Pacific Fisheries Resource Conservation Council

Conflicts Between Agriculture and Salmon in the Eastern Fraser Valley

Prepared by

Dr. Marvin L. Rosenau and

Mr. Mark Angelo

June 2005

Conflicts Between Agriculture and Salmon in the Eastern Fraser Valley
Dr. Marvin L. Rosenau and Mr. Mark Angelo

For quotes and short excerpts from the material covered under "fair use", we recommend the following citation:
Rosenau, M.L., and M. Angelo. 2005. Conflicts Between Agriculture and Salmon in the Eastern Fraser Valley. Vancouver, BC: Pacific Fisheries Resource Conservation Council.

For further information about this document and about the Pacific Fisheries Resource Conservation Council (PFRCC), contact:
Pacific Fisheries Resource Conservation Council
800 Burrard Street, Suite 590
Vancouver, BC, Canada V6Z 2G7
Telephone 604 775 5621
Fax 604 775 5622
www.fish.bc.ca
info@fish.bc.ca

Printed and bound in Canada

ISBN 1-897110-25-1

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

GLOSSARY

allochthonous	organic material that falls into a stream from the surrounding land
avulsion	the sudden movement of soil from one property to another as the result of a flood or a shift in the course of a boundary stream
berm	a mound or bank of earth, used especially as a barrier or to provide insulation
channelize	to make, form, or cut channels in a stream or floodplain
distributary	a branch of a river that flows away from the main stream
ecosystem	an ecological community, with its environment, functioning as a unit
ecotone	a transitional zone between two ecological communities containing the characteristic species of each
entraine	to carry (suspended particles, for example) along in a current
fluvial	relating to, or inhabiting, a river or stream
food web	a complex of interrelated food chains in an ecological community
footprint	an area affected or covered by a phenomenon
genetic	relating to genes
greenway	a corridor of undeveloped land, as along a river or between urban centres, that is reserved for recreational use or environmental preservation
hydraulic	of, involving, moved by, or operated by a fluid, especially water, under pressure
hydrological	the scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere
hyporheic	relating to subsurface water flows
large woody debris	the definition of large woody debris has evolved in the scientific, regulatory and political arenas to include wood as small as four inches in diameter and six feet in length. However, the preferred sizes are 18-36 inches in diameter and 12 – 32 feet in length
natal	of, or associated, with the place of one's birth
riparian	of, on, or relating to the banks of a natural course of water
salmonid	belonging to the salmon and trout family
slough	a stagnant swamp, marsh, bog, or pond comprised of non- or slowly-moving water
stochastic	involving chance or probability
thalweg	the line defining the lowest points along the length of a river bed
wetland	a lowland area, such as a marsh or swamp, that is saturated with moisture, especially when regarded as the natural habitat of fish or wildlife

EXECUTIVE SUMMARY

The lower Fraser River from Hope to Sumas, and its many tributaries play a key role in sustaining Fraser River salmon stocks which are amongst the greatest numbers in the world. Yet for more than 100 years, extensive agricultural operations in the eastern Fraser Valley have resulted in substantial changes to the area's waterways through the modification of streams, wetlands and riparian areas. This in turn has substantially reduced the habitat capacity of those aquatic ecosystems.

While the transformation of many lowland areas into agricultural landscapes occurred long before comprehensive ecosystem inventories and assessments were undertaken, current evidence suggests that pre-settlement aquatic conditions of the eastern Fraser Valley were extraordinary. Over the past century, aquatic ecosystems throughout this area have been significantly impacted by farming. Examples of large-scale agriculture-related alterations include:

1. Major diking and diversion projects along the Chilliwack, Fraser and Harrison rivers and their floodplains, resulting in major losses of side-channel and wetland habitats;

2. Draining of Sumas Lake, which resulted in one of the more significant freshwater river/wetland ecosystem losses in British Columbia's history;

3. Channelization of numerous highly-productive small streams, accompanied by the loss of wetlands, native vegetation and riparian cover.

In recent years, the trend towards the intensification of agricultural operations in order to increase production has resulted in further negative hydrological changes as well as losses in riparian cover. In order to bring new land into agricultural production, native vegetation continues to be cleared in a number of floodplain areas immediately outside the dike infrastructure in the eastern Fraser Valley. Many of these areas are ephemerally flooded and either had, or retain, important aquatic values.

Another issue associated with intensification of farming which continues to affect fish habitats in the eastern Fraser Valley relates to the maintenance of channelized-streams and constructed-ditches, including the regular cleaning of sediments and nuisance vegetation to facilitate their draining. Fortunately, local and senior government agencies have made great strides in dealing with this issue and their cooperative approach is one of the more positive aspects of fish/agriculture interactions in the eastern Fraser Valley. Less success has been achieved in protecting adequate riparian buffers between the cultivated portions of fields and the stream perimeters; much work remains to be done to resolve this issue.

An emerging significant threat to aquatic ecosystems in the eastern Fraser Valley is the development of lowland farmlands outside dikes. These areas include riparian or ephemerally flooded habitats, and they are being developed into more intensified cultivation and/or non-agricultural, high-impact activities. The latter activities include changes in land-use designation from agricultural to industrial/commercial, urban development, or resource extraction. It is the authors' view that the sequential development of these remnant eastern Fraser Valley lowland and riparian landscapes—from natural-floodplain ecosystems to agriculture, and then from agriculture to more intensively developed landscapes—constitutes one of the greatest threats to remaining aquatic values in the eastern Fraser Valley. Most importantly, what remains of the area's fisheries values and its lowland ecosystems will be jeopardized and eventually lost if we fail to conserve sensitive aquatic lands adjacent to the lower Fraser River and its key tributaries. We must

recognize and protect the key remaining areas, and implement appropriate planning and land-use practices, or make purchases for future safeguard.

On a positive note, federal and provincial agency efforts have recently resulted in a new initiative that encourages the development of Environmental Farm Plans (EFPs) for individual farming operations. The EFP is a tool that attempts to identify actual and potential environmental threats associated with agricultural operations and develop action plans to address these. While the development of EFPs remains voluntary at present, it's hoped that this initiative will resolve at least some current conflicts and enable an appropriate balance to be struck to help protect salmon and steelhead fisheries and other aquatic values in the eastern Fraser Valley while enabling agricultural operations to continue.

RÉSUMÉ

Le fleuve Fraser et ses nombreux affluents entre Hope to Sumas jouent un rôle important pour la survie de stocks de saumon qui comptent parmi les plus abondants du monde. Depuis plus d'une centaine d'années, les activités agricoles intensives dans l'Est de la vallée du Fraser ont cependant modifié de façon importante les voies d'eau de la région à la suite de l'altération des cours d'eau, des terres humides et des zones ripariennes. Ces altérations ont réduit de façon significative la capacité de l'habitat dans les écosystèmes aquatiques locaux.

Bien que la transformation d'un grand nombre de basses terres en terrains agricoles soit survenue bien avant la mise en œuvre des inventaires et des évaluations détaillées des écosystèmes locaux, les données actuelles montrent que les attributs des systèmes aquatiques dans l'Est de la vallée du Fraser avant la colonisation étaient à un niveau extraordinaire. Au cours du dernier siècle, les systèmes aquatiques de la région ont été gravement touchés par l'agriculture et notamment par les activités à grande échelle suivantes :

- La construction de grandes digues et la mise en œuvre de projets de diversion sur la Chilliwack, le Fraser et la Harrison, qui ont entraîné des pertes considérables d'habitats dans les chenaux et les terres humides qui ont ainsi disparu;
- Le drainage du lac Sumas, qui a entraîné la perte d'un des plus importants écosystèmes dulcicoles composés de cours d'eau et de terres humides de la Colombie-Britannique;
- La canalisation d'un grand nombre de petits ruisseaux productifs, qui s'est accompagnée de la perte de terres humides, de plantes indigènes et de couvertures ripariennes.

Au cours des récentes années, la tendance à l'intensification des opérations agricoles visant à augmenter le rendement a eu des répercussions hydrologiques négatives supplémentaires et a entraîné la perte de nombreuses couvertures ripariennes. Pour rendre cultivables de nouvelles terres, la végétation indigène continue à être éclaircie dans un nombre croissant de plaines inondables situées autour des digues dans l'Est de la vallée du Fraser. Un grand nombre des zones touchées étaient périodiquement inondées et possédaient donc une grande valeur pour les écosystèmes aquatiques.

Un autre problème lié à l'intensification de l'agriculture, qui continue à affecter les habitats des poissons dans l'Est de la vallée du Fraser, découle de l'entretien des cours d'eau canalisés et des fossés artificiels, notamment du nettoyage régulier des sédiments et des plantes nuisibles visant à faciliter le drainage. Fort heureusement, les organismes gouvernementaux locaux et supérieurs ont réalisé de grandes avancées pour résoudre ce problème et leur approche basée sur la coopération est l'un des aspects les plus positifs de l'interaction entre les responsables de la ressources halieutique et les agriculteurs dans l'Est de la vallée du Fraser. Des succès moindres ont été enregistrés pour ce qui est de la protection adéquate des zones tampons ripariennes situées entre les portions cultivées des champs et les abords des cours d'eau; il y encore beaucoup de travail à faire dans ce domaine.

Le développement de basses-terres agricoles en dehors des digues constitue une nouvelle menace, tout aussi sérieuse, pour les écosystèmes aquatiques dans l'Est de la vallée du Fraser. Ces zones incluent notamment des habitats ripariens ou occasionnellement inondés. Elles sont transformées en terres agricoles intensives ou réquisitionnées pour des activités non agricoles à fort impact comme le développement de zones industrielles, commerciales ou urbaines ou l'extraction de ressources. Les auteurs estiment que la transformation séquentielle des quelques terres basses et des zones ripariennes naturelles qui restent dans l'Est de la vallée du Fraser en zones agricoles

puis en zones d'activités encore plus destructives constitue la plus grande menace qui pèse actuellement sur les dernières valeurs aquatiques de cette partie de la vallée du Fraser. Ce qui reste des ressources halieutiques et des écosystèmes de plaine dans la région sera définitivement perdu si nous ne parvenons pas à conserver les zones humides sensibles adjacentes au cours inférieur du Fraser et de ces principaux affluents. Nous devons reconnaître et protéger les zones clés qui restent et mettre en place une planification et des pratiques d'utilisation des terres appropriées ou prévoir des mesures futures de prévention.

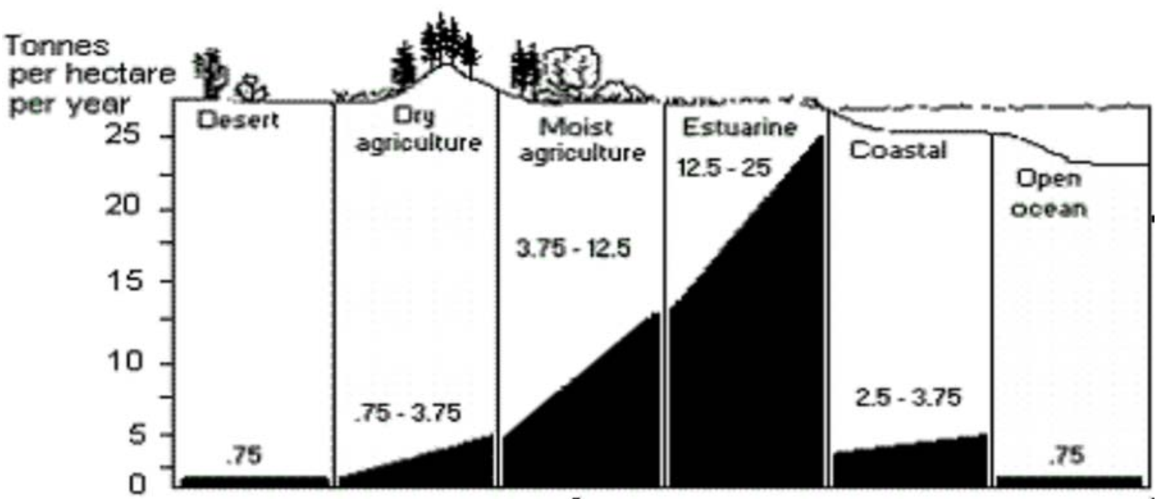
Côté positif, les organismes fédéraux et provinciaux sont récemment parvenus à mettre en œuvre une nouvelle initiative visant à encourager l'élaboration de plans environnementaux des fermes (PEF) par chaque exploitation agricole. Le PEF est un outil qui permet d'identifier les menaces environnementales potentielles et réelles associées aux opérations agricoles et d'élaborer des plans d'action visant à leur faire face. Bien que les agriculteurs soient pour l'instant libres d'élaborer ou pas un PEF, on espère que l'initiative permettra de résoudre au moins quelques-uns des conflits actuels et d'atteindre un équilibre approprié entre la protection des saumons, des saumons arc-en-ciel et des autres valeurs aquatiques dans l'Est de la vallée du Fraser et la poursuite des activités agricoles dans la région.

1. CONFLICTS BETWEEN AGRICULTURE AND SALMON IN THE EASTERN FRASER VALLEY

1.1 Introduction

The relationship between agriculture and aquatic ecosystems in floodplains and river-valleys has historically been one of conflict worldwide. On the one hand, because of the diverse topography, nutrient-rich surroundings and abundant water resources normally found in valley bottoms, lowland environments tend to support highly-productive and diverse natural biological communities. However, because of the moist and fertile soils generally associated with floodplains, these same landscapes are often attractive to agrarian interests (Fig. 1) and include some of the richest agricultural lands on earth, although many are now partially or completely isolated from natural inundation cycles as a result of diking and drainage (Welcomme 1985).

Figure 1. Plant biomass produced annually under a variety of moisture conditions.
The "Moist agriculture" category exemplifies floodplain growing conditions. Figure from Environment Canada, www.hww.ca/hww2.asp?pid=0&id=226&cid=2.

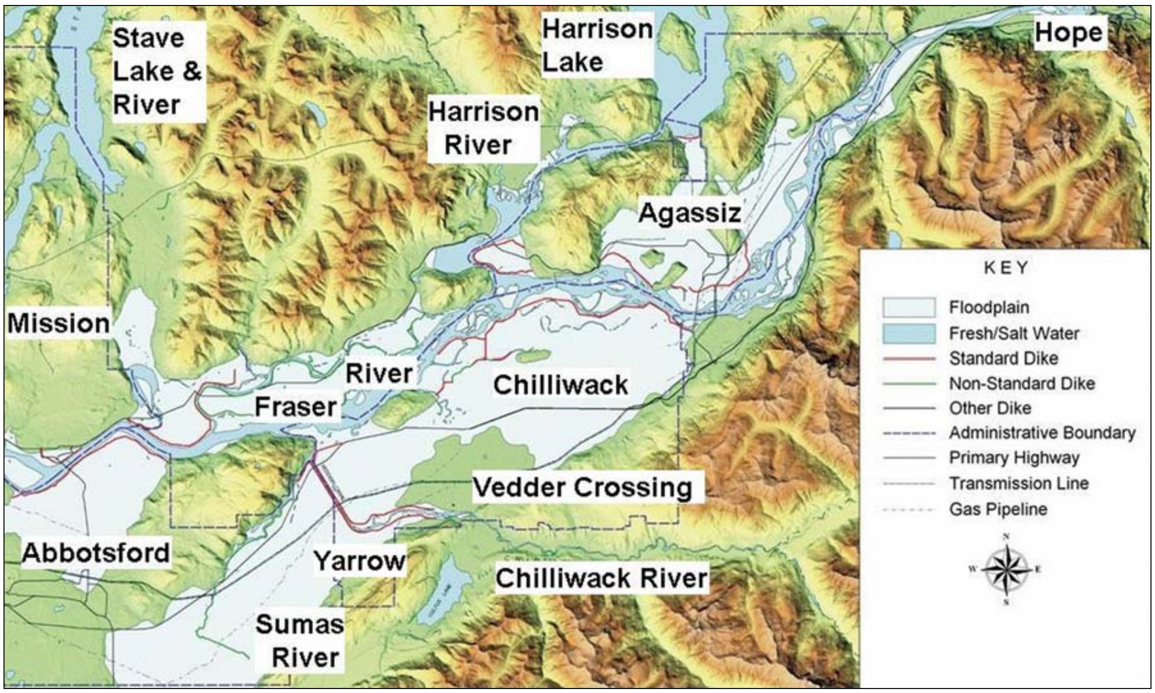


In the process of culturing crops and domestic animals, an area's natural characteristics are often altered, for example, extensive assemblages of native vegetation, topographic variability, streams, wetlands, and water inundating the landscape during natural flooding events. Usually farmers will drain, dike and clear land in order to prepare a site for agriculture. At the same time the local watercourses are routinely channelized and dredged in order to increase hydraulic conveyance and dry up the land. Natural stream banks in close proximity to fields are regularly armoured and protected from normal river-erosion processes in order to reduce the loss of the land base. In addition, as technology becomes more sophisticated, many farmers will mechanically level and drain-tile, or further ditch, their lands to promote enhanced drainage in order to maximize crop or animal production. All of these activities adversely affect the capacity of floodplain habitats to sustain aquatic-ecosystem communities. This damage has now occurred extensively in the eastern Fraser Valley (Fig. 2) of the Lower Mainland of British Columbia. Here, much of the low-lying land is floodplain and most of this area has been converted into agricultural production (Fig. 3) over the last century-and-a-half.

Prior to European settlement, this valley bottom comprised some of the most prolific ecosystems in western Canada and included habitats with exceptional aquatic values (e.g., Siemens 1968, Wells 1987, Ward et al. 1992, Kistritz et al. 1996, Boyle et al. 1997). Highly-developed indigenous cultures arose here, in part because of the remarkable river-based biodiversity which created opportunities to conduct salmon fisheries on local and migratory stocks as well as harvest other species of aquatic and wetland organisms (Siemens 1969, Wells 1987).

Figure 2. Map of the eastern Fraser Valley.

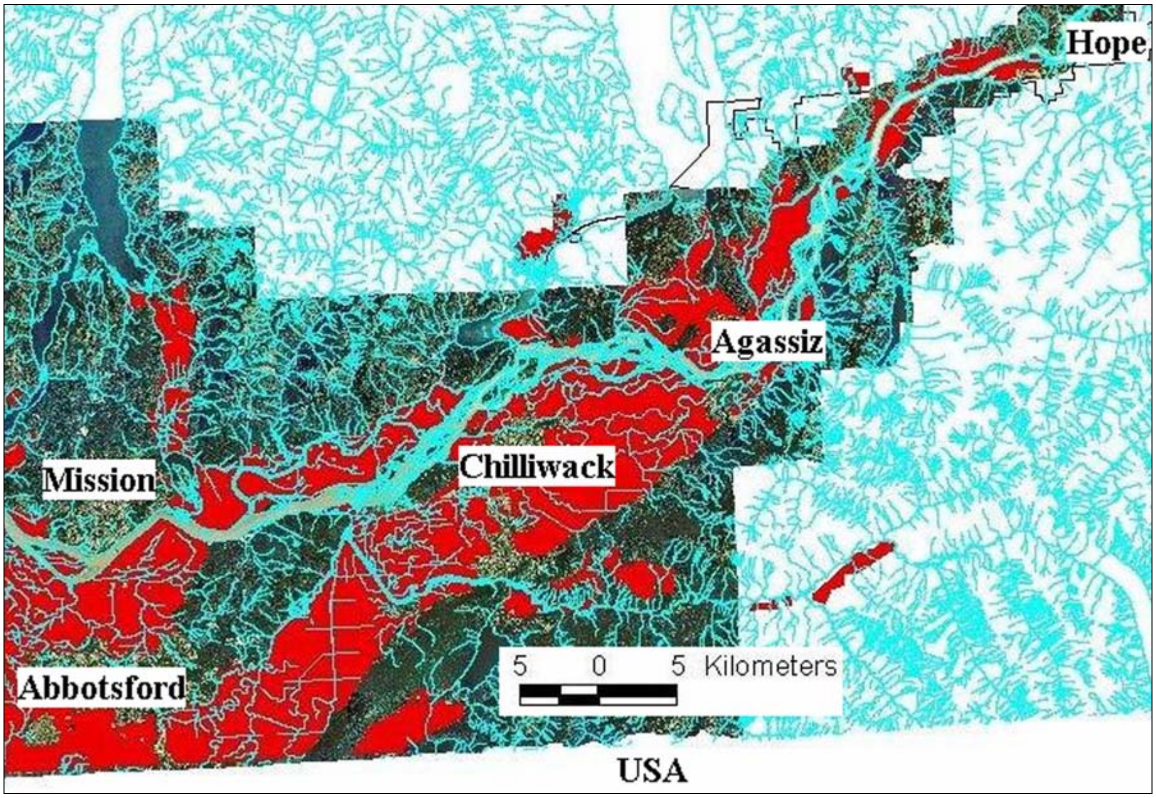
The grey coloration outlines the approximate boundaries of the historical floodplain areas considered in this report. Compare the extensive overlap of the floodplain area with the Agricultural Land Reserve designations in Fig. 3. Figure adapted from the Fraser Basin Council's current floodplain map for the lower Fraser River, 2004.



The bountiful freshwater ecosystems found in the eastern Fraser Valley were a product, in many ways, of the topography of the area and the fact that it was regularly inundated by nutrient-saturated and enriched water. Much of the physical structure of the eastern Fraser Valley bottom is the result of historical glaciations, the meandering of the Fraser River across the valley lowlands (Armstrong 1981) and the sediment-depositing floods that inundated the riparian areas during freshet events. Freshet floods during the spring snowmelt runoff, and fall-rain events, allowed sediments, plant material, nutrients, food, fish and other organisms to move laterally, longitudinally and vertically over the floodplain, enabling many species, especially plants, to fully exploit the landscape (e.g., Boyle et al. 1997). The main- and side-channels of the eastern Fraser Valley's rivers, the seasonally- and permanently-inundated lowlands, the myriad small streams criss-crossing the area and the lush riparian zones provided habitat for more than two dozen species of fish, including the seven Pacific salmon that still exist here.

Figure 3. Areas designated as Agricultural Land Reserve in the eastern Fraser Valley.

Farmland is indicated by red colour; watercourses are overlain on the image. Contrast with area designated floodplain in Fig. 2.



With the arrival of non-indigenous people to the area, clearing of land was soon undertaken on a large scale and agriculture became the predominant use of the valley bottoms well into the 20th century. While we have an incomplete understanding of the pre-European-fisheries productive capacity of the eastern Fraser Valley, it is clear that many salmon (*Oncorhynchus sp.*) and steelhead[1] (*O. mykiss*) habitats were profoundly changed as a result of the extensive diking, ditching, draining, clearing and tilling of these fertile landscapes. In particular, these activities became commonplace within and around the perimeters of the present-day communities of Abbotsford, Agassiz and Chilliwack (Fig. 2). Abbotsford significantly increased its agricultural capacity when the former Sumas Lake was drained and the newly exposed lake-bottom area was subdivided by the Crown and sold to farming interests. Sumas Lake aquatic values are thought to have been extensive prior to its draining and cultivation (e.g., Wells 1987).

While it is difficult to fully assess the historical losses of salmon and steelhead habitats in the eastern Fraser Valley as a result of agriculture, the current social and economic benefits to British Columbia from farming have been quantified (Table 1). Agriculture is a significant component of the economy with about 1.5 % of the province's workforce employed on farms and in other agricultural-related jobs. The industry generates about one per cent of the province's total GDP; total farm cash receipts reached over $2 billion in 2001 and crop sales exceeded $1 billion. Nevertheless, this economic activity was accomplished on a relatively small land base as less than 5% of the province is considered to be good agricultural land. The total area of land in British

1. Steelhead and cutthroat trout are now properly classified as Pacific salmon. The genus of cutthroat trout and steelhead was recently changed when it was determined through genetic and other studies that they were more correctly related to the Pacific salmons (*Oncorhynchus*) than the European trouts (*Salmo).*

Columbia is around 90 million ha, and about 4.7 million ha of this has been placed within the Agricultural Land Reserve. About 2.6 million ha are currently being farmed and about two-thirds of these are in crops and pasture (agricultural statistics from Web Citation 1).

A substantial component of British Columbia's agricultural sector resides in the eastern Fraser Valley. For example, Chilliwack farms cover more than 19,000 ha, and this comprises approximately 74% of the community's total land base. In 1996, this included 924 farms representing a cumulative investment of $668 million, mostly in land and buildings. Chilliwack's agricultural sector generates more than $150 million annually, with almost half of that coming from dairy farms. Furthermore, the sector employs 1,860 Chilliwack residents, or about 6.4% of the experienced workforce (Web Citation 2).

Similarly, there are over 100 farms in the Sumas Prairie basin in Abbotsford having an average livestock density of about 2.3 animals/ha. The land base of Sumas Prairie comprises 9,000 ha and agriculture in this area produced revenues of more than $68 million in 1991 (Web Citation 3). The floodplain areas east of Mission and Agassiz on the north side of the Fraser River, as well as at Laidlaw near Hope, also accommodate extensive agricultural operations.

Many of these farming operations continue to expand in size and efficiency as a result of better technology and the increasing value of the production. Because of the current intensification and high economic value of agriculture in this area, and the fact that farming in the eastern Fraser Valley occurs on both a restricted land base and within a major-lowland floodplain comprising sensitive aquatic ecosystems, conflicts between farming and fisheries interests continue to occur within those aquatic habitats which remain. In recent years there has been considerable dialogue amongst the farming community and government agencies in an effort to resolve some of these issues. While such discussions are certainly worthwhile and should be encouraged—and there have been significant strides in resolving some of the fish-farm conflicts—many difficulties and conflicts still remain to be resolved. Therefore, in this report we hope to expand on the discussion relating to the conflicts that exist between fisheries and agriculture in the eastern Fraser Valley as a contribution to a future resolution of the issues. The objective of this paper is to provide a forum to educate and stimulate thought on the subject.

Our report focuses on the changes and impacts to fish and aquatic habitats in floodplains resulting from both historical and current agricultural practices in the eastern Fraser Valley. While we recognize that waste issues (e.g., manure management) and chemical issues (e.g., pesticides) are important, and in some cases are related (e.g., the role of riparian areas in protecting streams from manure and pesticide inputs)—the centre of attention of this report will be the physical effects of agricultural practices.

This report is structured so that it first describes how salmon and steelhead and floodplains are related. We explain how important it is for properly functioning salmonid ecosystems to have the succession of flooding and drying of their riparian landscapes over the yearly hydrological cycle. We explain the role of river-bank erosion and deposition in maintaining quality salmon and steelhead habitats. The report then elaborates on what we know about past and present fisheries values of the eastern Fraser Valley. We have had to extrapolate what likely would have existed prior to European settlement, as many of the physical changes and declines in fish populations that resulted from agriculture occurred long before modern fisheries inventory and assessment were practised.

We then specifically outline the historical farming activities that affected fish habitat in the eastern Fraser Valley including the diversion, armouring and diking of the Chilliwack River and its floodplain, the diking of the Fraser River floodplain and extensive loss of side channels, the draining of Sumas Lake, and the channelization of numerous small streams in lowland areas.

In addition, the report discusses some of the current fish-agriculture issues in the eastern Fraser Valley. These include impacts from the intensification of farming and the role of agricultural-land rezoning and subsequent redevelopment into urban, commercial or industrial landscapes in the riparian areas. We also discuss how the regulatory agencies are addressing farm-drainage concerns with respect to impacts on salmonid habitats for small streams and constructed ditches. The report then reviews outstanding issues regarding conflicts between maintaining riparian boundaries along farmed fields and preserving of fish-bearing streams in the eastern Fraser Valley.

Finally, we provide some concluding opinions, observations and recommendations.

We recognize that society is not going to turn back the clock to the past ecological "utopia" of pre-European settlement. However, there is an urgency to protect that little which still remains of this once-vast aquatic ecosystem in British Columbia.

Table 1. Agriculture statistics for the eastern Fraser Valley. Abbotsford, Chilliwack, Harrison Hot Springs, Hope, Kent, Mission, and Electoral Areas A-H comprise the Fraser Valley Regional District.

Information compiled for 2001, British Columbia Ministry of Agriculture, Food and Fisheries, Solvej Patschke, pers. com.

	British Columbia	Fraser Valley Regional District	% of the Province Total
Population	3,907,738	237,550	6.1
Jurisdictional Area	92,973,000 ha	1,399,370 ha	1.5
ALR Area	4,724,300 ha	74,190 ha	1.6
Total Area Farmed	2,587,118 ha	48,670 ha	1.9
No. of Farms Reporting	20,290	2,661	13.1
Average Farm Size	127.5 ha	18.3 ha	14.4
Total Farm Capital	$15,831,578,331	$3,005,136,751	19.0
Total Gross Receipts	$2,307,697,089	$735,859,984	31.9

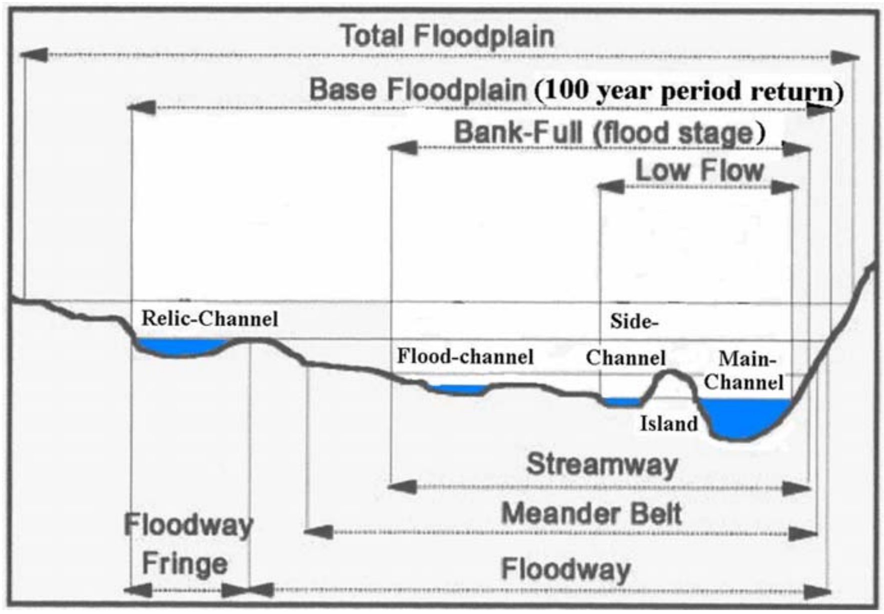
1.2 The Role of Floodplains as Salmon and Steelhead Habitats

1.2.1 Floodplains Defined

A floodplain can be defined in a variety of ways but is usually considered to be that part of the low-lying landscape adjacent to a stream which is inundated by water on a relatively frequent basis (Cordes 1972, Millar et al. 1997, Church and Eaton 2001) (Fig. 4). It is the repeated nature of the flooding over the hydrological cycle—within years and among years—that characterizes any given floodplain. During flood flows, many streams deposit rich sediments over the floodplain, creating a base of productive soils favourable to natural organisms adapted to intermittently-wetted conditions. We note that this phenomenon is also good for developing rich soils for agriculture and is common amongst many large rivers around the world (e.g., the Nile River).

Figure 4. Generalized schematic of a floodplain cross-section.

Note that the water surface elevation of the 100-year discharge return is considerably greater than base or low flows. Compare with Fig. 5. Adapted from Brown (2002).



The discharge of a stream throughout the period of a year can be shown using a hydrograph (Fig. 5). Hydrographs are charts that display the change of a hydrologic variable over time. Long-term hydrographs for most natural streams show that there are average discharges and patterns that are generally predictable for any given time of the year. Aquatic organisms living in streams are assumed to be adapted to the various discharge phenomena seen in their watersheds. This includes drought as well as flooding and inundation of the floodplain.

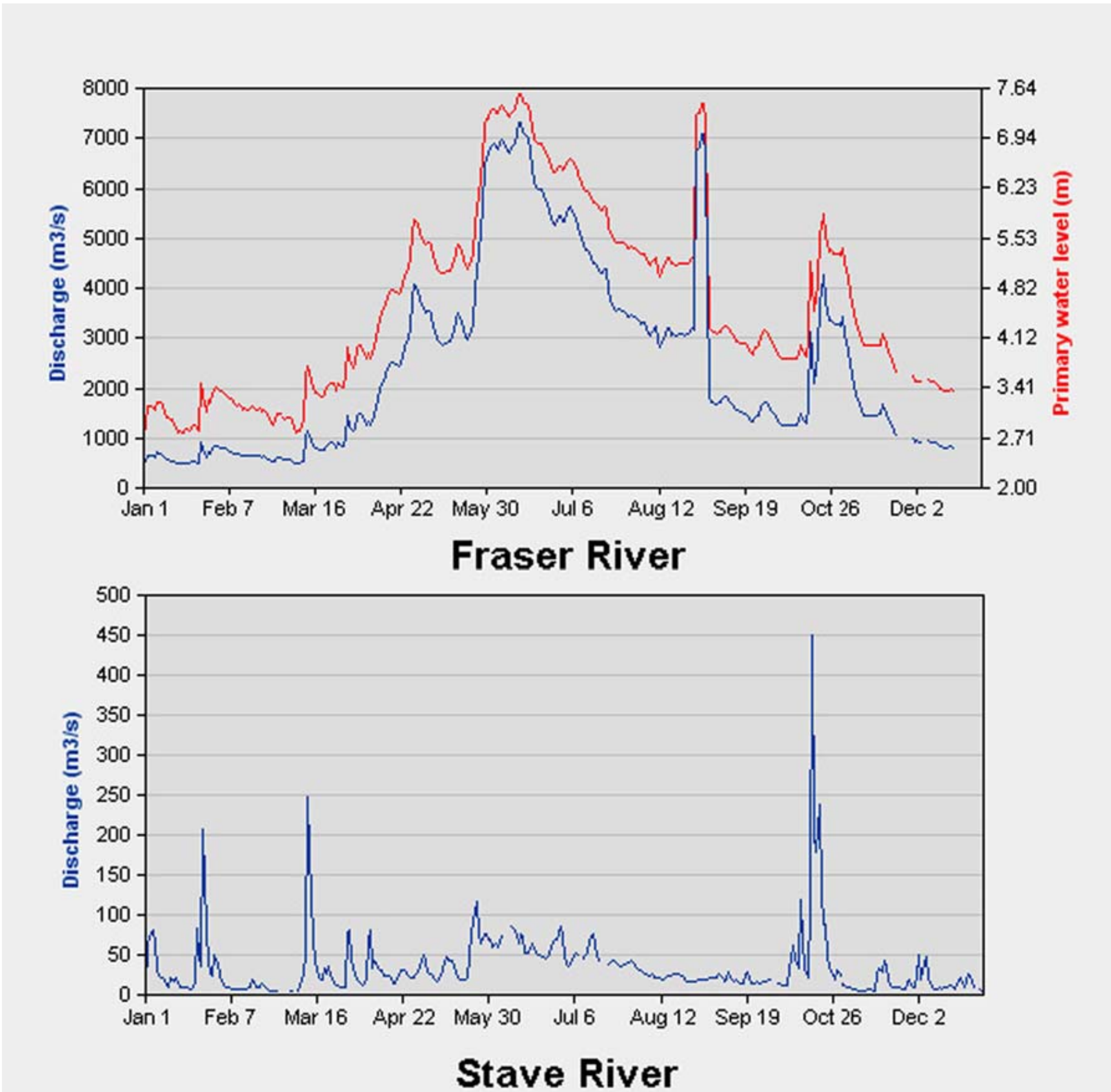
For most south-coast British Columbia streams, including the many tributaries of the lower Fraser in the eastern Fraser Valley, higher-than-average flows, or floods, normally occur during the spring. At this time, the winter-accumulated snow pack melts as temperatures warm toward summer (Fig. 5) and the floodplain is inundated. A second period of freshet and lowland flooding occurs during the late autumn and early winter when the Pacific storms drop their heavy rains in high volumes (Fig. 5). It is during this latter part of the year when the highest-peak discharges occur in the small and medium-sized eastern Fraser Valley streams. While spring freshet is comparatively lower in magnitude, it is normally more sustained than the autumn-winter discharges in these coastal watersheds.

In contrast, the much larger Fraser River, where it flows through the eastern Fraser Valley, has a flood cycle that is very different from these smaller local streams (Fig. 5). The peak discharge of the Fraser River occurs during late spring/early summer when much of the freshet discharge is derived from snowmelt-dominated watersheds in the interior of the province.

It should be noted that before extensive diking was put in place throughout the eastern Fraser Valley, much of the area outlined as floodplain (Fig. 2), and which is now dry in the spring due to flood-protection infrastructure, would normally have been inundated, and fish would have used most of these areas.

Figure 5. Comparison of yearly discharges between a Lower Mainland stream with a coastal-type hydrograph and the lower Fraser River.

Flows are over the period of 2003. The Stave River snowmelt flows in the spring (April through July) are sustained but the peaks are not as high as the autumn/winter flows; in contrast, the peak flows in the lower Fraser River are during late-spring/summer freshet. "Primary Water Level" on the y-axis of the Fraser River figure refers to the change in water surface elevation at the water-level recorder at Hope, which was over 4 metres in 2003, an average-peak-flow year, but can easily be much higher in other years. Note also difference in scale for discharge axis between the top and bottom graphs. Figures taken from the Environment Canada Water Survey web-site. www.scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp



1.2.2 Functional Aspects of Floodplains for Aquatic Ecosystems

Flow Cycle

Much has been written recently in the scientific literature about the role of floodplains in sustaining healthy endemic fish populations and aquatic ecosystems, and their relationship to the natural hydrological cycles of flooding and drought, (e.g., Annear et al. 2002, Benke 2001, Poff and Ward 1989, Welcomme 1979). While it is not the intent of this report to exhaustively review the subject, it is important to understand the basics of the relations between stream flow, or hydrology, and fish, in order to recognize the differences between properly-functioning aquatic habitats and floodplains converted into agrarian landscapes. We note also that, specific to this province, one of the most comprehensive examinations of this topic was undertaken by Brown (2002) in his review paper "Floodplains, flooding and salmon rearing habitats in British Columbia", and much of the following discussion is based on that report.

Stream scientists studying the interactions between the aquatic ecology and physical structure of rivers indicate that ecosystem complexity is maximized on unconfined (un-diked, un-armoured, un-channelized) streams (Gregory et al. 1991, Stanford and Ward 1988, Hauer et al. 2004). It is the opinion of Hauer et al. (2004) that under natural conditions, biodiversity and biological production are greatest for both aquatic and terrestrial ecosystems on wide floodplains. They cite Hutto and Young (2002), Pepin and Hauer (2002), Mouw and Alaback (2003), and Harner and Stanford (2003) for examples demonstrating these relationships.

In British Columbia the productivity of aquatic ecosystems in salmon and steelhead streams is tied to the natural hydrological cycles which include the various aspects of regularly occurring flood events (Brown 2002). Brown (2002) suggested that when streams are separated from their respective floodplains and associated hydrological processes, considerable loss of salmonid habitat eventually results.

In many ways, floods in streams define the character of individual aquatic ecosystems. They are an integral part of the hydraulic power that creates the structures of rivers and they ensure that the riparian areas continue to function properly through landscape renewal (Power et al. 1988, Junk et al. 1989, Reice 1994, Tabacchi et al. 1998, Stanford 1998, Lorang and Hauer 2003, Hauer et al. 2004).

Seasonal flooding has been determined to be so critical in maintaining aquatic ecosystems in western North American streams that a number of large-scale experiments are now being conducted on dammed rivers, where these flow regimes have been lost, in attempts to restore physical and biological attributes that are now missing as a result of dampened discharges. Examples of this include releases of flood flows down the Colorado River (Konieczki et al. 1997) and the Kootenay River (Korman and Walters 1999). In contrast, the control of flooding on floodplains is usually one of the first steps taken when converting regularly inundated lowlands into agricultural production. This in turn alters or interrupts natural biological processes.

Adaptation to Floods

Flooding in salmon-bearing watersheds, either during spring freshet or as a result of late-autumn rains, is natural and normal. Over many eons, fish and invertebrates have adapted to the seasonal and stochastic changes in stream flows, variations in water-surface levels, and the inundation of riparian, low-elevation, adjacent landscapes during floods (e.g., Brown 2002). Floods sometimes present problems for the survival of stream-dwelling organisms (e.g., displacement downstream), but they can also provide opportunities for aquatic animals. Fluvial organisms usually "know" when to migrate out of the heavy currents, and they will relocate laterally into slower velocities in order to secure protection from displacement, obtain new sources of food or search out new habitats in response to the opportunities provided by these changing flow conditions (Brown 2002).

It is also during floods that adult or juvenile fish often move into alternative spawning or rearing areas. Many of the spawning runs of Fraser River interior chinook salmon (*Oncorhynchus tshawytscha*) migrate from the ocean and up the river during peak freshet, apparently to gain access to habitats that are otherwise difficult to ascend to under lower flows. Similarly, juvenile coho (*O. kisutch*) use flood discharges to gain access to off-channel over-wintering or summer feeding areas that may otherwise be isolated from the main channel of a stream (Brown 2002, and citations therein).

High flows and floodplain inundation also entrain nutrients and leaf litter from the seasonally-dry riparian lands into the year-round wetted areas; this allows algae and insects to cycle these essential components of the food-web into the aquatic ecosystem. Many species of trees are adapted to floods (e.g., black cottonwoods) and their leaves and large woody structure are an integral component of the nutrients and physical configuration of fish habitat in streams.

When floods no longer occur, either through natural occurrences or man-made actions such as when a watershed is dammed or diked, plants and animals that are adapted to intermittent floods are replaced by others that are not. As a result of this activity, the ecosystem changes and generally becomes less diverse.

Floods and the Power of Stream-Flows to Create Habitat

Flowing water shapes the landscape. The Grand Canyon, which was created by the Colorado River, is a graphic example of the erosive power of moving water. The energy contained in the flowing stream is a major component creating the diversity of habitats found in gravel-bedded rivers.

High discharges and fast-moving water create a succession of habitats in streams over time through sediment erosion and deposition. This hydraulic action generates new channels and can cause older, more mature, channels to become secondary and senescent in terms of their discharge capacities. In broad floodplains the results of this activity can be seen in extensive meander patterns and oxbows. Because depth and velocity of discharge strongly define stream habitats, aquatic communities at any given location will change composition accordingly as the flow capacity of an individual channel is modified.

Floods in unconfined streams with wide floodplains can have not only areas of high-velocity water flow, but also large expanses of quiet waters outside of the perimeter of the main-discharge channel. At these locations even the fine sediments deposit on the floodplain due to a lack of velocity. However, once an area's waterways have been constrained with dikes and armoured banks, many of the slow-velocity areas can be lost, and the main-channel water velocities can be increased as a result of floodplain narrowing and throttling of the stream.

Floods are also important in that they clean and expose new spawning and rearing gravels for salmon and steelhead, thus revitalizing a stream's fish-producing capacities. During flooding events, aquatic plant communities can be eroded from a location in a stream but others may arise at nearby locations, in quiescent areas.

Floods and erosion also recruit large woody debris into waterways from riparian zones through the action of stream-bank erosion. Large uprooted trees floating down a stream can then aggregate and form log jams which help to stabilize and knit together the stream bed into a more secure matrix (Andrus et al. 1988, Bilby 1984, Maser and Sedell 1994). Large woody debris is also a key component of the physical diversity and creates key habitats for juvenile stream-rearing salmon and steelhead (Hartman 1965, Murphy and Koski 1989, Fausch and Northcote 1992, Maser and Sedell 1994).

In summary, the power of stream flows during flooding causes the habitats within these watercourses to change in space and time in ways that are generally predictable over long periods. This phenomenon has been termed the Shifting Habitat Mosaic (Stanford et al. 2001 cited in

Hauer et al. 2004), and in a properly functioning ecosystem this occurs across the floodplain. This complex and always-changing habitat "patchwork quilt" has all of the available habitat attributes present at any given time but their locations and prevalence change over the period of interest. In a floodplain environment, the Shifting Habitat Mosaic is spatially and temporally dynamic, is the essential and established template for supporting the biodiversity, complexity and production of a river system, and is sustainable only through geomorphic change driven by river hydraulics. The dynamic nature is of the Shifting Habitat Mosaic is driven by flowing water and predictable seasonal cycles, and the plants and animals that live there are adapted to its qualities.

However, once an area's waterways have been diked, armoured and channelized for the purposes of developing floodplains for agriculture, or other development purposes, the Shifting Habitat Mosaic is disrupted and a simpler and less diverse aquatic community results.

1.2.3 Some Important Macro-Features of Aquatic Ecosystems on Floodplains

Side Channels

Side or secondary channels of streams, which can be distinguished from the main channel, are an important macro-habitat component for both salmon and steelhead on floodplains. Side channels have direct and linear flow for all or part of the year, tend to be less vegetated, and have more unconsolidated substrates than wetlands.

Side channels often act as nursery areas for young salmonids and other species of fish. In many British Columbia streams, side channels are extensively used by juvenile coho, chinook and steelhead fry immediately after emergence from their incubation gravel. They are attractive to juvenile fish due to reduced water velocities, higher invertebrate production and generally warmer temperatures than are found in main channels.

Side channels are also commonly used for adult salmon spawning, particularly by chum (*O. keta*) and coho (*O. kisutch*) where groundwater up-wells out of the gravel in coastal streams. Extensive use of side channels by non-salmonid fishes also occurs in British Columbia streams.

Wetlands

Wetlands comprise an important component of the aquatic ecosystems of most properly functioning floodplains. Wetlands are a transitional zone between streams and terrestrial areas where the soil or substrate is at least periodically saturated or covered with water. Some wetlands contain surface water throughout the year while others are seasonal in nature. Seasonal isolation from fish-bearing streams can also be natural or the result of human intervention through activities such as diking.

Wetlands are usually physically offset from the main discharge of the stream and the velocity of water moving through them is normally very slow or non-measurable. Wetlands are usually naturally created and modified through erosion, stream meander and channel isolation. Freshet inundation can cause riparian areas to become temporary wetlands. Permanent wetlands can be slow flowing or stagnant water bodies that exist in what may have once been a major or secondary stream channel but, over time, have become isolated from the river's mainstem. Wetlands that are partially or completely disengaged from year-round stream flows will often contain low-oxygen- and high-temperature-tolerant species of fish, and any salmonids that may be present will most likely be transitory entering these habitats during those parts of the year when water quality is better (Slaney and Northcote 2003). Plants and animals adapted to wetland habitats can often survive and thrive to the exclusion of others because of their tolerance to inundation.

Where connections from wetlands to flowing water occur, either intermittently or permanently, they can be used by salmonids for overwintering, as refugia during floods or as off-channel rearing habitats. Brown (2002) indicates that many wetland habitats support higher densities of fish than riverine environments due to more favourable water temperatures and an abundance of food. Coho salmon, in particular, are adapted to use off-channel or wetland habitats (Sharma and Hilborn 2001, Brown 2002) although many other species, including both salmonids and non-salmonids, will exploit these environments.

Flooding can be very important in providing juvenile coho access to wetland habitats. Brown and Hartman (1988) examined the contribution of floodplain sites for juvenile coho salmon during a wet and dry spring and found the difference in production to be 23% versus 15%, respectively. Size and survival of coho in these off-channel habitats can be greater than in the main channel (Tschaplinski and Hartman 1983, Bustard and Narver 1975).

Chinook and other species of salmon are also known for temporarily using freshet-floodplain wetlands and flooded hayfields in the interior of British Columbia in spring. Brown (2002) reported that: "…Fedorenko and Pearce (1982) felt it was evident that sloughs and flooded pastures were important rearing areas for juvenile chinook in the lower Shuswap River". Following spring flooding, sockeye salmon (*O. nerka*) and chinook salmon fry have been found stranded in drainage ditches and fields adjacent to the Horsefly River where they were rearing (Brown 2002, Mueller and Kent 1988). Chinook juveniles have also been captured in a flooded riparian campsite on the Thompson River at Spences Bridge (R. Lauzier personal communication, cited in Brown 2002) and the senior author of this report has observed this phenomenon at a number of locations around the province.

It's widely believed that the movement of juvenile chinook salmon into flooded areas occurs during freshet flooding in the Fraser, Harrison and Chilliwack rivers in the eastern Fraser Valley, although the documentation to date has been poor. Brown (2002) suggests that the temporary use of flooded habitats has been poorly researched and is only realized when fish are stranded as the waters subside. The lack of documentation in this regard may be due, in part, to the difficulty in sampling these "swampy" habitats. Nevertheless, Levings et al. (1995) and Murray and Rosenau (1989) show evidence of the extensive non-natal wanderings of juvenile chinook during freshet in the lower Fraser River basin.

The Hyporheic Zone

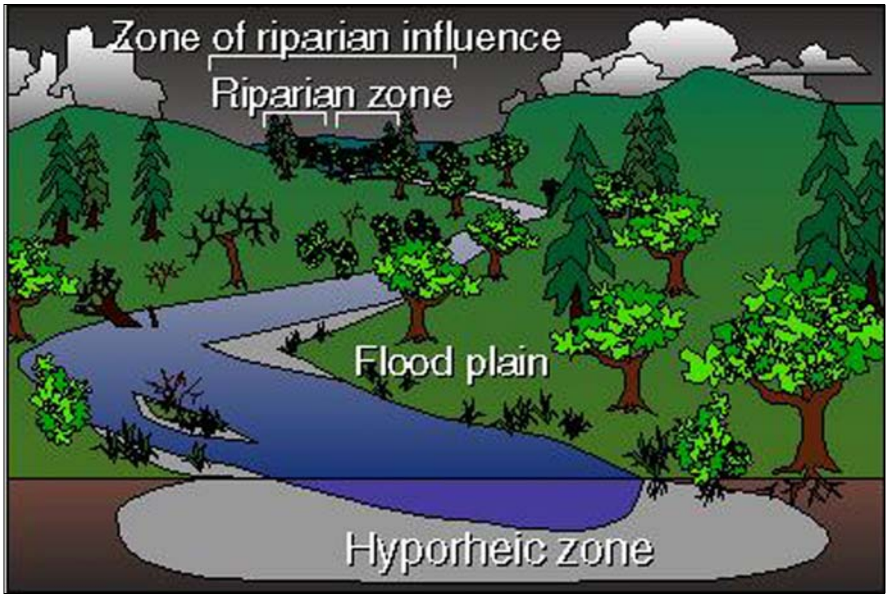
Wetlands without surface connections to a stream can still influence salmon and steelhead production through subsurface (groundwater) or hyporheic (Fig. 6) flows. The study of hyporheic zones is a fairly new science.

Many organisms can be found in the hyporheic zone, including stream-rearing invertebrates. These organisms become entrained into the subsurface habitats during drought when surface waters disappear. The hyporheic zone can be hundreds of metres across a floodplain and up to 10 metres deep in western North American streams (Stanford and Ward 1988). Changes to the surface topography and draining, as can happen when floodplains are converted to agriculture, will affect the hyporheic environment (Fisher 1996). Contaminants, such as manure or pesticides, deposited near a stream can enter into watercourses inhabited by salmon and steelhead through hyporheic flows.

Figure 6. The hyporheic zone.

This region comprises subsurface groundwater discharges which are linked to surface flows. Figure from www.fish.washington.edu/naturemapping/water/1fldhypo.html

See also: www.public.asu.edu/~nbgrimm/abstracts.html



The Riparian Zone

The riparian zone of a stream is a critical component of the floodplain and its aquatic habitats (Fig. 7). Riparian areas are transitional and located immediately adjacent to the wetted perimeter of the stream; they are neither wholly aquatic, nor wholly terrestrial. The riparian zone is a part of the landscape which is primarily influenced by moisture derived directly from the stream, and acts as an interface between wet and dry environments. This zone is viewed by some as an ecotone or an area that exists as a bridge between two different types of habitat or environments (i.e., aquatic versus terrestrial). In a practical sense, it is the vegetated area which often constitutes a buffer between the edge of the water and the surrounding uplands. As a general rule of thumb, the larger the stream, the larger the naturally occurring riparian zone.

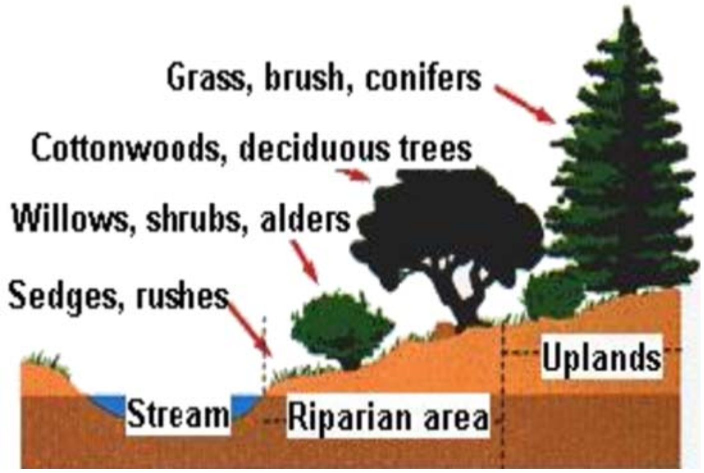
The makeup of the riparian area defines bank stability, recruitment of large woody debris, moderation of stream temperatures, reduction of sediment input, filtration of pollutants, functionality of allochtonous food webs (e.g., leaves dropping from trees providing forage for insects), and reduction in harmful ultraviolet radiation (Brown 2002). Castelle et al. (1994) and Correll (1997) provide reviews demonstrating the need for adequate riparian areas to protect aquatic resources in areas subject to human development. Disturbance of the riparian area, whether as a result of forest practices, agriculture or other forms of development, will normally have an adverse impact on aquatic ecosystems. Unfortunately, riparian zones are often lost or heavily compromised when agricultural activity intensifies in areas immediately adjacent to watercourses.

Much discussion has arisen regarding the size of riparian zones that is required to protect fisheries values in streams (e.g., Castelle et al. 1994, Correll 1997). The primary issue relates to the requirement to maintain appropriate widths under different land-use practices. There remains considerable confusion regarding the application of various Acts and regulations in British

Columbia in terms of how riparian protection applies to various land use activities such as forest harvesting, urban development, and agriculture.

Figure 7. Diagram of a riparian zone.

This area next to streams is particularly sensitive to physical impacts from cattle activity in agricultural settings. The riparian boundary is also important in modifying agricultural wastes and pesticides by minimizing the transfer of these materials from the surrounding fields to the watercourse. Figure adapted from Agriculture Canada web site—www.agr.gc.ca/pfra/land/gft14.htm



Riparian zones can also be negatively affected when the banks of a stream are "hardened" with rip-rap rock or other such non-native structures or materials to prevent erosion (Fig. 8). These materials are engineered into, or onto, the banks of the stream to prevent loss of land or infrastructure. Natural erosion processes of the riparian area are key to recruiting large woody debris and appropriately-sized sediments (gravel) for spawning and rearing, as well as creating side channels and wetlands through avulsion. Consequently, the hardening of banks in riparian areas damages fish habitat and significantly alters the Shifting Habitat Mosaic as described above.

Figure 8. The hardening of stream banks.

The use of: 1. of blasted rip-rap rock, 2. demolition waste, and 3. a constructed debris catcher, to protect stream banks from erosion. While the debris catcher provides more habitat opportunities for juvenile fish rearing, all three methods of bank protection disrupt fluvial processes and impact the Shifting Habitat Mosaic and are ultimately destructive to fish-habitat sustainability. Photos 1, 2—Fraser River; Photo 3—Vedder River.

1.3 Salmon and Steelhead Use of the Eastern Fraser Valley

1.3.1 Overview

The Fraser River watershed supports some of the world's largest salmon runs and is responsible for over 50% of the production of salmon species in British Columbia (Fraser River Action Plan 1998).

While the land base of the Fraser Valley and the watersheds that drain into the Fraser River represent less than 5% of the total area of the entire Fraser Basin, this area supports the production of approximately 80% of the Fraser watershed's chinook and chum salmon, 65% of its coho salmon, 80% of its pink (*O. gorbuscha*) salmon and significant stocks of sockeye salmon (Fraser River Action Plan 1998). Much of this productivity occurs in the eastern Fraser Valley.

The Fraser River Action Plan (1998) has also indicated that about 150 of the 300 significant streams in the entire Fraser River watershed that supported runs of spawning salmon, originated in or flowed through the Lower Fraser Valley. Again, a significant number of these are located in the eastern portion of the valley (e.g., Suicide/Norrish Creek, Vedder/Chilliwack and Harrison rivers) and are in direct or indirect contact with agricultural activity.

Finally, all of the salmon and steelhead runs originating upstream of the eastern Fraser Valley must pass through the Fraser River in this area, either as adults migrating upstream or as juveniles emigrating downstream. Thus, the juveniles out-migrating to the ocean passing through this area use it as rearing habitat ranging from short-term (hours) to long-term (months).

1.3.2 Mainstem Fraser River

The reach of the Fraser River that flows through the eastern Fraser Valley is one of the richest freshwater environments in British Columbia in terms of both the number of fish species present and total fish biomass (Rosenau and Angelo 2000; e.g., Fig. 9). The lower Fraser River in the Fraser Valley comprises spawning, rearing and/or migratory-pathway habitats for the almost thirty species that inhabit this area. Most of these species are distributed throughout its floodplain side channels as well as the main stream. Non-salmon species of note include the small eulachon (*Thaleichthys pacificus*), or candlefish, which swims up from the ocean in large numbers to spawn. The white sturgeon, which is the largest freshwater species in Canada and which grows to lengths greater than 4 metres, also spawns and rears in the Fraser River between Mission and Hope; the remaining large, un-impounded side channels are key sturgeon spawning habitats (Perrin et al. 2003).

Figure 9. Seine haul comprising a mixture of different species of fish from the mainstem Fraser River in the reach between Mission and Hope, 2001.

Because of the high level of fish biodiversity in this reach of the Fraser River, many species are normally caught in a single seine haul.

The Fraser River between Mission and Hope is used as a migratory pathway by all species of salmon and steelhead, including both local stocks and those that travel upriver beyond Hope. A lesser number of Fraser River salmon stocks originate downstream of Mission and, with the exception of Stave River chums and Pitt River sockeye, most of these are small in number.

The salmon species with the largest number of migrating adult fish using the Fraser River as it traverses the eastern Fraser Valley is the pink, followed by sockeye. Steelhead adults are fewest in number of the six Pacific salmon species primarily considered by this report, and their escapement to the entire Fraser River is less than 10,000 adults annually.

The mainstem of the Fraser River, as it flows through the eastern part of the valley, is also a key spawning river for some species of salmonids. Indeed, it currently comprises vital habitat for pink salmon, the largest spawning run of any salmon species anywhere in British Columbia. This run may have recently exceeded 10 million fish in the last spawning cycle for this part of the river (Bruce White, Pacific Salmon Commission; pers. com. 2004).

Chum salmon adults also spawn in the lower Fraser River in the eastern Fraser Valley but unlike the pink, which spawn in the mainstem, they predominantly use the large groundwater-fed side channels adjacent to, and attached to, the main river. The escapement of this species in the many side channels that exist throughout the eastern Fraser Valley now exceeds 1 million fish in many years (Farwell et al. 1987). Chum and pink salmon spawning in this reach of the Fraser River have increased markedly over the past two decades, possibly due to highly conservative harvest strategies.

It should be noted that while chums and pinks intensively use the mainstem Fraser River and groundwater-fed side channels between Hope and Mission for spawning, the other three species of salmon, and steelhead, do not regularly spawn there.

The mainstem of the lower Fraser River is also an important rearing area for all species of juvenile salmon. Nevertheless, while considerable numbers of young sockeye, coho and pink salmon, as well as steelhead juveniles, can be found in this part of the Fraser during springtime, they are in the midst of their migration from fresh- to salt-water rearing areas. The feeding period for these four species will be short, and they swim through this area in transition from fresh water to the sea in possibly as little time as a few hours to several days.

The two species that extensively use the lower Fraser River for rearing are chinook and chum salmon juveniles. Chum fry feed in fresh water for up to a number of weeks after emergence from the gravel. The large gravel bars and side channels provide rearing habitat for juvenile chum salmon in the Fraser River in the eastern Fraser Valley until mid spring (Ellis et al. 2004).

In contrast, juvenile chinook salmon can be found along the gravel bars and side channels of the lower Fraser River in the eastern Fraser Valley throughout the whole year (Levings and Lauzier 1991; senior author's personal observations). Levings and Lauzier (1991) examined the distribution of the mainstem Fraser River for chinook rearing and found that, over the extended geographic distance of this stream, the mean length of juvenile chinook increased with distance downstream (65 mm at km 770 to 97 mm at km 110). Their work suggests that the chinook juveniles found in the Fraser River grow as they move downstream.

Based on the concepts discussed in the previous section, we suggest that the physical integrity of the in-stream and riparian habitats is an important component of the habitat capacity of the Fraser River as it flows through the eastern Fraser Valley. The mainstem Fraser River in the eastern Fraser Valley has probably maintained considerable variability in its physical habitats due to its size and power, and it continues to sustain a significant degree of biodiversity albeit at a considerably reduced level from pre-settlement times. The greatest loss in habitat has been of the large side channels and expansive floodplain that historically were attached to the main river (Ellis et al. 2004). We discuss this issue further in our report and show that the development of agriculture in the eastern Fraser Valley was the initial and primary reason for these Fraser River attributes to be separated from their main channel.

1.3.3 Eastern Fraser Valley Streams—Key Tributaries of the Lower Fraser River

Background

Most of the myriad tributaries to the Fraser River in the eastern Fraser Valley are used by salmon and/or steelhead for spawning and/or rearing. Because of their widely varying physical, chemical, temperature and flow characteristics, they provide different habitats for species assemblages that may not normally be found in the larger Fraser River and its extensive large-stream floodplain. Many of these small streams are, or have been, influenced by agricultural activities (Table 2). They range in size from tiny Dunville Creek in the eastern hills of Chilliwack (it can normally be waded in knee-high boots) to the Vedder/Chilliwack River flowing out of the Cascade mountain range (mean annual discharge is 64 cubic metres per second), and up to the Harrison River, on the north side of the Fraser River at Agassiz, which has a mean annual discharge of 482 cubic metres per second and contributes over 10% of the peak Fraser River flows during freshet periods.

Small Streams

Many of the smaller streams in the eastern Fraser Valley provide spawning and rearing habitat for a variety of salmon species, and these are primarily chum, coho and cutthroat trout. Most of these streams have at least a portion of the watershed flowing through currently or historically farmed land. Many of these habitats are also dominated by rearing juvenile cutthroat trout (*O. clarki*) (Fig. 10) and young-of-the-year coho salmon (Fig. 10). Coho salmon in the south coast of British Columbia normally require a year of freshwater rearing before migrating to sea, while cutthroat trout usually require two or more.

The number of salmon spawning in the various tributaries of the lower Fraser River prior to European contact is unknown and very little information is available prior to the early 1950's. Over the past 50 years, most of these small eastern Fraser Valley streams have had populations of adult coho salmon estimated to peak in run-size in the hundreds to the low thousands. However, the general trend over that time appears to have been one of decline (Fig. 11). These declines are the result of overfishing, fluctuations in marine survivals, and freshwater-habitat degradation and loss.

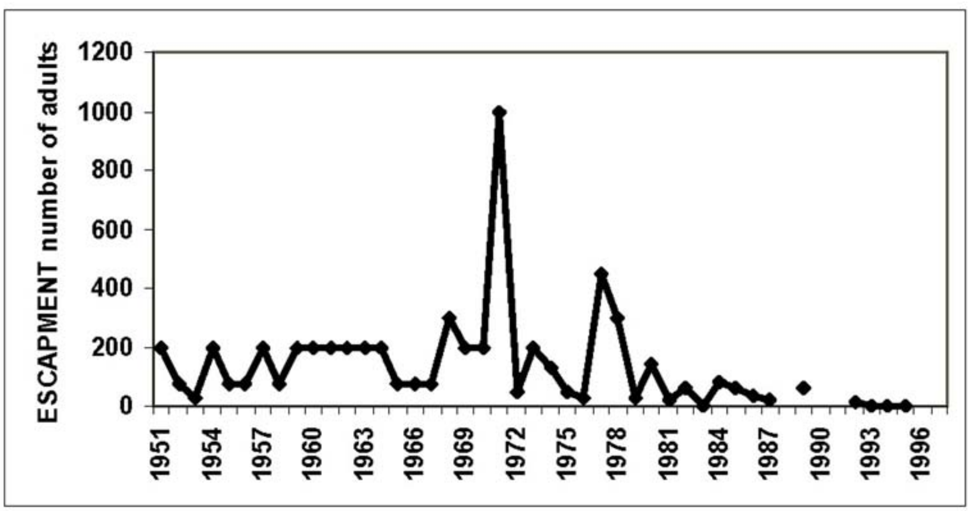
Most of the small eastern Fraser Valley streams have been channelized or modified in order to convey more discharge and lower the water table as they flow through the lowland farmlands. Channelization of many of these streams occurred sometime after the turn of the last century as the eastern Fraser Valley was settled and farmed. Because much of this in-stream activity occurred before escapement estimates were undertaken by government agencies, the true extent to which fish stocks and habitats were impacted remains unclear, but the abundance of wild salmon is likely but a fraction of what it was before the arrival of the Europeans to the area.

Figure 10. Juvenile salmonids of the eastern Fraser Valley which require an extended period of freshwater stream rearing.

Steelhead parr photo taken from ***www.bccf.com/steelhead/photo-gallery.htm*** *; chinook fry, author's photo.*

Figure 11. Coho escapement for Dunville Creek, eastern hillsides, Chilliwack, 1951-1997 inclusive.

Data are from Fisheries and Oceans Canada nuSEDS (Salmon Escapement Database System) and should not be considered absolute, but relative, although they do provide order-of-magnitude values. Blanks indicate years where no enumeration occurred. We view this trend in coho escapement estimates for Dunville Creek to be representative of most of the small eastern Fraser Valley agricultural streams.



Side Channels

The Fraser and Vedder/Chilliwack rivers still have a number of groundwater side channels which have not been diked or diverted. These relatively intact streams normally comprise spawning habitats that are used extensively by spawning chum and coho salmon, and rearing juvenile fish of these and other species.

Chum and coho salmon sometimes also use impounded side channels that have been cut off from the Fraser or Vedder/Chilliwack rivers as a result of diking. These streams, however, do not appear to have nearly the same level of habitat capacity for these species of spawning fish. The semi-isolated Fraser River side channels include Maria and Hope sloughs; Atchelitz, Chilliwack and Luckakuck creeks are former lower-river channels of the Chilliwack River. Few salmon remain in any of these channels (e.g., Table 2) except for Maria Slough (Fraser River at Agassiz).

In recent years fisheries enhancements have been undertaken for some of these channels in an attempt to rehabilitate their lost production. There have been extensive local efforts to restore habitat for chum salmon by Fisheries and Oceans Canada over the past three decades in the eastern Fraser Valley, and Maria Slough and Peach Creek (Vedder River) are locations with some apparent success.

Table 2. Fisheries and Oceans Canada adult-coho spawner escapement data for Luckakuck Creek.

From the mid-1980's until now there has been extensive conversion from agricultural to urban and commercial development of the adjacent riparian and upslope landscapes ,and this has been co-incident with the declining number of spawners present.

Year	Status	Amount	Year	Status	Amount	Year	Status	Amount
1951	*Present*	200	**1966**	*Present*	75	**1981**	*Present*	60
1952	*Present*	200	**1967**	*Present*	113	**1982**	*Present*	146
1953	*Present*	75	**1968**	*Present*	25	**1983**	*Present*	75
1954	*Present*	75	**1969**	*Present*	25	**1984**	*Present*	160
1955	*Present*	200	**1970**	*Present*	25	**1985**	*Present*	150
1956	*Present*	75	**1971**	*None observed*	0	**1986**	*Present*	75
1957	*Present*	75	**1972**	*Present*	75	**1987**	*Present*	180
1958	*Present*	75	**1973**	*Present*	50	**1988**	*Present*	100
1959	*Present*	200	**1974**	*Present*	250	**1989**	*None observed*	0
1960	*Present*	75	**1975**	*Present*	50	**1990**	*Present*	3
1961	*Present*	75	**1976**	*Present*	25	**1992**	*Not inspected*	-
1962	*Present*	200	**1977**	*Present*	100	**1993**	*Present*	30
1963	*Present*	75	**1978**	*Present*	250	**1994**	*None observed*	0
1964	*Present*	75	**1979**	*Present*	20	**1995**	*Present*	58
1965	*Present*	25	**1980**	*Present*	92	**1996**	*Not inspected*	-
						1997	*Not inspected*	-

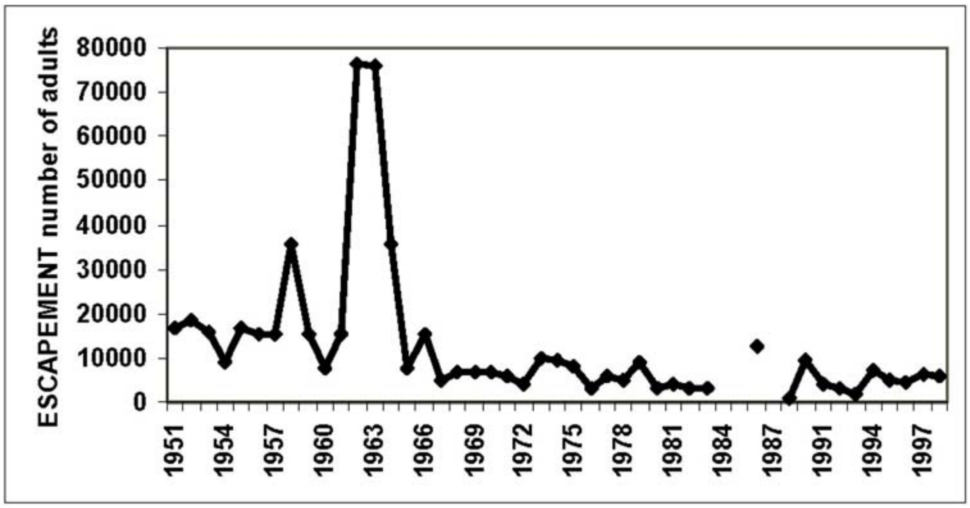
Chilliwack/Vedder River

All six species of salmon spawn in the Chilliwack/Vedder River watershed. Chinook, coho and steelhead juveniles are also commonly observed rearing in the Vedder/Chilliwack River. This is different from the coho/cutthroat trout community that is predominantly found in the smaller eastern Fraser Valley streams (Hartman 1965, Hartman and Gill 1968). Steelhead juveniles (Fig. 10) require 2-4 years of stream rearing before smolting while coho juveniles (Fig. 10) live in fresh water for a year and chinook (Fig. 10) smolts in southern British Columbia generally leave fresh water for the ocean after a few months.

Wild coho salmon, probably the most influenced by floodplain development in the eastern Fraser Valley due to wetland losses, have been on the decline in this watershed over the past 50 years (Fig. 12). However, because of many other factors influencing production of coho (e.g., overfishing, ocean survival) the relative importance of the various factors that may have led to these declines is not known. To further confound the issue, Vedder/Chilliwack River coho are now extensively influenced by hatchery production.

Figure 12. Coho escapement for Chilliwack/Vedder River, 1951-1998 inclusive.

Data are from Fisheries and Oceans Canada nuSEDS (Salmon Escapment Database System) and should be considered relative only for wild fish. Blanks indicate years where numbers were not estimated.



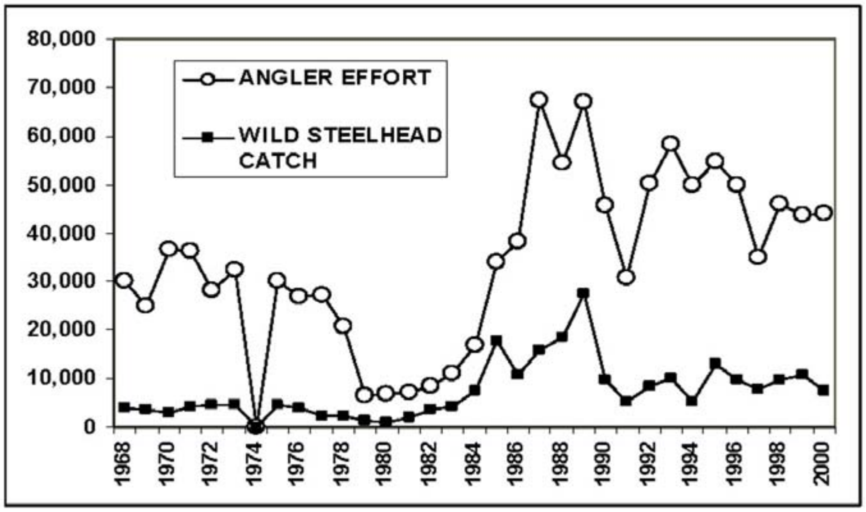
In most years chum and pink salmon runs are moderately abundant in the Vedder/Chilliwack River and there has been a general upward trend over the past half century, including those areas of the watershed impacted by agriculture. Reasons for this may include changes in harvest management, which has become more restricted in recent decades. Furthermore, restrictions on human activity in this stream, and a natural recovery of upstream riparian areas historically impacted by the extensive logging that occurred several decades ago, may also be assisting in the revitalization of the watershed. Consequently, due to recently improved stream conditions we may now be seeing the partial recovery of some Chilliwack River stocks that had bottomed out by the middle of the last century, although it is unlikely this is anywhere near pre-European historical abundances.

The wild steelhead escapements in the Vedder/Chilliwack River, over the past 50 years, have varied considerably and have likely been extensively affected by habitat changes associated with agriculture, forestry and other developments in the floodplain of this stream long before the initiation of stock-abundance estimates (Fig. 13). Steelhead had declined to low levels by the late 1970s, at which point the harvest of wild fish by anglers was curtailed. Steelhead smolt production is particularly sensitive to both the quality and abundance of freshwater habitat, and the combination of over-harvesting and cumulative habitat destruction had seemingly taken its toll.

By the mid-1980s, the extensive stocking of hatchery smolts by the fisheries agency provided the opportunity for anglers to harvest cultured steelhead. Any incidentally-caught wild fish were required to be released. Catch-and-release impacts to wild fish appear to be negligible (Nelson et al. 2004). The Vedder/Chilliwack River is British Columbia's most important steelhead watershed in terms of effort with annual angler-days routinely reaching the 50,000 fish per year mark.

Figure 13. Angler effort and wild steelhead catch for the Vedder/Chilliwack River, 1968-2000.

Data from the British Columbia Ministry of Water, Land and Air Protection Steelhead Harvest Analysis. Note that the catch includes both harvested and released fish, but by the early 1980s all wild fish were to be released by regulation. Significant hatchery production (fish allowed to be killed) had occurred in this watershed by the mid-1980s. Note also that the current catches of wild fish include many fish that are caught more than once (Nelson et al. 2004).



Harrison River

The Harrison River is an extraordinarily rich salmon stream and is unique to southern British Columbia for its size and the large lake immediately at its head. The stream is highly stable and has extensive groundwater percolation because of these characteristics. These attributes appear to contribute to high spawning survivals. Reports in the latter part of the 20th century estimated that the Harrison River sustained the largest spawning run of chinook salmon in British Columbia; these numbers are thought to have been in the hundreds of thousands. This population of white-fleshed chinook salmon has declined considerably in numbers since the 1970s.

Juvenile chinook salmon (Fig. 10) from the Harrison are thought to mostly rear in non-natal off-channel areas of the lower Fraser River watershed for some months prior to migrating to the ocean (Murray and Rosenau 1989). They may have traditionally used the Harrison's large left-bank floodplain for rearing purposes prior to its isolation from the stream by agriculture. There have also been numerous large-scale changes to the landscape through development in the lower Fraser River (the estuary), where these fish are known to rear extensively, since the 1970s and this may have accounted for some production loss as well.

All other species of salmon spawn and/or rear in the Harrison River. Pinks are especially abundant in odd-numbered years, as are chum salmon, every year routinely reaching escapement levels in the hundreds of thousands. Coho salmon are abundant in the Chehalis River, a tributary to the Harrison, and the confluence of the two streams is particularly good habitat for this species. It's also possible that coho salmon in some abundance once reared in the Harrison River's left-bank floodplain, before diking.

1.4 Historical Impacts to Fish Habitat Resulting from the Development of Agriculture in the Eastern Fraser Valley

1.4.1 Settlement and the Development of Agriculture

The eastern Fraser Valley became habitable to plants, animals and humans after the last ice age ended about 10,000 years ago. Highly productive post-glacial ecosystems became established and a sophisticated aboriginal culture arose in the area, in part because of the abundant and available food (Siemens 1968). Today the First Nations people of the eastern Fraser Valley are known as the Sto:lo, or the People of the River, and they have long inhabited and used areas along the Fraser and Chilliwack rivers as well as the former Sumas Lake, the primary waterways of the area.

Settlement of the lands in the eastern Fraser Valley by non-aboriginals started to occur about the middle of the 19th century. Prospectors seeking gold in the Interior came through the valley and many saw its agricultural potential. It was obvious to experienced farmers that the lowland floodplains of the Fraser, Chilliwack, Sumas and Harrison watersheds, with their rich alluvial soils, could become productive farmland as they were relatively easy to clear and drain. Shortly afterwards, settlers began to establish farms in the area.

Initially, the landscape and its floodplains were converted to agriculture at only modest levels, and much of the area's produce was transported out of the eastern Fraser Valley by Fraser River cargo boats. This limited production opportunities. However, it soon became apparent that better transportation was needed in order to maximize and expand the available farming opportunities.

This became possible when the Canadian Pacific Railway line was built through the Fraser Valley in 1885. The further development of a spur line into Sumas in 1891, as well as subsequent rail lines built by Canadian National Railway and BC Electric Railway, enabled the transport of perishable goods, such as milk, to more distant markets as this was faster than by boat (Siemens 1968). In due course, the farming sector began to rapidly expand due to greater sales opportunities. As farmers began to populate the valley, land clearing accelerated and the area was progressively surveyed, parceled out, sold, and then cleared and drained for agriculture (Seimens 1968).

All of these activities had an extensive effect on fish and aquatic habitat. Many of the wetted areas and their riparian zones, such as the floodplains of the Vedder/Chilliwack River and the Fraser in the eastern Fraser Valley (Fig. 2), were modified by the land clearing and draining. For example, all these rivers historically had an extensive network of channels until farmers began to systematically block off the most peripheral streams as they converted the natural landscape for agriculture. Subsequently, many of these eastern Fraser Valley wetlands and side channels have been isolated through the diking of channels or lost through the placing of fill, as a result of land "reclamation" for agriculture. Smaller tributary streams in the area were also channelized and diverted with the wetter areas drained for better crop and animal production. About the same time, one of the most dramatic impacts to aquatic ecosystems in the history of British Columbia occurred when Sumas Lake was drained for farming in the 1920's.

Finally, as modern farming techniques were developed and adopted, intensification occurred through the mechanical levelling of the land and the installation of extensive networks of drainage tiles. This was required in order to tightly control the hydrology of the fields. As a result, little remains of what were once vast and diverse aquatic ecosystems in the eastern Fraser Valley.

Below we discuss these historical events in detail.

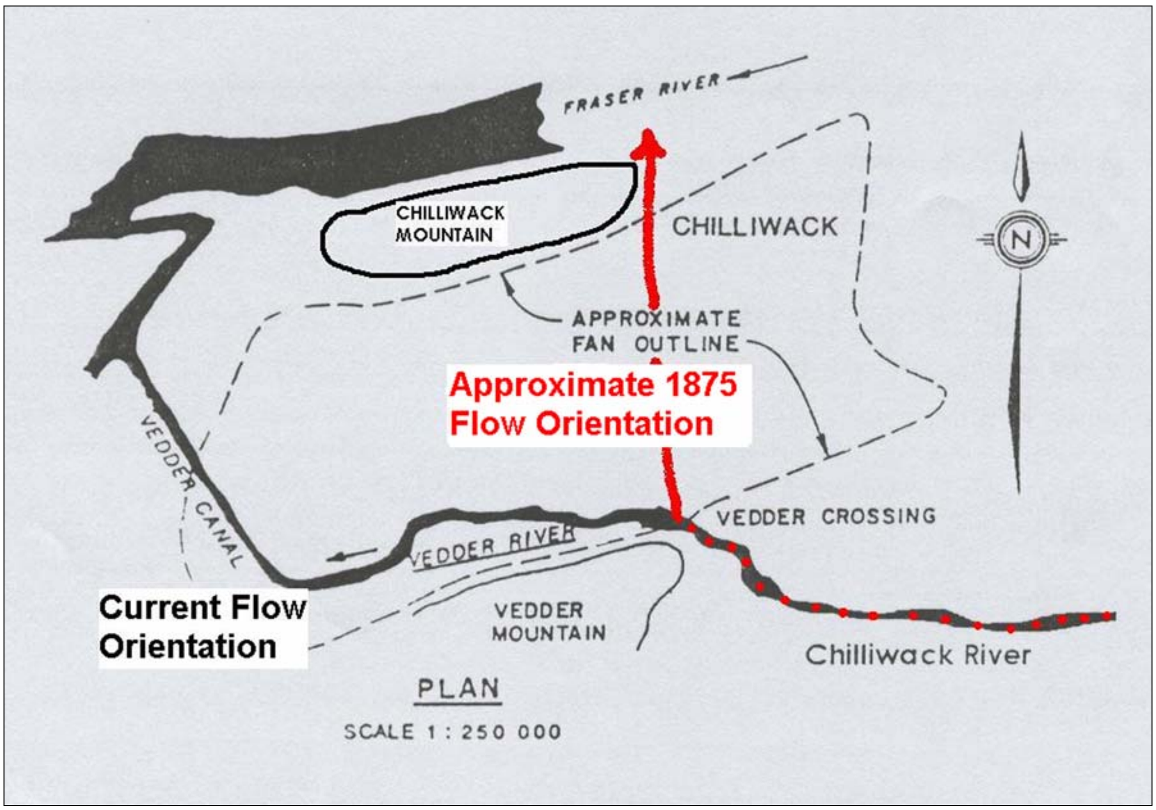
1.4.2 Agriculture and the Vedder/Chilliwack River

Early-European Settlement History in the Area

Even prior to European settlement, the Chilliwack River had always been a highly wandering stream—from due north to due west—once it reached its low-gradient downstream area. Indeed, the direction of the Chilliwack River fan has probably changed many times since the last ice age, over a 90^0 angle, as a result of the high rate of sediment outputs and the subsequent channel shifts (Fig. 14) (McLean 1980). This stream normally carries a high gravel and sand load, arising from upstream sources, and this material drops out in a large deposit once it reaches the low-gradient areas downstream of Vedder Crossing (Fig. 2). Ham (1996) indicated that the river transports around 55,000 cubic metres of sediment every year from upstream areas and the quantity of sand and gravel has likely increased over the last century due to human activities—logging, land clearing, agriculture, and settlement-related development—that have disturbed much of the floodplain and upland slopes.

Figure 14. Chilliwack River fan and a comparison of historic and current flow directions. Black indicates current flow direction, red indicates 1875 orientation.

Adapted from Bergman (1994).



The first substantial farming-related impacts to fish habitat in the eastern Fraser Valley area occurred between 1875 and 1884 with the diversion of the Chilliwack River from a northerly direction of flow into its current permanent westward orientation. In 1875, near the present-day communities of Vedder Crossing, Sardis, and the western portion of Chilliwack, the Chilliwack River flowed in a northerly direction and entered the Fraser River at the eastern base of Chilliwack Mountain. (Figs. 14, 15, 16; Wells 1987). However, following a series of natural and man-made events commencing that year, the Chilliwack River was re-directed into Sumas Lake via a small stream named Vedder Creek, which flowed off Vedder Mountain to the west. At that time land had been cleared and farming had already begun to the north and the west on the Chilliwack River fan.

The historical accounts indicate that on November 22, 1875, a heavy rainstorm caused a logjam to be deposited in the Chilliwack River at Vedder Crossing partially blocking the main channel. The Chilliwack River flows were then split approximately equally into Vedder Creek, and into Luckakuck Creek, another tributary stream flowing north through Sardis. As a result of this change in flows, the farmers in the northerly direction were threatened by the new discharge patterns of the river. It appears there was flooding and/or erosion where their farms were located.

Historical accounts then suggest that in 1882 someone deliberately felled another large tree across the still partially northward-flowing Chilliwack River. An extensive log jam soon ensued as it collected river debris, diverting most of the water westward into Sumas Lake. Then, the 1894 freshet seems to have added even more wood to this jam and the blockage became permanent, with all of the Chilliwack River discharges finally flowing westward into the lake (Web Citation 4).

While the diversion of the Chilliwack River waters from its traditional northern route resulted in flow stability for the Sardis farmers, it caused some severe problems for farmers to the west. As a result, these farmers pursued the issue through the courts but to no avail when Judge Howay deemed that Sumas Lake was the natural destination of the Chilliwack River (Web Citation 4). The odd nomenclature of the stream—which is referred to as the Chilliwack River upstream of Vedder Crossing, and the Vedder River downstream—is the result of this historical re-orientation and joining of the flows of the two streams.

Over time, the many sizeable, but mostly dewatered channels remaining from the former northward-flowing Chilliwack River became a series of slow-moving sloughs and small streams. The flows in these channels became largely comprised of groundwater discharge and local-surface runoff (Fig. 17). These remnant channels can still be seen today scattered throughout the communities of Vedder Crossing, Sardis and western Chilliwack if one looks closely. All of these dewatered sloughs and small streams are now in an advanced state of eutrophication and biological succession, and the habitat quality has mostly declined (Fig. 17). The water quality of the remaining flows is probably being increasingly affected as the surrounding landscape undergoes a conversion from agrarian use to commercial and urban development. Based on the most recent inventory and assessments, the salmonid-fisheries values in these water bodies are declining and most of the salmon stocks are near extinction (e.g., Table 2).

Figure 15. Configuration of pre-settlement eastern Fraser Valley Chilliwack River and Sumas Lake drainages as drawn by the 1871 British North American Boundary Commission.

Note that Sumas Lake and the streams to the left (Chilliwack River watershed) are not connected on this map. Area bounded by red polygon outlines approximate geographic perimeter shown in Fig. 20. This figure is digitally modified from an 1871 British North American Boundary Commission map. www.mqup.mcgill.ca/files/cameron_laura/crownproperty.html

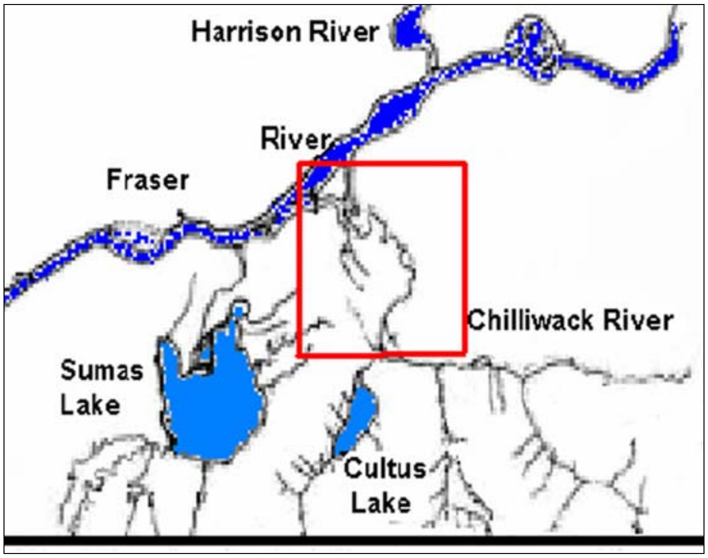
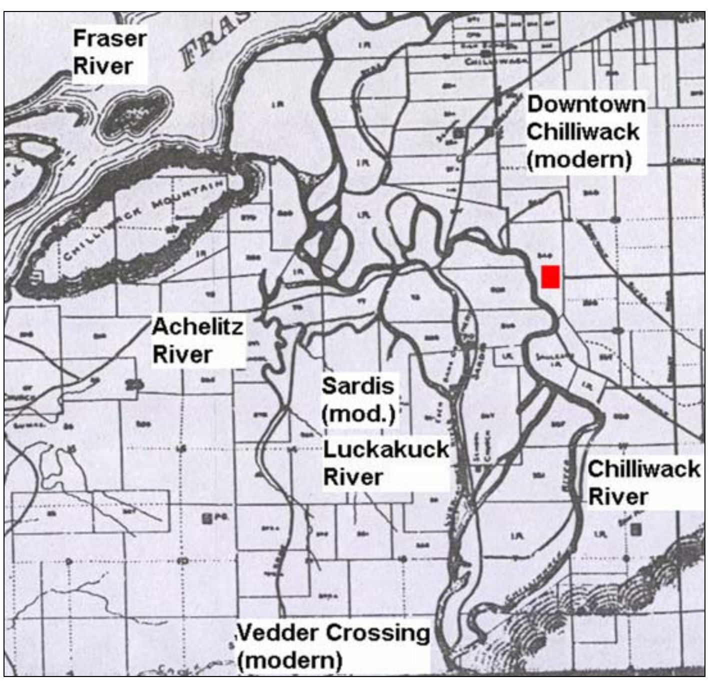


Figure 16. Old surveyor's map showing myriad channels which were part of the pre-diversion northern flow of the Chilliwack River.

Area bounded by red polygon in Fig. 15 outlines approximate geographic perimeter outlined in Fig. 16; square red dot indicates location of photo in Figure 17. Note the maze of channels that historically flowed from the modern-day location of Vedder Crossing to the Fraser River, a condition that is far more diverse than the current situation.



Lost Fisheries Values Resulting From the Shift in Stream Orientation

The fisheries values of the Chilliwack River watershed before diversion are unknown but, based on conversations with a number of local First Nations elders, Wells (1987) indicates that they were considerable. This makes sense when you consider that the current Vedder/Chilliwack River is still very productive compared to most streams in southwestern British Columbia—despite the large losses in physical diversity.

With the directional change in Chilliwack River flows from the north to the west (Figs. 14, 15, 16), there were no longer substantial amounts of water to inundate the remaining northward-oriented channels downstream of Vedder Crossing (Fig 17); this lack of flow substantially altered their fish-habitat capacity. Nevertheless, despite the lack of surface discharge, many of these streams did maintain some fisheries values—and in some cases may have been very productive—for a period of time before finally collapsing (e.g., Table 2).

The present-day configuration of the westward-flowing Vedder River—which now carries all of the pre-1875 Chilliwack River flows— has a much reduced heterogeneity compared to the historical wanderings and multiple channels of the historic lower Chilliwack River.

Thus, the habitat changes to the Chilliwack River arising from these early farming-related activities would have been profoundly negative to fish habitat. Because of the reduction in the number of channels, not only was the total river length reduced but the physical diversity would also have been substantially lessened. The Vedder River now has a relatively single-channel, straightened configuration (Fig. 18) and it has been armoured between cribbing (Fig. 18) and rip-rapped banks (Fig. 19) to minimize any future meandering. These actions guard against flooding, erosion and channel formation, key components of the Shifting Habitat Mosaic and a productive aquatic ecosystem. As a result of these historic actions, the fisheries agencies and land planners now have to deal with these agriculturally-influenced physical changes to the watershed.

Figure 17. The small flow which remains in the historic channel of the Chilliwack River's northward orientation downstream of the pre-1900 diversion by agriculture.

This photo was taken as part of an earlier provincial government fisheries reconnaissance inventory program (Usher 1975). Further urbanization has occurred near this location in the two decades since this photo was taken. Location of this photo indicated on Figure 16; compare the current size of this stream with Fig. 18, the new orientation of the Chilliwack River.

Figure 18. The joining of the Chilliwack and Vedder rivers at Vedder Crossing, in 1910 and 2000.

Both photos were taken at a roughly similar orientation, looking upstream in an easterly direction at the bridge. The log cribbing seen in the left photo was constructed post-1894 to ensure that the Chilliwack River never again flows in a northward direction. In the modern photo the space behind the cribbing has been filled in and trees are now growing over the original channel. Photos from Chilliwack Museum. www.chilliwack.museum.bc.ca/history/cov/vedder.htm

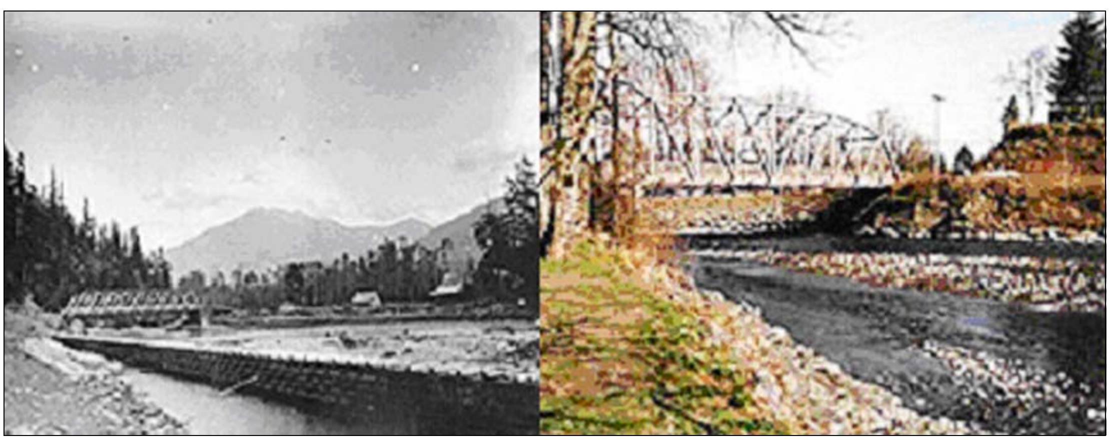


Figure 19. Large rip-rip-rap rock engineered into the Vedder River just downstream of its confluence with the Chilliwack River.

The large rip-rip-rap rock prevents the stream from eroding its banks and flooding into neighbouring farm fields and new urban subdivisions. It also disrupts fluvial processes and, as a result, destroys aquatic ecosystem habitat. Author's photo.

Construction of the Rail Line across the Vedder River Floodplain

While the effects of altering the directional orientation of the Chilliwack River channel by farmers in the late 19th century are thought to have been considerable, as time passed there continued to be more agriculturally-related impacts to habitat in this watershed. One such example of collateral impacts is the construction of the BC Electric Railway line across the floodplain of the Vedder River in 1910. This railway was key to the transportation of agricultural goods from the eastern Fraser Valley to the centres of population around New Westminster and Vancouver and it made further agricultural development of the area economically feasible (Siemens 1968).

The construction of the railway across the Vedder River floodplain (Fig. 20) involved the building of a raised bed upon which the tracks were set. In doing so, the total discharge of the Vedder River was forced through a bridge opening that was very narrow relative to the size of the floodplain (Fig. 20, 21). While the small-discharge capacity of the bridge opening and resulting narrowing of the floodplain wasn't a problem at low discharges, it became a significant issue during large floods.

Soon after construction of this railway in 1917, a major flood destroyed the railroad bridge. Similarly, in 1932, about 400 metres of the rail bed was washed out during a smaller flood (Bergman 1996). Then in 1989 the left abutment of the railroad bridge was destroyed during a large storm event and the ensuing flood. Finally, in 1990 a relief opening (flood channel), which was constructed through the rail bed adjacent to the bridge to help deal with such flood emergencies, was also washed out (Bergman 1996).

River engineers and the rail company naturally deemed it unacceptable to allow the river to erode through their rail bed, and began to harden the adjacent river banks. The location of the rail line and bridge meant that the river was now permanently locked into this hydraulically awkward orientation (Fig. 20). The hardening of the stream banks, and the small bridge opening, effectively disrupted the meander pattern of the stream and concentrated the Vedder River more or less into a single channel for much of its length both upstream and downstream of where the railway crossed the floodplain.

This confining of the river channel effectively eliminated the opportunity for the stream to create additional habitats and side channels through erosion and deposition. In other words, it effectively disrupted the fluvial processes instrumental in creating the Shifting Habitat Mosaic which is critical to maintaining productive aquatic ecosystems. A more recent assault on the ability of the Vedder River at this location to maintain habitat productivity has been the hardening of the stream through the development of debris catchers immediately downstream of the rail bridge (Figs. 20, 21).

In summary, it is our view that the construction of this rail bed had a very significant, but relatively unrecognized, impact on fisheries values throughout the Chilliwack/Vedder River watershed for which fisheries managers are seeing the consequences of today.

Figure 20. Photo mosaic of the railway crossing the Vedder River floodplain near the town of Yarrow.

Rip-rap armouring upstream of the rail bridge has completely disrupted the normal fluvial-meandering processes of the Vedder River floodplain. This has substantially damaged fish habitat by isolating side channels and interrupting the Shifting Habitat Mosaic. Note that the area which was formerly farmland prior to the construction of the floodway dikes (magenta lines) in the 1980s is now gradually becoming feral floodplain. "D C" refers to the location of the debris catchers illustrated in Fig. 21.

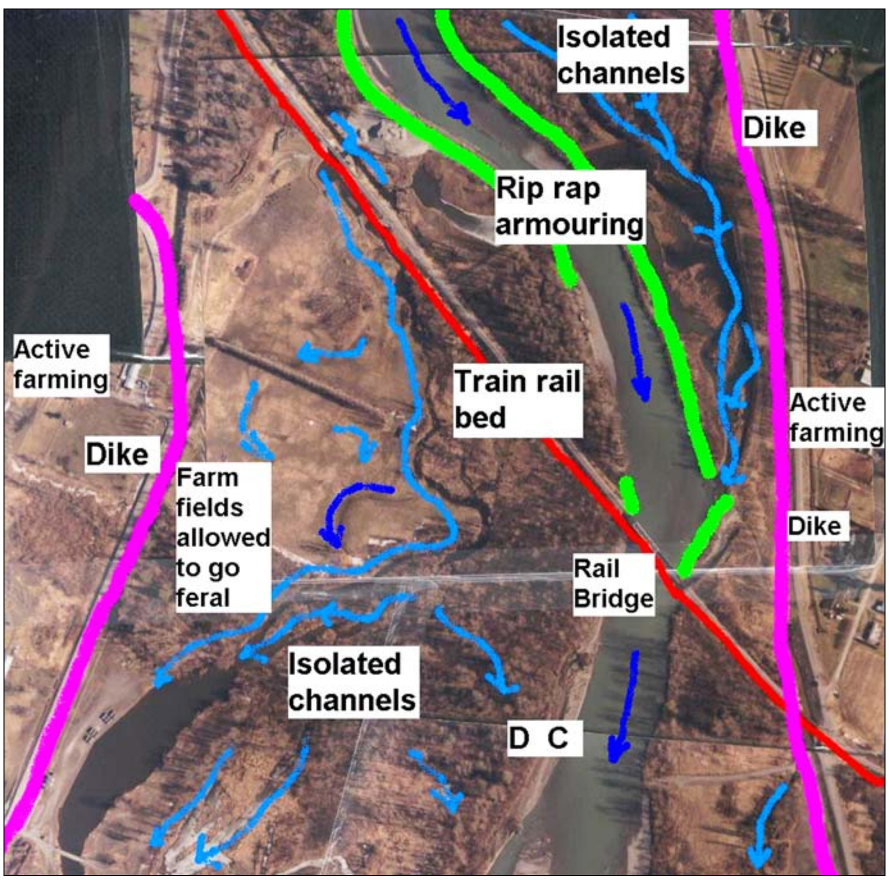


Figure 21. Train-track bridge crossing and bank protection of the Vedder River near the town of Yarrow.

Direction of flow is from right bottom of the photos and across to the left. The bridge opening is small relative to the size of potential flood flows for this watershed causing considerable concerns to flood managers. Lower photo is of bank-protection debris catchers (located immediately downstream of this bridge at DC in Fig. 20) recently installed to reduce bank erosion and meander. In light of the extensive bank armouring of the river that has already occurred, we view the installation of these structures as continuing the destruction of the aquatic ecosystem through disruption of the Shifting Habitat Mosaics. Author's photos.

Settlement of the Area

As more people began moving into the eastern Fraser Valley, agriculture intensified along the banks of the Vedder River and changes to the floodplain and riparian areas became increasingly pronounced. At many locations, extensive amounts of native vegetation were removed from within the floodplain and along the perimeter of the stream to create additional farmland (Fig. 22).

To ensure that the Vedder River would not re-orient itself through erosion and avulsion into these developed landscapes, which in turn would threaten newly established farmland and infrastructure, the inner stream banks of the stream were heavily armoured with cribbing (Fig. 18) or rip-rap (Fig. 19), constraining the river between immovable banks (Fig. 22). This further disrupted the natural fluvial processes and maintenance of the Shifting Habitat Mosaic that, in the past, had helped to sustain and create salmon and steelhead habitat. The multiple-channel configuration seen in the pre-1894 orientation (Fig. 16) began to disappear as the Vedder River was forced to take on the attributes of a single-thread stream throughout its entire length.

The first major effort to constrain Vedder River flood flows and protect the surrounding agricultural lands took place in 1952 when the British Columbia Department of Public Works drew up plans for the construction of setback dikes from Vedder Crossing to the Vedder Canal (IPSFC 1977). The International Pacific Salmon Fisheries Commission (IPSFC 1977) report indicated that maps prepared in 1956 showed that the filling in of flood channels by development interests "…had been started [even] prior to this date, apparently for protecting and reclaiming private lands….". It should be noted that that a large area on the river's south bank, upstream of the rail bridge at Yarrow, was "reclaimed" as recently as 1975. This activity resulted in the loss of many productive side channels and currently much of this area is still used for agriculture.

Starting in 1963, extensive diking (Figs. 20, 22) and rip-rapping (Fig. 19) were carried out between Vedder Crossing and the BC Electric Rail Bridge by the Township of Chilliwack with the objective of minimizing the effects of floods. The dike locations were similar to those that were later constructed in 1976 following a severe flood in 1975 (IPSFC 1977). At that time, because of the sediment deposition of the Vedder River, which was and continues to be extensive, gravel removal also started to be regularly used as a flood prevention method, albeit initially on an ad hoc basis. Over time the build-up of gravel in the Vedder River channel, through bedload movement and recruitment, reduces the flow-carrying capacity of this stream and exacerbates the flooding on the surrounding floodplain.

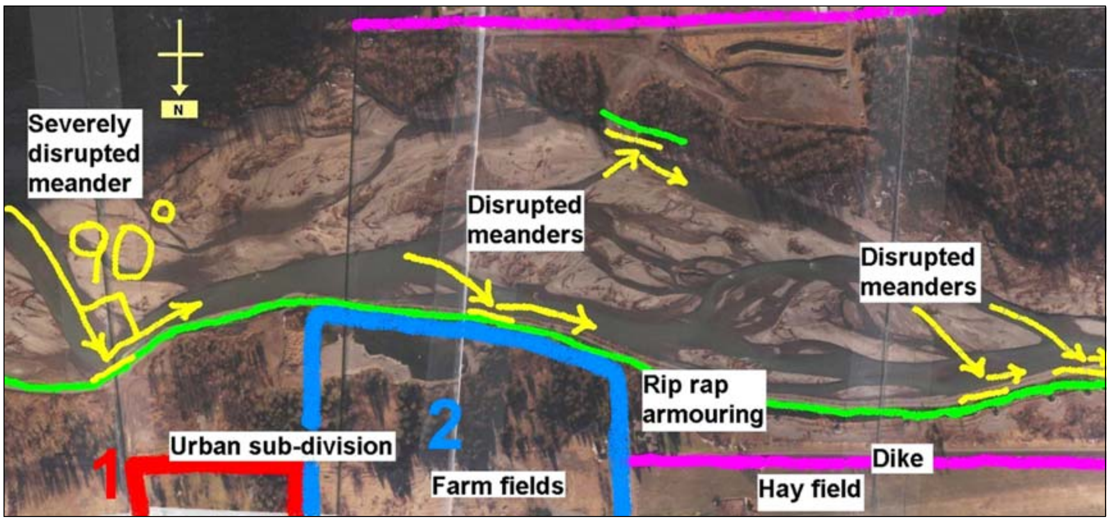
Then, in December of 1975, a large flood overtopped the banks on the Yarrow side of the river, inundating farmland and property (Fig. 23). This spurred on the development of an extensive flood protection program of setback dikes that had already been initiated earlier that year. The main objective of these efforts was to tie in the dikes on both sides of the river, from Vedder Crossing to the Vedder Canal, and establish a flood capacity that could handle a 1:200 year flow plus two feet of freeboard. The dike was also to be built large enough to account for any sediment deposition (Fig. 24). The return flow for a 1:200-year event was, at the time of construction, calculated to be 24,000 cubic feet, or 680 cubic metres, per second (IPSFC 1977). These discharge estimates have since been updated by government agencies to a considerably greater degree.

While these flood-control dikes were set back from the main channel, the placement of bank rip-rap confined the stream for most of its length upstream of the rail line, eliminating the natural tendency of the river to meander. Thus, this diking and bank-hardening program has been, and continues to be, extensively destructive to aquatic and floodplain habitats and disruptive to the Shifting Habitat Mosaic to the benefit of the surrounding farmland.

Figure 22. Agricultural-land development encroaching on the natural floodplain of the Vedder River.

Photo was taken in the early 1990's and the location is about 2 km downstream from Vedder Crossing bridge.

*Note that the meander patterns, and fluvial erosion and deposition processes, have been disrupted due to rip-rap rock protection (green lines) along the river banks in order to protect the floodway dikes (magenta lines) running along the perimeter of the stream. Note also the extensive loss of riparian vegetation due to agriculture. Area bounded by red polygon (**1**) has been converted from rural zoning and has now been developed into an urban subdivision, as have many other parts of this historic floodplain, ensuring the permanent disruption of the Shifting Habitat Mosaic. Area bounded by the blue polygon (2) at Webster Road was released from the Agricultural Land Reserve in 2004, and rezoned for urban development in 2005, despite extensive opposition to this development, for environmental reasons, in the 1990's when the first request for exclusion occurred. This also included a strong opposition by the Minister of Environment, Lands and Parks. There appears to have been little opportunity for comment by the public on the latest attempt at removal of these lands from the ALR.*



During the period of dike construction about one million cubic yards (0.76 million cubic metres) of gravel was excavated from the Vedder River (IPSFC 1977). Much of the river downstream of the BC Electric Railway bridge was channelized and the physical heterogeneity that is commonly associated with properly-functioning salmon and steelhead streams was lost. We note that after 30 years, the river between the BC Electric Rail bridge and the Vedder Canal has recently only started to regain some of the lost physical features that it would have had prior to the extensive construction and dredging activities in-stream and on its floodplain.

During the design and construction phases of the setback dikes, it was recognized by all of the agencies and local governments that due to the now-restricted discharge capacity of the floodway, sediment would probably have to be indefinitely removed on a regular basis given that the historic sediment deposition patterns were unlikely to change. The requirement for ongoing maintenance and management of the floodway led to the development of the 1983 multi-agency Vedder River Management Area Plan (Fig. 24). This was developed by the relevant regulatory agencies and local communities including the provincial environment ministry, the federal fisheries department, and the communities of Chilliwack and Abbotsford (Vedder River Management Committee 1983). The Management Plan had multiple objectives including the maintenance of flow capacity and fisheries enhancement and protection, and it is still in effect. Agriculture was one of the main beneficiaries of the diking and gravel removal. However, in recent years large-scale urban development has started to move into the area as a result of this flood protection and is replacing rural and farming interests on the floodplain. This succession from natural floodplain, to agriculture, to development, is commonly seen in the eastern Fraser

Valley and throughout British Columbia, and has resulted in extensive losses to aquatic ecosystems throughout this province.

The Vedder River Management Area Plan requires its implementation to be an open and transparent process whereby all interested stakeholders can attend the decision-making meetings, provide useful input and voice their concerns. Approximately every two years (a non-pink-salmon spawning year), the Vedder River channel is surveyed and hydraulic modeling (HEC-RAS model) is undertaken to see if and where the flood profile has changed (Table 3). Sediment excavations are to be undertaken using best available knowledge, engineering and fisheries science in order to minimize the impacts to the environment (Table 3, Fig. 25).

While not without difficulties, the Vedder River Management Area Plan is a reasonably workable solution to a situation where aquatic resources, including salmon and steelhead habitats, have been severely compromised as a result of a series of historical changes to the floodplain and the stream. Furthermore, it is our opinion that the greatest impact associated with the continued removal of sediment is the disruption of the natural fluvial processes that maintain the Shifting Habitat Mosaic described by Hauer et al. (2004), rather than the actual footprint extractions which have significant impacts in their own rights.

Figure 23. Flooding of farmland and infrastructure during the December 1975 Vedder River flood.

This event occurred prior to the construction of the extensive diking system shown in Fig. 24, which resulted in extensive riparian, wetland and side-channel losses. Note the BC Electric Rail bridge and line in the upper left; flow is from right to left. "" in Fig. 24 denotes location of photo in Fig. 23. Bruce Wright, photo.*

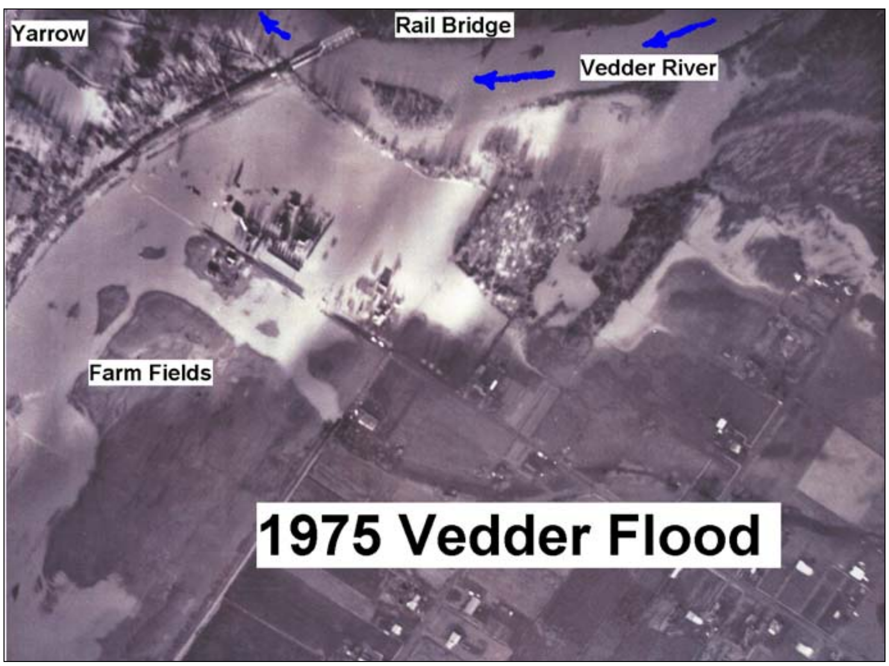


Figure 24. Setback dikes define the Vedder River floodway-area perimeter.

Note that the area to the north and west in this air photo is primarily farmland. Parallel red-dashed lines at the left of the photo represent the Vedder Canal dikes which are designed to contain Vedder/Chilliwack River winter storms and Fraser River spring-freshet backwatering. The solid red lines represent dikes that are designed to prevent a 1:200-year Chilliwack River flood plus 0.75 m freeboard. The Vedder River Management Area is, for all practical purposes, the area between the red solid and dashed lines. A comparison of the width of the floodplain in Figs. 2, 14, 15, 16 to the constrained floodplain in Fig. 24 gives a sense of the magnitude of the losses in aquatic productivity.

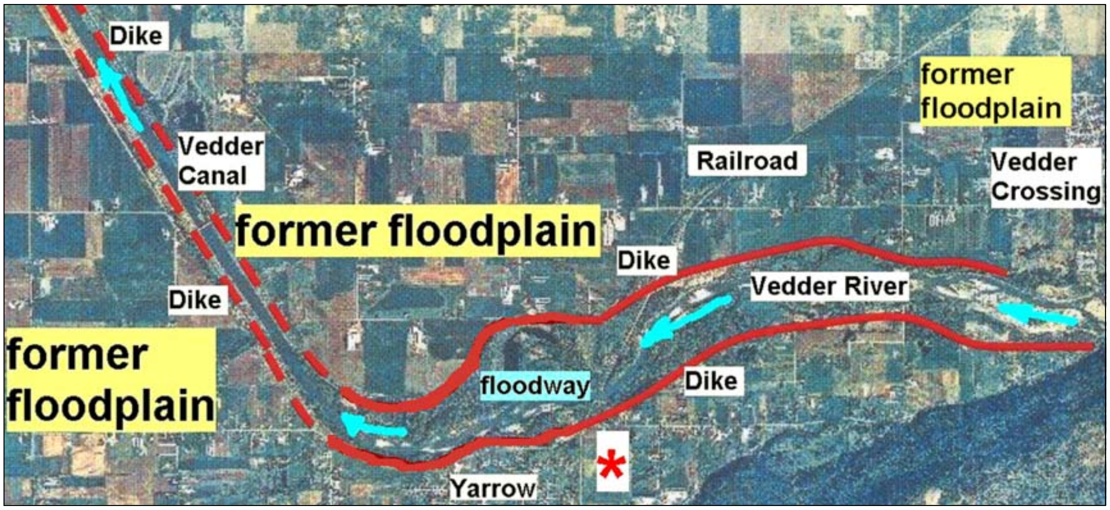


Table 3. Iterative process followed by the agencies in the Vedder River Management Area Plan area for its floodway maintenance.

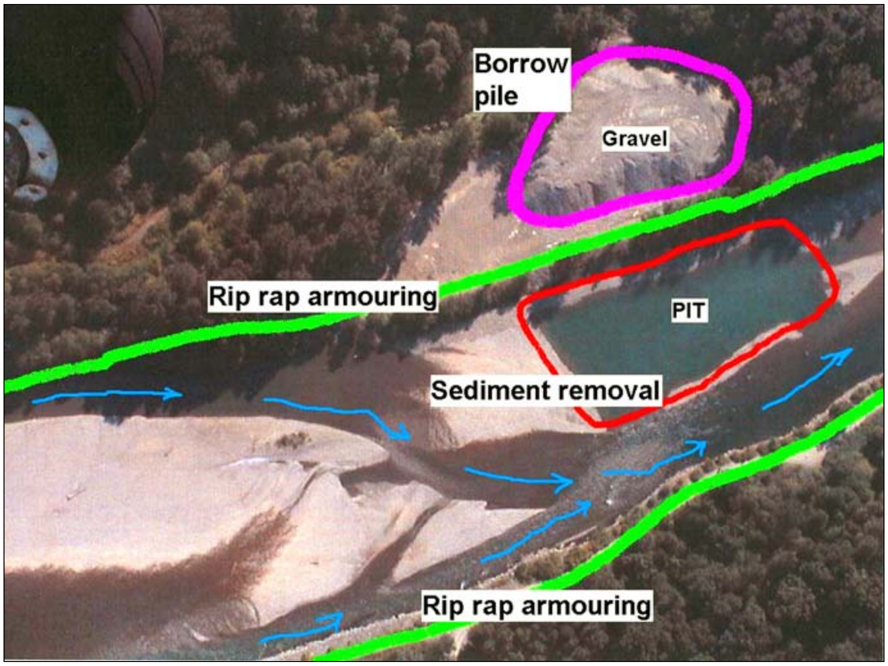
Presented by the City of Chilliwack engineering department to the Sto:lo Nation Referral Advisory Committee Meeting October 17, 2003.

Every two years:

- Survey river and canal cross sections
- Carry out hydraulic modeling to determine problem areas with reduced freeboard
- Identify gravel removal sites to reduce flood profile and minimize environmental impacts
- Remove gravel from identified areas as per design and mitigation plans

Figure 25. Gravel removal site on the Vedder River, 2002.

This location is adjacent to the rail line that crosses the floodplain in Fig. 20. Note that the river is severely confined by rip-rap armouring at this location, limiting historical natural river meander, and disrupting floodplain processes and the Shifting Habitat Mosaic. Bruce Wright photo; drawing is supplemental.



1.4.3 Interactions between the Development of Agriculture and Aquatic Ecosystems on the Fraser River Floodplain of the Eastern Fraser Valley

Historic Diking of the Floodplain and Isolation of Its Side Channels

Like many other large temperate waterways around the world, the floodplains of the Fraser River at its delta and in the eastern Fraser Valley (Fig. 2) comprise landscapes that are capable of supporting intensive cultivation (Fig. 26). However, in order to realize the area's agricultural potential, the lowlands had to be isolated from the natural hydrological cycle of spring-freshet flooding (Figs. 27, 28) using dikes and other hydraulic-control infrastructures.

As agriculture expanded onto the eastern Fraser Valley floodplain through the latter part of the 19th and early 20th centuries, farmers were subjected to the capriciousness of freshet flooding. The Fraser River spring/summer freshet flood of 1894—which established a record discharge of 17,000 cubic metres per second to which the present-day dike elevations are designed—inundated vast areas of the floodplain. Despite the fact that relatively few people had settled in the eastern Fraser Valley at that point, the impacts to property were nevertheless notable (Siemens 1968). In 1948, a smaller flood, which peaked at 15,200 cubic metres per second, damaged even more crops and property when several dikes were breached (Fig. 28; Siemens 1968).

To control the flooding on agricultural land and the expanding nearby communities in the eastern Fraser Valley, government authorities began to instigate aggressive diking starting in the late 19th century (Table 4; Figs. 29, 30). With the support of the British Columbia government, a major diking project to protect the town of Chilliwack and surrounding area was undertaken in 1899 and completed in 1903 (Ellis et al. 2004). This effectively cut off a substantial number of the area's large secondary channels from the main flows of the Fraser River. Other dikes built over subsequent years also isolated many of the channels with important aquatic habitat (Table 4; Figs. 31, 32).

Ellis et al. (2004) described the extensive network of secondary channels prior to the diking of the eastern Fraser Valley Fraser River floodplain. They showed that in the Chilliwack area many of these streams flowed around large vegetated islands and that these channels were particularly prevalent on the left (south) bank (Figs. 29, 30). Nevertheless, large channels were also abundant on the right (north) bank just east of Mission at Nicomen Slough, and other locations such as near Agassiz (Fig. 33). Many of the large islands formed by these channels were cleared and diked very early on by settlers expanding their farming interests due to the rich soils. In doing so the Shifting Habitat Mosaic was extensively disrupted on the Fraser River floodplain.

In order to estimate side-channel disruption, Ellis et al. (2004) estimated the change in total bank-line length of the historic Fraser River in the Chilliwack area floodplain. Their figures show a substantial decrease over the past century of about 44%, from an estimated maximum of 247.31 km of bank-line before 1903 to 137.24 km in 1999, most or all of it being part of side channels. The majority of this loss occurred when the first large dike was constructed prior to 1903.

In a similar vein, Ham and Church (2002) reported that diking had caused a large reduction in the eastern Fraser Valley floodplain while also narrowing active channel width. Also, Rosenau and Angelo (2000) estimated that over 100 km of the Fraser River floodplain side channels had been blocked at one or both ends between Hope and the Sumas River confluence (e.g., Fig. 32).

Since the 1880's, over 80% of foreshore wetlands, marshes and riparian forests in the lower Fraser River (including the eastern Fraser Valley) have been logged, diked, drained and converted to agricultural uses. Many of these farmlands have subsequently been developed for urban, commercial, and industrials uses.

North and Teversham (1984), in their review of historical floodplain vegetation in the Fraser Valley, give some empirical assessments of this impact. Kistritz et al. (1996) mapped some of the changes in historical fish habitat in the Harrison River lowlands and suggest that the historic losses to present day are from 1,247 ha of fish habitat down to 321 ha (Fig. 33), a change of about 75%. Such changes are probably typical of the kinds of losses that occurred through the conversion of the floodplain land to agricultural development.

Many of these lowlands would have been used directly or indirectly by rearing juvenile chinook, coho, and chum salmon (Birtwell et al. 1988, Smith 1991, Langer et al. 2000, Levings 2000, Brown 2002) prior to the development of farming on this large floodplain. Langer et al. (2000) considered the lower Fraser River in its current state to be almost completely separated from both its floodplain and broader riparian zone. Nevertheless, there is no comprehensive accounting of the physical habitat losses or the resulting change in habitat capacity that can be attributed to diking the Fraser River and its side channels. However, our sense is that it must have been extensive based on some cursory observations. Recently, Perrin et al. (2003), Ellis (2004), and Ellis et al. (2004) reported on the morphological and biological characteristics of the few remaining large, and somewhat intact, Fraser River side channels in the eastern Fraser Valley. Among these are Greyell Slough, Minto Channel and Herrling Channel. Their work recorded the exceptional variability in habitat structure and the high utilization of these areas by salmon and other fish species.

Brown (2002) has also suggested that all the wetland habitats in the lower Fraser River have the capacity to support salmonids if access is available. Of particular interest are the various observations that juvenile chinook often rear in seasonal sloughs, marshes and tributaries of the lower Fraser River and have a propensity to move into seasonally flooded sites for some weeks or months before going to sea (Levy and Northcote 1982, Levings et al. 1995). It is certainly possible that mainstem-rearing juvenile chinook move to side-channel habitats as refugia in the eastern Fraser Valley when the Fraser River is at its greatest spring discharges, and this is an area for further research. Thus, these studies provide us with a sense of the extraordinary, pre-European-settlement ecosystem values that must have existed on a broader scale prior to the extensive diking.

As a final note regarding the large change in floodplain attributes for the Fraser River in the eastern Fraser Valley, Brown (2002) noted that: "…[h]uman activities [in floodplains] cannot be sustained where serious damage from flooding can be expected. Thus, measures to prevent flooding are often undertaken and, in doing so, the floodplain ecosystem is usually destroyed. In a developed floodplain, social pressures exceed environmental concerns and few viable options to maintain or regain lost fish habitats are available. On an undeveloped floodplain, consideration can be given to limiting activities to those that are consistent with maintaining natural systems." As a result, it is our view that the few remaining floodplain areas that still exist in the Fraser River lowlands and floodplain in the eastern Fraser Valley need to be protected from further encroachment if there is going to be any semblance of sustainability.

Figure 26. Extensive agricultural activity being undertaken on the Fraser River floodplain near Agassiz.

In many cases, farming is conducted to the water's edge, and this has resulted in an almost complete loss of native riparian vegetation at these locations (perimeter of yellow dots). Rip-rap protects these farmland banks from eroding. Green dots indicate the perimeter of large-cultured pulpwood plantations on extant floodplain islands, but these softwood crops are not protected by dikes. Also, compare large main channel with multiple side channels in this braided portion of the Fraser River. Viewed from Cheam Mountain, October 2003, author's photo.

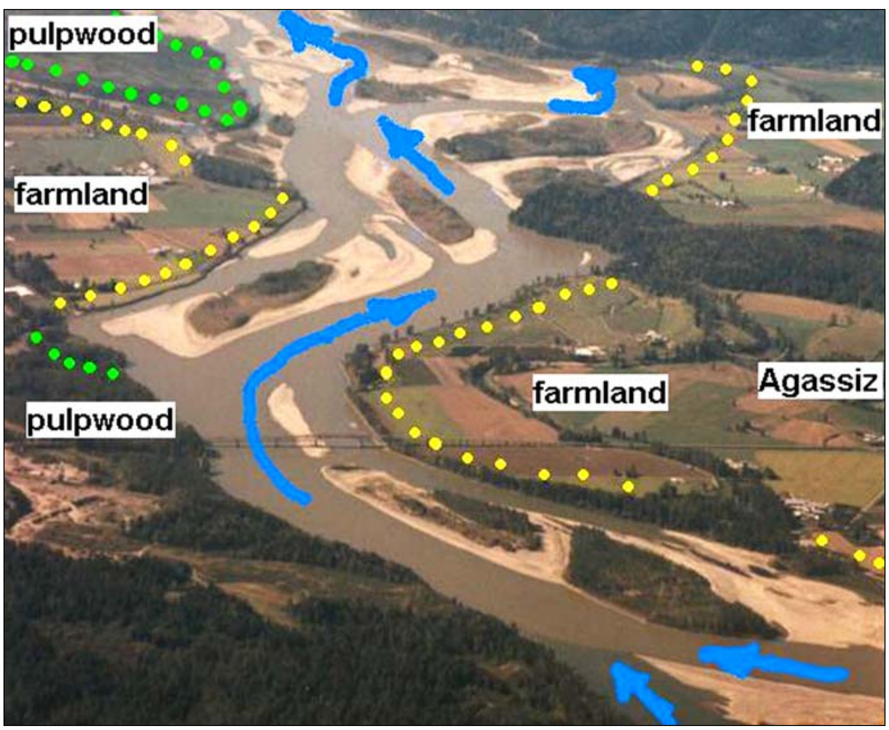


Figure 27. Inundation of the Fraser River floodplain at Island 22, Chilliwack, during freshet flood, showing exceptional aquatic habitats.

Photos were taken early July 2002 with discharges of about 10,000 cubic metres per second. These wetlands are ephemeral and the water-surface elevation and inundation are directly related to the magnitude of the Fraser River spring flood. Much of Island 22 is zoned for agriculture but there are extreme pressures to re-assign this land for other resource-extraction uses which would destroy these aquatic habitats. Much of the floodplain area shown in Fig. 2 must have resembled Island 22 during the spring/summer freshet before the dikes separated these landscapes from the main Fraser River. Lower photo taken by Solvej Patschke.

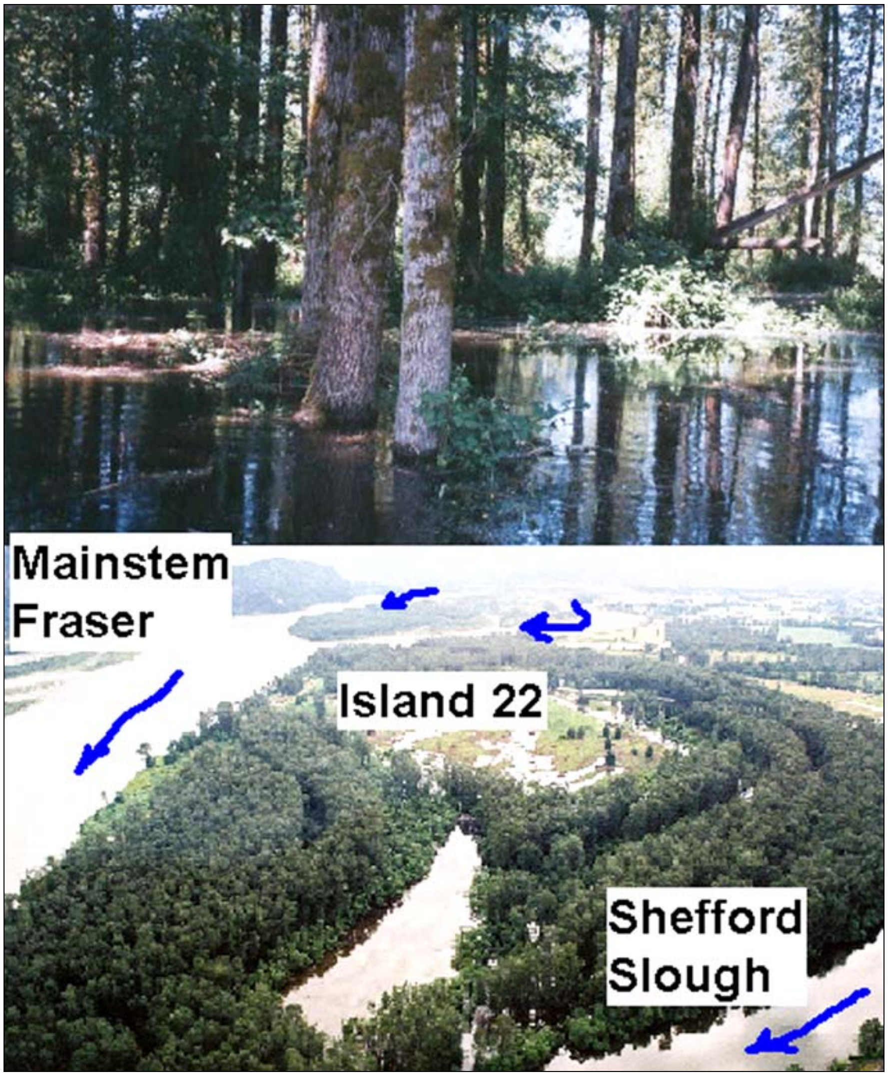


Figure 28. Aerial view of the 1948 flood in the eastern Fraser Valley.

Note that the western area of the former Sumas Lake (top right) did not flood in this photo as the dikes held, while the eastern portion of the former lake (left of Sumas Mtn.), and Nicomen Island, were inundated when the dikes at these latter locations were breached. This photo provides a visual sense of the magnitude of the spring/summer-freshet wetted-area floodplain before diking. Photo from www.sts.gsc.nrcan.gc.ca/clf/TSD_images_results.asp

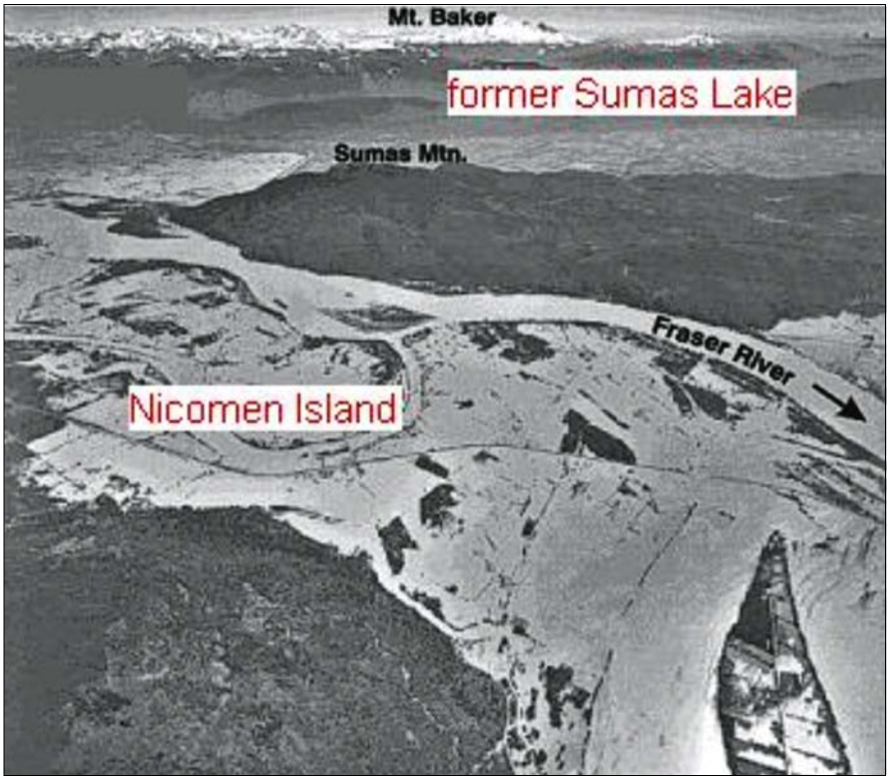


Figure 29. A comparison of the pre-settlement side-channel configurations of the eastern Fraser Valley floodplain of the Fraser River to present diked conditions.

This figure shows the large-scale losses to the active floodplain and side channels in the Chilliwack area resulting from dike construction south of the Fraser River, with the Hope Slough being an approximate perimeter for spring/summer freshet flooding. The extensive area shaded green south of the dike (red line) is no longer inundated by spring/summer floods. Adapted from Ellis et al. (2004).

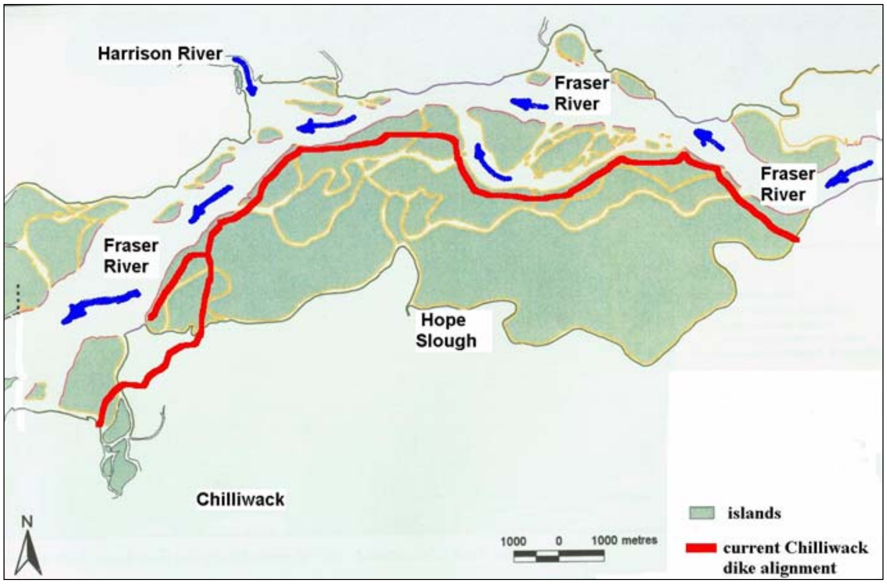


Figure 30. Diking, bank-hardening and flow-control infrastructure on the eastern Fraser Valley floodplain of the Fraser River to facilitate the expansion of agriculture and development.

This figure accompanies Table 4. Figure from Ellis et al. (2004).

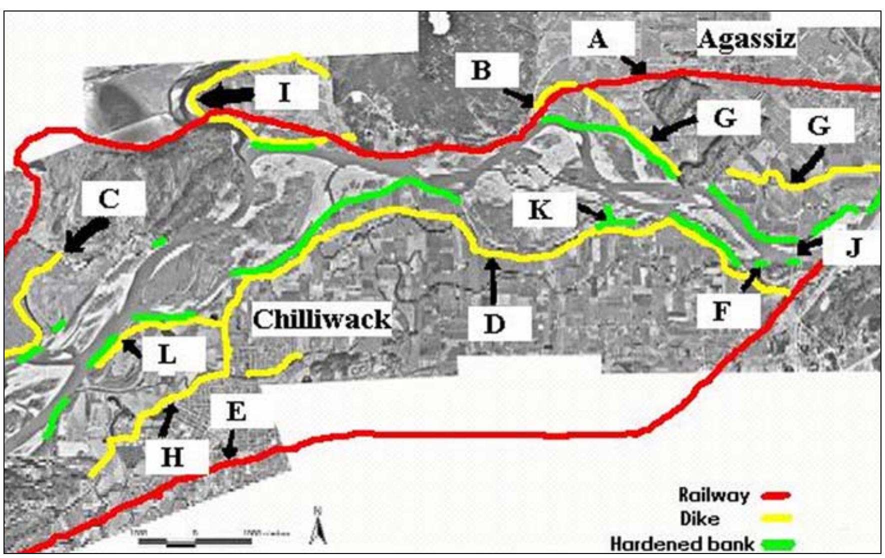


Table 4. Chronology of dike and flow-control structures, eastern Fraser Valley Fraser River floodplain.

Table and explanations from Ellis et al. (2004). This data set was assembled by consultation with provincial and local officials, as well as archival records. It was not always possible to assign an exact date to an event, in which case either an estimate of the year (prefixed with a '~') or the range of years is given. Figure 30 of the study reach shows the approximate location of the construction events where a map reference has been provided.

Year	Activity and Location	Source	Map reference
1878	Sumas Dyking District instituted	[1], p.76	
1878	Chilliwack Dyking District instituted	[1], p.76	
…	Various dyking projects, not well engineered, repeated failures	[1], p.76	
1885	CPR completed through lower Fraser Valley (N side of river)	[2], p.52	A
1894	Largest flood on record		
1899	Chilliwack - contract signed to build a permanent dyke (Lachlan McLean, contractor)	[5]	
1890's	Agassiz Dyking District built short dyke at west end of present dyke (Hammersley), as well as a pumping plant	[3]	B
~1913–1927	Nicomen Slough closed off at upstream end by Bell Dam, project undertaken by Dominion Government	[3], [7]	C
1903	Chilliwack - dyke complete (March 1903)	[3], [6]	D
1910	Chilliwack / Sumas - BC Electric Railway line to Chilliwack completed (south side of river)	[2], p.52	E
1924	Sumas Lake drainage complete	[2], p.38	
1948	Second largest flood on record		
~ 1943–1949	Dyke constructed to bridge the secondary channel between Ferry Island and Island 32	[7]	F
~ 1949	Agassiz – Fraser Valley Dyking Board (FVDB) built new dyke and re-built existing short dyke	[3]	G
~ 1949	Chilliwack - FVDB reconstructed almost the entire existing dyke Chilliwack - FVDB built new dyke closing gap between existing dyke and Atchelitz R.	[3]	H
~ 1949	Sumas - FVDB reconstructed Vedder R. dykes and Fraser R. dyke	[3]	
~ 1949	Harrison Mills - FVDB built new dykes	[3]	I
1956	Agassiz-Rosedale bridge constructed		J
1974/75	Chilliwack - Greyell Slough weirs (4) and wing dyke constructed	[4]	K
1990	Chilliwack - wing dyke (Shefford Slough) constructed	[4]	L

[1] *History of Dykes and Drainage in B.C., Transactions of the 10th British Columbia Natural Resources Conference, J.L. MacDonald, Dyking Commissioner, 1957*

[2] *Lower Fraser Valley: Evolution of a Cultural Landscape, edited by Alfred H. Siemens, 1968*

[3] *Reconnaissance Report on Reclamation Works in the Lower Mainland, V. Raudsepp, Hydraulic Engineer, Sept. 7th, 1953 (File 0105865), Ministry unknown.*

[4] *Operation and Maintenance Instructions Flood Control Works, Volume 3: As Contructed Drawings, Canada - British Columbia Fraser River Flood Control 1968 Agreement, The Corporation of the District of Chilliwack*

[5] *Chilliwack Archives, bid for tenders and contract (signed 8-Sep-1899): Chilliwack Dyking District, Contract #2, Land & Works Dept.*

[6] *Chilliwack archives, newspaper article, date: Mar. 4, 1903*

[7] *date (or interval) derived from air photo record*

Figure 31. Hope Slough 1908 and 2004 at Fairfield Island, Chilliwack.

Hope Slough would have comprised exceptional sturgeon and chum salmon spawning habitats prior to historical upstream dike construction. This observation is based on comparing the morphology and fish use with those of other extant channels; none of these habitats remain in Hope Slough by 2004 while different aquatic highly-eutrophic biological communities have replaced the former ecosystem. See Fig. 29 for location of the Hope Slough. Historical photo from Chilliwack Museum, www.chilliwack.museum.bc.ca/history/cov/fairfield.htm

Figure 32. Formerly-connected side channels of the Fraser River at Island 22 are now isolated from the main flows due to diking.

Note the water-colour differences between Minto Channel which contains main Fraser River flows (brown) and the tertiary-channel discharges (black) which primarily comprises seepage. A large wing-dike was constructed on Island 22 as part of Chilliwack's main diking system for the Fraser River several decades ago and this was to protect both agricultural and urban infrastructure. These more-recent changes have profoundly altered the aquatic ecosystems within the blocked channels, including fish passage, probable salmon and sturgeon spawning and rearing habitats, and the Shifting Habitat Mosaic. Solvej Patschke photo.

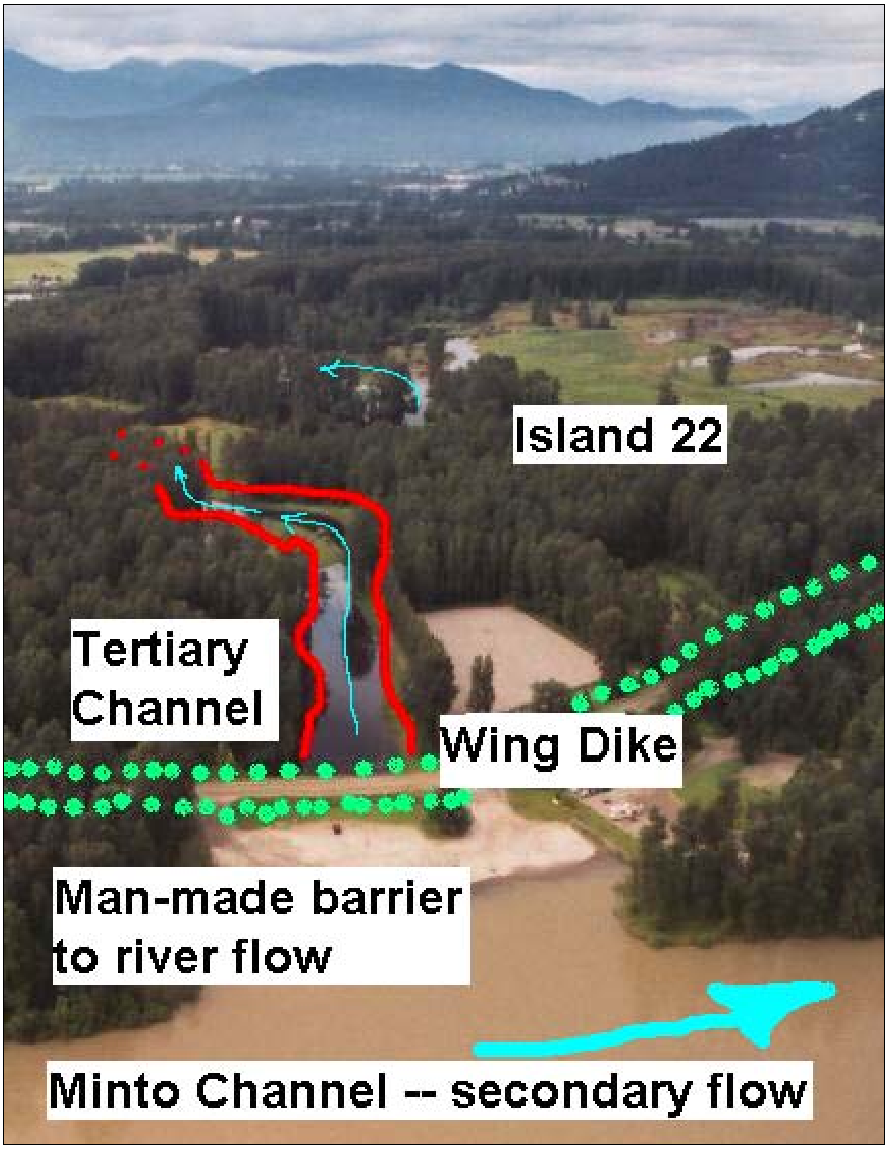
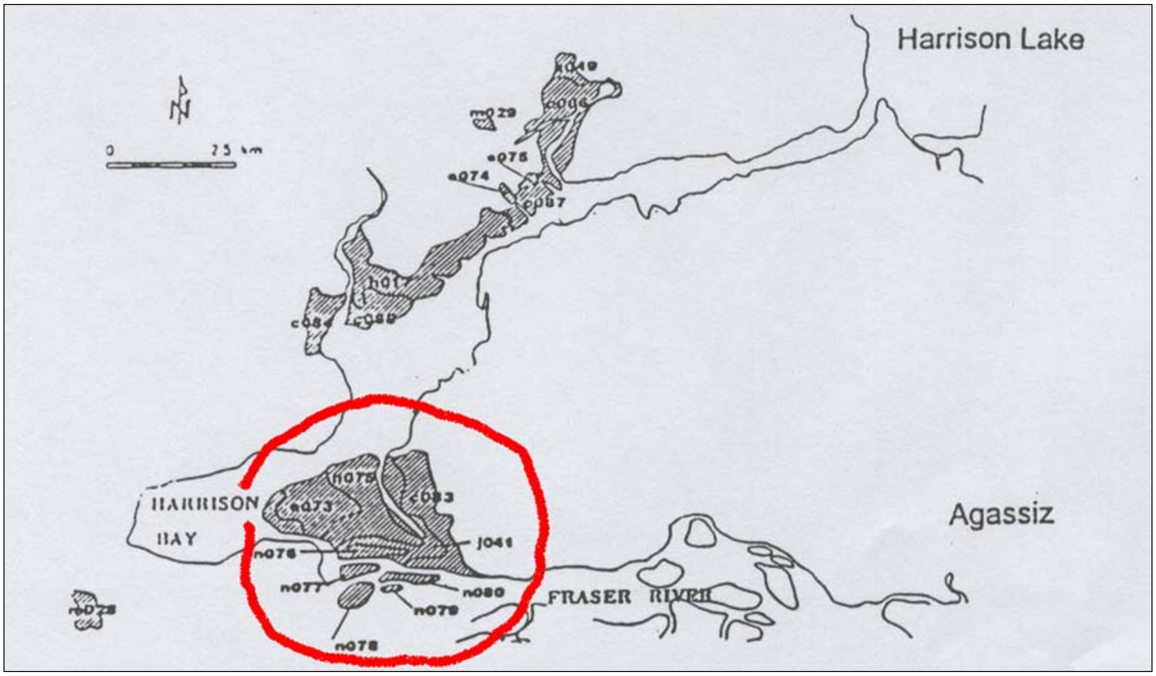


Figure 33. Pre-European-settlement fish habitat on the Harrison/Fraser River floodplain.

The change in habitat area, mostly due to conversion of floodplain to agriculture and diking, was from 1,247 ha to 321 ha; the losses are depicted by the red-encircled area. See original paper for alphanumeric designations of vegetation types. See map reference "I" in Fig. 30 and Table 4. From Kistritz et al. (1996).



Impacts from Bank Hardening and Riparian Vegetation Removal

The Fraser River from Hope to Mission is classified as a "wandering gravel-bedded river" (Desloges and Church 1989). It is characterized by substantial lateral-channel migration which occurs as a result of sediment erosion, deposition and avulsion. This, in turn, accounts for the creation of the lower Fraser River's considerable number of side channels, emerging and disappearing islands and bars, and its expansive floodplain (Figs. 2, 26, 29). Much of the biodiversity, of the Fraser River in the eastern Fraser Valley area, including what remains of its formerly extra-ordinarily rich aquatic ecosystem, is thought to be due, in part, to this exceptional physical variability (Church et al. 2001).

Lateral erosion in streams (Fig. 34) is one of the mechanisms that creates and re-vitalizes habitat and is a key component of the development of the Shifting Habitat Mosaic. Under natural conditions, erosion is countered and slowed by riparian vegetation, which plays a key role in stabilizing streambanks by helping to bind sediments through its roots and woody accumulations (Bratty 2001). Where large cottonwood and other species of trees are allowed to grow and mature along the perimeter of the bank, their recruitment into the stream perimeter—through stream-bank erosion—can act as an effective natural mechanism to slow down the process of bank erosion when naturally anchored by large root-wads. These alignments tend to mitigate the lateral erosion by reducing the scour velocities along the banks of the Fraser River while providing complex in-stream habitat for fish and other aquatic organisms (Fig. 35).

Besides promoting bank stability, riparian vegetation is also important for other aquatic-ecosystem processes such as stream shading, the provision of cover for fish, the filtering out of pollutants, and as a source of insects and leaf litter. Thus there is a delicate natural balancing act between erosion and stabilization that occurs under properly functioning river conditions, and vegetation maintains this rate of change. In the eastern Fraser Valley, the Fraser River has lost extensive amounts of riparian vegetation through land clearing for traditional agricultural crops or the harvest of cultured pulpwood (Fig. 26). Accelerated erosion of the banks of the Fraser River is thought to have occurred in many places when riparian vegetation was removed from the river's edge (Bratty 2001). Lateral erosion has, in some locations, caused extensive loss of private and public property on the Fraser River floodplain in the eastern Fraser Valley (Figs. 36, 37, 38, 39).

In an effort to prevent such losses from occurring, river banks are often "hardened". This entails the placement of a non-eroding material such as demolition-waste concrete (Fig. 40) or large angular rock (Fig. 41). Hard non-eroding material made from blasted rock and placed on stream banks is generally referred to as "rip-rap". Once in place it can be very effective at stabilizing stream edges, yet it also disrupts the natural lateral-erosion migration rate of the stream. This results in the loss of the recruitment of critical woody habitats and disrupts important fluvial processes to which aquatic ecosystems are adapted (Schmetterling et al. 2001). In short, the rip-rapping of stream banks is damaging to fish habitat and the integrity of the Shifting Habitat Mosaic.

Fifty-five km of the outer banks of Fraser River between Mission and Seabird Island, out of a total of 137 km, are now hardened (Church et al. 2001). Much of the armouring of the stream banks of the Fraser River in the eastern Fraser Valley has taken place to protect agricultural land from erosion, in addition to protecting the main dikes and other infrastructure such as train tracks, bridges and pipeline. The percentage of the Fraser River's outer bank in the eastern Fraser Valley that is now non-erodable is 60% if rip-rapping for rail-bed protection along the Fraser is also included in the calculations. Figure 30 graphically shows the extent to which bank hardening in this area has occurred over the past century.

Due to extensive efforts by local and senior governments to armour the stream banks of the Fraser River in the eastern Fraser Valley in recent decades, the amount of bank/island erosion has now changed dramatically and is far less than what it used to be. A clear indication of this can be found by a recent study by Ham and Church (2003). Net losses of sediment from bank/island erosion/deposition between 1952 to 1984 reached almost 5 million cubic metres of sand, gravel and overbank material, or almost 125,000 cubic metres per year (Ham and Church 2003). In contrast, from the mid-1980's to 1999, after most of the bank hardening had been put in place, the erosion of this material totalled only 150,000 cubic metres of sediment, or less than 8 thousand cubic metres per annum. This represented a 15-fold drop in net lateral sediment erosion and it appears likely that this decline is attributable to the hardening of the Fraser's banks.

Thus, the Shifting Habitat Mosaic of the Fraser River floodplain has been altered and disrupted through both riparian-vegetation removal and bank armouring—one activity unreasonably accelerating natural erosion rates, and the other halting it completely. These activities continue unabated today on the Fraser River of the eastern Fraser Valley without any comprehensive requirements by the regulatory agencies for mitigation or compensation for these extensive losses to fish and aquatic habitats.

Figure 34. Cross-section diagram of lateral channel erosion at the bend of a river.

The natural addition of gravel on top of the bar on the inside of a bend builds up its profile. As fine sediments are then deposited over the high tops of the bars by floodwaters, floodplains are created and vegetation becomes established. At the same time there is undermining of the outer bank so that the main channel is in a new location. From Collins and Dunne, 1989.

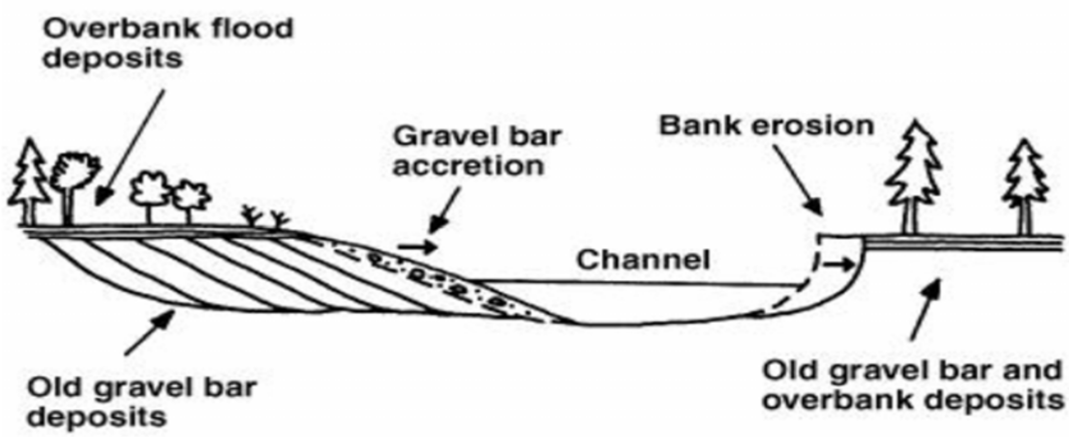


Figure 35. Large woody debris aligned against the stream bank at an ecological reserve on the Fraser River near Chilliwack.

Note that the configuration of the trees and the orientation of the root wads can act as a natural bank protection (red arrows). Compare with Figure 36.

Figure 36. Lateral bank erosion at Island 22, December 2003.

Removal of the natural vegetation along the riparian zone for the development of this area into a recreational park with its attendant tree removal has accelerated the collapse of this shoreline. The blue lines indicate approximate current (erosion) orientation. Losses of habitat values, private property and public property, and threats to dike infrastructure, can occur through poor land-use practices in riparian areas. Compare with Figure 35. Author's photo.

Figure 37. Erosion of a farmer's field upstream of Harrison River on the Fraser River in the 1990's.

Note the complete lack of native riparian vegetation. The blue lines indicate approximate current (erosion) orientation. Fisheries and Oceans Canada photo.

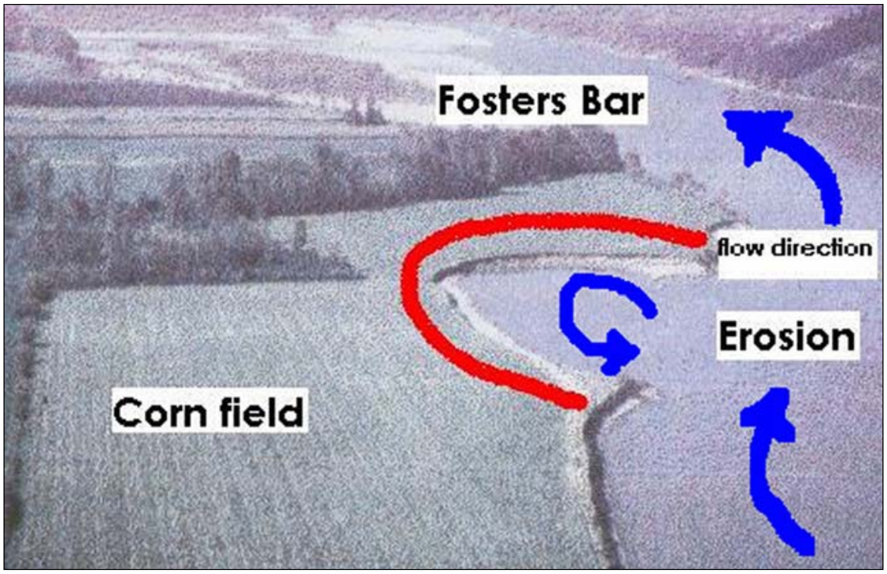


Figure 38. Eroding bank on a Fraser River island where pulpwood was extensively harvested.

Arrows point to cut stumps which have fallen into the wetted perimeter. Note that all of the pulpwood forest was removed at the current stream-bank edge.

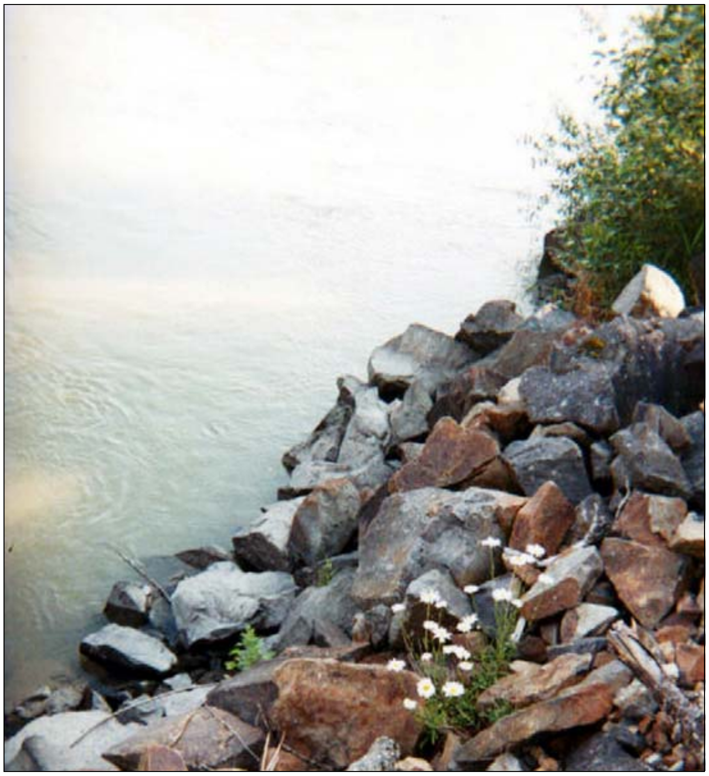
Figure 39. Complete loss of native riparian vegetation on an Agassiz farm field, right to the edge of the Fraser River.

There is now a lack of root structure from native trees to protect this bank from erosion. Demolition waste, shown in Fig. 40, and rip-rap in Fig. 41, were used to armour this field. Author's photo.

Figure 40. Demolition waste used as bank protection.

Photo taken in 2004 at site of Fig. 39 where the removal of native bank/riparian vegetation resulted in accelerated bank erosion requiring the use of armouring to protect the property. It is remarkable that this type of construction waste is still allowed to be used as bank protection in the Fraser River in the eastern Fraser Valley. Author's photo.

Figure 41. Rip-rap protecting farmland at Agassiz.
Photo taken at site of Fig. 39. Author's photo.



1.4.4 Draining of Sumas Lake for Farmland

A large area of farmland was created in the eastern Fraser Valley by converting the rich aquatic ecosystem of Sumas Lake into an agricultural landscape in the early part of the 20th century (Wells 1987, Brown 2002, Web Citations 4, 5, 6). This occurred as a result of the diking and draining of this large wetland area, an undertaking that resulted in perhaps the single greatest impact to a freshwater environment by agriculture in the history of British Columbia.

In its natural state, Sumas Lake was a shallow-water depression located just west of the present-day community of Chilliwack (Fig. 15). Its headwaters still flow primarily northward from the United States across the International Border, south of Abbotsford, and then into the Fraser River. As indicated earlier in this report, when the Europeans first settled the area, the Sumas River watershed was not physically linked to the Chilliwack River, but became so only when the latter had its flows re-directed from a northerly direction at Vedder Crossing to a more westward orientation (Fig. 14).

While the verdant natural grasslands around the perimeter of the lake were used for forage when farmers first settled the area in the late 19th century, seasonally-fluctuating water levels prevented maximum exploitation of the area. Brown (2002) indicates that this shallow lake was also tidally influenced. In addition, Sumas Lake greatly increased in size (perhaps by as much as three times) during freshet flooding as the high Fraser River water levels would backwater the area during spring and early summer (Fig. 42). The lake's depth normally ranged from 3-10 metres and, at low Fraser River flows, it was estimated to be about 11,600 ha in size. About 3,600 ha of its area was comprised of open water while approximately 8,000 ha was made up of marshlands and sloughs. The dense mosquito population living in the area was also viewed as a problem and this issue was used as one of the arguments for draining the lake. This primary reason, however, was the additional farmland that would be created.

In the early 1920's, a group of engineers developed a specific plan to drain the lake (Web Citations 4, 5, 6) using large-scale dredging (Fig. 43), diking (Fig. 44, 45) ditching (Fig. 46), and pumping (Fig. 47). These efforts were needed in combination to both drain the lake and keep the landscape dry year round (Fig.48) in order to support agriculture. Local farmers responded well to the proposal and, with the financial support of the Provincial Government, work commenced soon afterwards. By 1925 the task was completed and a vast aquatic ecosystem for fish and other wildlife was lost.

No rigorous estimates of the environmental losses resulting from the draining of Sumas Lake have ever been made. Brown (2002) suggested that 230,000 to 23,000,000 juvenile salmon might have reared in the lake but has commented on the difficulties in providing an exact estimate. (T. Brown, pers. comm.).

Laura Cameron (Web Citation 4) has provided a number of historical oral accounts which indicate that Sumas Lake was rich in a variety of species of fish. She reports that:

> *"…Robert Joe told anthropologist Wilson Duff about the past existence of a large sturgeon weir that crossed the Sumas River at the point where the river left the lake at a width of 100 yards and a depth of up to 20 feet. The weir was owned by the Sumas First Nations but they allowed outsiders to use it: after catching what sturgeon they wanted, they opened the weir. (From Wilson Duff, "Stalo Fieldnotes," 1950-52, p. 17-18)…[a]ccording to Sumas Band members, the remaining Sumas Reserve was renamed Kilgard, derived from Kw'ek'e'i:qw, meaning "fish heads sticking up," in recognition of the trapped sturgeon that were left exposed on the lake bottom. In an interview with Gordon Mohs in 1985, elder Edna Douglas stated that live sturgeon were being ploughed up by the farmers as recently as the late 1930's, knowledge that still troubles her… Gordon Mohs, "Sumas Lake: Review of Reclamation & Native Use," for Roy Mussel, Stó:lo Tribal Council, 198?)" (Web Citation 4).*

Cameron (Web Citation 4) also quotes John Cherrington's 1992 *The Fraser Valley: A History* and states that:

> *"…the Sumas accomplishment was considerable and he justifies the Reclamation Project in terms of the "loamy soil beneath." The pumps that drained the lake were the largest in Canada, emptying 300,000 cubic feet per minute, enabling the creation of what Cherrington calls the "richest, most efficient dairy, berry and hop growing region of the province." The hundreds of "dead and flopping fish" including large sturgeon on the lake bottom becomes nothing more than a "unique sight." ".*

Vast flocks of waterfowl and other species of animals and plants also used Sumas Lake as habitat prior to the draining of the basin and most of these have all but disappeared (Wells 1987). In short, despite the fact that we do not have a clear understanding of the exact magnitude of its historic aquatic values, it is clear that that a rich, vibrant and perhaps unparalleled ecosystem once existed here. What remains today is only a mere remnant of what once was and, to many, Sumas Lake exemplifies the ecological legacy of the expansion of agriculture in the eastern Fraser Valley.

Figure 42. Beach scene on Sumas Lake circa 1910, prior to draining.
MSA Museum photo.

Figure 43. Dredging required to facilitate drainage of Sumas Lake.
***MSA Museum** photo.*

Figure 44. Vedder Canal flowing northward to the Fraser River.

Direction of flow is from right to left. The large dike on the right side of the photo maintains protection against Fraser and Vedder rivers re-flooding the former Sumas Lake bottom. The Vedder Canal's stream bed appears to be slowly increasing in habitat capacity through the limited recruitment of gravel that has naturally come from upstream areas over the ensuing decades since it was first dredged; these substrates are now being intensively used by spawning salmon. Extensive sediment removal—back to the construction design condition—would re-set the clock to a highly damaged state.

Figure 45. Current configuration of Sumas Lake watershed, June 2002.

Fraser River discharges were at 10,000 cubic metres per second when the photo was taken, backwatering the Sumas River. Note that the areas inside of the red perimeters would normally have been aquatic habitat prior to diking and flood control, but are now largely farmland. Solvej Patschke photo; author's text and additions.

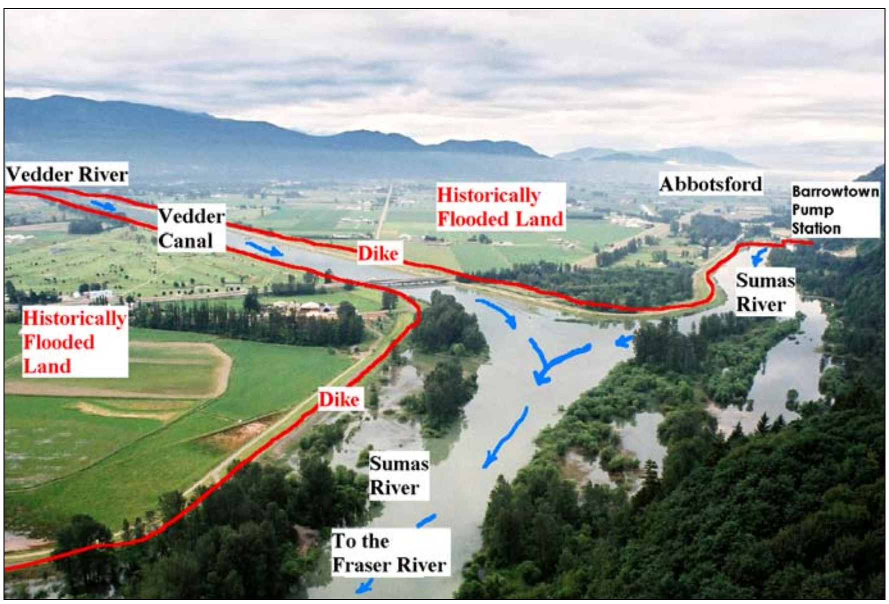


Figure 46. Extensive network of constructed ditches keep the former Sumas Lake bottom sufficiently dry to cultivate.

Author's photo.

Figure 47. The Barrowtown pump station and dike on the Sumas River keeps the Fraser and Vedder/Chilliwack rivers from re-inundating the former Sumas Lake.

A recent upgrade of the pumping infrastructure is more fish-friendly than the older pumps which were replaced (Thomson 1999a). Author's photo.

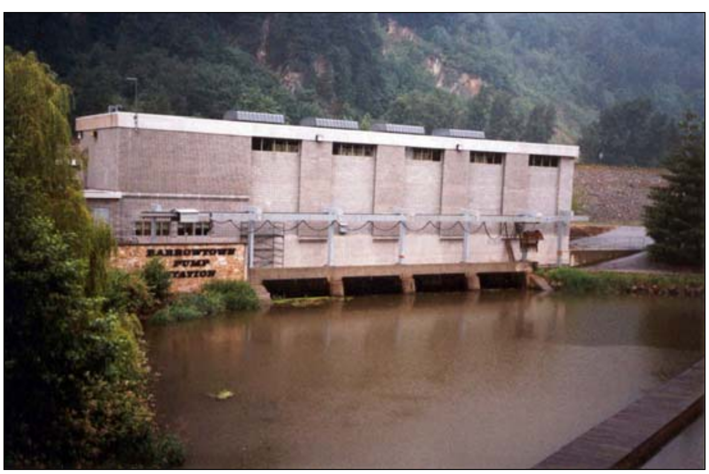


Figure 48. Cultivated fields on the bottom of the former Sumas Lake on a misty spring day, 2004.
There is little to suggest that this landscape was once one of British Columbia's extraordinary aquatic ecosystems. Author's photo.

1.4.5 The History of Agriculturally-Mediated Impacts to Small Eastern Fraser Valley Streams

Overview of Stream Channelization and Ditching of Small Streams

Drainage is a key component to bringing floodplains into agricultural production.[2] Most agricultural crops do not grow well in standing water or saturated soils. Wetlands are also difficult to operate equipment on and till. Thus, it is usually necessary to drain fields, and the levels of moisture in the soil must be controlled in order to maximize production (Lalonde and Hughes-Games 1997).

Draining of farmlands occurs through a variety of methods including: 1. modifying the level and slope of the land, 2. drain tiling to improve the flow of water off of the land and from the soil, 3. channelizing, straightening or moving existing streams, and 4. digging ditches. These activities increase the transport of water away from the fields. Dredged, channelized and straightened streams, ditches, and accelerated water flows rarely have the same aquatic habitat quality or quantity as their natural counterparts and, thus, agricultural drainage normally adversely affects aquatic habitats (Brown 2002, Nener et al. 1997).

Channelized or relocated streams are highly engineered and rarely have the characters of natural watercourses. Channelization is the modification of the shape of the stream into an un-natural form (usually more homogeneous) in order to assist in increasing the hydraulic conveyance and efficiency of flows. As a result, the normal fluvial processes which define the key physical characteristics of a watershed (including the erosion and deposition of sediments, the recruitment of woody debris, in-stream and riparian vegetation growth, and the tendency to meander) and its aquatic habitat capacity are interrupted or substantially modified (Fig. 49). Routine channel

2. In researching the agricultural literature it is interesting to note how often the terms such as "reclaimed" and "improvements" recur, ironically, in relation to the facilitated drainage of water from actively or potentially cultivated areas. While the "benefits" are clearly in the direction of increasing the productive capacity of the land for food production, benefits are rarely seen by the natural aquatic ecosystems that reside in these habitats. In other words, in anthropomorphic terms, it is unlikely that any of the resident organisms would actually view the wetlands as being "improved" by draining their habitats, or "reclaimed" by destroying their homes.

clearance and bank armouring are often continuing aspects of channelization. In short, the processes leading to the Shifting Habitat Mosaic are completely disrupted.

Channelized streams do not normally have the same degree of sinuosity that they would have possessed prior to being re-routed (Chapman and Knudsen 1980). Funk and Ruhr (1971) and Huet and Timmermans (1976) indicate that a straightened watercourse is often only one-half as long as the original stream. As a result, both stream length and total wetted area are reduced as a result of channelization. Subsequently, there is usually a correlating loss of habitat capacity as a function of these changes.

Within their wetted perimeters, channelized streams are also normally far less complex than natural watercourses. Their in-stream structure tends to be very uniform (Fig. 49), thus reducing the number of hiding places for both small and large fish. This is a characteristic that does not lend itself to good rearing habitat under higher and faster flow regimesm, as fish can be displaced by the swift water into sub-optimal habitats, or become vulnerable to predation or stranding without the presence of these physical niches (McMahon and Hartman 1989).

Figure 49. Channelized coho stream in the eastern Fraser Valley in an area of intense agriculture.

This stream has been recently cleaned, is very homogeneous in structure and has little resemblance to what it would have looked like in its un-channelized natural state.

Armouring is sometimes undertaken along the edge of the stream bank after the channel is dredged to protect it from erosion. Uniform and straightened channels generally experience increased flow velocities due to the increase in gradient when a meander is shortened, and this can also add to the rate of bank erosion. However, armouring of the banks usually reduces the natural complexities of the edge of the stream (Fig. 50) which in turn limits its productive-habitat capacity (Bisson et al. 1988). Rip-rapping and other forms of bank armouring have been demonstrated to negatively affect stream habitats (Schmetterling et al. 2001). In short, channelized and armoured streams, by their very nature, cannot maintain natural fluvial processes such as erosion, deposition and meandering which are critical to retaining healthy aquatic ecosystems (Brown 2002).

Figure 50. Ditch maintenance in the eastern Fraser Valley using small rip-rap to stabilize the banks and control vegetation.

Due to habitat losses relating to reduced re-growth of riparian bank vegetation, the agencies requested that this activity be stopped, and the local government engineering department quickly complied.

The impacts associated with the channelization of streams on fish habitat, including those modified for agricultural purposes, are rarely short-term in nature. Cowx et al. (1986) and Headrick (1976; cited in Brown 2002) indicate that these impacts may persist for many years after the original work takes place. Furthermore, the design of the new stream channel can have a significant bearing on the productivity of the watercourse. For example, Brown (2002) suggests that under some situations, a deeply-excavated watercourse may not have adequate water-level elevations in order to facilitate movement of juvenile fish into nearby tributary rearing or overwintering areas. That is, the hydraulic difference, or jump, between the upstream watershed or wetlands, and the water-surface elevation of the channelized stream or ditch, may be too great for fish to ascend. Channel management may also incorporate sediment traps to reduce the deposition of sand and gravel in the downstream areas, and these structures can also function as barriers to fish (Fig. 51).

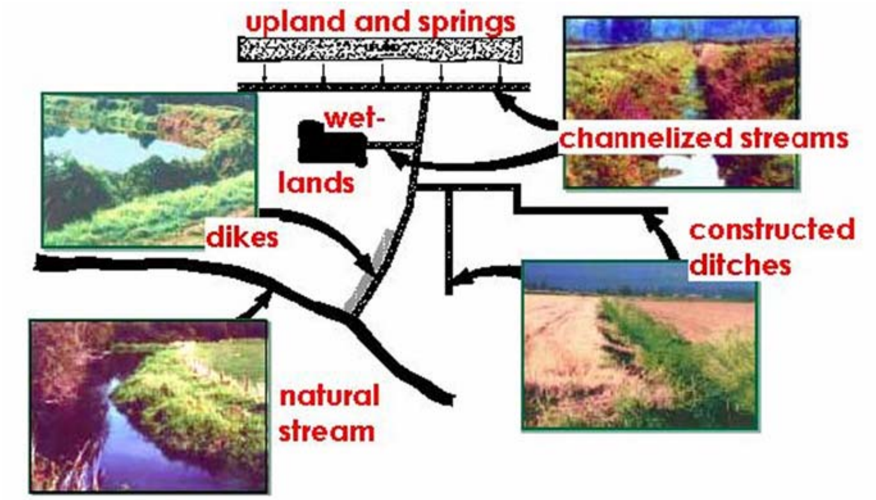
The surface-drainage channels historically constructed and used by agriculture to drain fields in the eastern Fraser Valley have been categorized into three primary forms: natural streams, channelized/relocated watercourses (which historically meandered across the lowlands), and constructed ditches (Partnership Committee on Agriculture and the Environment 2001; Fig. 52). When working with these channels, it is not always immediately obvious that an altered waterway may have once been a “natural stream” without closer examination of the topography or history of the site. In many cases, such waterways may be channelized streams, as compared to a constructed ditch, even though it looks like a ditch due to its engineered configuration. This has important implications in terms of both the biology of the stream and the regulatory requirements that apply to the maintenance of the channel (Partnership Committee on Agriculture and the Environment 2001). On the other hand, even a constructed ditch can have high aquatic ecosystem values, and these values may not always be captured under regulatory guidelines for maintenance (Partnership Committee on Agriculture and the Environment 2001).

Figure 51. Elk Creek sediment trap, 1975, in the eastern Fraser Valley.

Above this check-dam was a large pool which was regularly excavated of sediments that had been recruited from upstream areas and deposited in the trap. The objective of the trap was to keep gravel and other sediments from depositing into farm fields or filling up the stream in its lower reaches. Historically, this structure had no provisions for allowing upstream-migrating salmon to pass by, despite an abundant run of coho spawning immediately downstream. However, a fish-pass was incorporated into a new trap which was recently constructed to replace the old structure (P. Hiede, City of Chilliwack, pers. comm.). Bruce Usher (1975) photo.

Figure 52. Examples of British Columbia's Agricultural Watercourse Classification for drainage channels.

Schematic diagram showing examples of British Columbia's Agricultural Watercourse Classification for drainage channels adapted from Resource Management Factsheet, Ministry of Agriculture, Food and Fisheries Order No. 810.200-1 May 2001 Agriculture GIS Watercourse Classification, from Web Citation 7. As a cautionary note, while the effort by the regulatory agencies to classify the different agricultural watercourses is important, the protection of significant aquatic-ecosystem values can be missed during the maintenance of the constructed streams under this particular scheme. This is because ecological values are arbitrarily assigned to each class of channel, based on the historical characteristics rather than on the individual stream's actual aquatic community.



Eastern Fraser Valley Historical Perspective

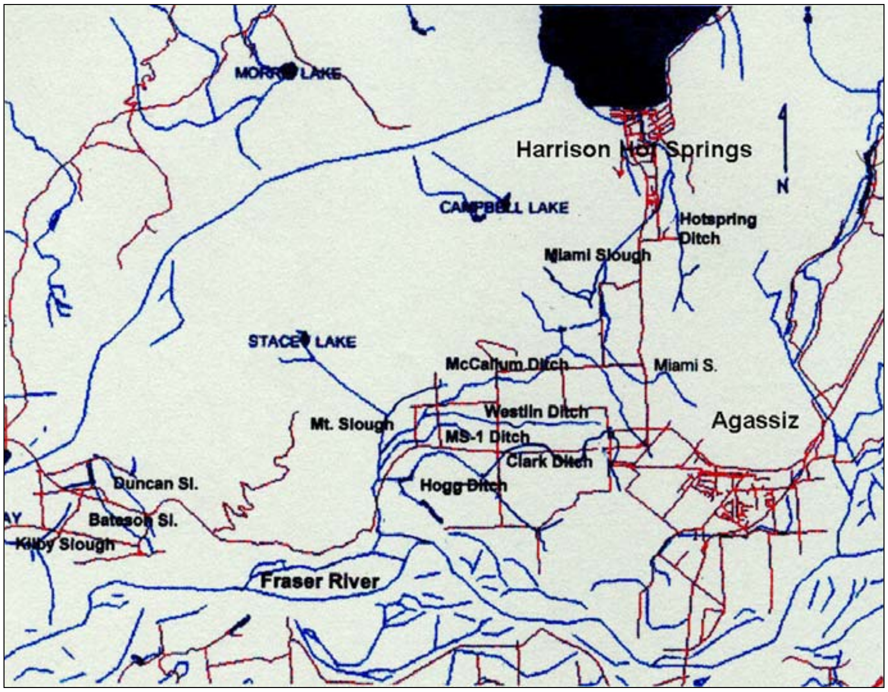
Many of the small but highly-productive streams flowing from the adjacent hills on the north and south sides of the Fraser River, and then across the agricultural floodplains, were channelized and/or straightened, or otherwise impacted by farming (Table 5), as early as the turn of the 20th century in the eastern Fraser Valley (Fig. 53). Around the time of the First World War, most of the area in East Chilliwack was sold by government to private interests for agriculture. Draining and clearing proceeded in earnest (Web Citation 6) with large interception channels being built across these swampy lowlands to facilitate drainage (Fig. 54). Ditching, tiling and draining of these wetlands followed to further dry out the land.

Because there has not been a systematic attempt to comprehensively quantify the historic pre-settlement habitat capacity of these small-stream and wetland aquatic habitats in the eastern Fraser Valley, we can only guess as to their fisheries values before these changes were made. Nevertheless, we know that most small lowland streams in the Lower Mainland that still retain some semblance of their natural features are highly productive. Undoubtedly, most if not all of these small streams in the eastern Fraser Valley provided exceptional habitat for coho and chum salmon, as well as cutthroat trout.

Fraser Valley historian Mary Hickman (Web Citation 6) wrote about the early settlement in the area and provides us with a sense of the extensive aquatic ecosystem that is now largely gone due to the development of agriculture and/or subsequent development. Her following quote describes the pre-settlement topography of East Chilliwack stating: "…John Parker's place had more low-lying land than we had. This, in Spring, was very boggy and often the horses were obliged to wear clogs on their feet to do the work. We, on the high land, thought poorly of the Big Prairie. It was very rich soil but badly needed draining. So much water came from the hills and found a resting place on the flat!"

Figure 53. Overview of drainage watercourses in the City of Chilliwack and the Agassiz area.

City of Chilliwack (bottom) and the Agassiz area (top).These eastern Fraser Valley watercourses include natural streams, channelized streams, and constructed ditches. From Milne and Wright (2002), bottom, and Slaney and Northcote (2003), top. The geometrically-squared-off shapes of many of the watercourses in these figures indicate historically-channelized streams and/or ditches.



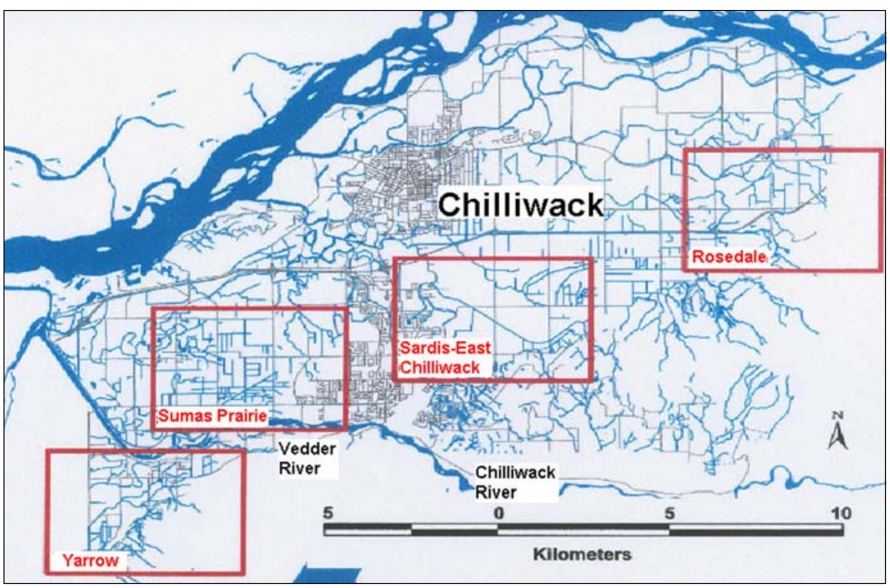


Figure 54. Elk Creek just upstream of its confluence with Hope Slough.

This is a highly-productive channelized stream which still contains a significant coho run but flows through agricultural land in the eastern Fraser Valley. It was converted into one of the large interception channels that were constructed early in the development of the area to drain land for farming in East Chilliwack (the local name is Big Ditch). Note: the height of the domestic water pipe suspended above the water-surface elevation of the stream gives a sense of the extensive depth of excavation that has occurred in this watercourse to facilitate drainage. Author's photo.

Table 5. A partial list of streams affected by agriculture in the eastern Fraser Valley.

Based on information in the Fraser River Action Plan (1998) and personal observations by the authors and other fisheries professionals.

- Anderson Creek
- Arnold Slough
- Atchelitz Slough
- Barrett Creek
- Bouchier Creek
- Bridal Creek
- Brousseau Creek
- Calkins Creek
- Camp Slough
- Chawuthen Creek
- Chilliwack Creek
- Chilliwack River
- Chilqua Slough
- Dunville Creek
- Durieux Creek
- Elk Brook
- Elk Creek
- Ford Creek
- Gravel Slough
- Harrison River
- Hatzic Slough
- Hawkins Creek
- Hicks Creek
- Hope Sough
- Hopedale Slough
- Inches Creek
- Johnson Slough
- Kilgard Creek
- Legace Creek
- Lonzo (Marshall) Creek
- Lorenzetta Creek
- Luckakuck Slough
- Marblehill Creek
- Maria Slough
- McGillivary Slough
- Miami Creek
- Miller Slough
- Mountain Slough
- Mud Slough
- Nevin Creek
- Nicomen Slough
- Norrish (Suicide) Creek
- Oru Creek
- Peach Creek
- Pye Creek
- Quaamitch Slough
- Railway Creek
- Ruby Creek
- Ryder Creek
- Saar Creek
- Salwein Creek
- Semmihault Creek
- Seux Creek
- Shefford Slough
- Siddle Creek
- Stewart Creek
- Street Creek
- Sumas River
- Vedder River
- Wahleach Creek
- Wilson Slough
- Worth Creek
- Zaitscullachan Slough

In a more recent assessment of the impacts of settlement on eastern Fraser Valley streams there is a 1998 report entitled "Wild, Threatened, Endangered and Lost Streams of the Lower Fraser Valley" (Precision 1998). The authors indicate that from Stave River to Hope, on the north side of the Fraser Valley, and from Abbotsford to Hope, on the south side, only 5% of the remaining streams could now be classed as "wild" (i.e., intact, not affected by human activities; Table 6). It is also important to note that most of the "wild" streams listed in this report are at elevations where agricultural activity would be unlikely to take place. In contrast, 20% and 70% of the streams within the same study area were considered to be "threatened" or "endangered" respectively, while another 5% had been permanently lost through activities such as infilling or culverting (Precision 1998).

Table 6. Summary of stream status in the eastern Fraser Valley in the areas of human settlement.

Data from Precision (1998).

Area	Wild	Threatened	Endangered	Lost	Total Incl. Lost
Abbotsford to Hope	8	17	142	6	173
Stave River to Hope	4	34	35	6	79
TOTAL	12	51	177	12	252
% of Total	5%	20%	70%	5%	100%

As more people moved into the eastern Fraser Valley after the Second World War, the effects of agriculture on aquatic ecosystems increased as farming intensified. Many of the activities that involved drainage improvements in the eastern Fraser Valley in the latter half of the 20th century were the result of senior and local governments providing support to the agricultural community through the ALDA (Agriculture Land Development Act) and ARDSA (Agriculture and Rural Development Subsidiary Agreement) programs. Drainage also became more efficient through advances in modern drainage technologies, further impacting aquatic ecosystems.

The more recent program, the ARDSA initiative, has been a joint federal, provincial and municipal scheme that provided money to farmers and local communities to improve drainage and irrigation on farmland. Grants were made available to construct dikes, pumping stations and drainage infrastructure. Under the conditions of the agreement, ARDSA funds could be used on altered natural streams or constructed ditches but were usually expended on channelized streams. ARDSA criteria were set to ensure that specific field drainage efficiencies were met (Table 7). Once constructed, the participating municipalities were, and continue to be, required to continue to maintain these channels in a way that's consistent with the designs specified in the partnership agreements (Partnership Committee on Agriculture and the Environment 2001).

As farming intensified in the eastern Fraser Valley, not only were additional surface channels constructed and deepened, but subsurface drainage was expanded as well. From 1946 to 1977, over 3 million metres of subsurface drains were installed in British Columbia (Figs. 55, 56, 57). Lalonde and Hughes-Games (1997) estimate this to be equivalent to the draining of 5,700 ha of sub-standard farmland, most or all of which would have comprised wetlands and aquatic ecosystems. Furthermore, government programs such as ALDA and ARDSA facilitated an additional equivalent of 2.75 million more metres of drain tiles through to 1983, and the Fraser Valley accounted for 60% of these subsurface drain installations.

It's also important to note that ARDSA objectives specify that drainage channels have a 1.2 metrefreeboard in outlet ditches (Table 7). Drainage systems constructed to these specifications cause damage to aquatic wetland ecosystems adjacent to streams, channelized waterways or drainage ditches through drying and desiccation, as well as disrupting the hydrology (rate of flow). When these criteria are implemented they can also act as a barrier to juvenile fish passage into adjacent wetland habitats.

Accompanying the installation of drainage tiles was the extensive levelling of farm fields in the eastern Fraser Valley (Fig. 58). This activity removed many wetlands and ponded areas from fields where cultivation was intended. Such wetted areas are important in maintaining aquatic ecosystem values and can also contribute to the productive capacity of adjacent salmon streams where there is a linkage, either through overland connections or through the hyporheic zone.

Table 7. Drainage criteria for agricultural channels in British Columbia.

These are also known as the ARDSA criteria. Table adapted from Resource Management Factsheet, Ministry of Agriculture, Food and Fisheries Order No. 535.200-1 June 2002 Planning for Agricultural Drainage. www.agf.gov.bc.ca/resmgmt/publist/800series/810200-1.pdf .

The channels shall:

- Remove the runoff from the 10 year, 5 day storm, within 5 days of the dormant period—November 1 to February 28
- Remove the runoff from the 10 year, 2 day storm, within 2 days in the growing period—March 1 to October 31
- Between storm events and in periods when drainage is required, the base flow in channels must be maintained at 1.2m below field elevation
- The conveyance system must be sized appropriately for both base flow and storm-design flow

Figure 55. Total length of subsurface drains installed between 1946 and 1996.
From Lalonde and Hughes-Games (1997).

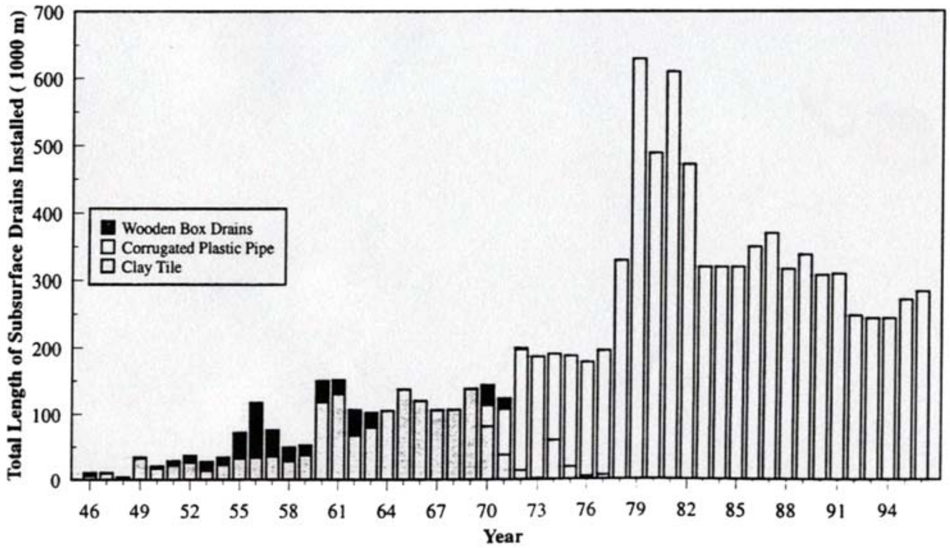


Figure 56. Drain tiles flowing into a channelized stream in the eastern Fraser Valley.

Figure 57. Effect on field-water levels by using drain-tiling systems in order to increase drainage and agricultural production.

www.fao.org/docrep/R4082E/r4082e07.htm#6.2.2%20subsurface%20drainage

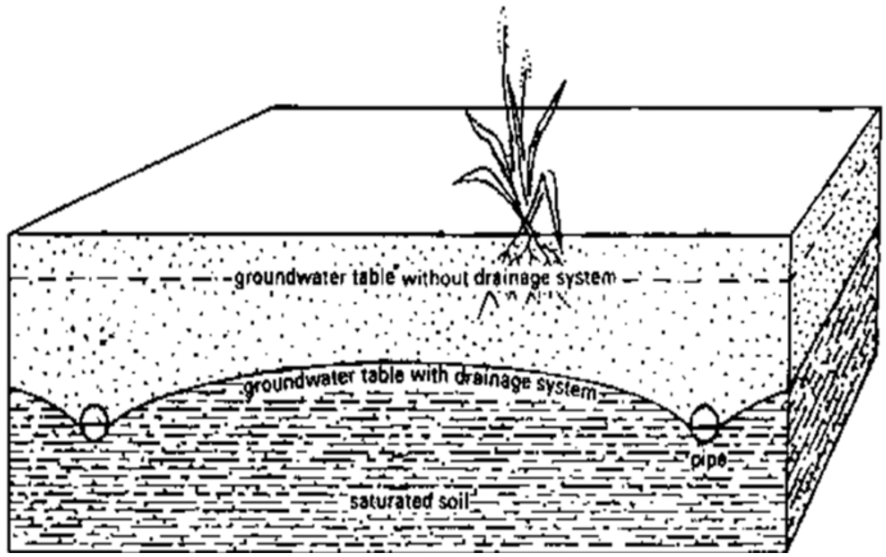
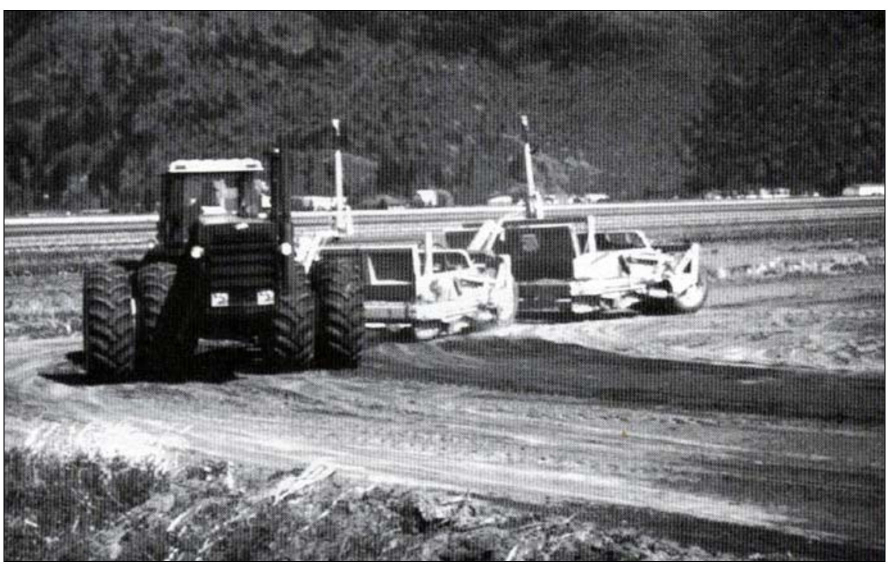


Figure 58. Land levelling facilitates drainage of water.

This activity extensively reduced the physical heterogeneity of the eastern Fraser Valley and, as a result, widespread but unaccounted-for amounts of aquatic and terrestrial biodiversity were lost. Photo from Lalonde and Hugh-Games (1998).



1.5 Current Impacts to Fish Habitat by Agriculture in the Eastern Fraser Valley

1.5.1 Introduction

While extensive changes to aquatic ecosystems of the eastern Fraser Valley resulted from the development of agriculture by settlers in the region, many of the remaining habitats continue to be under stress from farming. This is important to understand if aquatic ecosystems are to be sustained and/or restored in this area.

A number of different activities continue to damage these remaining aquatic habitats. First, continued intensification of the existing farmland is currently a concern to the fisheries agencies as more wetlands and streams are increasingly being drained and riparian areas cleared in order to maximize food and crop production. Many of the formerly “marginal” agricultural lands are now being brought into production as a result of new technologies or economic incentives that now provide an opportunity for these areas to be cultivated.

Second, pump stations and flood boxes draining water through dikes continue to kill fish though mechanical action of the pumps, or block fish from key rearing and/or spawning areas. Furthermore, as we “run out of land” in the Lower Mainland due to human population growth, more and more land is being removed from the Agricultural Land Reserve for development. In many cases, land which is considered to be marginal for farming is also thought to be a good candidate for exclusion from the Reserve; unfortunately many of these “marginal” lands comprise high quality fish and wildlife habitats. Finally, the maintenance of ditches and floodway streams through sediment removal, and the associated clearing of natural vegetation and cultivation in riparian areas, continue to be a major concern.

In the following sections of this report, we comment on some of the existing issues relating to current impacts to fish and aquatic habitats associated with today’s agricultural practices in the eastern Fraser Valley.

1.5.2 Intensification

The intensification of agriculture in order to increase farm production—through the construction of new dikes (Fig. 59), the infilling of wetlands (Fig. 60), and land clearing (Fig. 61)—remains a continuing issue for eastern Fraser Valley floodplain areas and salmon and steelhead ecosystems. Impacts relating to intensifying agriculture in the eastern Fraser Valley also include the planting of crops right to the perimeter of streams without providing adequate buffer zones between the cultivated areas and the stream edge (e.g., Figs. 26, 62). Also, in recent years, large-scale planting and harvesting of pulpwood on the large floodplain islands and perimeter lands outside the dike on the Fraser River have changed the native-species composition and the biodiversity of these aquatic riparian areas (Fig. 63). Changes in natural ecosystem attributes will inevitably change salmonid values.

These activities have the effect of disrupting the Shifting Habitat Mosaic by preventing natural flood flows from accessing the remaining floodplain, preventing riparian inundation, and removing the native plant and animal communities. While the scientific literature is very clear about the impacts to aquatic communities from these activities, they continue to occur with little interference from the regulatory or conservation agencies.

Figure 59. Development of an agricultural dike on the Chilliwack River.

Recently demolition waste was used to construct a private dike on the Chilliwack River floodplain in order to prevent flooding of a farm field. The impacts of this berm on fish habitat include the following: 1. overland floodplain flows and fluvial processes are now disrupted, and 2. eventually this waste will enter the normally wetted perimeter of the river as the stream naturally erodes the unconsolidated floodplain substrates that the material has been set upon (Fig. 32). The horizontal white line from the perimeter of the dike indicates that the distance to the water's edge is less than 10 metres at many locations.

Figure 60. Current in-filling of Fraser River floodplain wetland adjacent to farm field at Laidlaw, August 2004.

The farmer is expanding his land at the expense of the aquatic ecosystem and riparian vegetation. Author's photo.

Figure 61. Recent clearing of the floodplain outside the dikes, Old Orchard Road, Chilliwack, September 2004.

Location is adjacent to the Fraser River on farm land. Author's photo.

Figure 62. The Sumas River near Abbotsford, 2004.

Note the lack of a riparian buffer zone on the left shore as the farmer cultivates crops to the top of bank. Klassen (1995) notes that the Sumas River, which is a low-gradient flowing stream, has little substantive riparian cover remaining as a result of the farming activity that now occurs along 91% of its length. Compare with Fig. 92 where the Americans are aggressively restoring riparian vegetation in the same watershed. Author's photo.

Figure 63. Cultivation of pulpwood on Herrling Island, 2004.

There is a lack of natural vegetation biodiversity in the riparian area of the plantation due to the monoculture nature of this type of cultivation. These island plantations are extensive within the Fraser River floodplain (Fig. 26) and the ground is often levelled by earthmoving equipment to facilitate the production of pulpwood; this reduces the physical heterogeneity of the floodplain, a key component to biodiversity and salmonid production. Also, because these trees are young and small, the potential for large trees to be recruited along the bank during natural erosion is minimal and this prevents the woody debris at this location from providing any meaningful stream-bank protection (compare with Fig. 35). Author's photos.

1.5.3 Flood Boxes and Pump Stations as Barriers to Fish

If the eastern Fraser Valley dikes are to function as designed, they must prevent the flood waters from the Fraser, Vedder, Sumas or Harrison rivers from inundating protected areas while still allowing accumulated water on the landward side of the dike to drain back into the river. In other words, dikes must act as a barrier to floods but, at the same time, must not trap and block the flow of water from the developed (landward) portion of the floodplain. Water that accumulates on the developed lowland side of the dike may be from a variety of sources, including: 1. local streams and drainage ditches entering from upland areas; 2. pooled surface water from precipitation; 3. groundwater flows that have surfaced; or 4. seepage from the river that has travelled through, or under, the dikes.

During the late spring when the Fraser River freshet-flow discharge elevation in the Fraser, Harrison, Sumas or Vedder rivers can be higher than the surrounding lowlands, excessive water on the land side of the dikes can become a problem (Fig. 64). Similarly, winter rain events and flood flows can be a significant issue to the surrounding farmland on the Chilliwack/Vedder and Sumas watersheds (Fig. 23). If this standing water is not removed, both crops and infrastructure can be affected, although fields are usually the first to be impacted by ponded water as buildings are normally constructed on higher ground (i.e., they are floodproofed by design as required by regulation).

Floodplain dikes are usually designed with a portal of one kind or another in order to facilitate the movement of water away from the developed floodplain and into the river. For the eastern Fraser Valley dikes this egress structure may include a pump station, flood box, or combination pump station/flood box (Fig. 65). There is an extensive network of pumping stations and flood boxes throughout the eastern Fraser Valley that are part of the diking system (Fig. 66).

Flood boxes are passive drainage structures that are constructed through a dike to allow the flow-through of water at lower river flows; they allow the egress of water when flows upstream of the box warrant and reverse flows from the downstream direction are not a threat. Flood boxes are designed to be barriers to backwatering via a flap-valve, or gate, during downstream flooding.

Pump stations have a mechanical pumping device that propels water over or through the dike. The pump stations that are located throughout the Lower Mainland diking system are used to pump water from a stream or ditch into a larger waterway outside a dike, such as the Fraser River (Thomson 1999a, b). In the Lower Mainland, such pumps can be privately owned or operated by municipalities or districts (Thomson 1999a).

Pumps, when combined with flood boxes, can interrupt, delay, or impede migration of fish. The pumps can also injure or kill salmonids as a result of the mechanical action of the impellor. The major pump types used for flood control in the Fraser Valley are classified as propeller, centrifugal and Archimedes screws. The propeller pump is the most damaging to fish, while the screws pumps usually have the least impact (Thomson 1999a).

Most of the eastern Fraser Valley flood boxes now in place impact salmon at one stage or another as a result of being closed during juvenile smolting, adult kelting and/or juvenile salmon overwintering or rearing periods (Thomson 1999a, b, 2000). Murray and Rosenau (1989) showed that densities of non-natal-rearing chinook fry in lower Fraser River tributary streams with flood-control barriers were limited, compared to streams with free migratory access.

Several pump structures in the Fraser River floodplain of the eastern Fraser Valley are of particular concern at present because of their impacts to fish. These include the Hatzic Slough pumping station at Mission, the Miami Creek pumping station at Harrison Hot Springs, and the Hammersley pumping station at Mountain Slough in Agassiz (Thomson 1999a). As shown in Fig. 66, much of the pumping infrastructure is designed to protect agricultural land.

In summary, most of these floodbox/pumping station facilities currently appear to constitute a significant impact to salmon production in the eastern Fraser Valley. Most of these facilities are associated with agriculture. While some attempt has been made to address this problem in recent years (Thomson 1999a, b, 2000), additional efforts are required both to assess and to remedy potential impacts associated with these structures.

Figure 64. Standing water in farm fields behind the flood dikes in the eastern Fraser Valley.

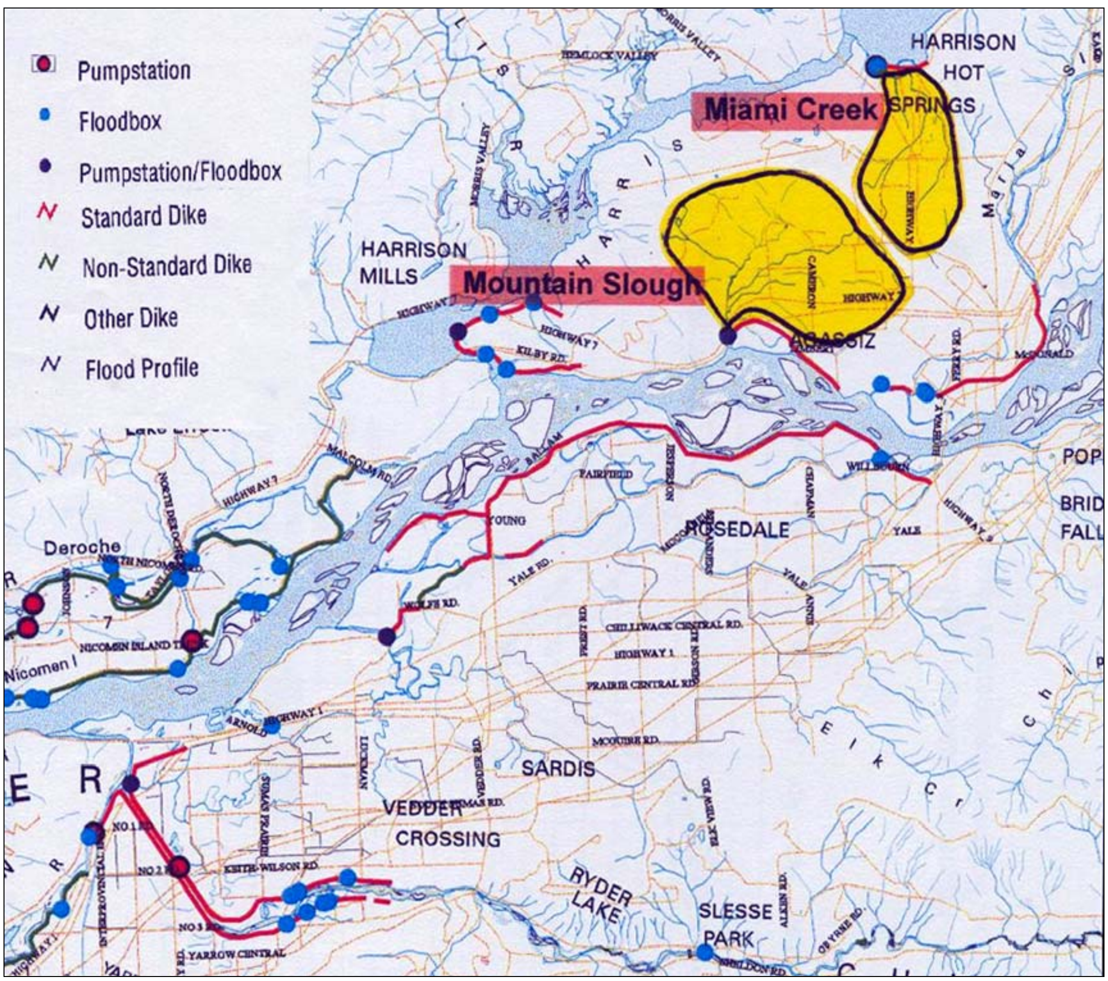
This sight is common during the winter storms and spring freshet when the water is trapped by the dikes due to the closing of floodboxes and must be pumped over the dikes rather than simply flow into the river. Author's photo.

Figure 65. Floodbox and pumpstation at Mountain Slough near Agassiz.

Photo from Thomson (1999a).

Figure 66. Pump stations and floodboxes of the eastern Fraser Valley.

The yellow areas outline specific watersheds controlled by floodbox/pump stations. From Thomson (1999a).



1.5.4 Changes in Designation of Use to Agricultural Land

Much of the landscape outside the main flood-protection dikes of the eastern Fraser Valley is currently designated for agriculture (Figs. 2, 3, 29, 30). The farming activities in these lands range from dairy and produce production to the culture of pulpwood. Nevertheless, in the past two decades, changes to the official land-use zoning—from agriculture to industrial, commercial and urban development, and from aggregate extraction—have increasingly impacted the riparian habitats in many remaining lowland-floodplain areas of the eastern Fraser Valley.

Property Development

The development of landscapes into commercial, urban or industrial uses is normally viewed as being more damaging to aquatic ecosystems than most agricultural operations because of the extensive disruption of fluvial processes and the permanent removal by development of most or all landscape vegetation. Langer et al. (2000) noted that while adverse impacts to fish habitats in streams adjacent to farms in the lower Fraser Valley were significant, the aquatic communities of these watersheds in agricultural lands were usually far more intact than for those where development had occurred. Langer et al. (2000) commented that, ironically, while farming is not benign to fish habitat, agricultural-land legislation and zoning often kept the much more damaging urban, commercial and industrial development away from many sensitive habitats near lower Fraser Valley streams.

Development on un-diked floodplains in British Columbia is generally not encouraged through legislation or zoning. This serves to minimize the costs of compensation (e.g., through the Provincial Emergency Program) should flooding lead to property damage. Consequently, development on the un-diked lowlands adjacent to the larger streams in the eastern Fraser Valley has generally been minimal. However more recently, as land for expansion of commercial, urban and industrial activity in the eastern Fraser Valley has become more valuable and scarce as a result of population growth, there has been increased pressure to re-zone marginal lands that have historically been designated as farmland, in order to enable the development of these properties (e.g., Figs. 67-71). Furthermore, for those farming areas that are being converted to other forms of development outside the main Fraser River dikes, government agencies have encouraged or regulated developers to ensure that all construction is "flood proofed" (through building on elevated fill and/or diking the perimeter) to flood-discharge-design elevations. This latter activity has significant footprint impacts on the native aquatic communities and ecological integrity, and may influence the floodway capacity. It also completely disrupts the Shifting Habitat Mosaic.

Impacts to aquatic ecosystems arising from this conversion of lowland and riparian floodplain habitats to commercial/industrial or urban development in agricultural areas include:

1. Disruption of the riparian continuity between upstream and downstream locations where inadequate buffer zones are incorporated into the project design (i.e., the riparian areas [green-space or greenbelts] along the stream perimeter are no longer connected). Connectivity is key to maintaining biodiversity (Fig. 68).

2. Destruction of ephemeral wetland communities through clearing of vegetation and flood-proofing by the construction of dikes or placement of fill (i.e., the footprint impact) (Figs. 67-71).

3. Urban drainage (culverts, storm drains, increased impervious surfaces) changes the basic hydrology of the streams and wetlands within and adjacent to the footprint of the development, and disrupts flow patterns to which aquatic ecosystems are adapted (Fig. 71).

4. The opportunity for natural meander, erosion, deposition and channel formation is completely disrupted due to stream-bank armouring in order to protect the development's investments (Figs. 68, 71).

5. The potential for interruption of subsurface flows (Fig. 67, 69) and contamination of hyporheic discharges due to polluted or non-inert fill (Fig. 70).

While substantial portions of the floodplain landscape that were previously designated for agriculture on the south side of the Fraser River have already been removed from the Agricultural Land Reserve, we expect more of this to continue due to population growth, scarcity of land and increasing property values in the eastern Fraser Valley. The consequence will be to further damage what little remains of the formerly vast Fraser River floodplain and its aquatic ecosystem in the eastern Fraser Valley, and to negatively affect the Shifting Habitat Mosaic.

Figure 67. Conversion of lowland floodplain from agricultural land to industrial at McGillivary Slough area, September 2004.

Area is now being filled with sediment in order to provide height-of-land flood-proofing as this property is outside the main dike. The activity shown in this figure is taking place within the former farmland perimeter of Figure 68. Almost complete losses of riparian vegetation have resulted along the water's edge of the general development area. Author's photo.

Figure 68. Encroaching fill on ephemerally wetted former farmland that is now re-assigned to non-agricultural uses.

Area encompassed by green perimeter has been re-zoned from agricultural purposes into a development area. Note that during the Fraser River discharges when this photograph was taken, the lower field is wetted from direct backwatering of the river and constitutes fish habitat; the upper fields behind the berm, or the area currently under fill, would also have been inundated during some freshets but are now isolated from the contiguous aquatic ecosystem due to this landscape disruption. The impacts to aquatic ecosystems of these highly destructive land-use practices cannot be mitigated. Solvej Patschke photo.

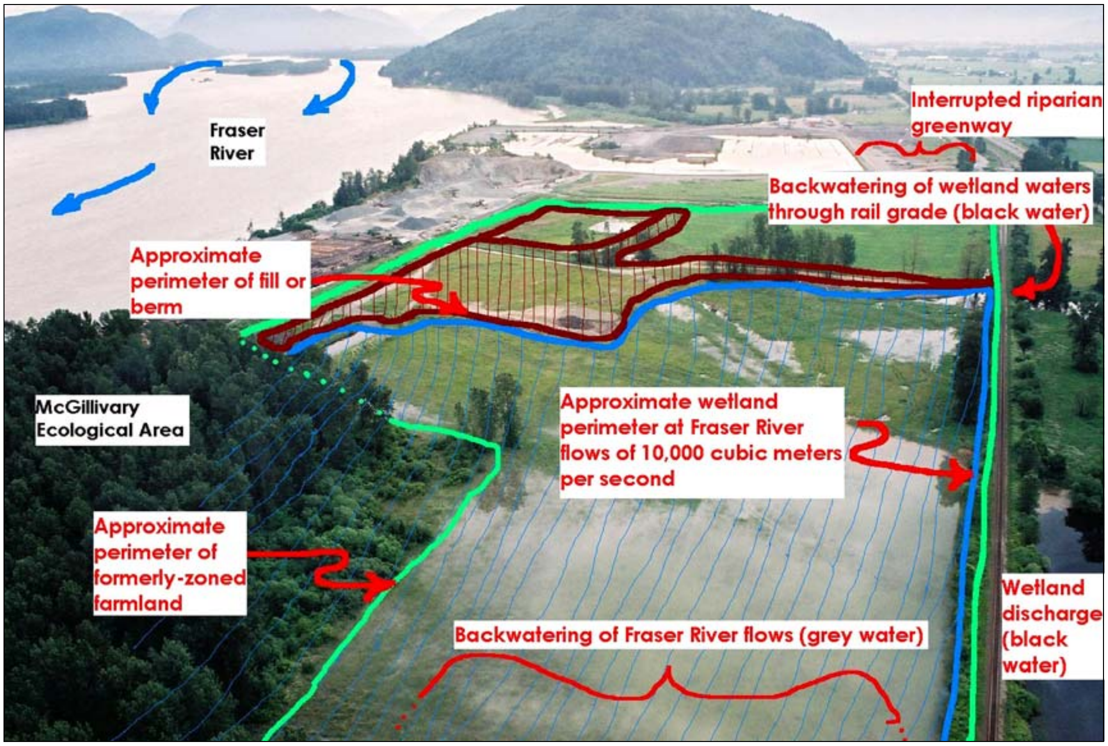


Figure 69. Encroaching fill on a floodplain hay field outside the main dikes in the eastern Fraser Valley, which is also an ephemeral Fraser River wetland.

This area was inundated during freshet 2002; the land was removed from the Agricultural Land Reserve so it could be developed as large-scale industrial or commercial property.

Figure 70. Use of wood waste to develop flood-proofing on a floodplain being converted from agricultural to industrial or commercial land.

The use of this material may impact subsurface and surface water quality and hyporheic communities, as it decomposes. Note that this field was flooded by spring/summer freshet flows yet was still permitted to be developed using wood-waste for flood-proofing.

Figure 71. Development in the Vedder River riparian area, October 2004.

A number of large urban subdivisions (in the general area outlined in red in Fig. 22) have now been developed near the river. Further adjacent lands have been re-assigned, or application has been made for their removal from their rural/agricultural designation, in anticipation of further development. This kind of land-use severely limits the opportunities to maintain lowland and riparian resource values in a meandering-stream floodplain where the fluvial processes have already been severely compromised (Figs. 14, 24). Large rip-rap bank protection (middle) is required to prevent the river from attacking this subdivision, but also completely disrupts the Shifting Habitat Mosaic processes (90° change in flow alignment; Fig. 22), and creates severe problems for river managers. Author's photos.

Aggregate Extraction in Agricultural Floodplains

The changes in land-use practices—from agriculture to other types of activities—in the remaining floodplain areas of the eastern Fraser Valley lowlands include not only development, but also the large-scale extraction of sediment (gravel) for construction purposes (Fig. 72). The extraction of aggregate from open pit mines from within the Fraser's floodplain in the eastern Fraser Valley has now become substantial at some locations, destroying the local biodiversity and disrupting the natural fluvial processes and the Shifting Habitat Mosaic. Furthermore, when the resulting pits fill up with water from either hyporheic sources or precipitation, they provide minimal aquatic values due to a lack of productivity that are a result of the extensive water depths which occur through these types of extractions. Because the footprints of these pits are so large, substantial areas of riparian vegetation and local biodiversity are also lost.

Once these gravel pits are constructed, normal river meanderings (fluvial processes) must be prevented from occurring at these locations by extensive bank armouring. This is due to the potential for otherwise natural lateral erosion to result in the collapse of the floodplain should the thalweg channel migrate into the extraction areas (Kondolf 1997; Fig. 73).

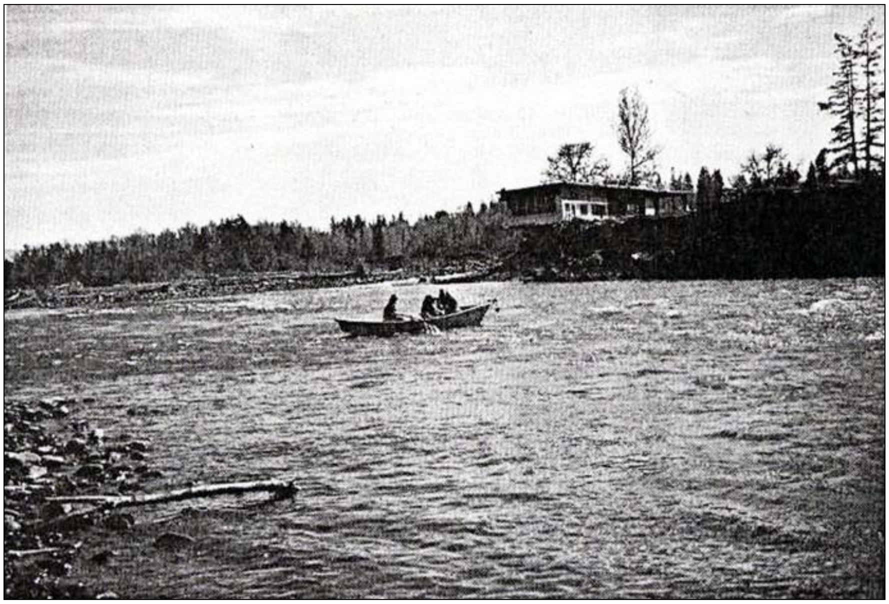
We point out that there has been no meaningful mitigation for the impacts to these fish habitats over the history of gravel extraction for sites on agricultural lands in the floodplain of the Fraser River. Furthermore, there is little indication that aggregate extraction on these riparian agricultural lands will abate in the near future.

Figure 72. Large-scale deep-pit aggregate extraction from the floodplain of the Fraser River near Chilliwack, outlined by red perimeters.

Note that the conversion of this land use on the Fraser River floodplain is from agricultural to gravel pits. Once these pits have been constructed, Kondolf (1997; Fig. 72) indicates that the river cannot be allowed to meander through the floodplain without dire consequences (i.e., extensive lateral erosion) due to the magnitude of the extraction. Photo from UBC Geography; author's markings.

Figure 73. Example of damage to a California stream and riparian area where a deep-pit gravel-extraction operation was located in the floodplain.

The floodplain unravelled once the main river eroded into the large adjacent riparian gravel pit. From Kondolf (1997).



1.5.5 Current Agricultural-Drainage Issues in the Eastern Fraser Valley

Despite historic adverse impacts to many eastern Fraser Valley streams, a number of these agricultural watersheds continue to maintain remnant populations of salmon and trout. In recent years, two of the most significant drainage-related issues that continue to affect the protection of these small, yet still remarkable, aquatic-ecosystems include:

1. The management of impacts associated with the removal of accumulated sediment and vegetation from drainage channels to facilitate hydraulic competence (i.e., ditch and channelized-stream cleaning and maintenance); and
2. The maintenance (or lack thereof) of riparian boundaries along the watercourse banks where cultivated fields are adjacent to streams.

Effects of Ditch and Channelized-Stream Cleaning

The soils of farmed fields are regularly disturbed during the seasonal cycles of plowing, conditioning and harvest. Because disturbed soils are subject to erosion and transport by water, sediments from cultivated fields are often deposited into adjacent drainage channels (Spence et al. 1996). Upland, non-agricultural, areas can also be a source of sedimentation as the bedload mobilized in higher-gradient areas—through natural or human-induced causes—tends to settle out in these lower-gradient streams of valley bottoms. As a result, these watercourses begin to agrade and this vertical infilling of the agricultural-drainage streams normally reduces their hydraulic conveyance through a reduction in channel cross-sectional area. Subsequently, the water surface is increased in elevation, inundating fields, and this increased flooding can be detrimental to crop production even under normal precipitation regimes.

Deposited clays, silts and sands can reduce the productive capacity of the stream by the infilling of pools and other micro-habitats (Waters 1995). Over-wintering juvenile micro-habitats can be smothered as a result of sedimentation. Also, the inundation of the interstitial spaces of stream-bottom-ravel reduces the amount of living surfaces available for invertebrates, which in turn affects fish production. Suspended sediment is normally also detrimental to small salmonid streams and can decrease primary productivity through the attenuation of light. Other potential impacts of high suspended-sediment and bed loads include reduced survival of incubating fish eggs and alevins, the clogging or abrasion of gill surfaces for both fish and invertebrates, and the altering of fish-feeding behaviour (e.g., Waters 1995).

Alternatively, the fertile sediments deposited in these agricultural channels can also stimulate lush aquatic or semi-aquatic plant growth, and this sometimes creates excellent in-stream habitat for fish. Heavy plant growth within stream channels, nevertheless, usually further reduces the ability of the drainage channel to convey water, as this reduces the hydraulic capacity of the stream. (Note that these agricultural sediments may also contain farming-related contaminants which may be bad for fish health when mobilized during ditch cleaning.)

Local drainage authorities clean out constructed ditches and channelized streams in order to retain their discharge capacity. This usually means removing the deposited soils or ingrown vegetation from the stream using mechanized equipment (Fig. 74). The channelization of streams (Negishi et al. 2002, Sheilds et al. 1994), and the routine removal of sediments and vegetation, are known to negatively affect these already altered, but potentially highly-productive, fish ecosystems in the eastern Fraser Valley (Figs. 74, 75, 76). Furthermore, it is recognized that despite the development of best management practices, and mitigation efforts, there will always be some unavoidable impacts that will continue to occur in the eastern Fraser Valley as long as ditches and channelized streams are excavated (e.g., Figs. 75-78).

Figure 74. Cleaning of a channelized stream in the eastern Fraser Valley.

Seine net in foreground is part of the fish salvage operation. The heron in mid-photo is presumably foraging on small fish, other vertebrates, and invertebrates that are disturbed by the operation.

Figure 75. Before and after the cleaning of a drainage channel in the East Chilliwack area.

There was an exceptionally high capture of fish in a minnow trapping assessment (70 coho juveniles) in its un-excavated condition; the excavated channel, a few weeks later, had zero catch. Dewatering had occurred in the situation shown in the excavated channel, and the dredging and clearing may have contributed to this condition. Both in-stream and riparian vegetation have been removed.

Figure 76. Mortality of a juvenile coho salmon resulting from a stream-cleaning exercise in East Chilliwack.

Numerous dead coho were seen at this particular operation several years ago when vegetation was swathed from the stream and the plant material left within the wetted perimeter.

Figure 77. Trial development of a pool-riffle structure in an excavated, channelized stream in the eastern Fraser Valley.

The mitigation pool-riffle was constructed with small rip-rap, to offset impacts of channel excavation. Assessment of excavation impacts and the mitigation benefits of this structure are presented in Figure 78.

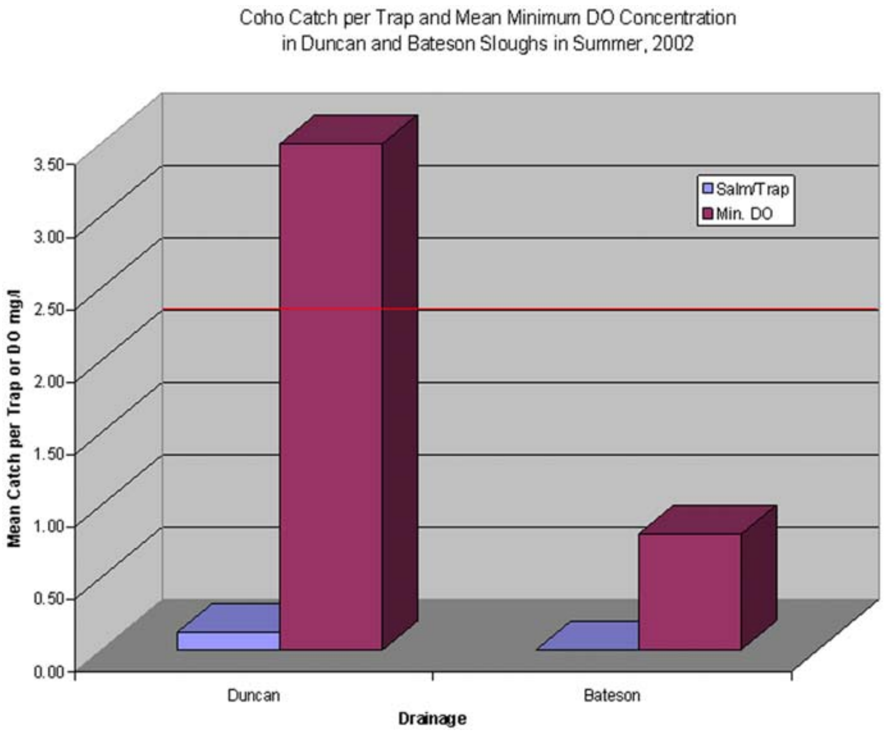
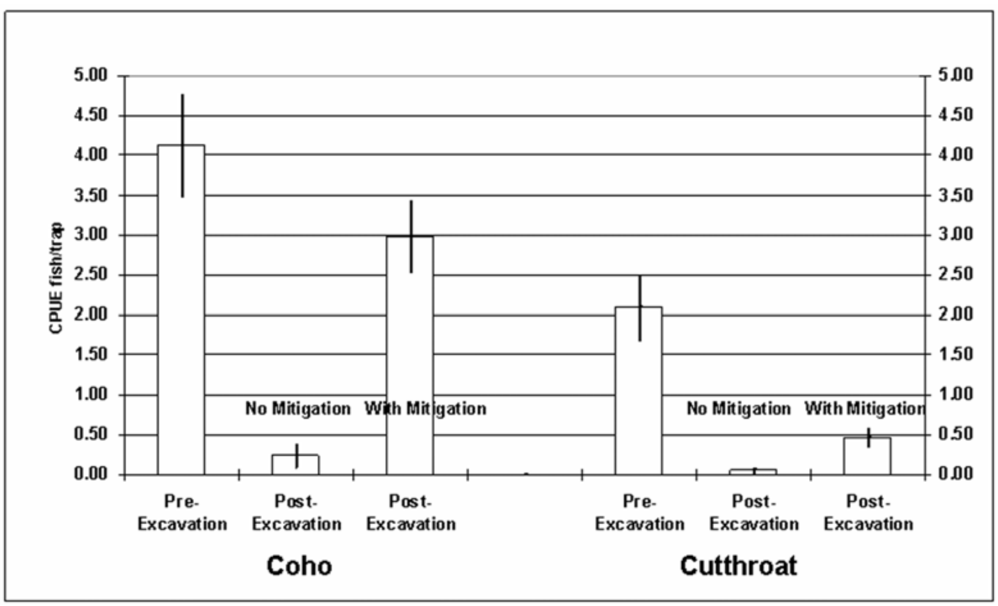


Figure 78. Changes in catch rate of juvenile coho salmon and cutthroat trout from a number of eastern Fraser Valley streams subject to mechanized cleaning.

The study includes an assessment prior to stream cleaning, and immediately after, as well as with and without mitigation structures. This field trial suggests that although channel clearing can have a substantial effect on fish abundances, the installation of habitat structures, as shown in Figure 77, can significantly reduce the impacts.



Agency Initiative to Resolve Ditch-Cleaning Issues

Historically, farm-drainage maintenance and excavation of ditches in the eastern Fraser Valley were not well regulated in regards to their impacts to fish habitat. However, by the mid-1990s it became clear to the field staff of the fisheries agencies that many of these watercourses were still important spawning and/or rearing habitats for salmon and trout. As a result, the fisheries agencies recognized that the potentially destructive aspects of this activity fell under the statutory aegis of the Canada Fisheries Act (Web Citation 8; Appendix A) and they began to move to address this outstanding issue.

As provincial and federal fisheries staff began to exercise their statutory authority regarding agricultural-drainage channel cleaning, inter-agency, inter-governmental, and agency/agricultural-community conflicts arose (Fig. 79). As a result, the agricultural industry felt fettered by the increasing interest that Fisheries and Oceans Canada and the British Columbia Ministry of Environment, Lands and Parks (now Ministry of Water, Land and Air Protection) began taking towards ditch cleaning. Section 35 of the Canada Fisheries Act is pertinent legislation because it addresses harmful alterations, disruptions or destructions in fish habitat that may occur as a result of human activities, including agricultural-drainage channel maintenance. Fisheries and Oceans Canada policy and legislation require mitigation and/or compensation as well as agency authorization if fish habitat is going to be impacted as a result of such activities.

Figure 79. Eastern Fraser Valley farming-community perspective on the fisheries agencies regarding watercourse maintenance in the 1990s.

Much of the controversy stimulated the three levels of government—federal, provincial, and local— to start to work together to resolve these issues.

In an effort to resolve these conflicts, the local, provincial and federal governments began to work together to address the statutory, regulatory and technical aspects of maintaining adequate drainage in the eastern Fraser Valley while minimizing the impacts of this activity on fish habitat. This co-operative approach began through dialogue, the development of protocols and implementation of specific actions and methodologies for best management practices (Partnership Committee on Agriculture and the Environment 2001). While fish-habitat protection was a primary focus, the agencies attempted to minimize bureaucratic inefficiencies in order to develop better ways of maintaining channels yet still protect habitat and allow farmers to conduct their business.

One result of this inter-agency cooperation was the committee-produced *Agriculture Watercourse Maintenance Guide for the Lower Fraser Valley/Vancouver Island* (Partnership Committee on Agriculture and the Environment 2001), and the contributing authors included staff from the British Columbia Ministry of Agriculture, Food and Fisheries, the Ministry of Environment, Lands and Parks (Ministry of Water, Land and Air Protection) and the Fisheries and Oceans Canada. This Partnership Committee on Agriculture and the Environment also recognized that the costs of stewardship needed to be shared amongst various parties and that the *Guide* was one tool to help reach that objective.

From a practical perspective, the document provided a number of options to deal with the conflicts between fish and drainage maintenance. This included a step-by-step outline of specific actions for watercourse maintenance, as follows:

- Identify maintenance needs (e.g., determine what is required for drainage specific to type of crops, rotation, flooding, etc.);
- Determine the watercourse classification (classify the watercourse needed to be excavated according to appropriate criteria) (Fig. 52);
- Review and determine Department of Fisheries and Oceans and Ministry of Environment, Lands and Parks (now Water, Land and Air Protection) requirements;
- Identify timing work windows (these are laid out in the Guide for specific watercourse types; Appendix B);
- Specify conditions for maintenance of constructed ditches (activities that may, or may not, involve contact with the regulatory agencies for watercourse maintenance work includes items listed on in Appendix B); and
- Provide guidelines on how to conduct works in constructed ditches (practical suggestions on how to do the excavations).

The *Agriculture Watercourse Maintenance Guide* was a major and positive step toward the implementation of best management practices for channel maintenance in the eastern Fraser Valley, as well as other parts of the province. Most of the directions and suggestions in the document were effectively designed to protect aquatic ecosystems, at least to the degree that was thought to be practical. This document was finalized June 15, 2001 but was considered to be valid only until September 30th 2001.

During the implementation of the *Guide* it became apparent that, despite the efforts and its utility and scope, the implementation of these new ways of doing business was still cumbersome. There were a number of complaints from the agricultural sector that the process needed to be better. Subsequently, the agencies began to work towards an even more streamlined set of best management practices in order to facilitate drainage and habitat protection at the field level. These efforts are currently ongoing and are discussed in the document *Drainage Management Guide* released on MAFF's website http:/www.agf.gov.bc.ca in June 2005. (Ted van der Gulik, British Columbia Ministry of Agriculture, Food and Fish; pers. com.).

Field Trials and Mitigation Efforts

The agencies have also recently undertaken field trials in real-life channel-maintenance situations in order to understand the impacts of stream dredging, to develop best management practices, and to mitigate the effects of this activity on fish and fish habitat. These agencies have included Fisheries and Oceans Canada, British Columbia Ministry of Water, Land and Air Protection and the City of Chilliwack working co-operatively on various aspects of drainage management.

A recent eastern Fraser Valley study suggests that the impact of channel cleaning on salmon and trout can be substantial. Catch rates (a reflection of abundance and habitat quality) of juvenile coho salmon dropped by almost 20 times after agricultural-channel extraction took place. Similarly, the cutthroat trout catch rate declined by about 40 times at the same site (Fig. 78). At a trial site, pool-riffle structures were constructed in the stream in order to provide some within-channel habitat (Fig. 77). For those dredging sites that included the installation of mitigation structures, juvenile coho abundance remained at about 75% the pre-dredging values. Also, while there was still a considerable reduction in cutthroat trout numbers, mitigation techniques were also helpful in reducing these losses, albeit not at the same rate as for the smaller juvenile coho salmon (Fig. 78).

This trial experiment demonstrated two important things: 1. losses to fish habitat can be substantial in eastern Fraser Valley agricultural streams where stream cleaning takes place, but 2. there are some simple ways of minimizing at least some of the impacts.

Another method that is sometimes used to reduce the impacts of channel maintenance is the excavation of pools within the stream (Fig. 80). Such pools are used to minimize the buildup of stream-bed materials in downstream areas by trapping mobilized sediments. These traps are regularly excavated and this can thereby minimize dredging maintenance in downstream areas as the pool then becomes the primary footprint area for cleaning. Deep pools also act as refugia areas for adult and juvenile fish. As a result, this method of ditch maintenance achieves two objectives and helps minimize adverse effects.

Figure 80. Pool structure incorporated into the design of channelized-stream maintenance in the eastern Fraser Valley.

Many agricultural channels are very uniform and shallow and provide little over-wintering or adult holding habitat. This design provides another kind of habitat that is often in short supply in agricultural streams and can be used to mitigate some of the impacts of channel clearing.

The agencies and local governments have also used other techniques for protecting fish habitat in agricultural streams in the eastern Fraser Valley. Constructing fences along these watercourses keeps cattle away from the stream, and prevents the breaking down of the channel banks and bottom. Cattle traffic along banks and within the perimeter of a stream normally moves sediment into the water by disturbing the integrity of the substrate. Keeping cattle away from streams, thus, can lessen the frequency having to clean out the channel, as less sediment is entrained into the water (Fig. 81).

Figure 81. Constructed pool and fence on an agricultural stream in the eastern Fraser Valley.

This alcove pond provides a dual role by increasing water depths for fish to hold and rear, and trapping sediment before it gets to downstream areas. Note also that the fencing keeps cattle from disturbing the banks and lessening sediment inputs, and allows riparian vegetation to re-grow. Large woody debris was also placed in this pond to provide cover for fish. Most agricultural streams in the eastern Fraser Valley have little or no woody habitat left in them. From Carl et al. 2001.

District of Kent/Agassiz/Harrison Hot Springs Agricultural-Stream Maintenance

The local governments in the District of Kent, Agassiz and Harrison Hot Springs have recently been pro-active in addressing the issue of conflicts between fish and drainage maintenance by soliciting expert advice from fisheries scientists. The District of Kent is on the north side of the Fraser River in the eastern Fraser Valley and much of this area is farmland. Its fields are typically low-lying, both inside and outside the main flood dikes. Furthermore, a considerable number of streams—both natural and channelized—as well as constructed ditches flow through the agricultural floodplain to the Fraser River (Figs. 53, 82). The Agassiz area contains three low-lying, small-stream drainages including the Miami Creek watershed, the Mountain Slough watershed and the Agassiz-Cheam Slough (Slaney and Northcote 2003). A fourth drainage is found in the Harrison Mills area and is comprised of two sloughs and a constructed ditch. These are connected to the Harrison River via pump stations.

Northcote (2001), using a map-based analysis of the Agassiz-Harrison Hot Springs drainage system, came to the conclusion that through the development of constructed ditches between 1972 and 1991, the length of channels in the Miami Creek and Mountain Slough watersheds had been increased in length by 13 and 18 km, respectively. This reflects the intensification of agriculture in the area and the further draining of wetland habitats over that period. Northcote (2001) also suggested that the further channelization of drainage ditches in the District of Kent under the ARDSA program may have contributed to the decline in the overall productivity of habitats in this area.

Many of the drainage channels in the Agassiz area have low gradients. As a result, their water velocities are slow and this facilitates sediment deposition and fills up ditches. Furthermore, prolific vegetation growth occurs in many of these streams and it is likely that this is further facilitated by nutrient inputs from the surrounding agricultural activity. Subsequently, the removal of vegetation and sediments has become necessary, on a regular basis, in order to ensure the flow-capacity of these channels. For the 60 km of agricultural drainage in the Kent District, 76% receives maintenance every two to seven years and, of these, 88 % have been maintained at a frequency of every 2-3 years (Northcote 2001).

Slaney and Northcote (2003) recognized that most, but not all, of the agricultural drainages in the Agassiz area comprise salmonid habitats; coho salmon was the predominant species they encountered. Their observations also indicated that channels without trout and salmon often supported non-salmonid species of fish. That is, other non-fish-bearing wetland and ecosystem values are still extensively found in Agassiz-area watersheds. Most of these non-fish-bearing streams also contribute food and nutrients to salmon habitats in downstream areas.

Slaney and Northcote (2003) suggested that one of the primary issues limiting the productive capacity of habitat in the District of Kent agricultural watercourses was water quality and, specifically, temperature and oxygen. The period of greatest concern for these two parameters was during the summer and, while water temperatures during this period bordered on sub-optimal for many streams, the lack of adequate dissolved oxygen levels in a specific group of channels seemed to be most limiting to the rearing of juvenile coho salmon (Fig. 83).

For those District of Kent ditches that had dissolved oxygen levels that approached, or were below, lethal levels, salmon disappeared from those watercourses. For some of the streams studied, dissolved oxygen levels were often adequate during mid-day but during the night, when plant and algal photosynthesis stopped, levels would drop to lethal levels as a result of *in situ* biological-oxygen demands. Ditches with slow-moving flows, poor physical structure (i.e., few or no riffles to re-oxygenate the water) and extensive submergent or emergent plant growth was where this phenomenon was most commonly observed.

The less-tolerant salmonids (compared to other non-game species which can live in under lower oxygen regimes) re-distributed themselves to other locations, or perished, during times of the year when these conditions of stress prevailed. Slaney and Northcote (2003) suggested that active sediment removal could be used to maintain the quality of the habitat for salmonids by removing in-stream plants and their nightly oxygen demands. We note, however, that they did not discuss the impacts of sediment removal on other non-salmonid aquatic values that may be of equal or more importance to the overall floodplain ecosystem. Older, un-maintained ditches tend to have more stable and diverse aquatic communities than regularly maintained streams and care must be taken to ensure that these values are not lost in the attempt to increase water quality for certain species of fish to the exclusion of other organisms. This latter issue was not extensively discussed in the Slaney and Northcote (2003) report.

Slaney and Northcote (2003) had a number of suggestions with respect to channel maintenance and protecting fish in these agricultural streams in the District of Kent/Agassiz/Harrison Hot Springs area, including:

1. The removal of material should take place in late summer when the flows are lowest to minimize disturbance at a time when fish numbers are least;

2. The removal of material should occur just from the thalweg (deepest part of the stream) in order to concentrate flows for fish;

3. There is a need for the planting and maintenance of large-bodied vegetation (i.e., trees) along the banks of the ditches to provide shade in order to cool water and reduce the growth rates of in-stream grasses (e.g., reed canary grass) through shading.

The underlying basis of their recommendations was to increase depths and water volumes of excavations in these channels so that water quality (specifically temperature and oxygen) could be improved. In addition, they emphasized the need to keep the riparian/channel-bank vegetation structure intact in order to trap sediments flowing from the fields, minimize ditch-bank erosion, and keep the shade- and insect-producing plants viable along the water's edge.

Slaney and Northcote (2003) also recommended using a "porous" bucket excavator to excavate the sediments in order to allow many of the fish to fall back into the stream (Fig. 84). It was their opinion that, in these highly vegetated streams, most fish-salvage exercises conducted prior to channel cleaning either resulted in a high level of mortality or were inefficient. The use of excavators with porous buckets should be explored on an experimental basis.

Slaney and Northcote (2003) concluded that invasive dredging of these fish-bearing drainages, that removes 100% of the vegetation on the bank and stream edge and digs deeply into the watercourse bottom, are harmful and require compensation under Canada Fisheries Act legislation. They provided a number of recommendations which included a local stewardship component and land purchase for those areas that are deemed to be most sensitive in order that they may be set aside as a reserve.

Finally, another agriculture-related issue that affects fish in the District of Kent/Agassiz/Harrison Hot Springs is the disruption of migration through the historical construction of culverts at stream crossings (Fig. 85). There are at least 37 culverts or bridges in the three eastern drainage systems, many related to the undertaking of farming activities, and some of these are likely to be impediments to fish and require upgrading (Northcote 2001).

Figure 82. Miami Creek at Agassiz.

Much of this stream runs through agricultural landscapes. Photo from Northcote (2001).

Figure 83. A comparison of dissolved oxygen levels and coho salmon catches in Duncan and Bateson Slough in the District of Kent (Agassiz).

Minimum DO levels should be at least 2.0 mg/l. From Slaney and Northcote (2003).

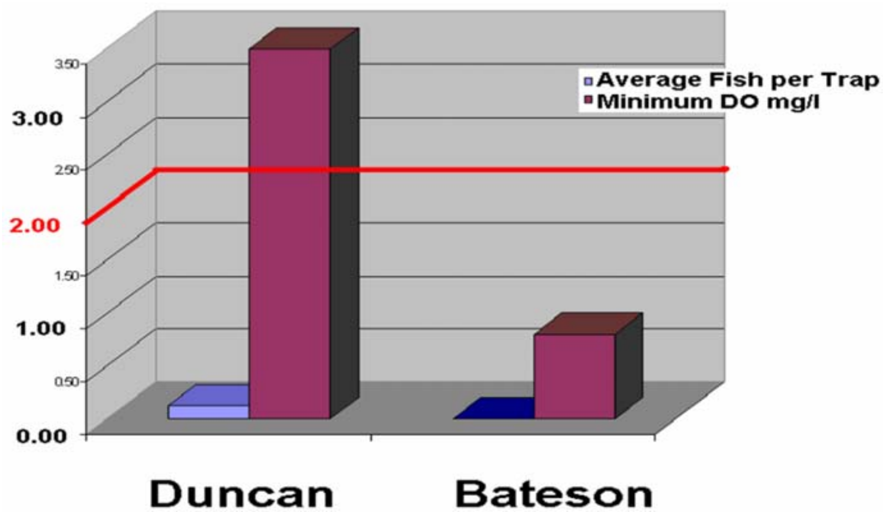


Figure 84. A "softer" approach to sediment removal from stream channels by using a "porous" bucket on an excavator.

This "porous" bucket apparatus allows many of the fish to escape back into the stream while removing vegetation and sediment. From the Agriculture Watercourse Maintenance Guide (Partnership Committee on Agriculture and the Environment 2001).

Figure 85. Culvert in an Agassiz watercourse.
Some of these structures are barriers to fish and this issue needs to be addressed. From Northcote (2001).

City of Chilliwack Agricultural-Stream Maintenance

A large number of small agricultural streams are found within the boundaries of the City of Chilliwack in the eastern Fraser Valley (Fig. 53). Each year the City of Chilliwack undertakes extensive cleaning of drainage channels in farming areas in order to ensure discharge conveyance is maintained. In 2001 the City of Chilliwack cleaned 38 km of watercourses. For 2002 the City proposed to clean 26.3 km of non-fish-bearing streams (which have have food and nutrient values that are used by downstream fish-bearing streams), and 24.1 km of fish-bearing channels. It should be noted that the streams that are classified as non-fish-bearing may be used by fish episodically (i.e., during winter periods) even though they do not normally have fish during the rest of the year.

Despite the level of channel-cleaning efforts, and observed impacts to fish habitat (Fig. 78), in recent years Chilliwack's engineering department and the fisheries agencies have worked together to resolve some of the issues which, in earlier years, would have been a source of conflict. Indeed, 50% of the budget for drainage works in the City of Chilliwack is now expended on environmental monitoring and fish salvage during stream cleaning (Pearson 2004).

The City of Chilliwack typically uses environmental consultants to monitor the effects of their channelized-stream-cleaning maintenance (Carl et al. 2001). The monitoring program includes:

- Collection of data prior to and following maintenance
- Determining fish presence or likely fish presence prior to maintenance
- Salvaging fish where appropriate
- Monitoring of the maintenance activities at each site
- Maintaining a database on the various systems
- Reporting on each year's activities

- Timing windows are also part of the protocols—streams considered to be fishless are normally cleaned by the engineering department outside the fisheries window while fish-bearing streams are cleaned between August 1 to September 30

As part of these efforts in dealing with the maintenance of agricultural drainage, a number of enhancement projects have been undertaken on Chilliwack-area streams, including projects on Semmiault Creek, Moore Ditch, Achelitz Creek and Upper Marble Creek.

Chilliwack and government fisheries agencies have also tried some innovative approaches to stream-channel maintenance. Blair and Wright (2003) report on the successful experimental clearing of channelized streams using a hand-maintenance program. This is in contrast to the more traditional use of heavy machinery (Fig. 74). The "softer" maintenance efforts include alternate methods of dealing with vegetation, including the hand removal of blackberries and their replacement with native plant species. Other options that have been pursued under such an approach include the placement of woody debris and boulders in the channels to enhance in-stream cover for fish. Pearson (2004) reported that experimental "soft" clearing of flow-disrupting vegetation showed much promise for Salwein Creek, a tributary to the Vedder River.

We would like to point out that experimenting with "softer" approaches to agricultural-channel maintenance is not just occurring in the City of Chilliwack, but in other parts of the world as well. For example Denmark, which is a lowland country with considerable farming, has a long history of channelizing streams in its agricultural lands. However, attitudes began to change in the latter part of the 20th century when Denmark instigated a new Watercourse Act in 1982. As part of their efforts to improve the management of streams, Denmark initiated a move towards "softer" weed clearance and stream cleaning, including a considerable amount of hand clearing of vegetation. This was seen as more costly, but the results appeared to be worth the effort. As a result, much of the country has headed in this direction over the past twenty years and the results are encouraging (Madsen 1995). We suggest that such an approach has applications in the eastern Fraser Valley, and the City of Chilliwack, to its credit, seems to be exploring these "softer" options.

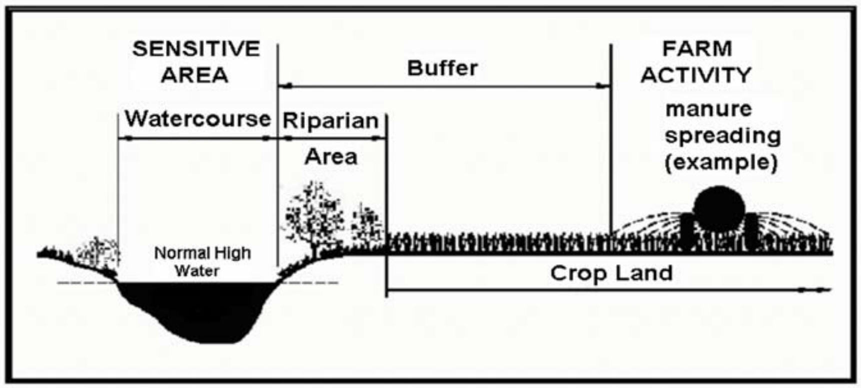
Protection of Riparian Areas

The role and importance of wetland and stream buffers to aquatic ecosystems is unequivocal (Castelle et al. 1994). Furthermore, while many of the conflicts that historically existed amongst agencies, local governments and the agricultural community regarding channel cleaning in the eastern Fraser Valley have been moving towards a greater resolution, the issues surrounding the maintenance of riparian boundaries along those same cultivated fields and watercourses remain largely unresolved here.

The issue of what size of buffer zone is needed to protect aquatic ecosystems in the face of stream-side development has received considerable debate, research and review over the last decade, both in British Columbia and around the world, usually evoking controversy. Thus, because of the importance of this facet of stream ecology, it is key for the purposes of this paper to discuss the issue regarding the question of adequate riparian buffers along streams in agricultural areas of the eastern Fraser Valley (Fig. 86).

Figure 86. Riparian area on an agricultural watercourse.

The reality is that due to limited land resources, the streamside areas of most small agricultural watercourses in the eastern Fraser Valley have inadequate riparian zones like those pictured in Figs. 87, 88, 89, 90. Figure from British Columbia Environmental Farm Plan documents www.bcac.bc.ca/efp_documents.htm



The maintenance of riparian areas benefits farm streams in a number of ways. Among these are: cooler water temperatures for fish through shading; the trapping of silt, manure and chemicals before they enter the stream from the adjacent fields; providing insects which live on or in the stream-side plants and then drop into the stream (i.e., food for fish); and the shading of undesirable low-level plants—such as reed canary grass—which minimizes their growth. Riparian areas also provide leaf litter which drops into the stream and which aquatic insects feed upon. They aid in the recruitment of large woody debris into the stream when streamside trees fall into the watercourse (this in-stream structure provides habitat for small fish and reduces stream-channel erosion), and can provide cover from avian predators.

In recent years, the prevalence of inadequate riparian zones has also been a concern to the City of Chilliwack engineering department; the perceived issue is the failure of narrow or non-existent buffers to keep agricultural fertilization (manure waste) from entering watercourses. High levels of run-off associated with poor manure-spreading practices are thought to exacerbate the growth of reed canary grass necessitating greater-than-average-frequency of channel cleaning (P. Heide, City of Chilliwack engineering dept.; pers. com.).

There has been much debate regarding how wide riparian areas should be if watercourses are to be protected in the face of development or stream-side disturbance. Castelle et al. (1994) looked at this issue by reviewing a wide spectrum of studies examining the needs of aquatic and riparian ecosystems in regards to buffer zones. They concluded that riparian areas of 15-30 m were the bare minimum to provide any protection for most criteria and that generally ecosystems required considerably more than this width. In addition, Castelle et al. (1994) came to the conclusion that most existing buffer zones regulated by government agencies are the result of political compromises and were not based on identifiable or quantitative levels of required protection for aquatic ecosystems.

For British Columbia, the Nener et al. (1997) agricultural stewardship document recommends 15 metres of riparian protection for farm watercourses. Following from this report, the British Columbia Ministry of Agriculture, Food and Fisheries is now developing a best management practices document for riparian areas on agricultural watercourses, the release of which is imminent (Ted van der Gulik, Ministry of Agriculture, Food and Fish; pers.com.). Nevertheless, many stream-side riparian buffers on farms in the eastern Fraser Valley rarely extend to the 15 metre recommendations made by Nener et al. (1997) and rarely achieve the 15-30 metres recommended by Castelle et al. (1994) due to the intensity of cultivation on the land base.

The utilization of the landscape by farming has become so concentrated in the eastern Fraser Valley that much of the land that has the potential for cultivation is used. Unfortunately, areas immediately adjacent to watercourses are often farmed, limiting the amount of available riparian vegetation. Extremes in this regard are exemplified by Figures 87, 88, 89, 90, although these examples are not far from the norm (e.g., Carl et al. 2001, Milne and Wright 2002).

Even when best management practices result in leaving an adequate boundary of vegetation on one bank, the opposite bank may be manicured virtually to the roots of the vegetation during the stream-excavation process (Figs. 91). This is usually done in order to see the stream while operating machinery but, as a result, field-based contaminants and sediments can more easily enter the stream from this bank due to the lack of a buffer.

The positioning and growth of larger woody plants with good shade potential adjacent to streams can, in fact, reduce the growth of noxious and excessive ground cover, as well as undesirable in-stream vegetation (Slaney and Northcote 2003) in addition to providing the usual riparian functions. We note that there are now watercourses on the U.S. side of the border that flow into eastern Fraser Valley drainages and are now being aggressively planted with larger woody vegetation in an effort to restore this component of the riparian zone (compare Figs. 62, 92).

While the removal of vegetation from the sediments from within stream channels (dredging) can directly impact fish and fish habitat as described above, the mechanical action of swathing (cutting) plants in the riparian maintenance area can also have undesirable affects on the aquatic ecosystems to eastern Fraser Valley farm watercourses. During this process, riparian vegetation along the perimeter of the stream, and sometimes from within the stream itself, is routinely cut with large equipment (Fig. 93). The aftermath can sometimes be deadly to fish when fragmented organic materials are left in the water (Fig. 76). “Softer” hand-clearing techniques may be able to mitigate this impact. Undertaking the work under cooler air or water temperature regimes may also mitigate these mortalities when vegetation particles are prone to enter the wetted perimeter.

Figure 87. Failure of the farmer to protect his soils from entering a high-value channelized coho-rearing stream in East Chilliwack.

Figure 88. Complete loss of vegetation on one bank of an agricultural watercourse in the eastern Fraser Valley.

The opposite bank has minimal riparian values.

Figure 89. Channelized stream in East Chilliwack which is highly productive for coho salmon.

Agriculture is practiced immediately adjacent to the watercourse and there is a complete lack of adequate vegetation in the riparian areas.

Figure 90. Wood shavings dumped by the farmer immediately adjacent to a watercourse.

This location is on Sumas Prairie, July 2004, and this material has the potential of exporting wood shavings, and leachate as it decays, into the watercourse. Author's photo.

Figure 91. A riparian area is left intact on the western side on this eastern Fraser Valley watercourse.

Note, however, that the eastern side of the channel is groomed almost to the vegetation roots; this is the side of the stream that the excavation equipment normally operates from. Photo from Carl et al. 2001.

Figure 92. Planting of woody riparian vegetation in the Sumas watershed, USA.

This activity was done in a farming setting, on the U.S. side of the international border. Blue cylinders prevent foraging by animals on the planted shrubs. Compare with Fig. 62, the Canadian side of the same watershed. Author's photo, August 2004.

Figure 93. Vegetation being swathed from a stream with high densities of juvenile coho salmon.

The work was done on a hot day and fragmented vegetation was left within the wetted perimeter once the work was done; while the in-stream habitat was not altered, a fish kill was noted, presumably from increased water temperature or the inputs of the detritus.

1.6 Discussion

The eastern Fraser Valley has undergone a radical transformation of its landscape in the last 100 years. Because of the intrinsically rich soils found here, much of this is the result of the historical development of the floodplain for agriculture. Diking, dredging, bank armouring, draining, clearing, tiling and land levelling have all contributed to the modification of the land base and the aquatic aspects of the area through the expansion of farming. Over a very short time period the result has been one of extensive losses to the expansive aquatic ecosystems which once existed in the eastern Fraser Valley since the last ice age.

Because current farming practices in the eastern Fraser Valley are generally conducted to the perimeters of the floodplain, and even to the edge of the streams, agriculture still has a substantial influence on the remaining aquatic ecosystems in this area. This activity is increasingly impacting aquatic habitats even now through intensification of the farming practices. Furthermore, rapid population growth in the Lower Mainland of British Columbia is continually expanding development eastward from Vancouver up the Fraser River corridor. Thus, not only is agriculture becoming more intense on the limited land base that is still available for farming, a change-over is now occurring of this landscape from food production to urban, commercial and industrial uses. Consequently, even the remaining aquatic habitats are now under threat due to the further intensification and expansion of farming, and the conversion of farmland and rural areas in environmentally sensitive areas into development. The impacts to these remaining aquatic ecosystems range from the subtle (Fig. 93) to the locally cataclysmic (Figs. 67, 68, 71, 72). Unless something is done quickly, the little that remains will be gone.

While there is much to be concerned about regarding the continuing impacts of agriculture to fish habitat in the eastern Fraser Valley, we are supportive where positive changes have been made in recent years to the new ways of conducting drainage-channel excavation. It is important that the local governments in this geographic area continue to realize the value of protecting and restoring these small waterways.

Another potential opportunity to address farming-related impacts to aquatic ecosystems in the eastern Fraser Valley involves a recent joint government initiative, the Environmental Farm Planning (EFP) program (Web Citation 9). This includes federal and provincial government agencies including the Ministry of Agriculture and Agri-Food Canada, the BC Ministry of Agriculture, Food and Fisheries, as well as the British Columbia Agriculture Council. These agencies have announced the signing of agreements with five farm organizations in British Columbia to deliver Environmental Farm Planning programs to agricultural producers in this province under the Agricultural Policy Framework. Workshops are now being conducted to explain Environmental Farm Planning to farmers and begin the process of completing a Planning Workbook that focuses on environmental risks and how these might be mitigated.

As a way of facilitating the program, agency technical advisors can be called upon by farmers for assistance. Once producers have completed their Environmental Farm Plans, they can apply for financial assistance. The program will pay between 30% and 50% of the eligible costs of implementing these plans to a maximum of $30,000. We must point out that this process is voluntary and confidential, so farms are not obligated to embark on this initiative.

Once an EFP planning advisor has approved the Environmental Farm Plan, the farmer will be eligible to apply for cost-shared incentives under the National Farm Stewardship Program and Greencover Canada. Through these programs, producers will have access to cost-shared funding to implement eligible Best Management Practices that address environmental risk priorities, including:

- Nutrient management improvements;
- Riparian protection;
- Grazing strategies;
- Irrigation planning;
- Wildlife issues;
- Integrated pest management;
- Shelterbelt development; and
- Biodiversity enhancements.

Most of these items affect fish and fish habitat.

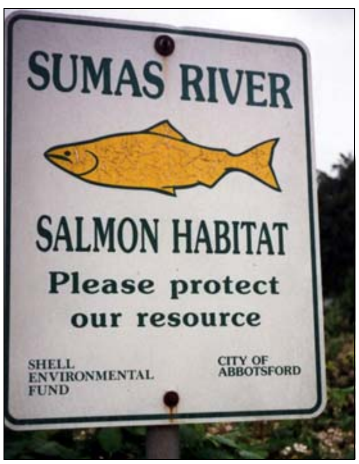
The Environmental Farm Plans also recognize the importance of physical ecosystem connectivity in order to maintain biodiversity. Key to this are un-interrupted riparian boundaries, or greenways/greenbelts, along stream channels (Web Citation 9). Clearly, this criterion has not always been adhered to in past agricultural practices in the eastern Fraser Valley.

In addition to changes in local farming practises, we can also learn from experiences elsewhere in the world. As mentioned in a previous section, Denmark has undertaken a much “softer” approach to stream-channel maintenance, with some good results (Madsen 1995). Other parts of western Europe are also looking at changing agricultural practices in order to restore ecosystems (Kleijn et al. 2004). For example, Dutch biologists have looked to re-establishing ecosystem integrity in intensively farmed landscapes by modifying farming practices. However, while their results were interesting, their efforts had limited success in restoring ecosystem values when environmental schemes were incorporated into existing highly-intensified agricultural activities (Kleijn et al. 2004). The Dutch study suggested that the extensive disruption of the hydrology of the area made it difficult to restore environmental biodiversity. A key message from their research is that, once an aquatic ecosystem is broken, it's very difficult to repair – but, if it can be fixed, it will require some dramatic changes in land-use practices.

In summary, we would like to make a few points which we feel are an important extension to this discussion. As a society, British Columbia is highly conflicted in regards to its environmental values (Fig. 94). Salmon are viewed as totemic and there appears to be adequate legislation, policy and regulation in place to protect them. (Appendix A). Still, losses to aquatic ecosystems throughout this province continue at a alarming rate, including habitats in many agricultural areas of the eastern Fraser Valley which retain the last remnants of an historically vast aquatic lowland environment.

Figure 94. Two signs on the Sumas River, 2004. The dichotomy of the messages is highly ironic.

Healy (1997) reported on the intense nature of agriculture on Sumas Prairie and indicated that this activity has created significant water-quality issues in terms of contaminants for those streams now flowing through the old lake bottom. Author's photos.



Perhaps our inability to protect and restore habitat is due not to a lack of statutory constraints, but a failure to remember what existed historically. As a result, we tend to undervalue what remains. Similarly, if we don't know what comprised the original ecosystem, it is unlikely there will be significant efforts to protect and restore it. This phenomenon has been termed the "shifting baseline syndrome" (Pauly 1995). It has now been observed by scientists that, from generation to generation, our understanding and appreciation of the earth's natural abundance undergoes shifting points of reference resulting from a loss of institutional and social memory as succeeding generations of managers and scientists arrive and assume responsibility. This results in an inability to comprehend key ecosystem components, causing society to discount what little remains.

Imbert Orchard in his 1983 historical book about the eastern Fraser Valley entitled "Floodland and forest: memories of the Chilliwack Valley" provides a retrospective overview of the Fraser and Chilliwack river floodplains prior to their settlement and development for agriculture. The following is one of the observations he recounts from the International Boundary Commission which, in 1858, was working in the area to pinpoint the exact location of the intra-continental border between Canada and the United States:

> *"…The British party had a depot near the mouth of the Chilliwack River [which still flowed northward in multiple channels from Vedder Crossing to confluence with the Fraser River at Chilliwack Mountain]. Two of its members, seeing the valley in all its primeval glory, went into raptures about it. "I think that this is the most beautiful place I was ever in," wrote Lieutenant Charles Wilson in his diary…And John Keast Lord, the Commission's naturalist, had this to say: "…we pitched our tents on the edge of a lovely stream. Waterfowl were in abundance; the streams were alive with fish; the mules and horses revelling in grass knee deep—we were in a second Eden!...The scenery is romantic and beautiful beyond description. Towering up into the very clouds, as a background, are the mighty hills of the Cascade range, their misty summits capped with perpetual snow— their craggy sides rent into chasms and ravines, whose depths and solitudes no man's foot has ever trodden…the Chilukweyuk [Chilliwack] river…washes one side of the prairie. Silvery-green and ever-trembling cotton-wood trees, ruddy black-birch, and hawthorn, like a girdle, encircle the prairie, and form a border, of Nature's own weaving, to the brilliant carpet of emerald grass, patterned with wild flowers of every hue and tint—all shading pleasantly away, and losing their brilliancy in the dark green pine-trees"…The picture is right out of J.M.W. Turner. And these were travelled men, familiar with many a beautiful landscape."*

Today, the very site where these men camped, and the place they described as "one of the most beautiful spots on earth", is the location of gravel pits, broccoli fields, a sewerage plant, sub-divisions, industrial development, and a radically disrupted Chilliwack River (Fig. 95). In the view of many, this comprises the historic baseline compared to that of John Keast Lord.

In conclusion, it is our opinion that, if remaining aquatic values throughout the eastern Fraser Valley are to be protected for future generations, an abrupt change in attitudes and actions towards these sensitive and rare areas must take place. We must also start to better understand what existed historically if we are to succeed in retaining what little remains.

Figure 95. Current view of the Chilliwack River near the 1858-9 International Boundary Commission's camp site at John Keast Lord's "Second Eden".

Author's photo.

1.7 Recommendations

In an effort to protect and repair aquatic ecosystems, the following recommendations are put forward in an effort to resolve some of the current conflicts that exist between agriculture and fish. All of these are consistent with the goals of existing legislation, policies and commitments of various levels of government having influence and authority over fish and agriculture in the eastern Fraser Valley.

1. Marginal agricultural lands with high wetland values in the eastern Fraser Valley need to be protected from further development that could range from further intensification of farming to rezoning from agriculture to urban or industrial activity. Such action is urgently needed in an effort to minimize further losses of these sensitive and increasingly rare ecosystems.

2. Riparian areas along the Fraser and Chilliwack rivers are particularly threatened and need to be protected. Mechanisms to achieve this could include the enactment of legislation and the development of covenants, or the outright purchase of land (e.g., Slaney and Northcote 2003). Protecting these areas could involve the establishment of greenway belts along these larger streams similar to what many other communities around the world are now doing. Determining the size and width of these protected riparian areas should be science-based taking into consideration the size of the stream, fluvial processes, width of the floodplain, and Shifting Habitat Mosaic.

3. Riparian areas in intensively cultivated fields along small streams in the eastern Fraser Valley must be protected and restored. One option to achieve this along channelized streams or constructed ditches with high fisheries values might entail the establishment of conservation covenants that could include tax incentives.

4. Various levels of government have made progress in improving practises that are used to clean and maintain constructed ditches and channelized streams in the eastern Fraser Valley. Government agencies and landowners should continue to work together in an effort to reduce fisheries impacts associated with these activities. Recent initiatives by both the Agassiz and Chilliwack engineering departments to take a softer and more mitigative approach to ditch clearing and maintenance are commended. Such efforts should be replicated elsewhere.

5. It is our opinion that deep-pit gravel excavations currently being developed on the Fraser River floodplain significantly impact riparian values, as well as aquatic and lowland ecosystems. Most of these pits are on former agricultural land, or are being proposed on existing farmland. Given the way in which this form of gravel mining is now conducted, the Shifting Habitat Mosaic will be significantly disrupted. The appropriateness of such an activity in close proximity to areas with high aquatic and fisheries values must be reconsidered.

6. The use of rip-rap for armouring streambanks has adverse impacts on fish habitat and aquatic ecosystems. It disrupts normal stream processes and interferes with the Shifting Habitat Mosaic. Much of the current rip-rapping on the larger streams in the eastern Fraser Valley was placed to protect farmland outside of dikes, or dikes that were inappropriately located. The agencies need to consider alternative opportunities, such as setting back dikes, when considering bank armouring. In addition, the decommissioning of existing rip-rap at locations of low-land values could also be explored.

7. Where development occurs on agricultural land in the eastern Fraser Valley outside of dikes, there is a need for the application of existing legislation (Canada Fisheries Act) and policies

(no-net loss) that adequately considers the fish-habitat values associated with spring freshet flooding. In particular, those areas that are periodically wetted during high flow periods constitute important fish habitat and need to be protected. Currently, many of these sites are being developed without adequate recognition of fish habitat values.

8. The BC Environmental Farm Plan initiative is a positive step in protecting aquatic ecosystems for streams affected by farming. At present, this is a voluntary initiative that could be expanded and applied in a more systematic manner throughout much of the eastern Fraser Valley. We recommend that this initiative continue to be supported and expanded and, perhaps in time, made compulsory.

1.8 References and Web Citations

Andrus, C.W., B.A. Long, and H.A. Froehlich. 1988. Woody debris and its contribution to pool formation in a coastal stream 50 years after logging. Canadian Journal of Fisheries and Aquatic Sciences 45:2080-2086.

Annear, T., et al. 2002. Instream Flows for Riverine Resource Stewardship. Instream Flow Council. 411 pp.

Armstrong, J.E. 1981. Post-Vashon Wisconsin glaciation, Fraser Lowland, British Columbia; Geological Survey of Canada. Bulletin 322. 34 pp.

Benke, A.C. 2001. Importance of flood regime to invertebrate habitat in an unregulated-river floodplain ecosystem. Journal of the North American Benthological Society 20:225-240.

Bergman, L.A. 1994. Report on Vedder River Gravel Management Plan. Water Management Division, British Columbia Ministry of Environment, Lands and Parks. 17 pp. & tables & figures & appendices.

Bergman, L.A. 1996. Report on Vedder River Gravel Management Plan. Water Protection Section, Water Resources Branch, Water Management Division, British Columbia Ministry of Environment, Lands and Parks.

Bilby, R.E. 1984. Removal of woody debris may affect stream stability. Journal of Forestry 82:609-613.

Birtwell, I.K., C.D. Levings, J.S. MacDonald, and I.H. Rogers. 1988. A review of fish habitat issues in the Fraser River system. Water Pollution Research Journal of Canada. 23:1-30.

Bisson, P.A, K. Sullivan, and J.L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Transactions of the American Fisheries Society 117:262-273.

Blair, D.S., and B.F. Wright. 2003. City of Chilliwack ditch hand maintenance program progress report. Nova Pacific Environmental. 3pp. & appendices.

Boyle, C.A., L. Lavkulich, H. Schreier, and Kiss, E. 1997. Changes in land cover and subsequent effects on lower Fraser Basin ecosystems from 1827 to 1990. Environmental Management 21:185-196.

Bratty, J.M. 2001. Managing waterborne wood debris for ecological integrity: the role of wood in large rivers and coastal ecosystems. Debris Management Group, Fraser Basin Council, Vancouver, BC. 50 pp. & appendix.

Brown, T.G. 2002. Floodplains, flooding and salmon rearing habitats in British Columbia: A review. Fisheries and Oceans Canada Sciences, Canadian Science Advisory Secretariat. Research Document 2002/007 155 pp. & appendices.

Brown, T.G., and G.F. Hartman. 1988. The contribution of seasonally flooded lands and minor tributaries to the production of coho salmon in Carnation Creek, British Columbia. Transactions of the American Fisheries Society 117:546-551.

Bustard, D.R., and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada 32:681-687.

Carl, C., R. Akester, and B.F. Wright. 2001. City of Chilliwack 2001 ditch maintenance program: environmental monitoring report. 18 pp. & appendices.

Castelle, A.J., A.W. Johnston, and C. Conolly. 1994. Wetland and stream buffer requirements—a review. Journal of Environmental Quality 23:878-882.

Chapman, D.W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Transactions of the American Fisheries Society 109:357-363.

Church, M., and B. Eaton. 2001. Hydrological effects of forest harvest in the Pacific Northwest. Technical Report to Central Coast Land Resource Management Planning Table. 76 pp.

Church, M., D. Ham, and H. Weatherly. 2001. Gravel management in lower Fraser River. (December 12, 2001 version). University of British Columbia Department of Geography. 110 pp.

Collins, B., and T. Dunne. 1989. Gravel transport, gravel harvesting, and channel-bed degradation in rivers draining the Southern Olympic Mountains, Washington, U.S.A. Environmental Geological Water Science 3:213-224.

Cordes, L.D. 1972. An ecological study of the Sitka spruce forest on the west coast of Vancouver Island. Ph.D. Thesis. University of British Columbia Department of Botany. Vancouver, B.C. Canada. 452 pp.

Correll, D.S. 1997. Vegetated stream riparian zones: their effects on stream nutrients, sediments, and toxic substances (An annotated and indexed bibliography). http://www.serc.si.edu/documents/ripzone.html

Cowx, I.G., G.A. Wheatley, and A.S. Mosley. 1986. Long-term effects of land drainage works on fish stocks in the upper reaches of a lowland river. Journal of Environmental Management 22:147-156.

Desloges, J.R., and M.A. Church. 1989. Wandering gravel-bed rivers: Canadian landform examples. The Canadian Geographer 33:360-364.

Ellis, E. 2004. Hydraulic geometry of secondary channels of lower Fraser River, British Columbia, from acoustic Doppler velocimetry. Department of Geography, MSc Thesis, The University of British Columbia. 188 pp.

Ellis, E., M. Church, and M. Rosenau. 2004. Characterization of 4 floodplain side channels of the lower Fraser River. Department of Geography, University of British Columbia, Vancouver, Canada. 104 pp. & appendices.

Farwell, M. N. Schubert, K. and C. Harrison. 1987. Escapements to streams entering Statistical Areas 28 and 29, 1951 to 1985. Canadian Data Report of Fisheries and Aquatic Sciences 601.

Fausch, K.D., and T.G. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences 49:682-693.

Fedorenko, A.Y., and B.C. Pearce. 1982. Trapping and coded wire tagging of wild juvenile chinook salmon in the South Thompson/Shuswap River System 1976, 1979, 1980. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1677. 63 pp.

Fisher, S.G. 1996. Natural disturbance and recovery of desert streams: a challenge to wetland management. In: C. Montes and G. Oliver, editors. Bases ecologicas para la restauracion de humedales en la cuenca mediterranea. Agencia de Medio Ambiente, Junta de Andalucia, Sevilla.

Funk, J.C. and C.E. Ruhr. 1971. Stream channelization in the midwest. In: Stream Channelization: A Symposium. AFS Special Publication #2. pp. 5-11.

Fraser River Action Plan. 1998. Lower Fraser Valley Streams Strategic Review. Habitat and Enhancement Branch, Fisheries and Oceans Canada, Vancouver, British Columbia. 442 pp. & appendices.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41:540-551.

Ham, D. 1996. Patterns of channel change on Chilliwack River, British Columbia. Master of Science, Department of Geography. 160 pp. & appendices.

Ham, D., and M. Church. 2002. Channel island and active channel stability in the lower Fraser River gravel reach. Report prepared for the City of Chilliwack by Dept. of Geography, University of British Columbia. 34 pp.

Ham, D., and Church, M. 2003. The sediment budget in the gravel-bed reach of the Fraser River: 2003 revision. University of British Columbia Department of Geography. 25 pp.

Harner, M.J., and J.A. Stanford. 2003. Differences in cottonwood growth between a losing and a gaining reach of an alluvial flood plain. Ecology 84:1453-1458.

Hartman, G.F. 1965. The role of behaviour in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 20:1035-1081.

Hartman, G. F. and C. A. Gill. 1968. Distributions of juvenile steelhead trout (*Salmo gairdneri*) and cutthroat trout (*Salmo clarkii*) within streams in southwestern British Columbia. Journal of the Fisheries Research Board of Canada 25:33-48.

Hauer, F.R., M.S. Lorang, D. Whited, and P. Matson. 2004. Ecologically Based Systems Management: the Snake River—Palisades Dam to Henrys Fork. Final Report to the U.S. Bureau of Reclamation, Boise Idaho. Flathead Lake Biological Station, Division of Biological Sciences, the Universty of Montana, Polson, Montanta. 133 pp.

Headrick, M.R. 1976. Effects of stream channelization on fish populations in the Buena Vista Marsh, Portage county, Wisconsin. Fish and Wildlife Service, U.S. Department of the Interior. FWS/OBS; 76/24. 38 pp.

Healey, C.F. 1997. Fraser Basin Ecosystem Study: Final Report: Prospects For Sustainability. (Final Report On The Tri-Council Funded Eco-Research Project At UBC) Principal Investigator, Lower Fraser Eco-Research Project, Westwater Research Unit Institute for Resources and Environment University of B.C.: Vancouver.

Huet, M., and J.A. Timmermans. (eds). 1976. Effects channelization on the fish population in small streams with a rather rapid flow. D. Hydrobiol. 46. (Abstract Only).

Hutto, R.L., and J.S. Young. 2002. Regional landbird monitoring: perspectives from the northern Rocky Mountains. Wildlife Society Bulletin 30:738-750.

IPSFC (International Pacific Salmon Fisheries Commission). 1977. An examination of erosion in the Chilliwack-Vedder River system. International Pacific Salmon Fisheries Commission, New Westminster, British Columbia. 26 pp.

Junk, W., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127 IN: D.P. Dodge (editor). Proceedings of the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Kistritz, R.U., K.J. Scott, and C.D. Levings. 1996. Changes in fish habitat in the lower Fraser River analyzed by two wetland classification systems. pp. 21-40 In: Levings, C.D., and D.J.H Nishimura 1996. Created and restored sedge marshes in the lower Fraser River and estuary: an evaluation of their functioning as fish habitat.

Klassen, H. 1995. Draft copy of Strategic Review of Fisheries Resources of Urban Streams in the Lower Fraser Valley. Fraser River Action Plan, DFO, March 1995.

Kleijn, D., F. Berendse, R. Smit, N. Gilissen, J. Smit, B. Brak, and R. Groeneveld. 2004. Ecological effectiveness of agri-environment schemes in different agricultural landscapes in the Netherlands. Conservation Biology 18:775-786.

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management 21:533-551.

Konieczki, A.D., J.B. Graf, and M.C. Carpenter. 1997. Streamflow and sediment data collected to determine the effects of a controlled flood in March and April 1996 on the Colorado River between Lees Ferry and Diamond Creek, Arizona: U.S. Geological Survey Open-File Report 97-224. 55 pp.

Korman, J., and C. J. Walters. 1999. Summary of the Kootenai River Adaptive Environmental Assessment modeling exercise. Prepared for the Kootenai Tribe of Idaho. Ecometric Research Inc. Vancouver, British Columbia, Canada.

Lalonde, V., and G. Hughes-Games. 1997. BC agricultural drainage manual. Ministry of Agriculture, Fisheries and Food, and Canada-British Columbia Green Plan for Agriculture. 271 pp.

Langer, O.E., F. Hietkamp, and M. Farrell. 2000. Human population growth and the sustainability of urban salmonid streams in the lower Fraser Valley. Pages 349-361 IN: E.E. Knudsen, C.R. Steward, D.D. MacDonald, J.E. Williams and D.W. Reiser, (eds), Sustainable Fisheries Management: Pacific Salmon. Lewis Publishers, Boca Raton, New York.

Levings, C.D. 2000. An overview assessment of compensation and mitigation techniques used to assist fish habitat management in British Columbia estuaries. Pages 341-347 IN:E.E. Knudsen, C.R. Steward, D.D. MacDonald, J.E. Williams and D.W. Reiser, (eds), Sustainable Fisheries Management: Pacific Salmon. Lewis Publishers, Boca Raton, New York.

Levings, C.D., D.E. Boyle, and T.R. Whitehouse. 1995. Distribution and feeding of juvenile Pacific salmon in freshwater tidal creeks of the lower Fraser River, British Columbia. Fisheries Management and Ecology 2:299-308.

Levings, C.D. and R.B. Lauzier. 1991. Extensive use of the Fraser River basin as winter habitat by juvenile chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Zoology 69: 1759-1767.

Levy, D. A. and T. G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Canadian Journal of Fisheries and Aquatic Sciences 39:270-276.

Lorang, M.S., and F.R. Hauer. 2003. Flow competence and streambed stability: an evaluation of technique and application. Journal of the North American Benthological Society 22:475-491.

McLean, D.G. 1980. Flood control and sediment transport study of the Vedder River. M.Ap.Sc. Thesis. Dept. of Civil Engineering, University of British Columbia.

Madsen, B.L. 1995. Danish watercourses—ten years with the new Watercourse Act. Ministry of Environment and Energy, Denmark. Danish Environmental Protection Agency. 208 pp.

Maser, C., and J.R. Sedell. 1994. From the forest to the sea: the ecology of wood in streams, rivers, estuaries and oceans. St. Lucie Press, Florida, U.S.A. 200 pp.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46: 1551-1557.

Millar, J.N., N. Page, M. Farrell, B. Chillibeck, and M. Child. 1997. Establishing fisheries management and reserve zones in settlement areas of coastal British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2351:60 pp.

Milne, D.M., and B.F. Wright. 2002. City of Chilliwack 2002 ditch maintenance program environmental monitoring report. For: City of Chilliwack. By: Nova Pacific Environmental. 13 pp. & appendices.

Mouw, J.E.B, and P.B. Alaback. 2003. Putting floodplain hyperdiversity in a regional context: an assessment of terrestrial-floodplain connectivity in a montane environment. Journal of Biogeography 30:87-103.

Mueller, C., and R. Kent. 1988. Downstream fry enumeration of the 1985 brood sockeye and chinook escapement to the Horsefly River. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1980:38 pp.

Murray, C.B., and M.L. Rosenau. 1989. Rearing of juvenile chinook salmon in non-natal tributaries of the lower Fraser River, British Columbia. Transactions of the American Fisheries Society 118:284-289.

Murphy, M.L., and K.V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implication for streamside management. North American Journal of Fisheries Management 9:427-436.

Negishi, J.N., M. Inoue, and M. Nunokawa. 2002. Effects of channelisation on stream habitat in relation to a spate and flow refugia for macroinvertebrates in northern Japan. Freshwater Biology 47:1515-1529.

Nelson, T.C., M.L. Rosenau, J. Rissling, CEJ Mussell, and P. Caverhill. 2004. Run timing, migration, distribution, spawning locations, survival-to-spawning, and survival-to-kelt of angler-caught wild and hatchery adult steelhead in the Vedder/Chilliwack River, BC. For: British Columbia Ministry of Water, Land and Air Protection, Lower Mainland Region. By: LGL Environmental Research Associates. 33 pp. & tables & figures & appendices.

Nener, J. et al. 1997.Watershed stewardship: a guide for agriculture. Fisheries and Oceans Canada, and Government of British Columbia. 61 pp.

North, M.E., and J.M. Teversham. 1984. The vegetation of the floodplains of the Lower Fraser, Serpentine and Nickomekl, 1859 to 1980. Syesis 17:47-66.

Northcote, T.G. 2001. A review and evaluation of agricultural drainage/water quality/fish habitat problems, reports and jurisdictions in the Agassiz-Harrison Hot Springs area of the lower Fraser valley, British Columbia. 36 pp.

Orchard, I. 1983. Floodland and forest: memories of the Chilliwack Valley.

Partnership Committee on Agriculture and the Environment. 2001. Agricultural watercourse maintenance guide for Lower Fraser Valley/Vancouver Island. British Columbia Ministry of Agriculture, Food and Fisheries, British Columbia Ministry of Environment, Lands and Parks, Fisheries and Oceans Canada. 40 pp. & appendices.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10:430.

Pearson, M. 2004. Salewein Creek management plan: drainage, salmon and Salish Sucker recovery. For: Fisheries and Oceans Canada and City of Chilliwack. Pearson Ecological, Vancouver, B.C. 48 pp.

Pepin, D.M., and F.R. Hauer. 2002. Benthic responses to groundwater-surface water exchange in two alluvial rivers in northwestern Montana. Journal of the North American Benthological Society 21:370-383.

Perrin, C.J., L.L. Rempel, and M.L. Rosenau. 2003. White sturgeon spawning habitat in an unregulated river: Fraser River, Canada. Transactions of the American Fisheries Society. 132:154–165.

Poff, N.L., and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805-1818.

Power, M.E., R.J. Stout, C.E. Cushing, P.P. Harper, F.R. Hauer, W.J. Matthews, P.B. Moyle, B. Statzner, and I.R. Wais Debadgen. 1988. Biotic and abiotic controls in river and stream communities. Journal of the North American Benthological Society 7:456-479.

Precision Identification Biological Consultants. 1998. Wild, threatened, endangered and lost streams of the lower Fraser Valley—summary report 1997. Prepared for: Fraser River Action Plan, Habitat and Enhancement Branch, Vancouver, British Columbia. 28 pp. & appendices.

Reice, S.R. 1994. Nonequilibrium determinants of biological community structure. American Scientist 82:424-435.

Rosenau, M.L., and M. Angelo. 2000. Sand and gravel management and fish-habitat protection in British Columbia salmon and steelhead streams. Pacific Fisheries Resources Conservation Council Background Paper No. 2000/3. 70 pp.

Schmetterling, D.A., C.G. Clancy, and T.M. Brand. 2001. Effects of riprap bank reinforcement on stream salmonids in western United States. Fisheries 26:6-11.

Sharma, R., and R. Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (*Oncorhynchus kisutch*) and smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1453-1463.

Sheilds, F.D. Jr., S.S. Knight, and C.M. Cooper. 1994. Effects of channel incision on base flow stream habitats and fishes. Environmental Management 18:43-57.

Siemens, A.H. 1968. Lower Fraser Valley. Tantalus Research Limited. 209 pp.

Slaney, P.A., and B.K. Northcote. 2003. Fish habitat assessments and habitat compensation/improvement options for developing drainage maintenance protocols to achieve stewardship of the Kent District drainage system. Prepared for: Northwest Hydraulic Consultants Ltd., North Vancouver, B.C., for District of Kent, Agassiz, B.C. By: PSlaney Aquatic Science Ltd., Coquitlam, B.C. 68 pp. & photographs.

Smith, E.S. 1991. Floodplain management in the Fraser Basin. Pages 115-132, IN: A.H.J. Dorcey (ed) Perspectives on sustainable development in Water Management: Towards agreement in the Fraser Basin. Westwater Research Centre, U.B.C., Vancouver.

Spence, B.C., G.A. Lomincky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR .

Stanford, J.A. 1998. Rivers in the landscape: Introduction to the special issue on riparian and groundwater ecology. Freshwater Biology 40:402-406.

Stanford, J.A., and J.V. Ward. 1988. The hyporheic habitat of river ecosystems. Nature 335:64-66.

Stanford, J.A., F.R. Hauer, J.S. Kimball, M.S. Lorang, R. Callaway, and W.W. Woessner. 2001. Biocomplexity-Dynamic Controls on Emergent Properties of River Flood Plains. Funded proposal to the National Science Foundation.

Tabacchi, E., D.L. Correll, R. Hauer, G. Pinay, A. Planty-Tabacchi, and R.C. Wissmar.1998. Development, maintenance and role of riparian vegetation in the river landscape. Freshwater Biology 40:497-516.

Thomson, A.R. 1999a. Study of flood proofing barriers in lower mainland fish bearing streams. For: Department of Fisheries and Oceans, Habitat and Enhancement Branch, Pacific Region. By: Alan R. Thomson and Associates and Confluence Environmental Consulting, Vancouver. 93 pp.

Thomson, A.R. 1999b. Flood boxes as fish migration barriers in lower mainland streams. For: Ministry of Environment, Lands and Parks, Region. By: Alan R. Thomson and Associates, Vancouver. 41 pp.

Thomson, A.R. 2000. An overview of HCTF project "Operation Floodbox". For: Ministry of Environment, Lands and Parks, Region. Alan R. Thomson and Associates, Vancouver. 15 pp. & appendix.

Tschaplinski, P.J., and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (Oncorhynchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implication to survival. Canadian Journal of Fisheries and Aquatic Sciences 40:452-461.

Usher, B. 1975. A survey of tributary streams of the Vedder-Chilliwack River and six cutthroat streams near Chilliwack, B.C. Fish and Wildlife Branch, Chilliwack, B.C. 116 pp.

Vedder River Management Committee. 1983. Vedder River Management Area Plan. 44 pp. & appendices.

Ward, P., K. Moore, and R. Kistritz. 1992. Wetlands of the Fraser Lowland, 1989: An inventory. Canadian Wildlife Service Technical Report Series No. 146.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. 251 pp.

Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman Inc., New York, U.S.A 317 pp.

Welcomme, R.L. 1985. River Fisheries, FAO Fisheries Technical Paper 262. 330pp

Wells, O.N. 1987. The Chilliwacks and their neighbors. Talonbooks, Vancouver. 226 pp.

Web Citations

1. Agriculture statistics for British Columbia. http://www.agf.gov.bc.ca/stats/faststats/brochure2002.pdf
2. Farming still vital in Chilliwack . http://www.theprogress.com/pages/Millenium/MilleniumPages/agriculture.html
3. Freshwater Sustainability Analysis in the Sumas River Watershed: An Integrated Approach. http://www.capcollege.bc.ca/programs/envsc/ENSC506/Sumas99/sumas%20web.htm
4. Cameron, L. 1996. Disappearing a lake. http://www.mqup.mcgill.ca/files/cameron_laura/siteofmassacre.html.
5. Abbotsford History. http://www.abbotsford.com/history/
6. Chillliwack Museum. http://chilliwack.museum.bc.ca/history/cov/echilli.htm
7. Resource Management Factsheet, Ministry of Agriculture, Food and Fisheries http://www.agf.gov.bc.ca/resmgmt/publist/800series/810200-1.pdf

8. MAFF Watercourse Classification and Agricultural Ditch Maintenance
   http://www.stewardshipcentre.bc.ca/caseStudies/cs_builder.asp?request_no=249

9. British Columbia Environmental Farm Plan
   http://www.agr.gc.ca/cb/index_e.php?s1=n&s2=2004&page=n40909a
   http://www.wetkit.net/modules/1/showtool.php?tool_id=1532

2. APPENDICES

Appendix A

Statutory Aspects Affecting the Interactions Between Agriculture and Fish

Different facets of legislation, policy and regulation throughout various levels of government affect the relationships between agricultural activities and salmon and steelhead habitat in the eastern Fraser Valley. The following is a short synopsis of the most relevant statutory components relating to this issue.

Canada Fisheries Act

The Canada Fisheries Act is a statute that falls under federal jurisdiction. The habitat components of this Act can be relevant to the development of riparian areas and other lands for agriculture as well as the clearing and cleaning of ditches and other watercourses. Section 35 of the Fisheries Act states that no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat (s.35(l)). When this cannot be avoided or mitigated, the Act provides options to authorize the means and conditions for allowing development projects, including agriculture, to take place (s.35(2)).

The Policy for the Management of Fish Habitat (1986) gives DFO staff direction for interpreting the powers mandated in the habitat provisions of the Act. This policy calls for an overall net gain in the productive capacity of fish habitat and promotes habitat conservation and protection. Regarding impacts associated with human activities, this policy protects habitat through the application of a guiding principle centered on achieving a No Net Loss of the habitat's capacity to produce fish. While the Canada Fisheries Act legislation and associated policies are federal in jurisdiction, local Canada Fisheries and Oceans technical staff, the British Columbia Ministry of Water, Land and Air Protection (formerly Environment, Lands and Parks), British Columbia Ministry of Agriculture, Food and Fisheries, and local governments have been involved in developing locally-specific policy documents (e.g., Agricultural Watercourse Maintenance Guide for Lower Fraser Valley/Vancouver Island (Partnership Committee on Agriculture and the Environment 2001)).

Other parts of the Fisheries Act that are pertinent to agriculture include s. 32 (no person shall destroy fish), and s. 36 (deposit of deleterious—toxic or harmful—substances into waters frequented by fish, or in a place or under any condition where it may enter such waters). The latter may include pesticides, animal waste and sediments.

The Department of Fisheries and Oceans is the primary agency responsible for the implementation of the Fisheries Act; the British Columbia Ministry of Water, Land and Air Protection also provides input.

www.laws.justice.gc.ca/en/F-14/

British Columbia Fish Protection Act

The British Columbia Fish Protection Act provides protection to fish and fish habitat by prohibiting bank-to-bank dams on provincially significant rivers. It also establishes special rules in relation to water licences on “sensitive streams” where fish habitat is at risk. The Act allows for recovery plans to be developed for “sensitive streams” and allows streamflow protection licences to be issued to community-based organizations in an effort to ensure adequate flows for fish.

Temporary reduction in water use rights during periods of drought when the sustainability of fish is threatened can also be authorised under the Fish Protection Act. The Act allows the provincial government to establish directives for local governments in preserving streamside areas from residential, commercial and industrial development.

Some portions of the Fish Protection Act are currently not in force. Provisions that are in place are divided between the Ministry of Sustainable Resource Management and the Ministry of Water, Land and Air Protection. Regulations that accompany the Act are the Sensitive Streams Designation and Licensing Regulation, and the regulations pertaining to riparian areas. The riparian zone rules for agricultural operations are specific to farming.

www.qp.gov.bc.ca/statreg/stat/F/97021_01.htm

Agriculture Watercourse Maintenance Guide—Lower Fraser Valley and Vancouver Island

While the Agriculture Watercourse Maintenance Guide was not regulatory in nature, its intent was to provide direction to farmers that would allow them to conduct drainage maintenance activities on agricultural lands in a timely manner. It was produced jointly by the Canada Fisheries and Oceans, the British Columbia Ministry of Agriculture, Food and Fisheries, and the British Columbia Ministry of Environment, Lands and Parks. The guide was also intended to provide a process that would help ensure the terms and legislative requirements of the Canada Fisheries Act and the British Columbia Water Act were not contravened.

The guide provided information on watercourse classification, requirements by the fisheries agencies, conditions specified for maintenance of constructed ditches, and guidelines on how to conduct works in constructed ditches.

This document was viewed as being cumbersome in terms of implementation of its recommendations and was given an expiry date of September 30, 2001. To date, no replacement document streamlining the direction for working around agriculture watercourses has been developed, although at the time of the writing of this report a best management practices guide for constructed ditches is imminent.

www.agf.gov.bc.ca/resmgmt/ditchpol/guide/AgWatercourseMaintenance.pdf

British Columbia Farm Practices Protection (Right to Farm) Act

The Right to Farm Act applies to farmers operating in the Agricultural Land Reserve as well as in other areas where farming is currently being undertaken. This Act: allows a person to farm on land covered by these land classifications providing the farmer is operating under "normal Farm Practices". As a result, the Act protects the farmer against nuisance actions, court injunctions or specific municipal nuisance bylaws relating to the operation of the farm. This legislation is viewed by some as potentially being in conflict with certain aspects of the Canada Fisheries Act.

www.qp.gov.bc.ca/statreg/stat/F/96131_01.htm

British Columbia Waste Management Act

The Waste Management Act gives the Ministry of Water, Land and Air Protection responsibility for waste management throughout British Columbia. This Act establishes a prohibition on waste discharge unless it is authorized by a permit, approval, order, regulation or waste management plan; regulates the confinement, storage, disposal and transportation of special wastes; regulates spill prevention and reporting activities; requires the production of regional solid, and liquid management plans; designates sewage control areas; requires the implementation of solid and liquid waste management plans; regulates contaminated site remediation activities; provides authority to regional waste managers to issues pollution abatement orders and pollution prevention orders; includes enforcement provisions; and, provides for an appeal to the Environmental Appeal Board.

Pursuant to this legislation is the Agricultural Waste Control Regulation which addresses specific agricultural issues that can influence and affect fish-bearing streams. Among these are agricultural waste control, compost production and use, petroleum storage, antisapstain chemical waste control, and spill reporting.

Of note, a "watercourse" means a "place that perennially or intermittently contains surface water, including a lake, river, creek, canal, spring, ravine, swamp, salt water marsh or bog, and including a drainage ditch leading into any of the foregoing." Also, storage of agricultural waste "…must be located at least 15 m from any watercourse and 30 m from any source of water for domestic purposes…" (s.7(1)) and waste cannot be stored unless under specified circumstances.

www.qp.gov.bc.ca/statreg/stat/W/96482_01.htm

www.qp.gov.bc.ca/statreg/reg/W/WasteMgmt/131_92.htm

British Columbia Water Act

This Water Act regulates the use and diversion of the Province's fresh water as well as works in and about a stream. Provisions and legislated responsibilities covered by the Act include: granting and management of water licenses; entertaining objections to licenses; apportioning rights under licences; authorising licensees' rights with respect to compensation and expropriation; holding public inquires; regulating changes in or about a stream; operating appropriate appeal procedures to the Comptroller and Environmental Appeal Board; reserving and removing bodies of water from being used under the Act; and issuing certificates incorporating water users' communities. Agricultural interests using water for irrigation or livestock watering, influencing the flow of water (such as drainage ditches flowing into to a natural stream), or undertaking activities around a stream (building a bridge to access fields), may be subject to this legislation.

www.qp.gov.bc.ca/statreg/stat/W/96483_01.htm

British Columbia Local Government Act (formerly the Municipal Act)

The Local Government Act provides the enabling framework under legislation for municipal governments as well as regional districts and improvement districts to exist. The status allows for the creation of new municipalities, the definition of boundaries, the election of a council, the assessment and collection of taxes, administration, property management, and spending. Components of the Act's farming issues include: (1) community planning, (2) zoning, (3) nuisance regulations, (4) removal and deposit of soil, (5) weed and pest control, and (6) water use and drainage. Recent amendments address planning for agriculture. Changes to this Act state that community plans may include policies that help maintain and enhance farming and may now designate development permit areas to protect farming (e.g. buffering to separate farming and residential areas). The Local Government Act is limited on the extent to which it can be used to restrict farming, including the requirement for the approval of the minister responsible for Farm Practices Protection Act for any changes to land-use or zoning bylaws that would restrict the agricultural use of land in farming areas (designated within the Agricultural Land reserve).

www.qp.gov.bc.ca/statreg/stat/W/96483_01.htm

British Columbia Agricultural Land Commission Act

The Agricultural Land Commission Act provides a legislative framework for the designation of land resources useful to the agricultural industry and consistent with the needs of the province. The legislation defines the B.C. Agricultural Land Commission and outlines its objectives and powers. The fundamental purpose of the British Columbia Agricultural Land Commission is to preserve agricultural land within the Agricultural Land Reserve (ALR). There are a number of regulations governing the use and subdivision of land within the ALR. The Commission evaluates and adjudicates requests to either remove or add land to the ALR. The Commission takes into account factors such as: land capability, effect on surrounding agricultural uses, and impact on the community and region. This Act takes precedence over other provincial legislation and local government with regards to land use.

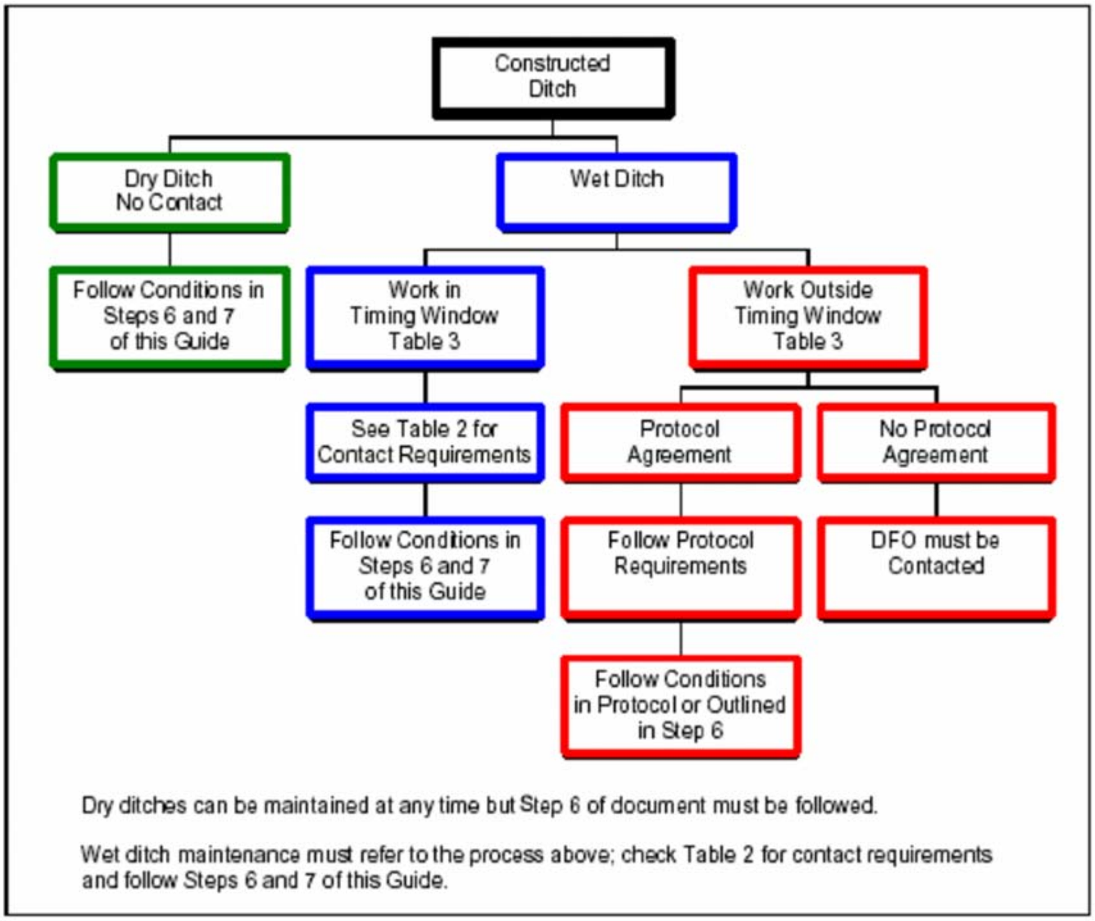
www.qp.gov.bc.ca/statreg/stat/A/02036_01.htm

Appendix B

Highlights of the British Columbia Agricultural Watercourse Maintenance Guide

Appendix B Figure 1. Agricultural constructed-ditch maintenance process as outlined in the British Columbia Agricultural Watercourse Maintenance Guide.

This process was designed to protect fish and aquatic resources in constructed ditches and an equivalent flow chart was also made available for channelized streams (Partnership Committee on Agriculture and the Environment 2001). The weakness of this system of is that biological attributes are not always considered in the maintenance of these watercourses.



Appendix B Figure 2. Ditch maintenance form for working in a wetted constructed ditch.
From the British Columbia Agricultural Watercourse Maintenance Guide (Partnership Committee on Agriculture and the Environment 2001).

Ditch Maintenance Form
(for Works in a Wet Constructed Ditch)

APPLICANT INFORMATION
Name: ____________________ Telephone: ____________
Address: ____________________ Fax: ____________

LOCATION OF WORKS (be specific, include map if available)
Ditch Name (if available) :
Length of Maintenance Works:______ m Habitat Classification (if available) ____________
Fish Presence ____________ Unknown ____________

ANTICIPATED WORK DATES ____________________
(NO LESS THAN 14 DAYS NOTICE IS REQUIRED)

DESCRIPTION OF WORKS CONDUCTED IN A WET CONSTRUCTED DITCH DURING JUNE 15 – SEPT. 30 (circle appropriate works).

- Localized pruning of riparian vegetation, which is overhanging into the wetted channel and obstructing water flow, to a point above the high water mark and/ or pruning of ditch bank vegetation to a height of not less than 4 meters. (> 100m)
- Hand *cutting* or machine mowing of emergent aquatic vegetation above the waterline of the ditch. (> 100 m)
- Hand *removal* of emergent aquatic vegetation from the thalweg (i.e. emergent aquatic vegetation along the edges of the ditch is not disturbed) (> 100m)
- Machine removal of riparian vegetation on the north and east side of a constructed ditch (wet or dry) only for the purpose of constructing an access for channel maintenance
- Installation, maintenance or cleanout of sediment traps which do not require the construction of any structures within the ditch (e.g. weirs, dams, trash racks, etc.)
- Localized removal of blockages to flow less than 5 meters in length (e.g. debris dams)
- Dredging or cleaning the entire bottom along a ditch length < 50 m / yr
- Replacement of an access road culvert with a culvert of increased length.
- New culvert installation that will not impact native trees and shrubs.
- Bank stabilization or repair by rip rap planted with vegetation, such as willows or other bio-engineered method (geo-fabric) if the area is less than 50 m^2.
- Construction of a livestock crossing through a constructed ditch
- Construction of new structures within the ditch e.g. irrigation gates
- Other works: ____________________
- ***PLEASE CHECK TABLE 2 FOR THOSE WORKS IN A WET CONSTRUCTED DITCH WHICH DO NOT REQUIRE SUBMISSION OF DITCH MAINTENANCE FORM.***
- ***ANY OTHER WORKS WILL REQUIRE AUTHORIZATION FROM DFO.***

SIGNATURE:
I acknowledge that I have read the guidelines and conditions attached:
Date: ____________________ Fax to DFO – see contact list in Appendix C
Signature: ____________________

Appendix B Table 1. Timing windows for in-stream work in the Lower Mainland and Vancouver Island.

From Partnership Committee on Agriculture and the Environment 2001.

Watercourse Type	Watercourse Condition	Timing Window	
		Lower Mainland	**Vancouver Island**
Constructed ditch	Dry ditch	Any time of year while dry	Any time of year while dry
	Ditch has been blocked in summer to prevent fish from entering channel. See section 4.2 dry ditch maintenance	Prior to November 1st	Prior to November 1st
	Wet	June 15th – September 30th	June 15th – September 30th
Streams (Channelized or natural)		August 1st – September 15th	July 1st – September 15th

Appendix B Table 2. Action items that need to be considered for agency contact or approval when undergoing watercourse maintenance.

Drain Tiles

- Installation or cleaning of drain tile outlets

Vegetation Maintenance

- Localized hand pruning of riparian vegetation above the high water mark (does not include whole tree removal)
- Hand cutting of aquatic vegetation below the waterline
- Machine mowing or removal of vegetation below the waterline
- Machine mowing or removal of grass vegetation above the waterline on the north or east side of a watercourse for the purpose of constructing an access for channel maintenance
- Machine moving or removal of grass vegetation on the south or west side of a watercourse
- Removal of woody riparian vegetation (i.e., shrubs or trees)

Fencing

- Installation, repair or maintenance of fences (provided that fencing materials are not in the stream channel, do not block debris and do not interfere with navigation)

Drainage Works

- Installation, maintenance or cleanout of sediment traps which do not require the construction of any structures within the ditch (e.g., weirs, dams, trash racks, etc.).
- Hand removal of flow blockages
- Dredging or clean out bank to bank

- Diversion or relocation
- New construction or infilling

Access Crossings

- Replacement of clear span bridge decking (superstructure only, does not include fittings)
- Construction of a clear span bridge crossing
- Replacement of an access road culvert with a culvert of the same length
- Replacement of an access road culvert with a culvert of increased length to a max of 12 m
- New culvert installation

Bank Stabilization

- Bank stabilization by planting vegetation and/or seeding with native species
- Bank stabilization or repair through bio-engineering techniques, using rock or other 'hard' engineering works
- Repair or maintenance of existing approved dikes or erosion protection works

Livestock Control

- Construction of a livestock watering area or livestock crossing

Structures

- Replacement of structures (e.g., weirs, dams, trash racks, irrigation gates) with a structure of the same size and function
- Construction of new structures or structural upgrade of different size or function (e.g., weirs, dams, trash racks irrigation gates)
- Construction or maintenance of a waterline crossing

Appendix C

Protocols for agricultural channel cleaning in the City of Chilliwack

Operation plans are usually developed in advance for excavation projects and an example of written protocols that the City of Chilliwack has used in the past is as follows:

- All excavated material and debris will be removed from the site or placed in a stable area above the high water mark of the stream as far as possible from the channel.
- All work will be done and completed in such a manner so as to prevent the release of deleterious substances such as sediment into any ditch.
- Machinery is to work from the stream bank and not in the stream channel.
- All machinery used on the sites will be in good repair and free of excess oil and grease.
- Care will be taken not to disturb streamside vegetation. Important aquatic vegetation such as cattails will not be disturbed.

- Stream banks will be mowed on the side the machinery has to work from to enable sufficient vision by the operator.
- All work to proceed in the dry or at low water levels.
- A qualified environmental monitor will be on site.
- Fish salvage will be conducted before work begins.
- Water temperature and the concentration of dissolved oxygen must be measured before and after cleaning.
- Where pools or plunge pools can be created to enhance the watercourse and habitat, they will be done at the consultant's discretion.
- A copy of the consultant's report will be made available to all parties after the completion of the 2002 Maintenance Program.

3. AUTHORS

Dr. Marvin L. Rosenau

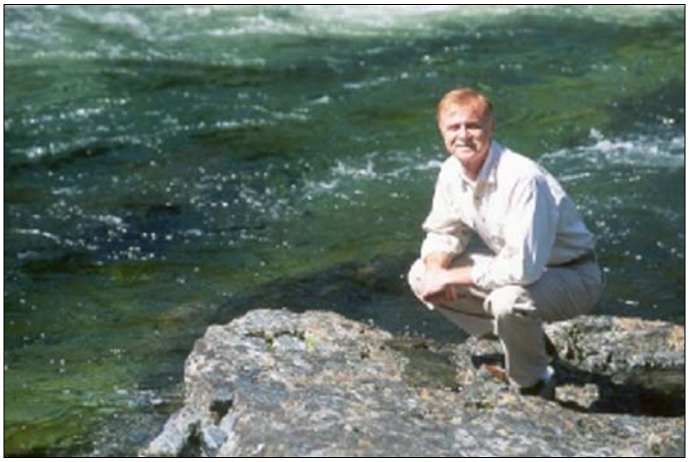
Dr. Marvin Rosenau comes by his agricultural experience of the eastern Fraser Valley honestly. He was born in Chilliwack, raised as a child on a dairy farm on Banford Road in the Township of Chilliwhack, and obtained his elementary education from Lotbiniere Elementary, a two-room school on Prest Road.

It was his fascination with the fishes in the ditches, sloughs and streams around his home, and the Fraser River, that led him into the field as a fisheries-habitat scientist. He still maintains a strong connection with the area as he lives in the Lower Mainland and still has many friends and relatives in the dairy industry in the Fraser Valley. He has seen many changes in the eastern Fraser Valley landscape over time, many of them not for the better, in his opinion. Until recently Dr. Rosenau was a fisheries biologist with the British Columbia Ministry of Water, Land and Air Protection. Marvin's role with the Ministry of Water, Land and Air Protection, and in the former Ministry of Environment, Lands and Parks, included fisheries work on sturgeon, the resolution of hydro-electric/fisheries impacts, and attempting to address ecosystem-impact-issues relating to gravel removal from streams and floodplain-development effects on fish habitat.

Currently Dr. Rosenau is on a dual secondment to the UBC Fisheries Centre as a Visiting Scientist working on a variety of issues including a 50-year fishery-harvest data base for British Columbia examining historical changes in this province's marine fisheries, and the British Columbia Institute of Technology teaching its Fish Management course. He holds a Bachelors Honours and a Master's degree in the zoological sciences from the University of British Columbia and a DPhil in biosciences from the University of Waikato in New Zealand.

Marvin has co-authored with Mark Angelo five different habitat reports for the Pacific Fisheries Resource Conservation Council since 1999. *Epur si muove!*

Mr. Mark Angelo



Mark Angelo is a noted river conservationist, outdoor leader, teacher and writer. He is Program Head and Instructor of the Fish, Wildlife and Recreation Department of the British Columbia Institute of Technology. He is a recipient of the Companion of the Order of Canada and also holds the Order of British Columbia, in recognition of outstanding achievement in preserving Canada's waterways. Mark Angelo was also the first recipient of the National River Conservation Award as Canada's most outstanding river conservationist in the past decade. His involvement with conservation issues in British Columbia spans three decades, and he has published more than 200 articles and editorials. He speaks regularly at conferences throughout Canada and in other parts of the world. Mark's "Riverworld" presentation, which takes the audience on an around the world journey by river while making a passionate plea to better protect the world's waterways, has been shown to enthusiastic reviews and packed houses across North America. He is the founder of BC Rivers Day, which attracts up to 75,000 participants annually, and Mark's river conservation efforts were recently recognized by the United Nations as part of the International Year and Fresh Water and Wonder of Water celebrations.

4. ACKNOWLEDGEMENTS

This report was supported by the Pacific Fisheries Resource Conservation Council. Hon. John Fraser, Chair, and the Council members provided insight, edits and direction to the theme of this study. Mr. Gordon Ennis managed the project and included very useful editorial commentary. Agency staff were also helpful in providing information with regards to the management of fish/agriculture interactions in the eastern Fraser Valley including Scott Barrett of the British Columbia Ministry of Water, Land and Air Protection; Tom G. Brown, and John Patterson of Fisheries and Oceans Canada; and Ted van der Gulik of the British Columbia Ministry of Agriculture, Food and Fisheries. We are particularly grateful to Blair Holtby of Department of Fisheries Oceans, and *ex officio* PFRCC, for his editorial comments.

Dedication

This report is dedicated to British Columbia's pioneering river stewards of another perspective and a different generation—Roderick L. Haig-Brown, Lee Straight, Mike Crammond, Ted Peck, Al Grist—who understood that a confined and shackled stream, is not a stream at all.

590 – 800 Burrard Street

Vancouver, British Columbia

Canada V6Z 2G7

Telephone: (604) 775 – 5621

Facsimile: (604) 775 – 5622

E-mail: info@fish.bc.ca

www.fish.bc.ca