning in these streams. The Harrison-Lillooet watershed also supports large runs of pink and chinook salmon. Small tributary streams are important not only to fish originating from those systems, but also to juvenile salmonids which originate from further upstream in the watershed; they utilize these small streams for feeding and rearing during their seaward migration. In addition to anadromous salmon, there are many other fish species which occupy the lower Fraser mainstem and tributaries for all or part of their life cycles.

In general, water quality in the lower Fraser River mainstem does not appear to differ from water quality upstream of the urbanized and industrialized areas of the Fraser Basin. Statistical analyses were not used here to compare data from upstream and downstream sites, however, means and ranges for most parameters were similar in the Lower Fraser to measurements obtained from upstream of Prince George. Shaw and El-Shaarawi¹ completed statistical analyses of Fraser River water quality data collected between 1985 and 1991, and report that due to the high flows of the Fraser River, contaminants from all but the largest discharges are diluted to near detection limits or background levels. The noted exception was for chloride released from pulp mills, however, at concentrations measured, chloride would not be harmful to aquatic biota. Unfortunately, the concept of total mixing most often does not apply to many discharges - results of several studies in the Fraser River show effluent plumes which tend to follow the shore line for considerable distances downstream from outfall pipes.^{2,3} Also, aquatic biota may be affected by contaminant levels near effluent outfalls, depending upon the effluent composition and volume discharged.

Fraser mainstem water samples are usually collected from well mixed, mid-channel areas, while near-shore areas are often not sampled. In the Lower Fraser, large discharges and the numerous discharges located in close proximity to one another, combined with tidal influences that cause stagnation, could lead to degradation of water quality in the near-shore areas which provide important fish habitat. Rhodamine dye studies of the Annacis Sewage Treatment Plant discharge were conducted under high river flow conditions, and demonstrated that the effluent tracks nearshore areas, and at times pools near the outfall to occupy 80% of the river width with only 10:1 dilution 100 m downstream from the outfall.¹ More attention needs to

be directed towards ensuring that water quality in the near-shore areas of the Fraser Mainstem, where many effluent discharge pipes and stormwater outfalls are located, is adequately protected.

Dilution does not protect aquatic life from persistent contaminants that will biomagnify and accumulate in the food chain, such as dioxins, furans, and PCBs. Recently collected data indicate that these contaminants in Fraser River fish (peamouth chub and mountain whitefish) have declined to very low levels in muscle. Concentrations of these chemicals have also declined in fish livers, although livers contained higher levels of persistent contaminants compared with muscle. The effects of the observed relatively low concentrations of contaminant mixtures on aquatic biota are poorly understood. The measured decline of dioxins, furans, PCBs, and other contaminants has largely resulted from the introduction of regulations which restrict the manufacturing, use, and disposal of persistent harmful chemicals.

It is evident from the water quality data and Stream Summaries provided for each HMA that present approaches to resource management are not protecting water quality in a way that ensures sustainable fish populations and healthy aquatic ecosystems. Water quality data for streams in the Lower Fraser HMAs show that intensive urban and agricultural land uses are usually accompanied by poor water quality, which mostly results from non-point sources of pollution. Results of watershed assessments involving the Brunette, Salmon, and Sumas Rivers and Matsqui Slough⁴⁻⁸ show that urban and agricultural runoff contribute significantly to the degradation of water quality in Lower Fraser tributaries. The scope of these problems can be expected to increase as tens of thousands of people move to the Lower Fraser Valley each year, resulting in the construction of new communities in previously undeveloped areas, densification of existing developed areas, and increasing intensification of agriculture. In unsettled areas of the Lower Fraser HMAs logging is the primary activity affecting water quality, particularly in the Chilliwack River and Lillooet River watersheds.

Efforts are necessary to improve water quality in many Fraser tributaries which are impacted by non-point source pollution from urban and agricultural development. With new development, all efforts must be made to protect water quality and habitat values in nearby streams, both during and after development.

Successfully protecting water quality and aquatic habitat in the Lower Fraser HMAs will be a major challenge due to very high development pressure combined with the severe fragmentation of watershed and ecosystem management. Water quality problems result from a complex interaction of land uses and human activities. Unfortunately, the control of these uses and activities is broken into many jurisdictions. Agencies make decisions daily about matters which can have a direct bearing on

water quality and aquatic habitats, without consideration being given to fisheries values and ecosystem sensitivity. In order to properly manage water quality, a long term and integrated approach is required. The structures necessary to implement such an approach do not exist.

The recommendations provided in Chapter 8 identify options for short-term actions that are achievable with existing jurisdictions. While these recommendations should lead to improved water quality and increased protection of aquatic habitats from future impacts, effectiveness will fall short of the benefits of comprehensive watershed management without jurisdictional barriers. Successfully protecting ecosystem integrity so that fish stocks can be sustained will likely require a shift from resource-based management which typically seeks

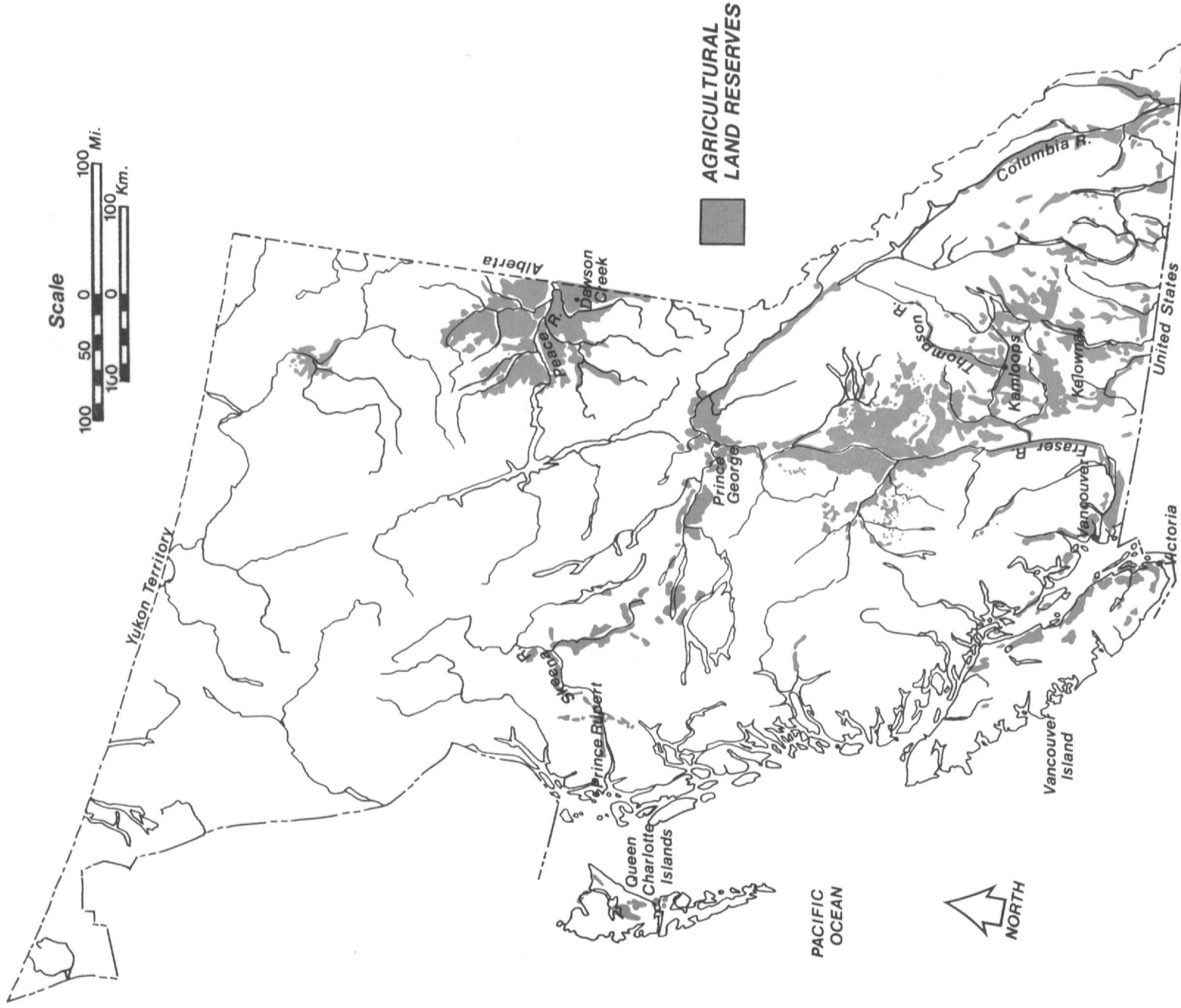
to maximize short-term economic benefits, to ecosystem-based watershed management approaches.

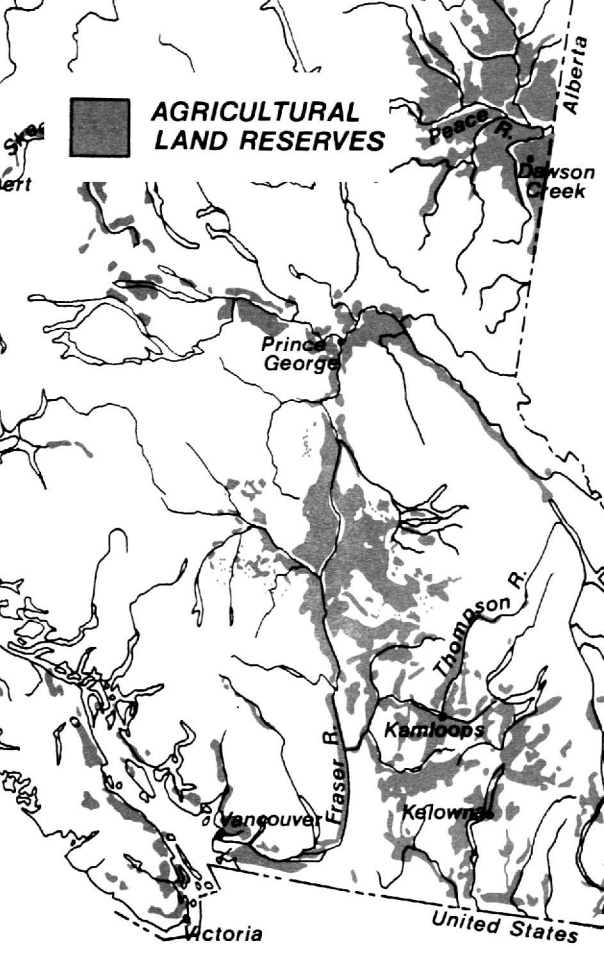
Protecting and/or restoring the ecological integrity of streams so that they can sustain healthy fish populations will require more than multi-agency co-operation; strong support from the public is essential. There are nearly two million people living in the Lower Fraser HMAs who all contribute to the non-point source pollution which presently degrades streams. While impacts resulting from the actions and choices of individuals may be small, collectively the impacts of this population on water quality and fish habitat are large. Significant efforts to educate the public about how to minimize individual impacts on water quality and aquatic habitats will be key to protecting and improving water quality in the Lower Fraser HMAs.

References:

- 1 Shaw, D.P. and A.H. El-Shaarawi. 1995. Patterns in water quality at selected stations in the Fraser River Basin (1985-1991). DOE-FRAP 1995-20. 85 pp. + Appendices.
- 2 Borstad and Associates. 1994. Effluent mapping using airborne digital imagery. Prepared on behalf of DFO, Unpublished information.
- 3 Seaconsult Marine Research Ltd. and ABR Consultants. 1995. Annacis Island wastewater treatment plant pre-discharge monitoring dilution/dispersion study. Interim Report. Prepared for Greater Vancouver Sewerage and Drainage District. 58 p. + Appendices.
- 4 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Sumas River Watershed - Summary Report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada, and Department of Fisheries and Oceans. DOE-FRAP 1994-21.
- 5 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Matsqui Slough Watershed - Summary Report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada, and Department of Fisheries and Oceans. DOE-FRAP 1994-22.
- 6 Wernick, B.G. 1996. Land use and water quality dynamics on the urban-rural fringe: A GIS evaluation of the Salmon River Watershed, Langley, B.C. M.Sc. Thesis, Faculty of Graduate Studies, Resource Management and Environmental Studies, University of British Columbia, Vancouver, B.C. 217 p.
- 7 Berka, C.S. 1996. Relationships between agricultural land use and surface water quality using a GIS: Sumas River Watershed, Abbotsford, B.C. M.Sc. Thesis, Faculty of Graduate Studies, Resource Management and Environmental Studies, University of British Columbia, Vancouver, B.C. 174 p.
- 8 McCallum, D.W. 1995. An examination of trace metal contamination and land use in an urban watershed. M.Sc. Thesis, Faculty of Graduate Studies, Department of Civil Engineering, University of British Columbia, Vancouver, B.C. 217 p.

LOCATION OF AGRICULTURAL LAND RESERVES IN BRITISH COLUMBIA





**AGRICULTURAL
LAND RESERVES**

Alberta

Peace R.

Dawson
Creek

Prince
George

Thompson R.

Kamloops

Kelowna

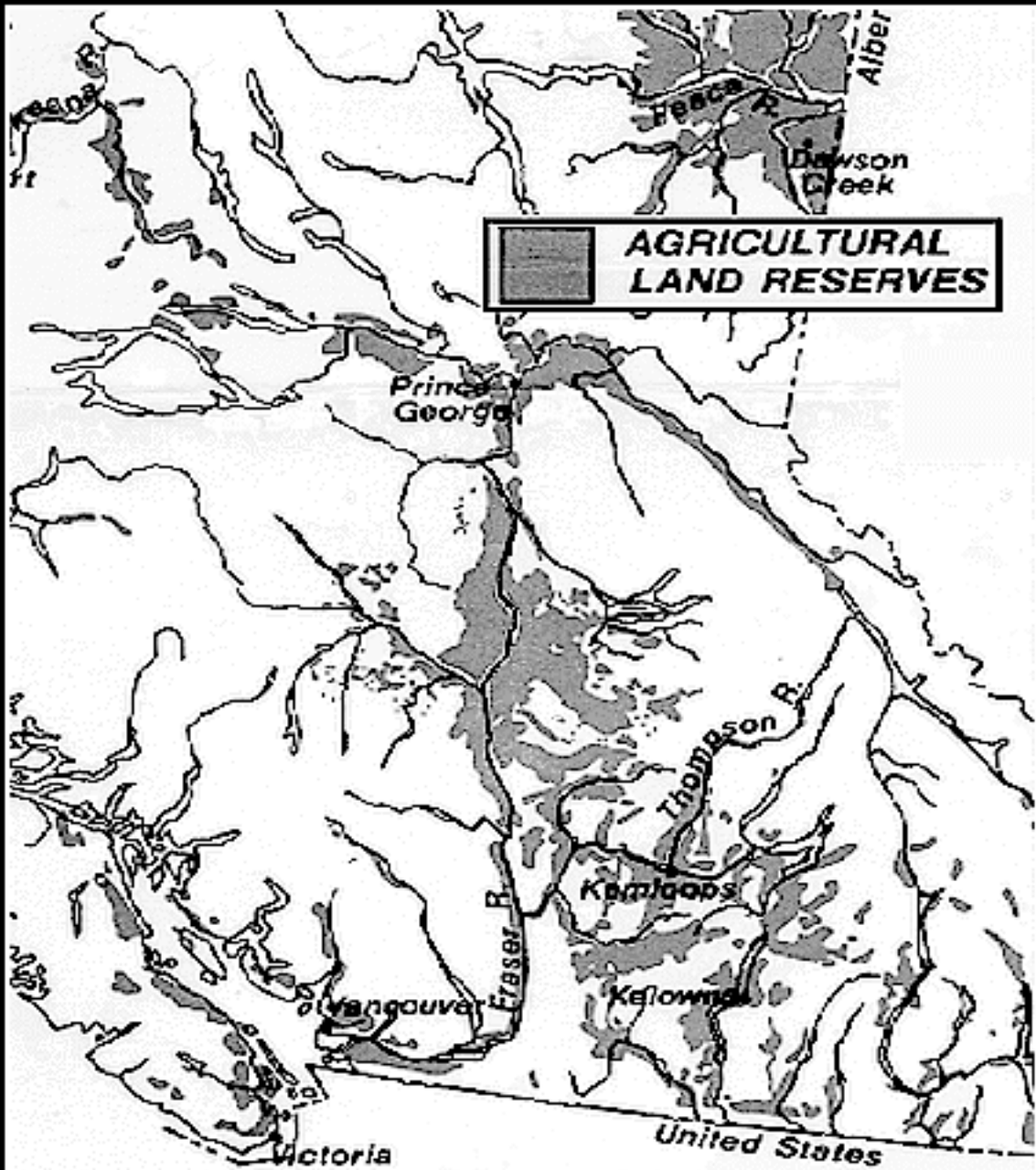
Fraser R.

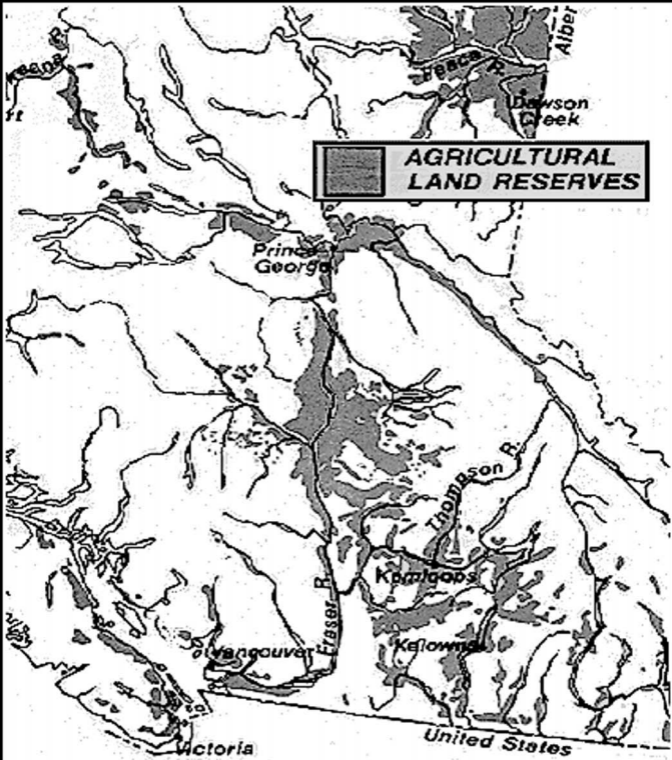
Vancouver

Victoria

United States

Skagit
ert





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.



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 $100 \text{ mg}\cdot\text{L}^{-1}$, or $10 \text{ mg}\cdot\text{L}^{-1}$ where natural levels are less than $100 \text{ mg}\cdot\text{L}^{-1}$.

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



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 $0 \text{ mg}\cdot\text{L}^{-1}$ to $60 \text{ mg}\cdot\text{L}^{-1}$ (expressed as CaCO_3) water is generally considered to be "soft". When hardness is in the range of $60 - 120 \text{ mg}\cdot\text{L}^{-1}$ it is considered moderate, and in the range of $120 - 180 \text{ mg}\cdot\text{L}^{-1}$ it is considered to be hard. Greater than $180 \text{ mg}\cdot\text{L}^{-1}$ is very hard. The global mean hardness of river waters is about $50 \text{ mg}\cdot\text{L}^{-1}$. When hardness is very low ($20 \text{ mg}\cdot\text{L}^{-1}$) 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.



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 ($> 20^\circ\text{C}$ 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.



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.



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 LC₅₀s, 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 (contam-

inants 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.



6 References:

- 1 McLeay, K.J., G.L. Ennis, I.K. Birtwell, and G.F. Hartman. 1984. Effects on arctic grayling (*Thymallus arcticus*) of prolonged exposure to Yukon placer mining sediment: A laboratory study. Can. Tech. Rep. Fish. Aquat. Sci. No 1241. West Vancouver, B.C. 96 p.
- 2 Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. No 1889. 96 p.
- 3 Richards, F.P., W.W. Reynolds, and R.W. McCauley. 1977. Temperature preference studies in environmental impact assessments: and overview with procedural recommendations. J. Fish. Res. Board Can. 34:729-761.
- 4 Houston, A.H. 1982. Thermal effects upon fishes. NRCC Associate Committee on Scientific Criteria for Environmental Quality. Publ. No. NRCC 18566, Ottawa, Canada. 200 p.
- 5 Coutant, C.C. 1987. Thermal preference: when does an asset become a liability? Env. Biol. Fish 18:161-172.
- 6 Claire, E. and R. Storch. 1977. Streamside management and livestock grazing: An objective look at the situation. Paper presented at symposium on livestock interactions with wildlife, fish and their environments, Sparks, Nev., May 1977. On file at University of California.
- 7 Brownlee, M.J., B.G. Shepherd, and D.R. Bustard. 1988. Some effects of forest harvesting on water quality in the Slim Creek watershed in the central interior of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1613. 41p.
- 8 Brett, J.R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Onchorynchus nerka*). Am. Zool. 11:99-113.
- 9 Evans, D.O., B.A. Henderson, N.J. Bax, T.R. Marshall, R.T. Oglesby, and W.J. Christie. 1987. Concepts and methods of community ecology applied to freshwater fisheries management. Can. J. Fish. Aquat. Sci. 44 (suppl. 2):448-470.
- 10 Robinson, C.L.K. and W.M. Tonn. 1989. Influence of environmental factors and piscivory in structuring fish assemblages of small Alberta lakes. Can. J. Fish. Aquat. Sci. 46:81-89.
- 11 Brown, L.R. and P.B. Moyle. 1991. Changes in habitat and microhabitat partitioning within an assemblage of stream fishes in response to predation by Sacramento squawfish (*Ptychocheilus grandis*). Can. J. Fish. Aquat. Sci. 48:849-856.
- 12 Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil, Conseil International pour l'Exploration de la Mer 39:175-192.
- 13 Beyer, J.M., G. Lucchetti, and G. Gray. 1986. Digestive tract evacuation in northern squawfish (*Ptychocheilus oregonensis*). Can. J. Fish. Aquat. Sci. 45:548-553.

Appendix 2 Guidelines for Organic Contaminants in Sediments and Fish Tissues

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

