Pacific Fisheries Resource Conservation Council

Conflicts between People and Fish for Water:

Two British Columbia Salmon and Steelhead Rearing Streams in Need of Flows

Prepared by
Dr Marvin L. Rosenau and Mark Angelo

September 2003

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EXECUTIVE SUMMARY

The amount of water flowing in a stream during the spawning, incubation and early life stages of salmon and steelhead is crucial to their health and survival. The freshwater rearing phase for all species of salmon requires the maintenance of the quality and quantity of water in terms of temperature, nutrition and spatial requirements and these parameters are affected by flow. Low flows can impact on salmon and steelhead rearing by reducing habitat capacity and availability for young fish as well as stressing or killing adult and young fish through increased summer water temperatures. Lowered flows can interrupt the passage of adult and juvenile fish to spawning and rearing areas.

The extraction of water from streams and lakes has undermined the production of salmon and steelhead in a number of high-profile British Columbia watersheds. Increasing human settlement throughout the past century has led to unprecedented demands for water for industrial, agricultural and domestic purposes. Indeed, it is the opinion of various fisheries professionals that the over-abstraction of water may have contributed to the decline of some southern-interior coho salmon stocks to the point that they have now been listed by the Committee on the Status of Endangered Wildlife in Canada. The withdrawal of water for an array of purposes has also adversely affected some east-coast Vancouver Island steelhead populations that were already in a crisis state.

There was hope that the implementation of a new *Fish Protection Act,* combined with changes to the provincial *Water Act,* would move government agencies direction more adequately protect flows for fish. However, despite a plethora of provincial and federal legislation, policy and regulation, historic problems with the over-allocation of water continue to persist.

In addition, new applications for water allocation are still being sought, and in some cases granted, in areas where extreme water extraction is already having an adverse impact on salmonids. This situation is further compounded by the fact that the efforts to recover flows for the benefit of fish have stalled in much of the province. The reasons for this problem range from inadequate monitoring of existing extractions to an apparent complacency about degraded habitats.

Two examples in British Columbia where these concerns continue to be an issue include the Nicola River basin, located in the south-central part of the province within the Thompson River drainage, and the Englishman River watershed, situated on the central east coast of Vancouver Island.

In the arid Nicola River basin, extensive withdrawals of water by the agricultural sector have had substantive effects in this important salmon and steelhead drainage. For several decades now, fisheries professionals and interested stewardship groups have pointed to declining salmon runs as evidence that all was not well with the state of fish stocks and the management of flows in this watershed. As a result, government agencies in 1983 completed the Nicola Basin Strategic Plan which contained provisions for the protection and recovery of salmon and steelhead through safeguards and proactive management of the area's water resources.

Subsequent to the executive sign-off of this plan, there was a slowing in the rate of further allocations of water within the basin. This trend involved the refusal of a number of license applications for water withdrawal from Guichon Creek, an important tributary of the Nicola River. As recently as 2002, these applications were once again denied by the Environmental Appeal Board of the province of British Columbia. In spite of this, intense pressure persists on

Land and Water British Columbia Inc., the new crown corporation responsible for water, to allocate additional water for both development and agricultural purposes within the Nicola River basin.

On a positive note, various groups and individuals continue to be active in fighting for the protection of fisheries-related flows in the Nicola River drainage. For example, the Pacific Salmon Foundation has helped develop the Coldwater River Watershed Recovery Plan for this major tributary of the Nicola River basin that has a history of water use conflicts. The Plan has the protection and restoration of habitat and flows as its major goals and has had input from a variety of local stakeholder groups including First Nations and the Nicola Watershed Community Roundtable. Also, in an attempt to highlight water management issues along the Nicola River, the Outdoor Recreation Council of British Columbia listed this basin in its 2003 Top 10 Endangered Rivers List, citing excessive water extraction as one of the issues that needs to be addressed to protect and restore the river's salmon and steelhead stocks.

In response to the widespread interest in maintaining adequate flows for fish in the Nicola River basin, government agencies and the public must engage in a commitment to protect and restore fish flows through a variety of means including:

1. The establishment of a moratorium on water licensing for diversion or extraction.
2. A review and update of the 20-year old Nicola Basin Strategic Plan.
3. The development of a hydrological budgeting process throughout the watershed, in order to allocate water to fish and agriculture in a fair, transparent and legal manner.
4. The launching of a license-compliance and beneficial-use audit of existing water licenses and water use in the basin.
5. The updating of the flow-release regime which is part of the Nicola Lake dam-operation plan to protect fish and meet appropriate water license requirements.
6. The exploration of opportunities to buy back water licenses for fish and ecosystem values similar to initiatives undertaken in parts of the western United States.

The Englishman River watershed on central Vancouver Island is another drainage where low flows and the extractive uses of water are considered to be a serious issue undermining the protection and restoration of salmon and steelhead. Although the Englishman River is a coastal stream, it flows in an eastward direction under the partial rain shadow of the mountains running down the spine of the Island; hence it normally experiences very low flows during the late-summer period. Because the local climate in August and September tends to be a little drier than elsewhere along the coast, fish flows on the Englishmen during late summer can be minimal, even without water withdrawals. This river historically sustained significant numbers of coho and steelhead but these populations have declined precipitously over the last three decades. A multitude of factors, including the excessive extraction of water, are thought to have contributed to these declines.

Like the Nicola River basin, the Englishman basin has been slated for a Watershed Recovery Plan, and this strategy has also been funded and facilitated by the Pacific Salmon Foundation. The Outdoor Recreation Council of British Columbia has similarly recognized the habitat-related problems of the Englishman River and listed this watershed as number 2 in its Top 10 Endangered Rivers List for 2003, citing excessive water withdrawal as one of the primary issues.

Some of the steps that could be taken to resolve flow-related problems for the Englishman River watershed include:

1. The use of stored water from the Arrowsmith Lake reservoir to keep flows in the mainstem of the Englishman River at a minimum of 20% of mean annual discharge (equal to 2.76 cubic meters per second), when the water supply is sufficient, and to ensure that short term flows do not fall below 10%. The system operations for this dam still need be properly developed in order to maximize efficiency of stored and released water.
2. The initiation of a compliance-assessment of existing water licenses.
3. Facilitating a hydrological-budgeting exercise for the watershed.
4. Restricting the issuance of further water licenses unless supported by off-channel storage
5. The investigation of new or innovative options to provide more water in tributary streams, including the storage of more water for release during dry periods.

It should be noted that global climate change may further exacerbate an already tenuous situation in the water-scarce parts of British Columbia by facilitating a drying trend in some locations or disrupting the hydrologic cycle to which salmon and aquatic ecosystems have historically become adapted. As a result, conflicts over water between fish and people will likely only increase as a result of the consequences of global warming and increases in human population in this province.

In light of rapidly changing environmental and demographic conditions, government agencies and the general public are urged to take a highly precautionary approach to the development and allocation of water in all sensitive watersheds. This should include an examination of options to utilize water more efficiently for both existing water tenures and proposed new water licenses as well as the implementation of suitable measures in all instances. There must also be an ongoing commitment to protect adequate flows on important fish-bearing waterways such as the Englishman and the Nicola rivers. Finally, every effort should be made to ensure that the more global aspects of our changing planet are adequately considered at a local level so as to ensure that the rivers, and the fish stocks they sustain, are protected for future generations.

SOMMAIRE

La quantité d'eau qui coule dans un cours d'eau pendant les stades de frai, d'incubation et d'alevinage est un facteur essentiel à la survie des saumons et des truites arc-en-ciel. Pour toutes les espèces de saumon, le stade de croissance en eau douce nécessite des conditions thermiques, trophiques et spatiales adéquates, conditions qui ne peuvent qu'être affectées par le régime d'écoulement. Un faible débit peut affecter la croissance du saumon et de la truite arc-en-ciel en perturbant les conditions habitationnelles nécessaires à la croissance des juvéniles, notamment en induisant une hausse excessive de la température de l'eau durant la saison estivale, ce qui peut affecter, voire tuer, les adultes autant que les juvéniles. Enfin, un affaiblissement du débit peut interrompre le déplacement des adultes et des jeunes poissons vers les aires de frai et les aires de croissance.

Les prélèvements d'eau pratiqués sur les lacs et les rivières ont perturbé la productivité du saumon dans plusieurs bassins importants de la Colombie-Britannique. En effet, le développement croissant qui s'est opéré tout au long du XX[e] siècle s'est accompagné par une demande sans précédent des approvisionnements en eau pour les besoins industriels, agricoles et domestiques. Les experts pensent que la surconsommation d'eau serait un facteur important dans le déclin de certains stocks de saumons cohos dans le sud de l'Intérieur, au point que ceux-ci figurent maintenant sur la liste des espèces menacées du Comité sur la situation des espèces en péril du Canada. Les prélèvement effectués pour diverses activités ont également eu un effet tel sur certaines populations de truite arc-en-ciel de la côte est de l'île de Vancouver qu'elles sont elles aussi en situation de crise.

On espérait que l'effet conjugué de la nouvelle *Loi sur la protection du poisson* et du *Water Act* de la province inciteraient les organismes gouvernementaux à adopter des politiques qui seraient de nature à mieux protéger les débits nécessaires aux stocks de saumons. Hélas, malgré la myriade de mesures législatives et réglementaires et les nombreuses politiques fédérales et provinciales, l'éternel problème des prises d'eau excessives continue à sévir.

De plus, de nouvelles demandes d'allocation d'eau sont encore déposées, et dans certains cas accordées, dans des endroits où les prélèvements excessifs ont déjà eu des impacts néfastes sur les salmonidés. Cette situation est aggravée par le fait que les actions visant à rétablir les débits nécessaires au poisson sont sans effet dans une grande partie de la province. Les raisons de ce problème vont du manque de surveillance des sites de prélèvement existants au désintérêt des riverains face à la dégradation de l'habitat.

Deux exemples où ce type de problème continue à être observé en Colombie-Britannique sont celui du bassin de la Nicola, situé dans la partie sud du centre de la province, dans le réseau hydrographique de la rivière Thompson, et celui du bassin de la rivière Englishman, situé dans la partie centrale de la côte est de l'île de Vancouver.

Dans le bassin semi-aride de la Nicola, les prélèvements importants pratiqués pour l'irrigation agricole ont depuis longtemps été considérés comme ayant un fort impact sur cet important habitat du saumon. Depuis plusieurs décennies, les experts et les groupes de protection clament que le déclin des remontes de saumon est symptomatique de la précarité des stocks et d'une gestion déficiente des débits d'eau dans ce bassin. En 1983, le ministère de l'Environnement de la Colombie-Britannique, en collaboration avec Pêches et Océans Canada, a établi un plan stratégique pour le bassin de la Nicola, lequel prévoyait des mesures pour la protection et la reconstitution des stocks de saumon, notamment les stocks de truite arc-en-ciel, grâce à la prise de moyens de protection et de gestion proactive des ressources hydriques de la région.

Le plan fut officiellement signé par les autorités responsables et il fut suivi par une diminution des prélèvements effectués dans le bassin, en partie grâce au refus d'autoriser un certain nombre de demandes de licences d'eau concernant la rivière Guichon Creek, important tributaire de la rivière Nicola. En 2002 ces demandes ont à nouveau été refusées par l'Environmental Appeal Board de la Colombie-Britannique. Néanmoins, de fortes pressions sont exercées pour que la Land and Water British Columbia Inc., nouvelle société de la Couronne responsable de la gestion des licences d'eau, accorde des licences additionnelles aux fins d'activités d'aménagement et d'agriculture dans le bassin de la Nicola.

Soulignons toutefois que divers groupes et individus continuent de se battre pour la protection des eaux poissonneuses du bassin de la Nicola. On peut citer la Pacific Salmon Foundation, qui a participé à l'établissement du plan de rétablissement du bassin de la rivière Coldwater, important tributaire du bassin de la Nicola dont l'aménagement fait depuis longtemps l'objet de conflits. Le plan, qui a pour objet principal la protection et la restauration de l'habitat et du débit, a bénéficié de la participation de plusieurs groupes d'intérêts locaux, notamment des groupes autochtones et de la Nicola Watershed Community Roundtable. En outre, afin de sensibiliser les autorités sur les problèmes de gestion hydrique que posait le bassin de la rivière Nicola, l'Outdoor Recreation Council of British Columbia a inscrit celui-ci sur sa liste 2003 des dix rivières les plus menacées de la province, citant les prélèvements excessifs comme l'un des problèmes à résoudre pour assurer la protection et le rétablissement des stocks de saumon et de truite arc-en-ciel présents dans le bassin.

Par suite du vif intérêt suscité par le maintien des conditions de débit nécessaires aux poissons dans le bassin de la Nicola, les organismes gouvernementaux et les citoyens doivent prendre des mesures pour protéger et rétablir les débits d'eau requis, notamment :

1. Imposer un moratoire sur l'attribution de licences de détournement et de prélèvement d'eau.
2. Procéder à un exercice de révision et de mise à jour du Nicola Basin Strategic Plan, programme vieux de vingt ans.
3. Établir un processus de bilan hydrologique à la grandeur du bassin, pour que les quantités d'eau attribuées aux activités piscicoles et agricoles se fassent de manière équitable, transparente et légale.
4. Établir un processus de vérification de conformité et d'utilité des licences d'eau existantes.
5. Actualiser le régime de gestion de l'écoulement du barrage de la Nicola, afin de mieux assurer la protection des stocks de poisson et la gestion des demandes de permis d'eau.
6. Étudier la possibilité de racheter des permis d'eau aux fins de protection du poisson et de l'écosystème, comme cela se fait dans diverses régions de l'Ouest des États-Unis.

Le bassin de la rivière Englishman, dans le centre de l'île de Vancouver, est un autre réseau hydrographique où la baisse de débit et les prélèvements d'eau ont eu un effet néfaste sur l'état des stocks de salmonidés. Bien qu'il s'agisse d'un cours d'eau côtier, la rivière Englishman coule en direction est, en partie dans l'« ombre pluviométrique » des montagnes qui traversent l'île de Vancouver du nord au sud, d'où les étiages observés en période de fin d'été. Et comme le climat local, en août et en septembre, tend à être un peu plus sec que dans les autres régions de la côte, les débits peuvent être considérablement réduits, même en l'absence de prélèvements. Soulignons que cette rivière a toujours abrité d'importants stocks de cohos et de truites arc-en-ciel, mais que ceux-ci ont dramatiquement diminué depuis les trois dernières décennies. Une multitude de facteurs, notamment les prélèvements excessifs, serait à l'origine de ce déclin.

À l'instar du bassin de la Nicola, le bassin de la rivière Englishman fait l'objet d'un plan de rétablissement qui a bénéficié de fonds et de l'appui de la Fondation du saumon du Pacifique. L'Outdoor Recreation Council of British Columbia a reconnu que la rivière Englishman avait des problèmes écologiques et a inscrit son bassin au deuxième rang des dix rivières les plus menacées de la province pour l'année 2003, citant les prélèvements d'eau comme l'une des principales causes du problème.

Parmi les mesures qui pourraient être prises pour résoudre les problèmes de débit de la rivière Englishman, citons :

1. L'utilisation des eaux stockées dans le réservoir du lac Arrowsmith pour maintenir le débit de la principale artère de la rivière Englishman à un taux minimal de 20 % du débit annuel moyen (soit un débit de 2,76 mètres par seconde), lorsque l'approvisionnement est suffisant, et pour que les débits à court terme ne tombent pas au-dessous de 10 %. Le mode d'exploitation de ce barrage doit être mieux étudié pour assurer un maximum d'efficacité du régime de gestion des stockages et des déversements.

2. La mise en place d'un dispositif de vérification de la conformité concernant les licences d'eau existantes.

3. L'exécution d'un exercice de bilan hydrique concernant le bassin.

4. La restriction des nouveaux permis d'eau accordés, à moins que ne soient prévus des dispositifs de stockage parallèles.

5. L'étude de nouveaux moyens d'assurer un apport d'eau dans les tributaires, notamment le stockage de plus grandes quantités d'eau en prévision des sécheresses éventuelles.

Il convient de souligner que le changement climatique risque d'aggraver une situation déjà difficile dans les régions arides de la Colombie-Britannique en induisant un assèchement du climat ou en perturbant le cycle hydrologique auquel les salmonidés et l'écosystème aquatique se sont adaptés depuis des temps immémoriaux. Il est donc probable que les conflits entre les besoins du poisson et ceux de l'homme iront en augmentant du fait du réchauffement climatique et de l'accroissement de la population.

Face au changement rapide des conditions environnementales et démographiques, il faut exhorter les organismes gouvernementaux et les citoyens à adopter une approche de précaution dans les décisions d'aménagement et d'attribution des ressources hydriques, et ce pour tous les bassins sensibles. Ceci implique l'étude de moyens qui permettront d'utiliser l'eau de manière plus efficace dans les concessions existantes et les concessions proposées, et la prise de mesures adéquates dans tous les cas. Il faut également prendre des moyens pour assurer les débits requis par le poisson dans les zones abritant des stocks importants, comme les rivières Englishman et Nicola. Enfin, tous les efforts doivent être déployés pour que les aspects plus globaux du problème du changement climatique soient convenablement pris en compte au niveau local et pour que les rivières et leurs populations de poissons soient préservées, pour le plus grand bénéfice des générations à venir.

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1.0 INTRODUCTION

Water is the key to life on our planet and Canada has about 20% of the world's total freshwater spread out over 755,165 square surface kilometres (Environment Canada 2003a). Because of this relative abundance, we as Canadians have had a tendency to believe there is an almost endless supply for our enjoyment and consumption. Despite the volume of water found within our country, less than half of this water, or about 7% of the world's supply, is available for human use . The greatest proportion (60%) flows northward into the Arctic Ocean while much of the rest is "locked up" in lakes, underground aquifers, and glaciers (Environment Canada 2003a). Indeed, for some parts of Canada, such as in Alberta, water shortages have become common during recent years in repeated drought conditions.

The outlook involves cause for concern, and a global shortage of water is considered to be one of the most critical issues facing the world in the 21st century. This should come as no surprise as the demand for water is increasing geometrically with the world's population; in 1950, the world's human population stood at 2.5 billion but this is expected to reach almost 8 billion by 2025. Exacerbating the situation is the fact that per-capita water-usage is increasing at an even greater rate than population growth, perhaps by as much as two times.

From an extraction perspective, worldwide irrigation for crop production consumes about 70% of all water used with most of the rest divided between industry, communities and private households. Nevertheless, the expanded use of water for agricultural purposes is expected to continue and the United Nations projects a 50- to 100-percent increase in the use of irrigation water by 2025 (SDIS 2003).

British Columbia has historically enjoyed the luxury of having an abundance of fresh water for most parts of this province. There are more than 24,000 streams and lakes (WLAP 2003) and these provide water for homes, power generation, farms, and industries in addition to maintaining aquatic and terrestrial ecosystems. Furthermore, groundwater aquifers, which are critical linkages to lakes and rivers, are important sources of water for over 600,000 people in British Columbia (WLAP 2003).

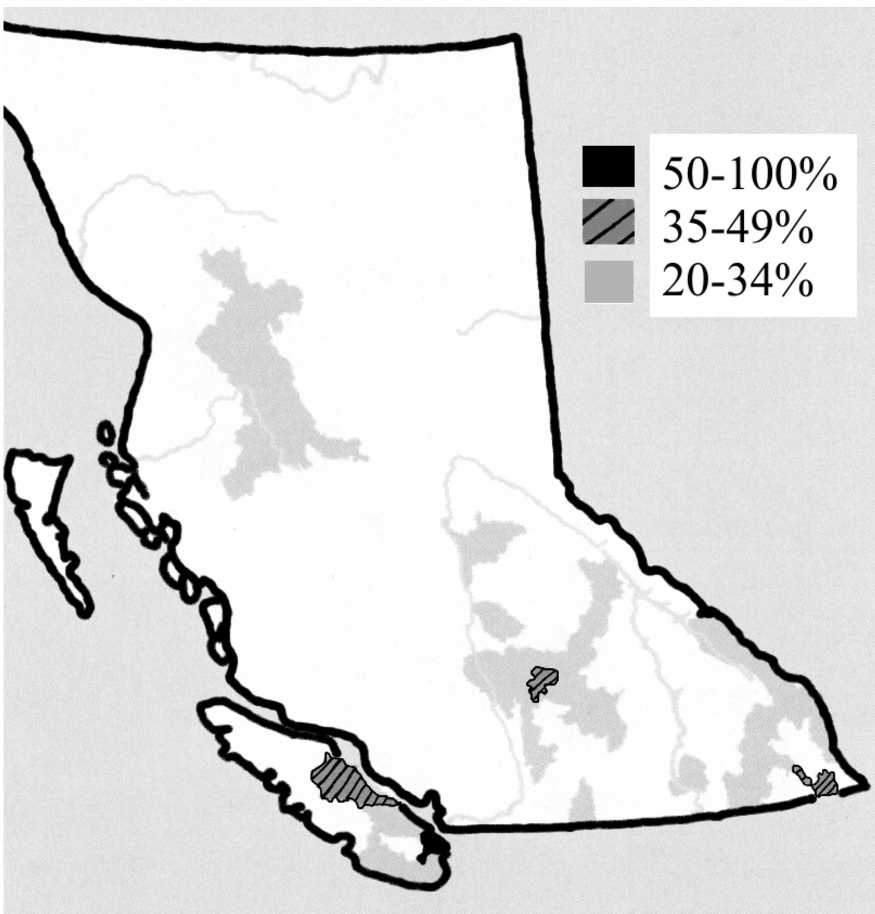
And yet, British Columbia's water supply is not as plentiful as it seems despite the appearance of abundance. For example, about 50,000 water licenses have been issued, or are pending, in the province. It has been estimated that for over 3,500 streams, the licensed diversion volumes are close to, at, or exceed available stream flow (Table 1.1). The British Columbia Ministry of Water, Land and Air Protection recently indicated that 17% of the surface water sources have reached, or are nearing, their capacity to reliably supply water for extractive uses (WLAP 2003). In addition, long-term trends of observation wells indicate that groundwater levels are declining in some areas of the province (WLAP 2003). High levels of withdrawal of sub-surface water have the potential of disrupting and reducing surface waters where there are streams that rely on groundwater re-charge. Thus, over-extraction of groundwater has the possibility of impacting on terrestrial and aquatic ecosystems and can affect salmon and steelhead streams, particularly during low-flow periods. Water flow is key to fish survival. Fish need to have water to migrate, to spawn, to overwinter and to put on growth in their freshwater stages. But water does more than provide a living space – the flow of water ultimately shapes the very habitat that fish utilize. Water moves and cleanses the gravels that fish spawn in, it also shapes the structure of the stream including the shaping of riffles, runs and pools so necessary for fish survival.

From 1950 to 2002, British Columbia's population increased from around 1 million people to over 4 million, and the current growth rate is over 1% per annum (British Columbia Statistics

2002). Because of this continued population growth it can be reasonably presumed that without serious consideration to the problem of sustainability, there will be serious problems in finding enough water for human needs and preventing conflicts with fish and aquatic ecosystems.

Many of these stresses in British Columbia watersheds are arising as a result of human extraction of water, in naturally dry and/or heavily populated parts of the province (Fig. 1.1), and a number of these watersheds contain important salmon and steelhead streams. Furthermore, it is not simply enough to have some water in a stream because the quality and quantity, as well as the abundance and timing of flows in freshwater, defines the productivity of a waterway from a fisheries perspective. Consequently, withdrawals of even moderate amounts of water have the potential to disrupt these key components of the aquatic environment, and fisheries scientists have seen evidence of this numerous times.

Figure 1.1 Areas in British Columbia with limited surface-water availability.
This figure depicts the percent of licensed streams in each water precinct which have been designated as "Fully Allocated". The working definition of fully allocated is, "a stream is fully allocated if there is a water shortage at least once in 5 years". Adapted from Ministry of Water, Land and Air Protection website: http://wlapwww.gov.bc.ca/wat/wamr/water_conservation/figure_2.gif



The primary focus of this report is to discuss the conflicts between flows for salmon and steelhead and the withdrawal of water for human needs. In British Columbia many of these streams are already stressed with low discharges. As part of this discussion, background information is provided on flow-related requirements for fish; a description of competing human uses of water and how these tend to modify instream flows; and the legislation, regulation and policies surrounding the anthropogenic use of surface water in this province.

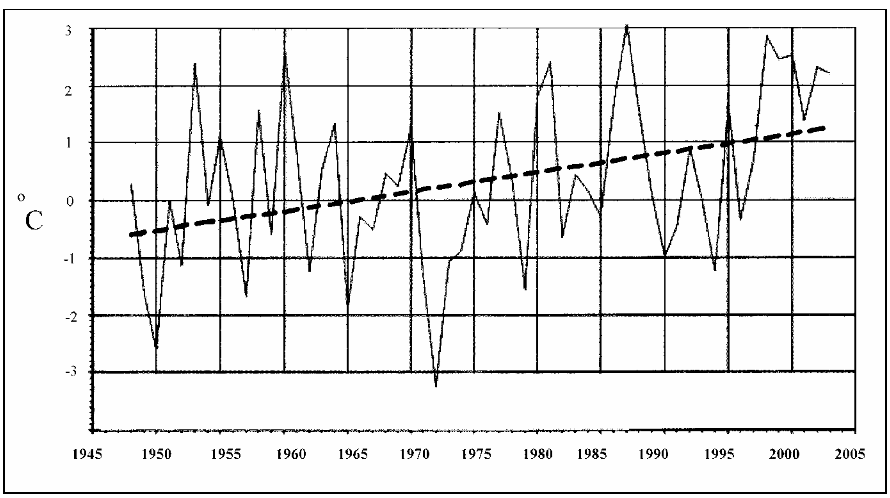
Finally, the water extraction impacts on both interior and a coastal salmon and steelhead drainage are assessed.

The Nicola River in BC’s southern interior and the Englishman river on the east coast of Vancouver Island were both historically important steelhead and salmon streams and are located in areas that have become water-limited during critical times of the year. Subsequent to extensive settlement in these regions, extraction of water for irrigation and domestic use became a dominant feature in the hydrology of these watersheds. As a result, the removal of significant amounts of water stressed salmon and steelhead stocks to the point where governments and the public have been forced to acknowledge the problems associated with excessive water extraction. These situations are highlighted here in the hope that clarification will help government agencies and the public address these issues, both at these locales and elsewhere across the province.

In summary, the issues of excessive extraction of water and the protection of salmon and steelhead are becoming even more problematic because of the effects of climate change that are now being superimposed upon the current hydrology of these watersheds. While there may be some debate about the causal mechanisms of climate change, there is little question that the average yearly temperature of Canada is increasing and a warming trend is upon us (Fig. 1.2). The scientific evidence is very strong that changes in climate affects stream hydrology and water-thermal regimes in British Columbia (Levy 1992, Foreman et al. 2001, Morrison et al. 2002).

Figure 1.2 Canadian winter national temperature departures and long-term trend, 1948–2003.

Adapted from Environment Canada Meteorological Services Branch, Climate Research Branch graph on website: http://www.msc-smc.ec.gc.ca/ccrm/bulletin/national_e.cfm



While changes to hydrological budgets within a particular watershed, as a result of global warming, are not easily predictable, the consensus appears that for many streams in British Columbia there will be less water during certain critical times of the year. Indeed, Dr David Schindler, internationally renowned freshwater ecologist from the University of Alberta, has stated that for Canada, global warming will cause many wetlands to disappear and there will be a reduction in habitat for cold-water fish (Schindler 2000).

Table 1.1 Water license summary for streams in the former British Columbia Ministry of Environment, Lands and Parks water management regions.

Table from Rosenau and Angelo (1999), and extracted from an internal MELP memo.

Region	Streams at or approaching full allocation	Number of licenses current or outstanding
Vancouver Island	600	5,464
Lower Mainland	117	5,840
Thompson/Nicola/Okanagan	1,183	18,237
Kootenay	808	10,853
Cariboo	450	3,710
Skeena	186	1,652
Omineca/Peace	207	1,691
TOTAL	3,551	47,447

2.0 BACKGROUND

2.1 The Hydrologic Cycle

Hydrology is 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. A basic knowledge of how water ends up in, and flows through, streams and lakes is essential in determining how to protect salmon and steelhead and their habitats in the face of increasing demands for water extraction.

Water naturally enters and flows through a river basin in a variety of patterns depending on the season, climate, local and region-wide topography, oceanic and climatic conditions (e.g., El Nino/Southern Oscillation, Pacific Decadal Oscillation), and stochastic, or random, weather events. The average, or time-specific, discharge patterns of water in a stream can be described by a hydrograph which is a representation of flows over a period of time.

In British Columbia, there are generally two types of hydrologic regimes. The first is from snow-melt-dominated streams where most of the water is discharged during the spring-summer freshet period and is typical of the British Columbia interior (Fig. 2.1, 2.2). The second is from coastal fall/winter-rainfall dominated watersheds (Fig. 2.3, 2.4).

Figure 2.1 Water Survey Canada discharge for the Nicola River, 2001.

Note the spring/summer snowmelt-dominated discharge compared to Figure 2.3, Englishman River, which is late-fall/winter-rainfall dominated. Compare also with average monthly flows for the Nicola River (Fig. 2.2). Nicola River is a good example of an interior-type hydrograph. Hydrometric station located near Merritt 08LG007 BC. http://scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp

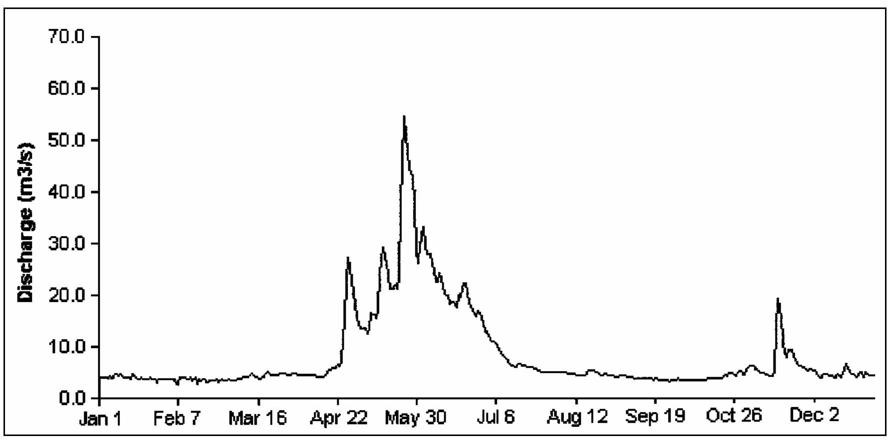


Figure 2.2 Average monthly flows for the Nicola River, 1911 to 2000.

Data from Canadian Hydrological Data © 1997, Environment Canada and includes 48 years of record. Compare the average values with that of a specific year, Figure 2.1, and the average monthly flows for the Englishman River (Fig. 2.4). Hydrometric station near Spences Bridge BC 08LG006.

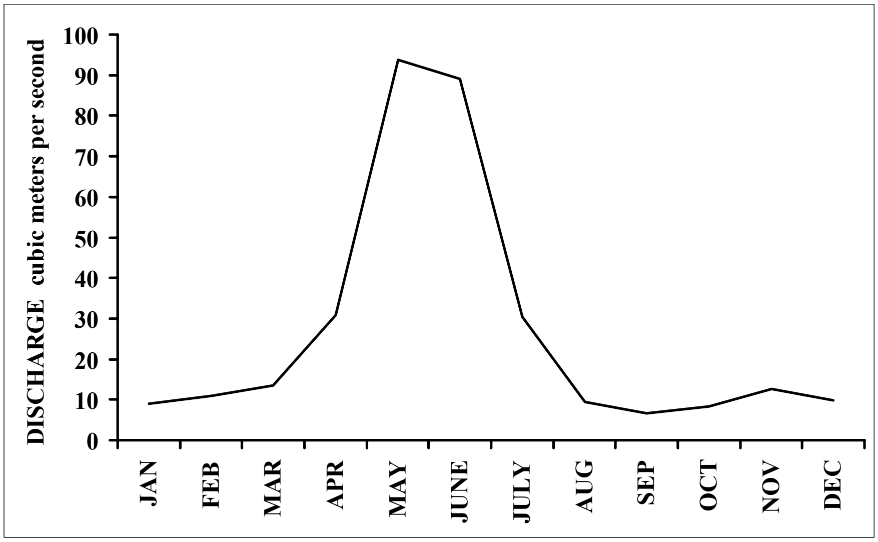


Figure 2.3 Water Survey Canada discharge for the Englishman River, 2001.

Note the late-fall/winter rainfall-dominated discharge compared to Figure 2.1, Nicola River, which is spring/summer-snowmelt dominated. Englishman River is a good example of a coastal-type hydrograph. Hydrometric station located near Parksville BC 08HB 002 BC. http://scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp

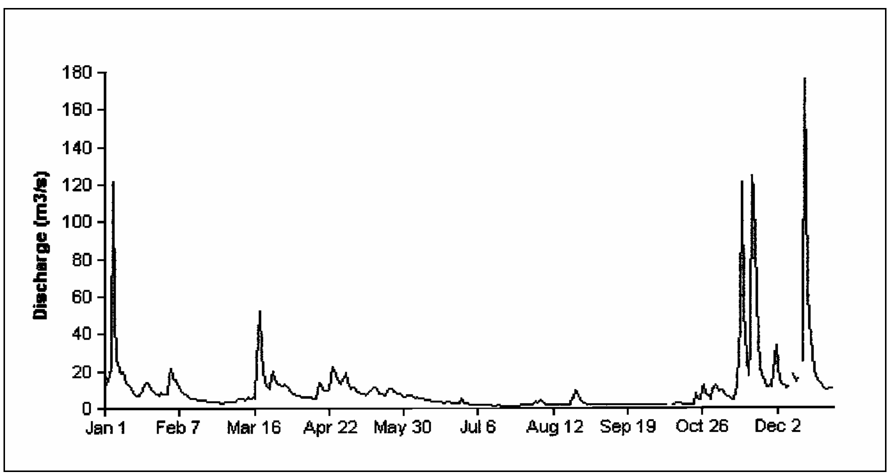
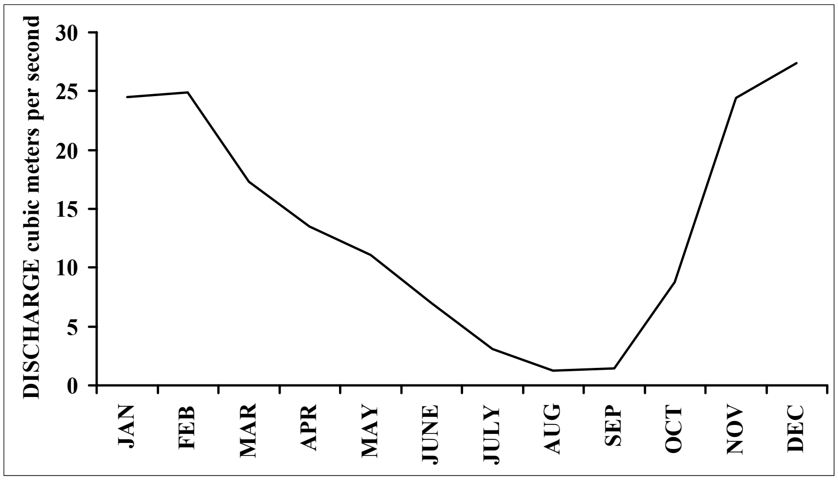


Figure 2.4 Average monthly flows for the Englishman River, 1913 to 2000.

Data from Canadian Hydrological Data © 1997, Environment Canada and includes 29 years of record. Compare the average values with that of a specific year, Figure 2.3, and the average monthly flows for the Nicola River (Fig. 2.2). Hydrometric station located near Parksville BC 08HB 002 BC.

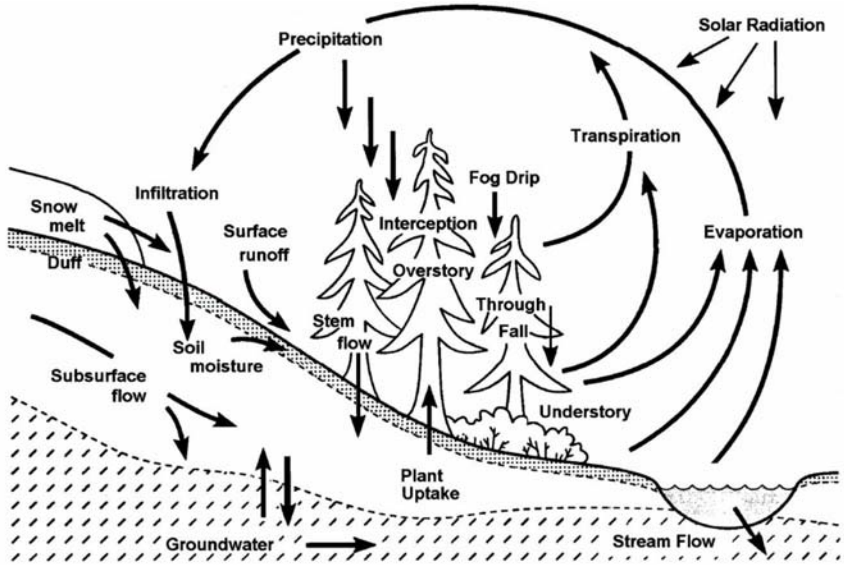


Water passing through a watershed initially falls as precipitation (rain, hail or snow). Vegetation can also cause water to enter the hydrologic cycle through fog drip (water condensing on the surface of vegetation) or rime (water freezing on cold vegetation surfaces). Water can go underground once it precipitates from the atmosphere, or it may be seen as streams, wetlands and lakes (Fig. 2.5). The surface discharge of a stream is normally referred to as runoff, but the total amount of water in a watershed, known as water yield, includes both sub-surface and stream flows.

The assessment of the impacts of water withdrawal on salmon and steelhead populations requires good hydrological information especially for standards and flow recommendations to restore stocks that have been historically affected by human diversion and extraction. The hydrograph and streamflow are determined by monitoring that may be undertaken using a hydrometric station, a measuring structure located on the stream. Discharges can be determined by manually reading a staff gauge (a measure of the height of water in a river) and calculating flows from the rating curve (a relationship between water height and water quantity). A discharge-rating curve, which is simply the functional relationship between flow and water height over a range of discharges, where the flow elevation is being measured, is plotted in order to estimate flow for the measured stage-elevations.

Flows and runoff can also be estimated for a stream in the absence of a hydrometric station or other direct flow measurements by using a computer model that incorporates measured discharges from a nearby stream, as well as other data from variables for the watershed of interest. These data include watershed elevation, area, temperature and precipitation. A British Columbia example of a flow model used to estimate stream discharge is the University of British Columbia Watershed Model and can be viewed on http://www.civil.ubc.ca/home/ubcmodel/index.html.

Figure 2.5 The hydrologic cycle.
Used by permission from Pike (1998).



For streams across the country, the Atmospheric Monitoring and Water Survey Directorate of Environment Canada maintains a Reference Index of Surface Water Data. Hydrometric surveys are conducted by the Water Survey of Canada under formal cost-sharing agreements with the provinces and territories, who contribute to the cost of the program in accordance with mutually agreed plans.

As indicated earlier, many factors influence flows in a stream. One potentially important feature that influences discharge in British Columbia is the amount of vegetation on the landscape and the human influence on its abundance and species composition. Forest-harvesting practices and development of land for agriculture have modified many areas of the province so that indigenous vegetation patterns no longer exist. Vegetation cover affects the rates of transpiration, evaporation, soil freezing and patterns of snow accumulation and melt, and therefore modifies the processes that control the water balance in space and time (Pike 2003). Removal of a significant portion of the vegetation can affect these parameters and, thus, affect the water quantities and its delivery to the stream network.

Increases in summer flows have been observed following logging in a number of systems in the Pacific Northwest (Rothacher 1970, Harr and Krygier 1972) and California (Keppeler and Ziemer 1990). Many of these watersheds are coastal and therefore tend to be wet. Studies conducted in drier, interior climates were more equivocal with Cheng (1989) reporting increases in summer streamflows for six years after logging of a basin in the British Columbia interior, but Troendle (1983) found no increase in summer low flows after wood harvesting in Colorado. Spence et al. (1996) suggested that when increases in summer flows occur after land clearing, they likely result from reductions in vegetation evapotranspiration losses.

When the effects to water discharges are considered over a longer period following logging, Hicks et al. (1991) determined that August streamflows in a central Oregon Cascade stream increased for 8 years following wood removal but decreased for 18 of the next 19 years with August streamflows averaging 25% lower than in pre-logging years. Their explanation was that reduction in streamflow occurred when coniferous species were replaced with more water-consumptive hardwood species. Therefore, the long-term effects of logging on low streamflows likely depend on vegetation composition before and after harvest (Spence et al. 1996).

In summary, changes to the density and volume of vegetation can vary the effects of water flows depending on the circumstances.

2.2 Life History of Salmon and Steelhead in Freshwater Streams

2.2.1 Spawning

Salmon and steelhead are anadromous fish, meaning that they reproduce in freshwater but then spend much of their lives in the ocean before returning to freshwater to spawn. The spawning event involves the adult female excavating shallow depressions into the stream bottom, using the digging motion of the body and tail. When the female is ready to lay her eggs the male salmon moves alongside and together they release eggs and milt. The eggs are covered up with gravel once they are deposited within this depression; the completed structure is called a redd (Fig. 2.6).

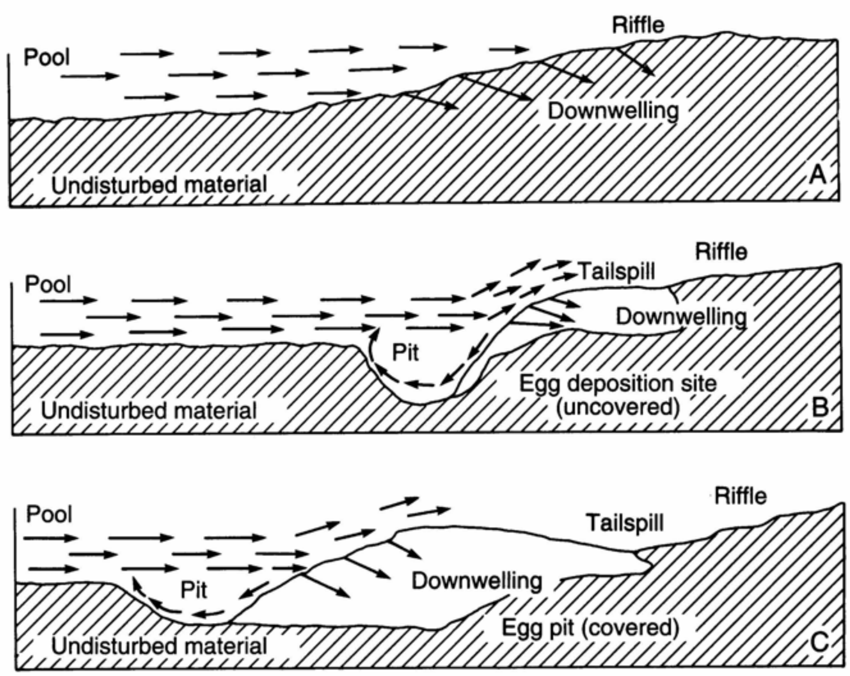
Figure 2.6 Longitudinal section of the construction of a salmon spawning redd.

Drawing and explanations from Sandercock (1991).

A: The change in depth from a pool to a riffle in a stream naturally forces water to percolate through the gravel (downwelling) in the shallower riffle.

B: The female salmon excavates a pit (nest) in the sediment at the downwelling near the riffle causing an increase in flow through the gravel; fertilized eggs are released into the nest.

C: The nest is covered with sediment (gravel) and flow percolates through the redd.



The developing eggs or embryos incubate in the redd over a period of some weeks before hatching into yolk-sac larvae called alevins. The alevins continue to develop within the gravel, again for some weeks or months depending on the species and water temperature, before they emerge from the gravel as free-swimming fry. While most populations of salmon and steelhead are stream-spawning, some sockeye salmon in British Columbia spawn in lakes (Groot and Margolis 1991).

Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), sockeye (*O. nerka*), and pink (*O. gorbuscha*) salmon are essentially “fall spawners” meaning that the spawning event usually takes place in late summer or autumn and the incubation of the embryos and alevins takes place through the fall and winter period; the young fish then emerge from the gravel the next spring. While the spawning in British Columbia for many populations of salmon occurs in October and November of the calendar year before the start of winter, some populations of some species of salmon may reproduce as early as late July. Others may not spawn until March of the “next year”, or the same calendar year that the young fry emerge from the gravel.

The steelhead (*O. mykiss*) is a spring spawner, and its fertilized eggs are deposited into the gravel in late winter or early-to-late spring. The fry emerge from the gravel during the spring or summer of the same calendar year in which they were spawned.

The continued development of the fertilized salmon and steelhead eggs as embryos, and then as hatched alevins, is maintained by sub-surface flow and the oxygen concentrations within the water discharge through the redd. The rate of development is strongly influenced by the water temperature (Murray and McPhail 1988, Groot and Margolis 1991). Emergence from the gravel by the free-swimming fry is usually timed to intercept increases in stream, estuarine or oceanic food abundances, and this normally occurs during the spring season.

Thus, the amount of water flowing in a stream during incubation, and its concurrent temperature, is critical to the survival and production of salmon and steelhead in this phase of their lives. Changing these water discharges, either as a result of Nature’s whims or through human influence, can strongly determine the survival and production of salmonids in a stream. For some watersheds in British Columbia the diversion and/or extraction of water while the spawn of fish are incubating within the gravel has been known to seriously and negatively affect the survival of these species.

2.2.2 Stream Rearing

The newly-emerged young fish of some species and/or populations of salmon go immediately to sea after emergence from the redd gravel while others, including steelhead, rear in freshwater for a protracted period before emigrating to sea. The term “smolting” is used to describe young salmon and steelhead undergoing the physical, physiological and behavioral transition that is required to migrate from freshwater to the ocean.

The freshwater rearing phase of salmon and steelhead can be very complex and is highly variable depending on the species, population, life-history stage, watershed and time of year (Scott and Crossman 1973, Groot and Margolis 1991). For example, young pink salmon emigrate from their natal streams as fry and spend virtually no time in freshwater before traveling to the sea for further rearing. Likewise, chum fry tend to spend a minimal residence time in fresh-water environments, although some populations do remain for stream growth over a period of a few weeks before entering marine habitats. Many stocks of chum rear in an estuary before going to sea and this behavior can provide accelerated growth and survival potential due to the abundant availability of food.

Most populations of sockeye rear in freshwater for at least one year before migrating to sea, unlike pink and chum salmon. The majority of sockeye stocks use lakes for this phase of their juvenile life history, although there are a few stream-rearing populations of this species in British Columbia (Groot and Margolis 1991).

Chinook and coho salmon, and steelhead are the species that are primarily stream-rearing during their juvenile lives, and are of specific interest to this study due to the critical nature of stream flows influencing their survival. Increasing the size of salmonid smolts provides a boost to their survival rates in the marine environment; thus, these fish have much higher survival rates per fish than the much smaller pink and chum fry once they reach the sea (Holtby et al. 1990). The length of time that chinook, coho and steelhead spend in the freshwater environment usually influences their size at migration. Even for these fish however, the residence period can be highly variable within and among populations and species.

Of these three species, Chinook salmon (Fig. 2.7) have the most flexible life history, with some populations heading directly to sea after emergence, but most spending at least a number of months in freshwater or the estuary before going to the ocean (Groot and Margolis, 1991). The juveniles of many Chinook populations will spend up to a year in freshwater before emigrating to sea and the Fraser River populations of Chinook salmon exhibiting this behaviour tend to be located in the more interior parts of the province.

Figure 2.7 A juvenile chinook salmon.

Photo courtesy of Reid Schrul, Capilano Hatchery.

It should be noted that Chinook salmon are notorious wanderers and often rear in non-natal streams before smelting (Murray and Rosenau, 1989). Thus, less-than-optimal conditions for freshwater rearing in the natal stream may not necessarily influence the production of that stream's Chinook stock if the juveniles normally find alternate habitat.

Coho salmon juveniles (Fig. 2.8) usually spend at least a year in freshwater although some juvenile fish rear over two winters. However, while some populations of coho will live along the shallow perimeters of lakes, most juvenile fish are associated with streams or the immediately-adjacent wetlands. Coho salmon are typically a small-stream-adapted fish.

Figure 2.8 Juvenile coho salmon.

Photo courtesy of Reid Schrul, Capilano Hatchery.

Nevertheless, because they spawn and rear in small, lowland streams, coho salmon are probably one of the most habitat-impacted of all of the six species of salmon including steelhead; this is because these low-elevation watersheds are usually the first to be affected by development, forest harvesting, the clearing of land for agriculture and the water withdrawals that often follow. Over the recent decades, declines in coho populations have occurred from southern British Columbia to California and have been attributed to several factors including habitat destruction and over-fishing. Juvenile coho salmon, which live in small streams, can also be impacted by water withdrawals given that there are often only residual amounts of flow remaining in these diminutive watersheds during the critical late summer period, and in some situations extraction has been known to completely dewater the stream.

Steelhead (Fig. 2.9) have the longest freshwater period of juvenile rearing for the six salmon species that we are discussing in this report. This can usually last from 2 to 4 years for most British Columbia stocks and generally tends to be shorter in the warmer, more productive, southern streams and longer in the slower-growth higher latitude streams. For steelhead, there is a very clear size-biased survival for the smolts going to sea and young fish generally must reach a minimum length of greater than 150 mm in order for marine survival to reasonably occur (Ward and Slaney 1988). Steelhead typically have the largest smolts of all of these six species in British Columbia.

Figure 2.9 A juvenile steelhead trout.

Photo courtesy of Craig Wightman.

It should be emphasized that stream-dwelling juvenile salmonids, such as steelhead, coho and chinook, are territorial for both spawning and rearing and compete for space with one another—within species and among species (Groot and Margolis 1991). This means that for any given stream and population of fish, there is a limit to the amount of available living area and, therefore, the numbers of individuals of a species that can attain and defend a territory.

Furthermore, space within a stream is defined, in part, by the total area of a stream. Area is a function of flow—the more discharge, the greater the area. However, if the total area of livable spaces is reduced, which can occur through the withdrawal of water during low-flow periods, the productive capacity, or the ability of a stream to produce fish, may be compromised.

It must be pointed out, also, that there is no linear relationship between flow in a stream and available space for rearing or spawning fish (Fig. 2.10). Not all areas of a stream are useable to the same degree by each of the various sizes, ages, and species of fish. The parameters that influence suitability of a location within the stream and that are affected by flow—depth and velocity—change as discharges increase or decrease. Steelhead fry, for example, prefer much slower water than the older and larger parr (Fig. 2.11) while steelhead parr prefer faster velocities than coho fry. Younger salmonids generally require less water than the older fish (Vadas 2000). Paradoxically, in some watersheds, during certain times of the year, too much water can also reduce the habitat capability of a watershed for stream-rearing salmonids because the flows may be too fast or too deep for these small fish (e.g., Smith 2000).

Figure 2.10 Generalized habitat-flow relationship for stream-rearing and -spawning salmonids.

Adapted from Hatfield and Bruce (2000).

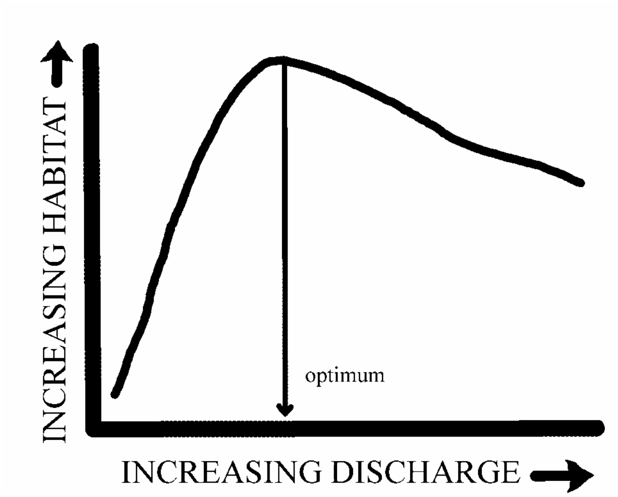
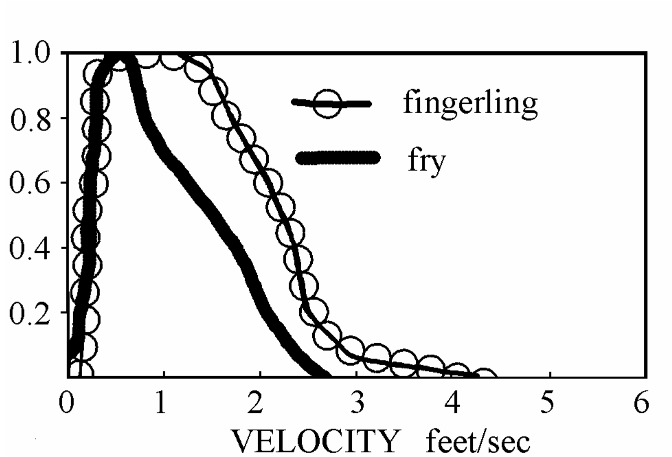


Figure 2.11 Water-velocity suitability for steelhead fry and parr in a stream.

Adapted from Bovee 1982. Note that the vertical axis is a unit-less scale from 0 to 1, with 1 being the most suitable velocity for this species at this size class. Other species or life history stages will have relationships to this parameter, and others (depth, substrate), that will vary according to needs.



In summary, because coho, chinook and steelhead spend a considerable length of time rearing in streams before smolting, the instream flows and habitat quality and quantity resulting from discharges in rearing streams are crucial for the ultimate survival and production of these species. Extraction and diversion of water from salmonid rearing streams have the potential to significantly reduce the habitat capacity and, as a result, the number and quality (size) of salmon and steelhead smolts produced.

2.3 Effects of Water Withdrawal on Instream Flows and Juvenile Salmonid Survival and Production

Salmon and steelhead are assumed to be adapted to the particular flow regimes found in their natal streams. Throughout their life histories, these species behave in certain ways that are based on ancient and evolutionary responses in relation to within-season, among-season, and among-year patterns of water flow. Thus, the introduction of radical changes to those average discharge patterns, such as when excessive extraction, diversion or water storage occurs, will inevitably affect the quality and quantity of the salmon populations.

Following from this, losses in production of these species, during incubation and/or rearing, can occur when the hydrograph of a stream is disrupted, either for the extraction of water for irrigation or other purposes or as the result of the capriciousness of nature. In the Pacific Northwest, persistent summer low flows have been shown to limit coho salmon production (Zillges 1977). Collings (1974) has demonstrated that the natural limiting discharge for coho and other stream-rearing salmonids is the median flow for the driest month. Researchers in western Washington have shown that coho and steelhead recruit most favorably during years of above average flows (Smoker 1953). Vadas (2000) suggests that salmonids need higher flows, as a percentage of mean annual discharge, in smaller streams relative to larger ones. Thus, populations of salmon and steelhead in smaller streams may be especially sensitive to flow reductions. Effects of excessive water withdrawal are compounded if the stream is already degraded through channelization or disruption of the riparian habitats.

Spence et al. (1996) indicate that many diversion and extraction activities have significantly contributed to the decline of salmonids in the Pacific Northwest and have summarized the impacts to fish from the removal of water for irrigation. They suggest that the:

> *" …hydrologic effects of dams and withdrawals for irrigation include water-level fluctuations, altered seasonal and daily flow regimes, reduced water velocities, and reduced discharge volume. In addition, drawdowns and diversions reduce available habitat area and concentrate organisms, potentially increasing predation and transmission of disease…"*

During the low-flow period, the range of flows in a stream with and without extraction, and with respect to the protection and sustenance of aquatic life, can generally be categorized as:

- **insufficient to protect aquatic life (i.e., complete drying up of the stream)**—excessive water withdrawal or natural drought can reduce flows in a stream to the point where embryos or alevins can be killed due to the desiccation or drying up of the redd. In addition, juvenile fish can be stranded or forced to migrate into sub-optimal alternative habitats;

- **conservation-level base discharges**—conservation flows are those flows that maintain or attempt to restore the seasonal pattern of the intra-annual (magnitude, duration, timing, rate of change) and inter-annual variability (frequency) of discharges in order to preserve or restore the natural ecological function of riverine resources. (Instream Flow Council 2002). The diversion of water in such streams may be undertaken in ways that still maintain conservation flows and will not result in a harmful alteration, disruption or destruction of habitat (HADD) or losses to aquatic biodiversity subsequent to the diversion of water. The biological performance indicators would include species numbers and abundance levels equivalent to the unaltered flow regime. Conservation flows attempt to achieve uncompromised conditions for fish rearing, incubation, spawning, passage or migration, fish food production, wetland linkage, channel formation and annual variability in water supply and use. An example of a conservation flow is the generic rearing-flow standard, for small juvenile fish, of 20% mean annual discharge. The object of setting this guideline would be to maintain this flow as a 30-day baseflow where possible (R. Ptolemy, pers. comm.).

It should be noted that excessive withdrawal of water can also impact water quality by increasing temperatures and reducing oxygen concentrations. Water quality is an essential consideration under already stressful conditions and Spence et al. (1996) indicate that: *"...return-flows from irrigated lands often exhibit high sediment content, turbidity, and pesticide and fertilizer concentrations…"* further exacerbating the situation.

In addition to the role of base flows in maintaining the health of an aquatic ecosystem, freshet flows during the spring are a principal component of the natural hydrograph and need to be considered when considering flow extraction, storage and diversion. The spring runoff is vital for recruiting nutrients and food from the floodplain to recently emerged juvenile fish and providing access for young salmon and steelhead to rearing areas. The powerful freshet flows also help clean the stream substrates of fine sediments. Clean gravel and cobbles are important for the production of insects, they provide winter rearing for juveniles in their interstitial spaces, and comprise quality spawning habitat, and the cleaning action by freshet of these important substrate features is seen as critical to the health of the aquatic ecosystem.

Despite the importance of freshet flows to fish, the capturing of snowmelt runoff is common and many agricultural and other water extractions are "backed up" by license through the storage of water in an impoundment behind a dam in a reservoir within the watershed (Fig. 2.12) in anticipation of use during low-flow periods. This can reduce the ability of spring flows to properly function in maintaining the aquatic ecosystem. For example, Spence et al. (1996) state that: "…impoundments alter natural sediment transport processes, causing deposition of fine sediments in slackwater areas, reducing flushing of sediments through moderation of extreme flows, and decreasing recruitment of coarse material (including spawning gravels) downstream of the obstruction…"

Figure 2.12 Nicola Lake dam upstream of Merritt on the Nicola River watershed.
Photo courtesy of Alan Caverly.

Other effects resulting from impoundment include the modification of the downstream temperature regime in the watershed. The storage of water in an upstream reservoir can change the thermal regime and water quality as:

> *"…temperatures may increase in shallow reservoirs and where return-flows from irrigation have been heated. Downstream of deep reservoirs that thermally stratify, summer temperatures may be reduced through release of hypolimnetic waters, but fall temperatures may increase as heated water stored during the summer is released. These changes in temperatures affect development and smoltification of salmonids as well as influence the success of predators and competitors and the virulence of disease organisms. Dissolved oxygen concentrations may be reduced during both summer and winter from withdrawals for irrigation. In summer, high temperatures of return-flows reduce the oxygen-holding capacity of water; in winter, drawdown of impoundments facilitates freezing, which diminishes light penetration and photosynthesis, potentially killing fish through anoxia…" (Spence et al. 1996).*

2.4 The Determination of Instream Flow Needs for Salmon and Steelhead in British Columbia

It is well recognized in British Columbia and throughout western North America that the manipulation of flows in streams, for human needs, can interfere with the discharges needed in order to maintain aquatic productivity and biodiversity. These vital flows for fish are commonly referred to as Instream Flow Needs (IFN's) and the amount of water required to protect biodiversity and fish production can vary depending on the time of year and species. In short, IFN's are discharges that are necessary to ensure that there is enough water in a stream for fish spawning, migration and rearing, insect growth, periphyton (algae) production, and other biological features, so as to sustain the trophic web that preserves an healthy aquatic ecosystem.

The science behind IFN's has expanded dramatically in the past few decades to serve the needs of fisheries agencies that are mandated to protect aquatic ecosystems in the face of increased water withdrawal. Historically, habitat biologists, fisheries scientists, water engineers and managers have permitted the extraction of water for human utilization in the absence of stream-specific information. In recent years, as water availability and fish stocks have declined, fisheries professionals have been required to ask the question: "In the face of a demand for extraction and diversion of water by human interests, exactly how much water should appropriately be allocated for salmon and steelhead and other aquatic life in streams?"

This question has led to considerable, and often acrimonious, scientific and non-scientific dispute across western North America given the large conflicts between using water for domestic use, industry, irrigating crops, or producing power through hydro-electric generation, and the protection of salmon and steelhead. These contentious debates seem to have been amplified in areas that are naturally arid.

Part of the problem has been the methods of determining fish flow needs. Numerous IFN's models, or methodologies, have been developed for a wide variety of uses and employ differing parameters. The result is diversity in terms of the model mechanisms and the subsequent outcomes (Korman et al. 1994; Hatfield and Bruce 2000). Indeed, the fact that there are numerous options, and this list continues to grow, provides evidence that the subject is fraught with uncertainty and frustration. Nevertheless, fisheries managers who deal with flow issues continue to grapple with the task of applying models and methodologies in order to assist them in making flow decisions.

One of the most commonly used IFN methodologies has been the Instream Flow Incremental Methodology, or IFIM as it is commonly referred to (Bovee 1982). The IFIM exercise is conducted in conjunction with the micro-habitat model physical habitat simulation, or PHABSIM for short. IFIM and PHABSIM engage hydraulic modeling to estimate the change in depths, velocities and substrates under a variety of flow conditions for a particular stream, and then incorporate the estimated suitability-of-use for these parameter estimates, and for various life-history stages of a species, in order to determine the amount of usable habitat in that stream over a range in flows.

There is considerable uncertainty with regards to how well the IFIM method actually represents reality. Mathur et al. (1985), Scott and Shirvell (1987) and Williams (1996) were all highly critical of IFIM/PHABSIM. In British Columbia there have been a number of well-known instances and controversies where IFIM has been used in flow negotiations. Most notable has been the deliberations regarding minimum flows in the Nechako River as part of the Kemano Completion Project. Water Use Planning exercises of BC Hydro also used IFIM including the efforts on the Campbell, Puntledge, Ash, Cheakamus and Alouette rivers.

Hatfield and Bruce (2000) also reviewed IFIM and they listed some of the criticisms applied to the use of this method, many of which are applicable to British Columbia, including:

- it is time consuming, expensive and technical
- ecological interactions are ignored
- results are user dependent
- statistical uncertainty can be large
- many of the underlying assumptions are never tested
- results are almost never verified or monitored
- PHABSIM optima are predictions based on the present condition of the stream; stream morphology may change once flow-regulation is in place.

Nevertheless, they recognize that fisheries managers will continue to use the IFIM methodology and suggest cautionary conditions for its use. Furthermore, Hatfield and Bruce (2000) have taken the methodology one step further and have developed a way to predict habitat and flow relationship through a meta-analysis of many previous stream-flow studies. Unfortunately, the inputs of the model or models use differing habitat suitability criteria and transect locations among the numerous study streams and this is one critisim of their society. Nevertheless, this iteration will presumably provide fisheries-flow managers with another, improved tool with which to work once validated for BC applications using local habitat suitability information.

Another way of determining appropriate instream flows for salmonids, that has been commonly used in western North America, is the Tennant, or Montana Method (Tennant 1976). The basis for this method is the assumption that streams have predictable geometries and symmetries related to that stream's particular discharge hydrograph. As a consequence, it is assumed that fish, and other aquatic organisms respond to these flow-related features in repeated and systematic ways. The percentages of Mean Annual Discharge (MAD) are used as the coefficients for the particular life-history stages, and flows can be determined in order to protect fish with the remainder extracted for human use.

The development of the Tennant method included 17 years of professional experience on coldwater and warmwater streams. This was then tested on streams in Nebraska, Wyoming and Montana.

Appropriate flows for fish and wildlife are represented as percentages of mean annual discharge.

FLOWS	October-March	April-September
Flushing or Maximum	200%	200%
Optimum Range	60–100%	60–100%
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or Degrading	10%	30%
Poor or Minimum	10%	10%
Severe Degradation	0–10%	0–10%

It has been argued by some that the Tennant Method has at least two primary weaknesses. The first is the lack of biological validation over the range that this is used. The second is the use of professional opinion (rather than hard empirical numbers) in the analysis. Another problem is that the hydrology of the watersheds where this method was developed can be very different to other geographically-distant streams (e.g., interior versus coastal hydrographs) and the Tennant Method as originally conceived is probably more applicable to interior west coast North American streams rather than coastal watersheds.

A made-in-British Columbia fish-flow system that is a modification of the Tennant Method is the Ptolemy Method (after Ron Ptolemy, BC Ministry of Water, Land and Air Protection biologist), also known as the BC Modified Tennant method. The Ptolemy Method is an adaptation of Tennant's (1976) seasonal flow recommendations and it calibrates percentages of mean annual discharge (MAD) to local hydrometric, geomorphic and ecological conditions for various times of the year specific to a particular life-history stage.

Ptolemy has suggested that flows used to develop the Tennant methodology are considerably different from those found in many British Columbia streams, and he developed a within-province modification of this concept in order to improve its rigor. The Ptolemy Method has also incorporated fish periodicity information (e.g., age of fish, life stage of fish, flow needs for different species, etc.) and ecological information.

Ptolemy's recommended flows for British Columbia streams.

Biological or Physical Requirement	Flow Recommendation (%MAD)	Duration
Rearing	20%	Months
Juvenile	20%	Months
Adult	>55%	Months
B. Overwintering	20%	Months
C. Incubation	20%	Months
D. Migration and Spawning	30–200%	Days–Weeks
Summer Steelhead Passage	50–100%	Days
Spawning	eqn: 1.56*MAD0.63	Days–Weeks
Smolt Migration	50%	Weeks
E. Short-term Maintenance	10%	Days to Week
F. Channel Maintenance	>400%	Days
G. Wetland Linkage	100%	Weeks

MAD = Mean Annual Discharge

The Ptolemy Method is based on ongoing field investigations, empirical fish behaviour-flow functions, instream flow studies in this province, and professional opinion of field staff in the agencies. Concerns regarding this method include a lack of clear validation and this has been expressed by some fisheries managers.

Another method that has been used to predict salmonid utilization in streams in British Columbia is the Habitat Quality Index model developed in Wyoming for trout (Binns and Eiserman 1979). Because of its geographic origin, this multiple-regression model was not deemed to be particularly applicable to British Columbia. A made-for-BC model that was a derivative of this Wyoming exercise proved to be even less successful (Rosenau and Slaney 1983).

In summary, while the above-mentioned capability and suitability models are simply a sub-set of a wide range of options that can be used to guide fisheries and water managers, some of which are more applicable than others, there is still a great deal of uncertainty with regards to what methodology should be used in British Columbia. Despite the uncertainties that still remain about the choice of models, it is clear that they indicate that many British Columbia streams have been considerably over-allocated for water extraction and fish habitat has suffered as a consequence. Most or all of the above models, when applied to these specific situations, point in that direction. Both IFIM and the Ptolemy Method's have been used on the Nicola and Englishman river watersheds, the two streams that we look at more closely in this report.

In summary, it is imperative for British Columbia to develop IFN standards that are consistent and are relevant to each geographic area and stream type. Work towards this objective is currently underway by the fisheries agencies and needs to be completed in a timely manner.

3.0 Legislation And Policy

The provinces and the federal crown share jurisdictional responsibilities for water in Canada. The provinces own water resources under the Canada Constitution Act of 1867 and this includes both surface and groundwater, while the federal crown is responsible for fish and the fish habitat that is adjacent to, or within, the watercourse. The following delineates some of the jurisdictional roles and responsibilities.

3.1 British Columbia *Water Act*

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

The Canadian provinces are responsible for flow regulation, the authorization of water-use development, and the authority to legislate areas of water supply, pollution control, thermal and hydroelectric power development. Much of the legislation controlling the use of water in this province is embodied in the British Columbia *Water Act*. The *Water Act* was formerly administrated through the Ministry of Environment, Lands and Parks but now, under the most current model of governance, water allocation and the licensing of diversions and storage now take place through a crown corporation, Land and Water British Columbia Inc.

Section **2** of the British Columbia *Water Act* clearly articulates the legislative jurisdiction by the province:

> ***2*** *(1) The property in and the right to the use and flow of all the water at any time in a stream in British Columbia are for all purposes vested in the government, except only in so far as private rights have been established under licences issued or approvals given under this or a former Act.*
>
> ***2*** *(2) No right to divert or use water may be acquired by prescription.*

An important point specific to Section **2** (2) is that no one can obtain rights to surface water simply because he or she has been using it over an historic time period. That is, with the exception of a few short-term or small-volume circumstances, an entity must have a license authorizing the use of water and this is issued by the provincial crown.

Precedence in obtaining a water license is also important from a rights and water-use perspective. The right to use water, when it is limited, ranks in priority by date using the “first in time - first in right” doctrine. A person having a water license that has an earlier date of application than someone else has first legal opportunity to use the water. This water must be used beneficially or the license holder loses the right to use that water. These two points are key to water law in western North America.

Licenses are authorized by the Comptroller of Water, or his designate, and entitle its holders to do one or more of the following in a manner authorized by the licence:

> *(a) divert and use beneficially, for the purpose and during or within the time stipulated, the quantity of water specified in the licence;*
>
> *(b) store water;*
>
> *(c) construct, maintain and operate the works authorized under the licence and necessary for the proper diversion, storage, carriage, distribution and use of the water or the power produced from it;*

(d) alter or improve a stream or channel for any purpose;

(e) construct fences, screens and fish or game guards across streams for the purpose of conserving fish or wildlife.

The *Water Act* allows water to be licensed for fish and wildlife conservation purposes. Section 7 stipulates that a license may be issued by the comptroller or the regional water manager to any of the following:

(a) an owner of land or a mine;

(b) a holder of a certificate of convenience and necessity issued under the Public Utilities Act, R.S.B.C. 1960, c. 323, or under the Water Utility Act;

(c) a municipality, improvement district, water users' community or development district;

(d) the Crown as represented by a minister appointed by the Governor General or the Lieutenant Governor;

(e) a commission, board or person having charge of the administration of any land, mine or other property owned or controlled by a ministry, department, branch or other subdivision of the government of Canada or of British Columbia;

(f) the Greater Vancouver Water District or the Greater Nanaimo Water District, or any other water district incorporated by an Act of the Legislature;

(g) the British Columbia Hydro and Power Authority.

This makes the prospect of holding a water license for conservation purposes restricted to those who own land. However, conservation groups that do not own the land in question, can work in conjunction with willing landowners (private or crown). By acting as agents for the landowner, conservation groups can handle the paper work and pay the necessary fees associated with licensing requirements to obtain water rights for conservation purposes.

Objections to the issuance of a Water License can be made by other license holders for that watershed, other applicants, or riparian landowners potentially affected. The Comptroller or his/her delegate can hold a hearing to address these issues. Conflicts can also be appealed through the BC Environmental Appeal Board.

License applications may be reviewed by the appropriate fisheries agencies and the Comptroller may take the agency comments into consideration during the deliberations relating to license issuance. For example, a fisheries agency may object to the issuance of a license insofar as the extraction or diversion of the water may harmfully alter fish or fish habitat; the Comptroller has been known to turn down a license on this basis. In other cases licences have been granted where fisheries concerns have been expressed.

An important component of diversion licences is that research in western North America has shown that water license compliance is generally low (Hubert et al. 1990). Many fisheries professionals familiar with the subject have the opinion that increased levels of compliance-monitoring are required to reach better performance with respect to over-extraction of water in British Columbia.

On a final note, British Columbia does not have comprehensive groundwater legislation. Extraction of groundwater has the potential for affecting fish flows in streams. Many conservation groups view this as an omission that needs to be corrected.

3.2 Canada Fisheries Act

http://laws.justice.gc.ca/en/F-14/index.html

The variety of federal responsibilities under the *Canada Constitution Act of 1867* includes areas of jurisdiction that have the potential for significant national interest, and this therefore includes fisheries. The Canada *Fisheries Act* is the federal legislation that articulates the permissible activities affecting fisheries, both inland and marine, including the harvesting of fish and the protection of fish habitat.

- Of note, the management of non-salmon inland fisheries in British Columbia has been delegated to the province by the federal government. This primarily includes the angling for, and the harvest of, the non-anadromous trouts and chars through the regulation of sport fisheries as well as the activities of hatchery-stocking these species of fish in lakes and streams. The management of the steelhead fishery is also by the province and is one of the few significant exceptions to the general rule of the administration of anadromous (ocean-migratory) fishery management in inland waters by the federal government.
- The management and protection of fish habitat for inland waters falls under the Canada Fisheries Act and the department of Fisheries and Oceans Canada administers this Act. It should be noted that the province through its mandate to regulate land and water use can prevent harm to fish habitat. Notable instances of provincial initiatives that take fish habitat into account include the provisions under the Forest Practices Code of British Columbia Act and the British Columbia Forest and Range Practices Act, and these acts regulate fish habitat impacts resulting from forest harvesting. The more-recently proclaimed British Columbia Fish Protection Act also has some influence on human activities in streams and resulting impacts to fish and will be discussed further in this report. This said, ultimate responsibility for fish habitat protection rests with the federal government.

With respect to maintaining protection for fish specific to the activities surrounding the withdrawal of water for human purposes, the Canada *Fisheries Act* has a number of detailed sections that apply in this regard. Providing safe passage in a stream where diversion has been constructed has been expressed in the following sections of the *Act*:

> ***21** (4) The Minister may require the owner or occupier of any obstruction to install and maintain such fish stops or diverters, both above and below the obstruction, as will in his opinion be adequate to prevent the destruction of fish or to assist in providing for their ascent.*
>
> ***22** (1) At every obstruction, where the Minister determines it to be necessary, the owner or occupier thereof shall, when required by the Minister, provide a sufficient flow of water over the spill-way or crest, with connecting sluices into the river below, to permit the safe and unimpeded descent of fish.*
>
> ***22** (2) The owner or occupier of any obstruction shall make such provision as the Minister determines to be necessary for the free passage of both ascending and descending migratory fish during the period of construction thereof.*

When the withdrawal of water from a stream becomes so great as to start affecting the productive capacity and safety of fish therein, Fisheries and Oceans Canada can order that water be released for the protection of fish and fish habitat. The authority to do this is articulated in the Canada *Fisheries Act* as follows:

> ***22*** *(3) The owner or occupier of any obstruction shall permit the escape into the river-bed below the obstruction of such quantity of water, at all times, as will, in the opinion of the Minister, be sufficient for the safety of fish and for the flooding of the spawning grounds to such depth as will, in the opinion of the Minister, be necessary for the safety of the ova deposited thereon.*

It should be noted that despite Section **22** (3) of the Canada *Fisheries Act,* and the fact that water-flows in some streams in the province routinely fall to crisis levels during drought periods, Fisheries and Oceans Canada has rarely enforced this provision for salmon and steelhead watersheds in British Columbia.

Finally, and of substantial relevance to the multitude water diversion facilities for irrigation that are often found in many salmon and steelhead streams in the dry interior parts of the province, the federal government can ensure that intakes are properly screened in order that the small fish do not get diverted out the rearing stream. The legislation that is specific to this is as follows:

> ***30*** *(1) Every water intake, ditch, channel or canal in Canada constructed or adapted for conducting water from any Canadian fisheries waters for irrigating, manufacturing, power generation, domestic or other purposes shall, if the Minister deems it necessary in the public interest, be provided at its entrance or intake with a fish guard or a screen, covering or netting so fixed as to prevent the passage of fish from any Canadian fisheries waters into the water intake, ditch, channel or canal.*
>
> *(2) The fish guard, screen, covering or netting referred to in subsection (1) shall*
>
> *(a) have meshes or holes of such dimensions as the Minister may prescribe; and*
>
> *(b) be built and maintained by the owner or occupier of the water intake, ditch, channel or canal referred to in subsection (1), subject to the approval of the Minister or of such officer as the Minister may appoint to examine it.*
>
> *(3) The owner or occupier of the water intake, ditch, channel or canal referred to in subsection (1) shall maintain the fish guard, screen, covering or netting referred to in that subsection in a good and efficient state of repair and shall not permit its removal except for renewal or repair.*
>
> *(4) During the time in which a renewal or repair referred to in subsection (1) is being effected, the sluice or gate at the intake or entrance of the water intake, ditch, channel or canal shall be closed in order to prevent the passage of fish into the water intake, ditch, channel or canal.*

Penalties for failing to comply with Section 30 include:

> ***69*** *Every owner or occupier of a water intake, ditch, channel or canal referred to in subsection* ***30*** *(1) who refuses or neglects to provide and maintain a fish guard, screen, covering or netting in accordance with subsections* ***30*** *(1) to (3), permits the removal of a fish guard, screen, covering or netting in contravention of subsection* ***30*** *(3) or refuses or neglects to close a sluice or gate in accordance with subsection* ***30*** *(4) is guilty of an offence punishable on summary conviction and liable, for a first*

offence, to a fine not exceeding two hundred thousand dollars and, for any subsequent offence, to a fine not exceeding two hundred thousand dollars or to imprisonment for a term not exceeding six months, or to both.

Another Section of the Canada *Fisheries Act* that may apply to the excessive withdrawal of water from a stream is **35** which provides for prosecution for the harmful alteration, disruption or destruction of fish habitat. This includes any river system that supports salmonids.

> ***35*** *(1) No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.*
>
> *(2) No person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act.*

This legislation gives the Federal government the power to prevent any extraction of water that poses a threat to the quality or quantity of salmon and steelhead habitat.

3.3 British Columbia *Fish Protection Act*

http://www.env.gov.bc.ca/fsh/protection_act
http://www.qp.gov.bc.ca/statreg/stat/F/97021_01.htm

For some time concerned British Columbians have recognized the inadequacy of the British Columbia *Water Act* and Canada *Fisheries Act* to deal with flow issues in streams where salmon and steelhead are affected due to water withdrawals. While the Comptroller of Water Rights, or his designates, have, in recent years, been somewhat sympathetic to the needs of fish for minimum flows, historically no legislation under the British Columbia *Water Act* provided for the legitimate requirements of water by fish through the restricting of the issuance of licenses for withdrawal.

A more recent attempt to address this has been through the development and passing of the British Columbia *Fish Protection Act* in July 1997. The prohibition of the construction of new dams on 14 rivers was brought into force at the passing of the *Act.* In addition, there were some minor sections also passed relating to offences and creative sentencing with additional aspects to be added later.

The initial intent of the *Act* was to deal with three categories of streams for the purposes of water allocation and approval decisions:

- General streams where fish and fish habitat are not an immediate concern (Section **5** of the *Act*).
- General streams where fish are present and flow or habitat concerns exist (Section **13** (2)(b) of the *Act*).
- Sensitive streams (under Section **6** of the *Act*)

The proposed general streams regulations (the first two bullets) under the British Columbia *Fish Protection Act* were to incorporate consideration of potential impacts on fish and fish habitat in water allocation decisions or approvals for changes in or about streams. Furthermore, the proposed regulation was supposed to codify existing policies and practices. The General streams' components of the *Act* (Sections **5, 13**) are, however, still outstanding and are not in force.

The third aspect of the *Fish Protection Act* focused on streams which were recognized as having serious problems with respect to flows and, as a result, were deemed to be "Sensitive Streams". In March 2000, Cabinet brought Sections **6** and **7** – Sensitive Streams and Recovery Plans – into force in March 2000 along with the Sensitive Streams Designation and Licensing Regulation. The Sensitive Stream designation was meant to be complementary to the Canada Fisheries Act and was an attempt to ensure that fish have enough water to survive.

When a stream is designated as sensitive, the following measures have been proposed and are intended to help protect threatened fish populations.

- The sustainability of fish will receive highest priority.
- Recovery plans may be required on Sensitive Streams that are unable to rehabilitate naturally.
- Water managers must consider the needs of fish before issuing a water license.
- Water license applicants may be required to provide water flow and fish habitat information, or find a reasonable alternate source of water.
- Water license applicants may be required to develop mitigation or compensation measures.

Furthermore, the following criteria have been developed and put forward by the province to help identify candidate Sensitive Streams:

- The stream is located in a watershed containing a significant population of salmon (coho used as an indicator species);
- The stream is a high priority for designation at present because of the precarious nature and value of fish stocks at risk, and the potential for high productivity given the nature of existing fish habitats;
- The stream is located in an area of the province with sensitive yearly flows and significant human populations or industrial water users;
- The stream flow limits fish production from achieving historic levels;
- Water abstraction and associated weirs, intakes, etc. are adversely affecting stream flows and fish migration;
- The stream offers good potential for recovery of fish populations, either with or without a recovery plan; and
- The stream is not otherwise being addressed under the BC Hydro Water Use Planning license review process.

There have been fifteen candidate streams for initial designation including Black Creek, Goldstream River, Englishman River, Little Qualicum River, French Creek, Little River, Fulford Creek, on Vancouver Island, Chapman Creek, Silverdale Creek, Kanaka Creek, West Creek, Lang Creek, Whonnock Creek, Nathan Creek, in the Lower Mainland, and the Salmon River in the Omineca/Peace.

The streams selected are included because they were deemed to have an immediate need for additional protection measures and it is expected that designation will have minimal impact on other users of the resource. While this is a good start, there are many notable BC streams that are not yet on the list and there is not a clear explanation from a fisheries or fish-habitat perspective why this is so. The attempted inclusion of other rivers has also been a contentious issue in several public forums and, therefore, the list has yet to be expanded or updated. Furthermore, efforts to develop Recovery Plans, for the most part, appear to have stalled for the listed 15 candidate streams.

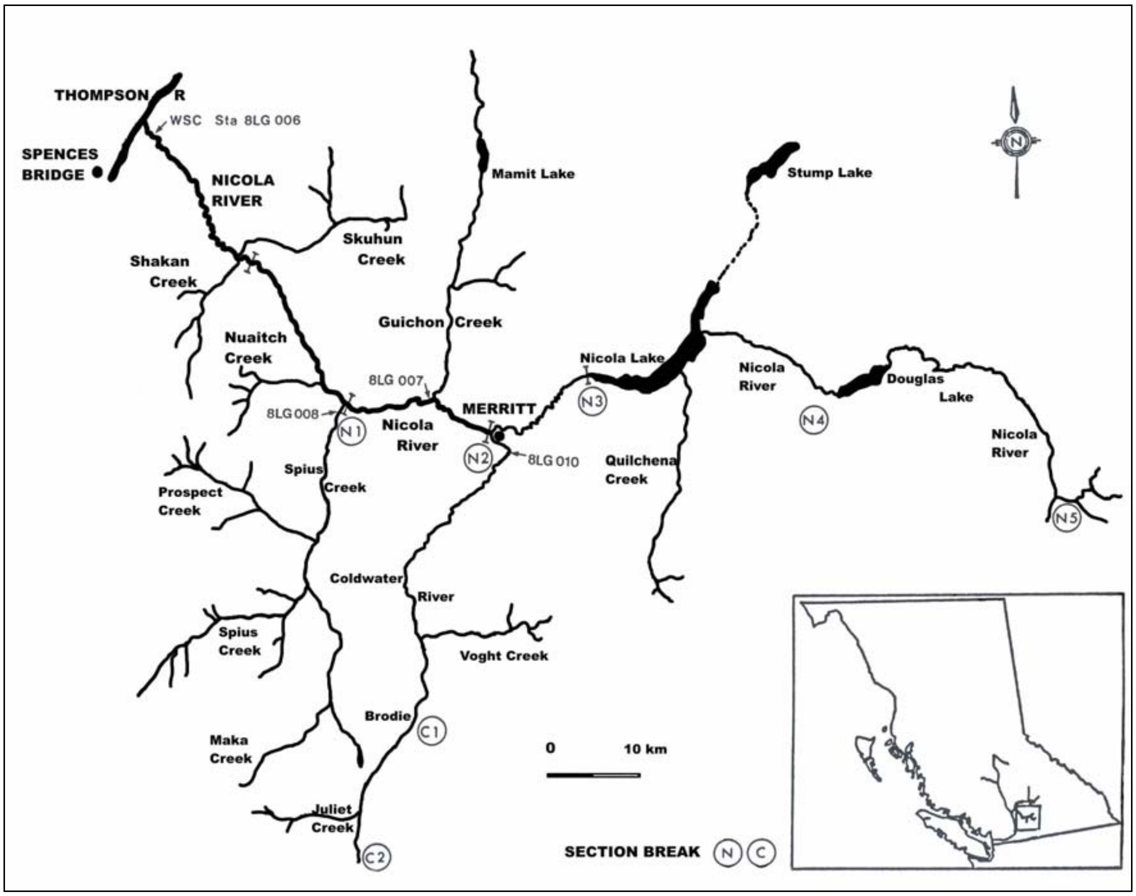
4.0 AN INTERIOR EXAMPLE: THE NICOLA RIVER WATERSHED

4.1 Geography and Hydrology

The Nicola River originates in the high country of the Douglas Plateau which, in turn, is part of the much larger Thompson Plateau in south-central British Columbia. It then winds its way down to the Thompson River at Spences Bridge over a distance of 150 km (Fig. 4.1). The Thompson Plateau has what is considered to be, a continental climate with temperatures ranging from minus 30^0C in winter, to plus 40^0C in summer.

Figure 4.1 The Nicola River basin.

Inset Shows area of study being British Columbia



The annual precipitation in the Nicola River basin varies from 15 to 75 cm (Shewchuk 1981). Most of the drainage tends to be more dry than wet, although the transition areas between coastal and interior zones in the upper Coldwater River (Fig. 4.1) and Spius Creek drainages can be quite moist in the spring and fall and have a considerable snow pack by the end of winter in most years. Hence, the snow accumulations in the higher areas are important in maintaining flows for many of the basin's streams during dry, and hotter periods of the year. The diversity of plant and animal life in this region is considerable and is partly a function of this high level of variation in geography, temperature and moisture.

The Nicola River is the primary stream in a basin comprised of a myriad of tributary streams (Fig. 4.1, 4.2) and more than 200 lakes. It has a widely varied terrain and range of elevations over an area of 7280 km^2. The altitude varies from180m above sea level to more than 2300 m. Low elevation areas on the rain-shadow side of the Coast Mountains are dry, while the higher areas tend to be wetter.

Figure 4.2 Flows in the Nicola River, March 2003.

Stream location just above the Coldwater River confluence; DFO specifies that required fish-flows released at dam must reach this point; about 50% of Nicola licensed water demand occurs between here and up to the dam. Photo courtesy of Alan Caverly.

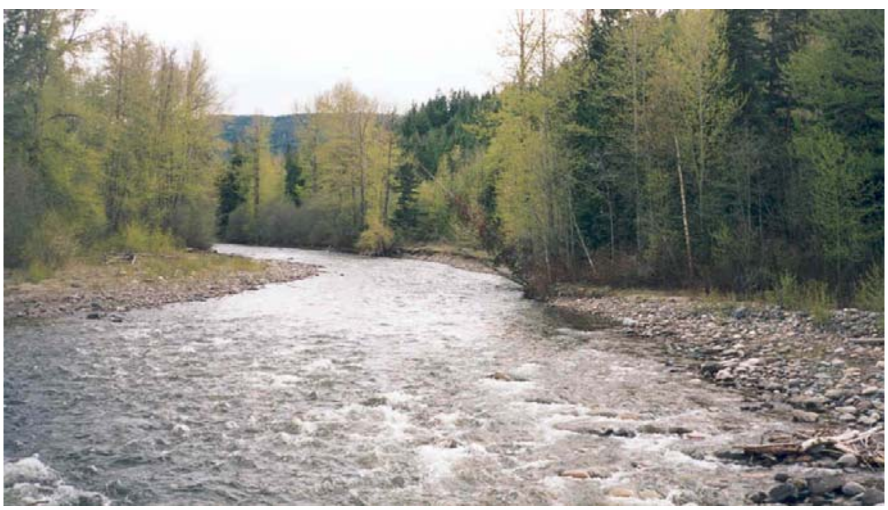
The Nicola River at Spences Bridge is a 6th order stream and has a mean annual discharge of almost 28 m^3/s (Canadian Hydrological Data © 1997, Environment Canada, Station 08LG006 at Spences Bridge). Most of the water flow in the Nicola River occurs during the spring-runoff period (Figs. 2.1, 2.2) although there are occasional years where large late-autumn/early winter floods occur. There are 138 water licenses on this stream and many more on tributaries of the Nicola, each of which authorizes water withdrawals; irrigation being the largest volume of water extracted. (Numbers of water licenses and physical detail for this section of the report are taken from: Ministry of Water, Land and Air Protection 2003.

Nicola Lake (Fig. 4.3) is the largest still-water body in the basin and comprises an area of 2490 ha. It has maximum and mean depths of 55 and 24 m, respectively. A control structure on the outlet of the lake (Fig. 2.12) allows for storage and withdrawal of water throughout the year as well as maintenance of flows downstream of this reservoir. This dam was initially constructed for hydro-electric power but has since been refurbished in 1986 for irrigation storage, flood protection, and fisheries flows. There are 13 water licenses on this lake.

Figure 4.3 Nicola Lake at the upper end looking to the north.

Douglas, Stump and Mamit lakes (Fig. 4.1) are also part of the Nicola River drainage and have surface areas of 660 ha (1 license), 70 ha (3 licenses) and 172 (13 licenses) ha, respectively. Spius Creek is the largest tributary to the Nicola River and has a mean annual discharge of 11 m^3/s and is a 5th order stream and has 6 water licenses. The Coldwater River (Fig. 4.4) the next largest, is a 5th order stream, and has a total length of 92 kilometers, with 34 water licenses on the stream proper. In contrast, the watershed as a whole has a sum total of 179 water licenses. The Coldwater River has a mean annual discharge of 8.75 m^3/s over 44 years of record since 1913 near its confluence with the Nicola River (Canadian Hydrological Data © 1997, Environment Canada, Station BC 08LG010 at Merritt).

Figure 4.4 Coldwater River near Kingsvale.



Other streams of importance in the Nicola River watershed include Clapperton Creek (0.56 m^3/s, 4th order, 30 km, 8 licences), Guichon Creek (1.0 m^3/s, 5th order, 81 km, 88 licences), Moore-Stump Creek (0.5 m^3/s, 4th order, 30 km, 43 licenses) and Quilchena Creek (0.75 m^3/s, 5th order, 93 km, 50 licenses).

It should be noted that water licenses have been issued in the Nicola watershed since 1871 (Starr 1977).

4.2 Human Settlement

Merritt is the largest town located within the Nicola River watershed area but smaller communities such as Lower Nicola, Quilchena and Logan Lake are also found there. The economic infrastructure relies predominantly on tourism, mining, forestry and ranching/agriculture.

The first human settlement in the Nicola River basin began after the last ice age and this area has been inhabited for thousands of years. Settlement by Europeans occurred in the latter part of the 19th century when the agricultural and ranching potential of the area began to be widely recognized (Shewchuk 1981). A community of Europeans was first established at the outlet of Nicola Lake in the late 1860's based predominantly on ranching. Road construction from 1875 to 1878 connected this area to Hope, Spences Bridge and Kamloops. The completion of the CPR in the 1880's led to the growth of the Douglas Lake Cattle Company and ranch, which is reputed to still be the largest of its kind in Canada.

In the early 1900's, the development of coal extraction at Merritt shifted the population base from the town of Nicola. Rail connections soon provided the stimulus for much of the growth in the Merritt area. However, as roads became better developed, the basin became more diversified in terms of its economic activities and forestry and recreation also became important. The development of the Coquihalla Highway in recent times has allowed the area to expand economically and increase in population.

It should be noted that water availability was the key to the settlement of the area over the ensuing years and particularly for the development of a thriving ranching and agricultural industry. In the 1980's the area of irrigated land was estimated about 10,000 ha and the water demands were supported by 70 storage reservoirs and in-stream withdrawals (Ministry of Environment 1983a). Because of the relatively dry nature of the basin, conflicts between water extraction for agriculture and fisheries values probably started to occur almost immediately as water began to be diverted for agriculture. These conflicts are recorded as early as the 1920's (Starr 1977).

Analyses have also suggested that this agricultural area in the Nicola River basin could be increased by 400% should more water become available for irrigation (Ministry of Environment 1983a). However, and it is the contention of this report, such water resources do not appear to be accessible without impacts to fish and the environment, and are unlikely to become available at any time in the near future.

4.3 Fisheries Values

The Nicola River basin is the home to some of British Columbia's more important upper Fraser River chinook runs, and some of the recently-listed endangered interior coho salmon populations. The lower Nicola River, near the confluence with the Thompson River, also has a small run of pink salmon (*O. gorbuscha*). A 1980's estimate of total-adult-salmon production, for all species, was about 30,000 fish (Table 4.1).

Table 4.1 A 1983 estimate of average salmon production from the Nicola River drainage.
Adapted from Table 3.6 of the Nicola Basin Strategic Plan Technical Document (Ministry of Environment 1983b) and reflects catch plus escapements.

Stream Section	Species	Estimated Adult Production
Nicola River	chinook coho pink	18,260 1,300 2691
Coldwater River	chinook coho	3,146 1,780
Spius Creek	chinook coho	745 924
Total	chinook coho pink	22,151 4,004 2,691
Total salmon		28,846

The Nicola River basin is also a key habitat for a population of the exceptionally large Thompson River steelhead. There are also other steelhead populations residing within the Nicola River basin that spend all of their lives in freshwater and may remain resident in the stream throughout their existence, or migrate between streams and lakes. Sebastian and Yaworski (1984) estimated that for this portion of the watershed, 75% of these *O. mykiss* are steelhead and the remaining 25% are resident rainbow trout.

Other species of fish in the Nicola drainage include bull trout (*Salvelinus confluentus*), Dolly Varden char (*Salvelinus malma*), Rocky Mountain whitefish (*Prosopium williamsoni*), longnose dace (*Rhinichthys cataractae*), bridgelip sucker (*Catostomus columbianus*), slimy sculpin (*Cottus cognatus*), prickly sculpin (*C. asper*), lake chub (*Couesius plumbus*), peamouth chub (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*), Pacific lamprey (*Entosphenus tridentatus*), leopard dace (*R. falcatus*), longnose sucker (*C. catostomus*), kokanee (a resident sockeye salmon—*O. nerka*), burbot (*Lota lota*), and carp (*Cyprinus carpio*) (Nelson et al. 2001)

4.3.1 Steelhead

The Thompson drainage steelhead (Fig. 4.5) are a particularly unique and prized race of anadromous trout in British Columbia. This is, in part, because they are large, very aggressive, and are readily caught on angler gear, including the fly rod and reel. Adult steelhead begin their upstream migration into the Fraser River at the end of summer, the run peaks in numbers during mid-autumn, and the steelhead carry on up to the Thompson River where they enter a winter-holding pattern. These fish then overwinter in the mainstem Thompson River from autumn until spring, and primarily between the confluence of the Nicola River and Lillooet, until they are ready to spawn. Then, during the spring, the various sub-stocks of Thompson steelhead migrate into their natal tributaries where they spawn.

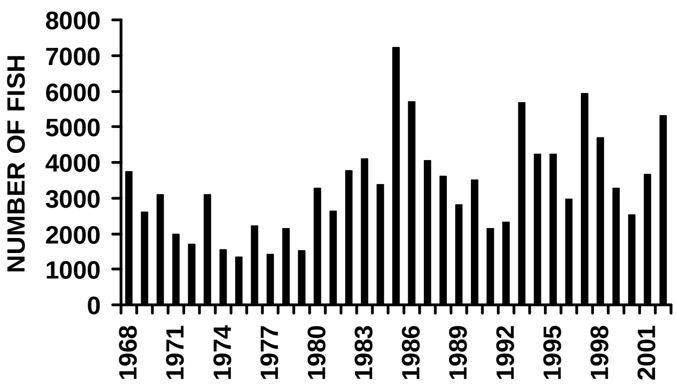
There have been no directed kill fisheries by anglers or commercial gear for wild Thompson River steelhead since the 1980's. First Nations have assisted by reducing the harvest of steelhead throughout the Fraser River downstream of Lytton. Furthermore, while there are no current hatchery programs releasing marked smolts, or fry, from this stock, there were releases of cultured fish during the 1980's. In British Columbia, anglers catching such hatchery-marked fish can usually harvest them as returning adults.

Figure 4.5 A Thompson River steelhead showing spawning colors.

Angler-catch-totals for the Thompson River Steelhead Angler Harvest Analysis, for the last 35 years, has ranged from a little over 1,000 fish to more than 7,000 steelhead landed (Fig. 4.6). In recent years, the estimated total number of fish caught is probably about 2 to 3 times the entire spawning escapement for the whole Thompson River watershed. This is, in part, because most fish are believed to be caught and released multiple times.

Figure 4.6 Numbers of steelhead caught by angling in the Thompson River drainage.

These data are from the British Columbia Ministry of Water, Land and Air Protection steelhead angler harvest analysis. Note that since the 1980's, most of the fish in this analysis were wild and were released unharmed.



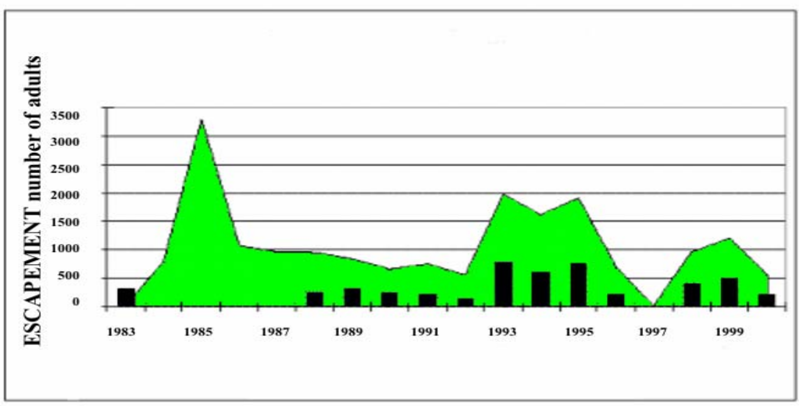
Some of these wild Thompson-drainage steelhead are nevertheless killed incidentally in the various commercial and First Nations net fisheries conducted along their coastal British Columbia migration route. This includes the autumn West-Coast Vancouver Island commercial fishery off the Nitinat River and the October/November lower Fraser River gillnet fisheries; both of these are primarily targeting chum salmon. Lower Fraser River First Nations food and sales fisheries also catch Thompson River steelhead incidentally during the latter part of the year (R. Bison, pers. comm.).

The sub-populations of steelhead predominantly use the major tributary streams of the Thompson River watershed for spawning and rearing. The Deadman, Bonaparte and Nicola river drainages are the three major tributaries to the Thompson River downstream of Kamloops Lake. The stocks therein each have their own subtle but unique life-history characteristics. These differences are thought to have a genetic basis. Only a limited component of this steelhead-stock-complex is thought to spawn and/or rear in the mainstem Thompson River. From a numerical perspective, the Nicola River is the most important of the Thompson River steelhead tributaries and the division amongst the three sub-drainages equals about 23% for Deadman River, 14% for Bonaparte River, and 62% remaining for the Nicola River over an 18-year assessment period (R. Bison, pers. comm.).

Steelhead escapement records for the Nicola River system go back to 1983 but they vary in quality. Estimated total numbers of steelhead spawning in the Nicola drainage ranges from 550 in 1992 to 3,300 in 1985, the year of best estimates, when aerial counts during the peak of spawning were conducted (Fig. 4.7). Adult steelhead are known to spawn, and their progeny rear, in the Nicola River proper, and its two main tributaries, the Coldwater River and Spius Creek. Some spawning and rearing also occurs in the smaller streams such as Guichon and Clapperton Creeks. However, these opportunities are severely reduced in the latter two streams due to the lack of water resulting from extreme diversion and abstraction. Excessive water use is thought to affect steelhead not only in these latter two tributaries but throughout the Nicola River drainage and this issue is the focus of this report.

Figure 4.7 Annual estimated steelhead escapements to the Nicola River watershed with the Coldwater River component segregated.

Figure taken from Nelson et al. (2001).



The majority of the adult steelhead in the Nicola River spawn and rear downstream of Merritt (Fig. 4.2), although some spawning and rearing occurs between Merritt and the Nicola Lake dam. A handful of fish usually make their way past Nicola Lake into the upper Nicola River, but this comprises a trivial component of the total production.

Millar et al. (1994) suggest that the most important contributors to total steelhead biomass (fry and smolt populations) included:

- Nicola River (68.3%)
- Coldwater River (13.2%)
- Spius and Maka Creeks (13.0%)
- Skuhun Creek (<5.0%)
- Nuaitch Ceeks (<5.0%)
- Guichon Creek (<5.0%)
- Shakan Creek (<5.0%)

In contrast, Nelson et al. (2001) suggest that in some years the Coldwater River may comprise the largest component of the Nicola River basin steelhead run, ranging from 23–42% of the whole drainage. Many of the best Coldwater River spawner-escapement estimates have been based, in large part, on helicopter observations and stream walks during years when the water clarity was quite good. However, due to the difficulty in seeing these fish as a result of turbid water conditions in the Coldwater River during spring runoff in many years, the most recent estimates are simply extrapolations from more accurate and precise estimates from other parts of the Nicola River basin and may not be nearly as good as in former years (Nelson et al. 2001; R. Bison, pers. comm.).

Steelhead are also known to spawn and rear in Spius Creek. Numbers of adult fish are estimated to range from 800 to 1,500 for those years where estimates have been made (R. Bison, pers. comm.).

Most of the Nicola River basin steelhead have had two to four years of freshwater rearing before going to sea (Nelson et al. 2001) and usually either two or three years of marine growth before returning to freshwater to spawn (R. Bison, pers. comm.). It is likely that the colder-water, higher-elevation Nicola River tributaries, such as the upper Coldwater and Spius, tend to produce more mature smolts because of the slower growth rates. Wightman (1979) suggested a steelhead yield for the Coldwater River of 8,000 smolts.

Some juvenile steelhead may be forced downstream and out of the Nicola River due to limited habitat availability; these fish may be rearing in the mainstem Thompson River. However, it is unclear exactly what role the Thompson River has in producing smolts from fish incubated in the tributary streams.

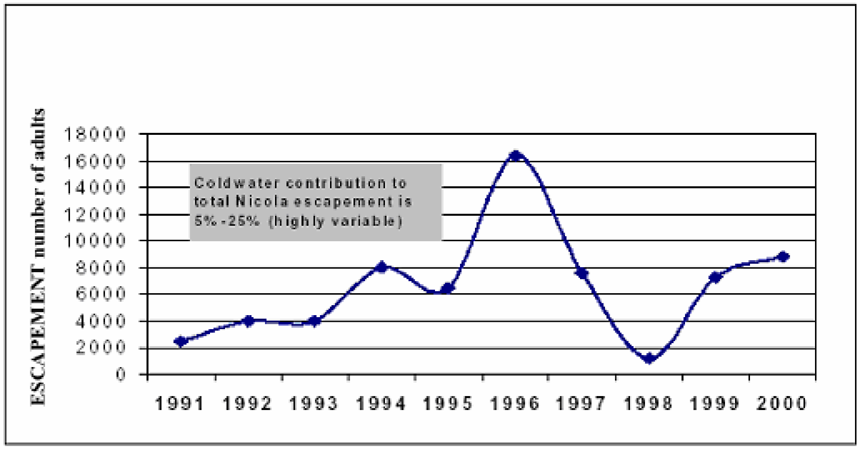
There were considerable hatchery releases of juvenile steelhead into some of the tributary streams in the 1980's to mid-1990's in an attempt to increase production (Nelson et al. 2001). This may have also somewhat confounded the understanding of the relationship between habitat and wild steelhead production.

4.3.2 Chinook

The Nicola drainage comprises an important facet of the Fraser River-watershed chinook salmon runs. There are three primary sub-watersheds where these fish spawn including the Nicola and Coldwater rivers, as well as Spius Creek, and considerable rearing of the juvenile fish also occurs in these natal streams. These chinook runs can further be categorized into earlier- and later-timed components, although by Fraser River standards both the "earlys" and the "lates" enter the Fraser ahead of most other runs, that is, by the end of spring.

The mainstem Nicola River below Nicola Lake, as well as upstream of the lake (Fig. 4.1), has both spawning and rearing fish, although the area below Merritt has the largest proportion of spawners (R. Bailey, pers. comm.). The Nicola River chinook salmon are late-summer/early-fall spawning fish. The escapement of chinook salmon into the Nicola River in recent years has ranged from about 1,000 to over 16,000 spawners (Fig. 4.8; Nelson et al. 2001).

Figure 4.8 Chinook salmon escapements to the Nicola River watershed.
Figure taken from Nelson et al. (2001).



Spius Creek and the Coldwater River are also significant habitats for spawning and rearing chinook. Based on run timing, there are two separate sub-populations of chinook salmon within these two watersheds. The earliest component of the Spius and Coldwater chinooks enters the streams during the spring around the start of freshet. The fish are known to hold over summer and they then start spawning in late July and/or early August (senior author's personal observation for the Coldwater River). The maximum number of spring-run chinook spawning in the Coldwater over the last two decades occurred in 1992 with 1,332 fish, while the lower-escapement-years had about 200 adults (Table 4.2). Spius Creek chinook numbers ranged from about 100 to over 500 adults during that same period (Table 4.2)

The early-timed chinook spawn in the Coldwater River upstream of the Coldwater Indian Reserve, while in the Spius Creek, the early component spawns in Maka Creek, a tributary of this stream. The later component of the chinook runs in these two sub-basins of the Nicola River watershed spawn in the lower reaches of the respective streams throughout September. Most of the adult chinook in Coldwater River and Spius Creek return to spawn age 4 and are therefore small-sized compared to most populations of chinook in the rest of the Fraser River watershed (Starr 1977).

Table 4.2 Escapements of spring-run chinook salmon for the Coldwater River and Spius Creek.

From Bailey et al. (2001); this report suggests that the harvest exploitation rate probably is at least a minimum of 33%.

Year	Coldwater River	Spius Creek
1986	450	425
1987	450	425
1988	220	120
1989	1050	565
1990	325	100
1991	325	248
1992	1332	250
1993	800	365
1994	400	162
1995	700	500
1996	unknown	500
1997	735	unknown
1998	230	300
1999	230	109
2000	715	432
Average	569	322

Nicola River basin chinook juveniles mostly spend one year in freshwater prior to migrating to the ocean. However, in the Nicola River basin there appears to be considerable amount of variability with regards to how much time they rear in their natal streams. Both Wightman (1979) and Beniston et al. (1987) suggest that there is significant downstream migration prior to winter and many of these fish may rear in the lower Nicola River, the Thompson River, or even the lower Fraser River.

In the 1980's, it was observed that many of the very small, recently emerged Coldwater River chinook fry were inhabiting the slow-water-perimeters of the main river in early spring during the high water in freshet. However, as the season progressed, these young-of-the-year chinook migrated into the main stream rather than staying in off-channel habitats, that were more conducive to juvenile coho. Movement of recently emerged young chinook temporarily into flooded riparian areas during the freshet period in the Thompson River drainage appears to be an important component of the productivity for this species. This behavior allows the young fish to access food and nutrients in a way that would not be possible if the floodwaters did not inundate these rich feeding areas, and the fish did not migrate into them accordingly.

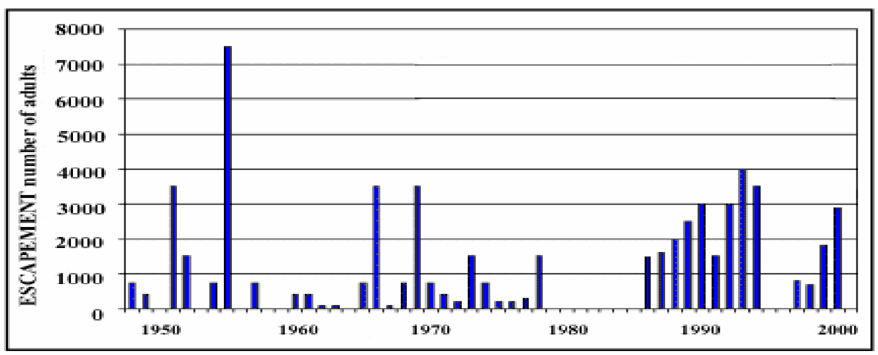
From 1985 to 1998, considerable numbers of early (spring) run chinook salmon juvenile fish were released by Fisheries and Oceans Canada from a number of Fraser River hatcheries including a facility at Spius Creek. While fry were released in the earlier years, all fish released from the Spius Creek hatchery since 1991, into both the Spius and Coldwater, were yearling smolts. The totals for Spius Creek numbered 143,625 while the Coldwater River releases included 535,263 fish and these releases included fish with coded wire tags. Bailey et al. (2001), and Nelson et al. (2001) provide summaries of recoveries of these tags in various fisheries along the coast and throughout the Fraser River and estimated harvest rates based on the observed tag frequency. These hatchery releases may be confounding the understanding of the relationship between habitat and returning adult fish.

4.3.3 Coho

Coho salmon are distributed throughout the Nicola River basin but in relatively small numbers. Adult spawners have been enumerated in the Coldwater River since 1948 and the majority of these records are from Fishery Officer observations (Fig. 4.9). Escapement records in the Coldwater River range from 7500 in 1955 to a low of 75 in 1967 although the records prior to 1998 are considered to be of questionable quality (Nelson et al. 2001). Millar et al. (1994) suggest that declines in coho populations appeared to be more serious than for chinook and steelhead. These coho, which are part of the interior Fraser River meta-population, have been recently listed as endangered by the Committee on the Status of Endangered Wildlife in Canada.

Figure 4.9 Coho salmon escapements to the Coldwater River.

Figure taken from Nelson et al. (2001).



Like chinook and steelhead, coho juveniles rear throughout this watershed. Unlike the other two species, they often use off-channel habitats such as beaver ponds that chinook and steelhead do not normally utilize, and particularly during the overwintering period. For the Coldwater River watershed, the majority of coho juveniles spend one year in this system before smolting (Wightman 1979, Beniston et al. 1987) although the numbers of two year smolts is not insignificant in some of the colder, and less productive, parts of the watershed (Author's observations; Swales et al. 1986, Swales and Levings 1989).

Wightman (1979) estimated the summer standing stock in the Coldwater mainstem to be 165,000 fry and 16,500 parr. Off-channel ponds in the Coldwater and Nicola rivers can have high juvenile coho densities, particularly during the winter, and up to 2.8 fish/m^2 (Swales et al. 1986, Swales and Levings 1989).

4.4 Flow Issues in the Nicola Basin

Because of the naturally dry conditions throughout much of the Nicola River drainage, significant changes to the flows within this watershed during low-discharge periods have the very real probability of affecting its fish-production capacity. Thus, it is important to be concerned about abstraction of water from the streams in this basin especially during late summer with respect to salmon and steelhead juvenile rearing, and during the winter when embryos and alevins are incubating in the gravel redds.

4.4.1 History

Conflicts between fish and agriculture for water in the Nicola River basin have occurred for some decades (Starr 1977, Fleming and Nathan 1985, Petrie 1986). One of the earliest clashes between fish and agriculture was over small juveniles being diverted out of the streams and into the hayfields due to a lack of screening at the irrigation intakes (Fleming and Nathan 1985, Petrie 1986). This situation appeared to result in high losses and significant mortality for the young salmon and steelhead that were being entrained.

The Canada *Fisheries Act* can require screening to prevent the entrainment of fish into irrigation canals. However, rather than prosecuting the ranchers under the Canada *Fisheries Act*, the Fisheries and Oceans Canada tended to take a softer approach in the Nicola River basin by attempting to work cooperatively with the landowners at the problem locations in order to resolve the issues, and find solutions, including funding. One issue was that the earliest irrigation intakes did not normally utilize even simple screening methods due to the difficulties in keeping the screens clear of debris and silt. Solutions to this problem came in the form of technological advancements and included the development and installation of the "Finnegan screen", a low-maintenance, gravity-fed self-cleaning device constructed on the diversion intakes in order to prevent fish from entering the irrigation waterworks. Many of these mechanical screens were installed within the Nicola River drainage between 1973 and 1985 (Fleming and Nathan 1985). Nevertheless, some intakes in this watershed are still lacking screens and fish are still being entrained onto fields or otherwise into the irrigation infrastructure and are being killed. In other instances, the screening-structure has been allowed to fall into disrepair allowing fish access (A. Caverly, pers. comm.).

Figure 4.10 Open ditch conveying water at Nicola Lake.

Another historic water-extraction issue impacting on fish in the Nicola drainage is that some of the instream diversion-dams, routing water from the stream into the irrigation ditches, also blocked access to spawning and rearing grounds (Fleming and Nathan 1985). In fact, some of these dams would occasionally stretch across the stream channel and in doing so block upstream fish passage. Furthermore, as flows became lower and lower, the rancher would continue to make the dams larger in order to divert more water making this obstruction even more difficult for the fish to traverse. Millar et al. (1994) indicate that there were 13 such major irrigation diversions along the mainstem Nicola River in the 1980's. Some of these dams have now been replaced by a sump and pumping systems, and Canada Fisheries and Oceans indicates that this situation has now mostly been resolved (A. Wall, pers. comm.).

Figure 4.11 Modern water intake on the Nicola Lake.

Photo courtesy of Alan Caverly, Ministry of Water, Land and Air Protection, Kamloops.

Still another water-issue that historically impacted on fish in the Nicola River basin included the simple but wasteful irrigation practices often employed in getting water into fields. Many irrigation facilities consist of a simple gravity-fed ditch running from the diversion intake and on down to the fields. Many of these ditches were not particularly efficient at conveying water (Fig. 4.10). Petrie (1986) indicated that up to 50% of the diverted water can be lost to seepage and evaporation from these conveyance channels before it gets to its intended destination. The replacement of some of these older techniques by more modern and sophisticated technologies, using pumps (Fig. 4.11), screens and sprinkler systems (Fig. 4.12), has reduced the direct mortality of fish and water-waste. However, some of these older and inefficient methods are still in use (A. Wall, pers. comm.).

Water extraction in the Nicola River basin has also had a probable impact on the system's water temperature. Low flow events exacerbated by high rates of withdrawal have increased high water temperatures during the summer. For a number of the streams in the watershed, including the Nicola and Coldwater rivers, empirical observations have shown that in some years there have been highly elevated water temperatures during the very warm and low-flow periods of summers.

Figure 4.12 Sprinkler systems upstream of Nicola Lake.

High extraction levels are thought to have contributed to the warming of the water. Extensive loss of riparian vegetation on ranchland riparian areas adjacent to streams has probably exacerbated the situation as has the removal of the shade trees along the stream banks (Fig 4.13). These high temperatures have, on many occasions, been recorded at lethal, or near-lethal, levels for juvenile salmon and steelhead.

Figure 4.13 Middle Coldwater River and hayfields view from the Coquihalla Highway.

Note loss of natural vegetation, including trees, shrubs and other wild plants, along the banks of the river, being replaced by low field grasses. This has resulted in a loss of riparian vegetation which is important for summer shading and cooling of the water, insect and leave drop for fish food and nutrients, and root structure which is important in maintaining the bank integrity.

For the Coldwater River, Walthers and Nener (1998) assessed water temperatures and found that the stream actually reached temperatures of up to 29^{o}C in 1994, an exceptionally warm summer. A report of 25^{o}C was recorded during the "normal" summer of 1995 (Nelson et al. 2001). Temperatures above 20^{0}C are generally sub-optimal for most salmonids, with 25^{0}C generally approaching lethal limits. Fisheries staff in the British Columbia Ministry of Water, Land and Air Protection office feel that short-term survival was possible at those locations where colder-water refugia (groundwater extrusions) were present in the Nicola River (A. Caverly, pers. comm.).

Fisheries and Oceans Canada staff have also routinely seen stress-level temperatures in the lower Nicola River during late summer when adult chinook salmon are attempting their upstream spawning migration. Substantial pre-spawning mortalities for adult chinook salmon were seen during the 1998 spawning run, also a period of particularly warm temperatures (R. Bailey, pers. comm.).

Despite the above-mentioned issues, the primary concern regarding water use and fish in the Nicola River basin is that extraction of water from many of the streams has been viewed as excessive during low flow periods. Too many times, inadequate flows may have occurred for either instream rearing juvenile fish, adult migration or the incubation of embryos and alevins, based on local fisheries management observations. Furthermore, flow issues may have worsened on occasion as a result of non-compliance by water license holders, be it intentional or otherwise, and in the absence of comprehensive compliance monitoring in this watershed. A lack of resources to carry out such compliance assessments is a common theme.

The core problem relating to low flows and salmon and steelhead revolves around the sustained growth in demand for water as a result of an expanding population in the basin throughout the latter part of the twentieth century. Increasingly more water was being sought and allocated, with little regard for habitat capability or the environmental stresses and consequences for fish.

In order to provide greater opportunities to utilize water in the basin for human use, especially during the low-flow periods, reservoirs were built throughout the watershed in order to store the spring-freshet discharge for use during late-summer droughts. However, as human settlement continued to grow, this was not sufficient to deal with the fish flow crisis that was emerging and it became clear that governments were going to have to deal with the situation.

By the early 1980s, there was a shortage of water for irrigated and cultivated lands in the area, and the survival and production of salmon, steelhead and other fish in many of the streams within this basin. During a particularly dry period in 1977, the conflict between irrigation and fish in the Nicola River basin came to a head when the BC Department of Fisheries decided in one instance to take legal action to protect minimum flows for salmon and steelhead at the possible expense of agriculture.

By the early 1980's, the amount of water licensed for extraction from the streams throughout the Nicola River watershed was about 64,000 dam^3 per year. While the total volume of water yield in the basin of 947,000 dam^3 per annum far exceeded the demands (Table 4.3), much of the water yield flowing through the system in an average year discharges primarily during spring freshet and not when it is required for irrigation during the dry, hot and low-flow late summer period (Figs. 2.1, 2.2). Furthermore, the geographic distribution of water was not proportional to demand by agriculture (e.g., Spius Creek was still considered to be a very water rich but has little irrigation demand; Table 4.3)

The development of more storage reservoirs was viewed as one likely solution to the problem of low flows. While extraction for agriculture comprised a licensed allocation of 53,000 dam^3 , only around 35,000 dam^3 of this amount was being stored in reservoirs for use by agriculture during the dry period of the year, based on a 1983 analysis. However, this solution has technical difficulties due to the topography of the basin, as much of the freshet water cannot be stored, regardless of intent.

Table 4.3 Average yearly water supply and demand in the Nicola watershed as outlined in the 1983 Nicola Basin Strategic Plan.

This table taken from Table 1 of the Nicola Basin Strategic Plan Summary Document (Ministry of Environment 1983a). Average annual flow from historical records; licensed diversion from Water License Records. 1 acre-foot = 1.2335 dam3. Upper Nicola is above lake; Middle Nicola is from lake downstream to Merritt; Lower Nicola is from Merritt to Spences Bridge.

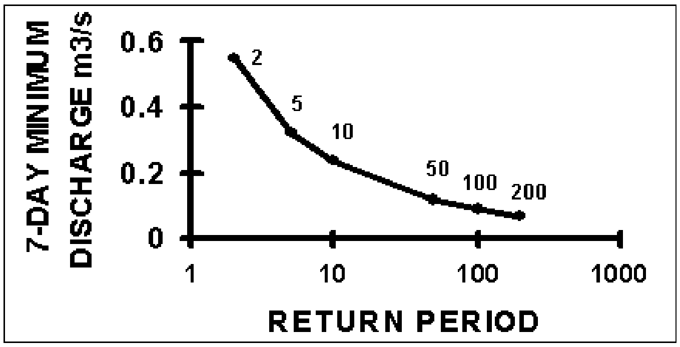
Watershed	Accuracy of Flow Estimates	Supply		Demand				
		Total Estimated Natural Supply	Mean Annual Flow	Licensed Diversions		Licensed Storage		Fishery Maintenance Flows
		dam^3	m^3/s	Irrigation dam^3	Other dam^3	Irrigation dam^3	Other dam^3	m^3/s
Upper Nicola	Good	133,000	3.92	9,650	105	10,500	0	0.80
Middle Nicola	Good	83,200	2.28	13,200	85	680	22,850	1.70
Lower Nicola	Good			9,600	2,420	0	0	4.9
Quilchena	Fair	24,300	0.752	590	0	5,000	0	n/a
Moore-Stump	Poor	17,100	0.482	1,925	0	5,460	0	n/a
Clapperton	Poor	21,400	0.564	2,900	0	3,080	0	0.14
Guichon	Good	40,800	0.990	6,810	2,820	7,800	940	0.20
Coldwater	Good	287,000	8.81	6,960	4,140	1,290	10	1.42
Spius	Good	353,000	11.1	1,625	1,625	75	0	2.22
Total		**947,000**	**28.8**	**53,260**	**11,195**	**34,625**	**23,800**	**11.40**

Numbers of Watershed Storage Licenses	Irrigation Licenses	Irrigation Applications	Other Licenses	Other Applications	Totals
Upper Nicola	12	0	0	0	12
Mid/Lower Nicola	7	2	0	0	9
Quilchena	13	0	0	0	13
Moore-Stump	15	3	0	0	18
Clapperton	1	0	0	0	1
Guichon	46	11	5	4	66
Coldwater	17	3	1	0	21
Spius	2	1	0	0	3
Totals	**113**	**20**	**6**	**4**	**143**

It is also important to remember that even though two thirds of the water licensed for diversion in the 1980's was being backed up by storage, in the all-too-common dry years the base flows are considerably less than the average flows, and this becomes a problem as the amount of water that is permitted to be diverted by license in any given year does not decrease concordantly with the stream volume decreases during a low-flow year. Furthermore, for the most part there are no water-conservation conditions imposed on licenses to offset drought conditions. In fact, in very dry years (e.g., Coldwater River, Fig. 4.14) the demand and extraction of water, legal or otherwise, is likely to be more intense than under normal or wet years.

Figure 4.14 Seven-day minimum daily discharge return period of Coldwater River for August/September.

Adapted from Nelson et al. (2001). Numerals next to the functional relationship refer to specific return periods. Note how little water needs to be withdrawn from the river during low flows in order to dry this stream up.



Even today, the problem of licenses that are not backed up by adequate storage persists. As an example, the most recent analysis of licensed use of water in the Coldwater River watershed indicates that this sub-basin has a total of 179 final or conditional licenses for storage and diversion of water. However, while the diversion demand is 7,765.4 acre-feet, this volume is only backed up by 2,053 acre-feet of storage, or 26.4% of the required amount (Table 4.4; Nelson et al. 2001).

4.4.2 Nicola Basin Strategic Plan

In an attempt to resolve this serious environmental issue, in 1983 the BC Ministry of Environment, then the provincial agency in charge of issuing and enforcing compliance of water licenses, completed the Nicola Basin Strategic Plan in co-operation Fisheries and Oceans Canada and other participants and stakeholders. The main purpose of the plan was to provide guidelines for the future allocation and management of water in each of the sub-basins of the Nicola River basin according to specific stated objectives.

The planning process involved: 1. an analysis of the hydrological characteristics of the basin, 2. a fish instream-flow-needs assessment, and 3. an assessment of the current and predicted requirements of water for human use. The hydrological model was one that had been been developed previously for this watershed (Bajard 1980; Ministry of Environment 1983a,b). Also, in conjunction to the water-use assessment process, the governments joined in assessments of fisheries productivity and habitat requirements in the Nicola Basin as a complementary adjunct to this exercise (Sebastian and Yaworski 1984; Kosakoski and Hamilton 1982).

Table 4.4 Water licensing summary for the Coldwater River drainage.
From Nelson et al. (2001).

Licence	Demand acre-feet	Number of Licences
Diversion		
Irrigation	5,033	71
Waterworks	2,673	7
Domestic	58	69
Other	1.4	1
...Stock watering	**7,765.4**	1
...Lawn watering		**149**
Total		
Storage		
Irrigation	1,459	23
Conservation	594	7
Total	**2,053**	**30**
Outstanding Applications		15
Diversion Breakdown	**Diversion Only (ac-ft)**	**All Licences**
Voght Creek	23.5% (1825)	50
Godey Creek	4.6% (357)	23
Midday Creek	5.0% (388)	13
Brook Creek	1.1% (85)	45
Coldwater River	65.7% (5,102)	48
TOTAL		**179**

The fisheries agencies used IFIM methodology to predict the amount of water required to optimize fish production, and the fish flow study suggested that the production of salmon and steelhead could be substantially increased by almost 200% and 400%, respectively, simply by increasing discharges for juvenile rearing during the low flow periods (Tables 4.5, 4.6). The most stream-oriented of the three species, the steelhead, was predicted to have the greatest potential rate of gains in production.

Another feature of the analysis indicated that streams such as Spius Creek, which only had relatively modest diversions, projected very large gains in smolt numbers with increased flows (Table 4.6). This suggested that some of these streams were already impacted by naturally low discharges in the late summer and any further reductions in flow would have an immediate negative impact on salmonid productivity.

The Nicola Basin Strategic Plan also came up with a number of conclusions. For example, it was recognized that much of the economic activity in the Nicola Basin depended on an assured water supply. The Plan was very clear that the consumptive use of water in some smaller watersheds had already approached the maximum amount of water available for non-instream uses. It also suggested that some of the low-flow shortages could possibly be met by storing water during the spring run-off behind dams, or making better use of the existing reservoir facilities. Subsequent experience has now shown that these opportunities are quite limited due to topographic constraints.

Table 4.5 Summary of actual and potential salmon production in the Nicola River drainage

Based on existing and suggested fisheries maintenance flows recommended in the 1983 Nicola Basin Strategic Plan Technical Document. Adapted from Table 3.6 (Ministry of Environment 1983b) and reflects catch plus escapements. Note that current estimates of production may be very different than those tabled in 1983.

Stream Section	Species	Estimated Existing Adult Production (as of 1983)	Predicted Optimum Adult Production with Suggested Maintenance Flows	Percentage Change in Production
Nicola River	chinook coho pink	18,260 1,300 2691	28,000 2,850 2691	153% 219% 0%
Coldwater River	chinook coho	3,146 1,780	6,000 9,000	191% 506%
Spius Creek	chinook coho	745 924	3,000 1,800	403% 195%
Total	chinook coho pink	22,151 4,004 2,691	37,000 13,650 2,691	167% 341% 0%
Total Salmon		**28,846**	**53,341**	**185%**

The Nicola Basin Strategic Plan suggested that the greatest demand for water was in the low flow period (July – September). However, incubation low-flows in the Nicola River in the winter have also now been shown to be an important consideration (A. Caverly, pers. comm.). It appears that more water is needed than is available to support both irrigation systems and instream flows for rearing and migrating anadromous fish if all factions were to be satisfied and optimized. In a water-scarce region like the Nicola Basin this is difficult to achieve.

The Plan also pointed out that inefficient irrigation practices resulted in higher-than-necessary withdrawals of water from streams. In an attempt to provide options for all user groups, the analysis showed that there were limited water yields in some watersheds with high potential for agricultural development.

Specifically, and stream by stream, it was the opinion of the drafters of the 1983 Plan that the following analysis reflected flows opportunities and demands for water throughout the drainage:

Upper Nicola, Quilchena and Guichon

- all licensed diversion requirements were being met
- in-stream flows for fisheries were not met except in wet years
- there was potential for more storage to support increased irrigation and/or fishery flows (however, the storage options, such as in Douglas Lake, might involve technical, environmental and social conflict)

Middle and Lower Nicola, Coldwater and Spius

- all licensed diversion requirements were being met
- Nicola Lake storage (originally licensed for power, not irrigation) now provides upstream storage support for licensed diversion and fisheries requirements on the Nicola River

- in-stream fishery flows are met in average runoff conditions with current levels of storage on Nicola River; under drought runoff conditions significant shortfalls occur (1:10 year return period)
- potential exists for increased storage and irrigation development
- no additional diversions could occur without affecting in-stream flow requirements unless supported by storage

Clapperton, Moore, Stump

- licensed diversions are not met in dry years
- in-stream flows for fisheries are not met except in wet years
- little surplus water or storage potential exists

Table 4.6 Detailed summary of actual and potential steelhead production in the Nicola River drainage

Based on existing and suggested fisheries maintenance flows recommended in the 1983 Nicola Basin Strategic Plan Technical Document. Adapted from Table 3.5 (Ministry of Environment 1983b). Note that we have revised the estimated 12% marine survival provided in the Technical Document to a more realistic 5% given existing current ocean productivity.

Stream Section	Relative Fisheries Value	Estimated Existing Smolt Production (as of 1983)	Resulting Adult Production at 5% Ocean Survival Rate	Suggested Fisheries Maintenance Flows m^3/s	Optimum Smolt Production with Suggested Maintenance Flows	Predicted Resulting Adult Production at 5% Ocean Survival Rate	Percentage Change in Production
Lower Nicola downstream point	H	41,000	2,050	5.66	1000,000	5,000	204%
upstream point				3.12			
Middle Nicola	L-nil	0	0	1.70	0	0	—
Upper Nicola	L-M	0	0	0.80	13,000	650	Substantial increase over 0
Coldwater	H	2,200	110	1.42	40,000	2,000	1818%
Spius watershed	H	6,800	340	2.22	25,000	1,250	3676%
Guichon	M	1,800	90	0.20	12000	600	667%
Skuhun	M	375	19	0.14	4,000	200	1053%
Skahan	M	0	0	0.09	0	0	—
Nuaitch	M	800	40	0.14	800	40	0%
Clapperton	M	300	15	0.14	1,600	80	533%
TOTAL		**53,275**	**2664**		**196,400**	**9820**	**368%**

As a result of this exercise, the Nicola Basin Strategic Plan recommended a management strategy to improve water supply and water quality controls. The Plan recognized that for all watersheds of the Nicola basin, the water was already fully allocated either to irrigation licensed users or to fisheries. That meant that no further licensing for water in any stream should be permitted without the support of additional storage.

The Plan also recommended that the then-current licenses could extend their irrigated acreage somewhat through the more efficient use of volumes of water already licensed but it was recognized that this would restrict future irrigation expansion to a few areas in the basin.

Water-supply management was expected to be achieved by:

1. devising institutional arrangements to finance, construct and operate new storage,
2. increasing hydrometric monitoring in selected tributary streams to improve water yield estimates for future storage development and resulting water allocation, and
3. the monitoring of licensed users to encourage more efficient use of water.

While not emphasized in the report, it was recognized that users were diverting more than was permitted by licenses and the only way to rectify this was to have more extensive flow monitoring during water diversion.

The Plan recommended included protecting anadromous fish by having minimum in-stream flows for fish as follows: in the Coldwater—1.42cms, for Spius Creek—2.22cms, and in the Nicola River flows should be as follows: N1 5.66cms, N2 3.12cms, N3 1.70cms (see Fig. 4.1 for locations). It was recommended that the Ministry of Environment should monitor selected diversions in the basin to ensure compliance with existing water license conditions. The Ministry was also tasked with designing a detailed contingency plan for allocating water between licensed users and fishery interests in the event of a major drought. The Plan also recommended that the agencies should examine switching diversion points from the lower reaches of some tributaries (Guichon, Clapperton for example) to the mainstem Nicola River in order to increase the production in the smaller streams. Stored water in Nicola Lake was expected to provide the alternative water for these requirements, and the water would be pumped to the required locations.

The development of water storage was an important consideration in the restoration and maintenance of fish populations in the Nicola River drainage. The Plan recommended that storage development in Nicola Lake be given first priority with the dam structure at the outlet of be repaired or replaced immediately. The Plan stated that hydrologic data for this part of the watershed were adequate for designing the storage structure and operating the facility, although subsequent analyses cast doubt on this opinion.

In the final analysis, it was the opinion of the Plan there should be enough water to supply the multiple needs of fisheries, stream water improvement and irrigation. Furthermore, it was viewed that, if institutional arrangements could be developed to construct and operate the dam on Nicola Lake, this would provide the basis for development of additional storages on other tributary streams in the future.

4.5 Post-Nicola Basin Strategic Plan Activities

Subsequent to the development of the Nicola Basin Strategic Plan, there were a number of actions and issues worth noting;

1. Water licenses were still being issued despite the recommendation that there be a moratorium on allocation if the extraction was not backed up by storage; however, the rate of license issuance appeared to decline significantly in the years following the development of the plan.
2. Some notable license applications were refused, to the credit of the water management agencies, including some significant proposed diversions for Guichon Creek The water licensing authorities began to assign more weight to fish conservation values in their evaluation.
3. Some compliance monitoring did take place subsequent to the recommendations of the plan but it was neither comprehensive nor adequate. Nevertheless, irrigators upgraded their works and are now using sprinkler systems and other more modern technologies for delivering water in more efficient and environmentally beneficial ways.
4. There were a number of fisheries topics addressed subsequent to the implementation of the Plan. It became clear that the portion of the Nicola River between the dam and Merritt was being heavily used by spawning and rearing fish, particularly by chinook salmon, and this had not been clearly articulated by the Plan (c.f., Table 4.6). The Plan did not have enough information to acknowledge the high fisheries value of this part of the watershed nor manage for adequate flows, including spring freshet requirements. This oversight appears to have been a major flaw in the Plan. The Plan also did not deal with the role of sediment-flushing flows during the spring freshet that maintain gravel quality particularly between Merritt and the Nicola Lake dam.

Also, a considerable amount of work was undertaken by fisheries scientists in the field of Instream Flow Needs subsequent to the completion of the Plan. The efforts by Kosakoski and Hamilton (1982), using IFIM-like methodology to calculate the flow regimes recommended by the Plan, now require updating given that 20 years of increased scientific understanding has occurred since then. Still, as another example is the role of spring inundation of the riparian zones for the early life-history of juvenile chinook salmon was not articulated in the Plan, yet large areas of productive habitat are not being fully utilized without a freshet flow (Fig. 4.15). Having said this, however, most of the basic aspects of the outcome of the original fisheries studies (e.g., Kosakoski and Hamilton 1982) on which the Plan was based study are consistent with the more recent professional opinions and the added British Columbia Modified Tennant approach to habitat capacity in this watershed (A. Caverly, pers. comm.). In short, the fish need water that has not been available.

An updated effort to understand the hydrology of the basin was also undertaken. Rood and Hamilton (1995) attempted to calculate the amount of water available in the Nicola River basin by constructing “naturalized” flows for the watershed, from the confluence of the Thompson River and upstream, adding up all of the base flows and extraction amounts (Table 4.7). Of note, for some of the streams, considerable differences were evident between the Rood and Hamilton calculations(1995) and the values contained in the Nicola Basin Strategic Plan. The Rood and Hamilton (1995) values also differ from current analyses being undertaken for the mainstem Nicola River relative to proposed operations of the storage dam at Nicola Lake (A. Caverly, pers. comm.). These inconsistencies amongst different analyses highlight the requirement to undertake a comprehensive hydrological evaluation and updating of the Plan. Despite the inconsistencies, Rood and Hamilton (1995) still show that natural flows in this stream during low-flow periods are often less than the 20% mean annual discharge, and routinely less than 10% on some of the streams (Table 4.7); flows that the models indicate are not optimal for fish production.

Figure 4.15 Floodplain of the Nicola River between Merritt and Nicola Lake during the spring of 2003.

Note that the storage of spring-runoff behind the dam on Nicola Lake diminishes the habitat capacity of these wetland areas by reducing the magnitude of the freshet flows at a time of the year when juvenile salmonids would normally use these food-rich inundated areas. This wide area of the floodplain should be flooded in the spring providing exceptional fish habitat yet it not longer normally is because the freshet waters are now being trapped behind the dam for allocation throughout other parts of the year.

Table 4.7 Summary of pertinent fish flows and water diversions for selected streams in the Nicola basin.

*From Rood and Hamilton (1995). Flow estimates are in m³/s, and are naturalized, which means that the data presented are estimates of discharges that would occur in the absence of all upstream water extractions, with accounting for storage flows. Note that the period of record is 1980 to 1989, which varies somewhat from WSC long term records for the respective gauges. * = remaining flows less than 20% mean annual discharge, which is viewed as good for juvenile salmonid rearing. Summer 7 day low flow – the lowest average flow for 7 consecutive days.*

Stream	Mean Annual Flow	20% Of Mean Annual Discharge	Licensed Demand August	Mean Monthly Flow August	Mean 7-Day Low Flow Summer	Remaining Flow, After Extraction, During 7-D Low-Flow Period: August	Remaining Flow % Of Mean Annual Discharge After Extraction: August
Nicola R	22.7	4.54	0.93	16.67	10.25	10.25 – 0.93 = 9.32	41.1
Spius Ck	9.33	1.87	0.02	1.85	0.98	0.98 – 0.02 = 0.96	10.3*
Maka Ck	2.6	0.52	0.00	0.51	0.24	0.24 – 0.00 = 0.24	9.2*
Coldwater R	7.42	1.48	0.79	2.02	1.16	1.16 – 0.79 = 0.37	5.0*
Spahomin Ck	0.62	0.12	0.52	1.03	0.38	0.38 – 0.52 = -0.14	0.0*
			Licensed Demand Sept	**Mean Montly Flow Sept**	**Mean 7-Day Low Flow Summer**	**September**	**September**
Nicola R	22.7	4.54	0.59	11.77	10.25	10.25 – 0.59 = 9.66	42.6
Spius Ck	9.33	1.87	0.01	1.41	0.98	0.98 – 0.01 = 0.97	10.4*
Maka Ck	2.6	0.52	0.00	0.39	0.24	0.24 – 0.00 = 0.24	9.2*
Coldwater R	7.42	1.48	0.52	1.53	1.16	1.16 – 0.52 = 0.64	8.6*
Spahomin Ck	0.62	0.12	0.31	0.40	0.38	0.38 – 0.31 = 0.07	11.3*

The institutional and technical re-arrangement of water extraction from the tributary streams to the Nicola River, meant to allow these streams to regain their fisheries productivity, never occurred. The proposal was to develop storage on the Nicola River in Nicola Lake, re-assign the point of diversion for some of the smaller streams to the Nicola River, and then pump the water up from the Nicola River to where it was needed for irrigation. This would have allowed the natural discharges in the smaller streams to flow all the way to the Nicola River without being extracted, yet still allow the license holders to retain their legal amount of water. This would have benefited fish in Guichon Creek, in particular.

Finally, a new dam was constructed at the outlet of the Nicola Lake in 1985. An operating plan was developed for the Nicola Dam and the Nicola Lake reservoir by the Ministry of Environment and Parks in 1987 (McNeil 1987). However, the recommended dredging of a channel in Nicola Lake to allow for greater drawdown was never undertaken, and 5 out of 8 years the downstream fish flow targets were not being met. The 1983 Plan did not fully understand water availability in the Upper Nicola watershed and discharges have fallen short of expectations. Furthermore, the development of an appropriate operating system for release of water has become far more complicated than expected.

4.5.1 Development of the Nicola Dam and Flow Releases

A dam was built in 1927 at the downstream end of Nicola Lake (Figs. 2.12, 4.1) for power generation and irrigation. Over the years, and by the time that the Nicola Basin Strategic Plan had been put in place, the dam had become dysfunctional due to a lack of repair, but there were still irrigation, fisheries and flood-flow-protection benefits to be gained in 1985 by rebuilding and operating of this structure with new rules for flow releases.

This included the 1.7 m^3/s fisheries-rearing flows be released from the dam between August and November and 1.13 m^3/s incubation flows from December to April that Kosakoski and Hamilton (1982) recommended. Also, the Nicola River between Merritt and the dam had a considerable silt problem due to groundwater boils flowing into the stream that resulted from the high levels of irrigation in the immediate area. Kosakoski and Hamilton (1982) further recommended flushing flows to clear this material from spawning gravels. Thus, the dam was viewed by the Nicola Basin Strategic Plan to be an important component in providing flows for fish and increasing water allocation to irrigation interests. It recommended flows similar to those proposed by Kosakoski and Hamilton (1982) (Ministry of Environment 1983a,b).

In 1985, the new dam, partly paid for by the Department of Fisheries and Oceans, was constructed at the outlet of Nicola Lake for the joint benefit of the farmers, ranchers and fisheries (Fig. 2.12). Department of Fisheries and Oceans obtained access by license to about 1/3 of the stored water for fish, with the rest allocated to the Province of British Columbia for further allocation. Part of the rationale for developing this project was to allow water withdrawals downstream of the dam to occur on the Nicola River rather than on these highly productive tributary streams such as Guichon Creek where licensed extraction had become excessive. Water storage in the lake would also be available for fish-base flows as per the suggestions by the Kosakoski and Hamilton (1982) Instream Flow Needs study and the recommendations by the Nicola Basin Strategic Plan.

Experience has shown that subsequent to the construction of the dam the potential water storage benefits have been limited by two conditions. The first is that dredging of the channel at the lake outlet, which would have allowed for more storage and negative drawdown, has not been completed. The second is that there are now private property constraints (flooding), possibly not warranted, on maximum lake levels.

Under the original dam-design concept and proposed operating orders, the outlet to the lake would have been dredged in order to access negative storage, which is water below the normal lake elevation. This was never undertaken and may never be. This is partly due to the fact that this action, combined with the system operations of drawing down the lake, may constitute a harmful alteration, disruption or destruction of fish habitat along the littoral areas of the lake. The shallow, productive areas of the lake would be dried out for long periods in the spring, thus impacting on fish and wildlife habitat upstream of the dam. Furthermore, it became apparent after some time that 5 out of 8 years following dam construction the expected flows downstream of the dam were not being met. There is now strong pressure for 2/3 of the stored water to be allocated to irrigation instead of for fish.

At present a joint Nicola Dam committee, comprised of federal and provincial government officials, meets several times a year to plan operations for the ensuing year in an attempt to resolve the fish-flow and irrigation issues. Table 4.8 describes a recently proposed flow option for releases from the dam that has been put forward by the fisheries agencies for the protection and maintenance of fish stocks. The option on the table is based, in part, on the British Columbia Modified Tennant Method. Note that the currently proposed flows exceed the recommended

Nicola Basin Strategic Plan flows (Table 4.8) by a considerable margin during the spring freshet, and this has been put forward as a result of new information on fisheries needs.

At the time of writing this report, there is considerable pressure by Land and Water British Columbia Inc. to allocate water to outstanding license applicants, especially for agriculture. This is in the face of a clear evidence that there is not enough water to provide base flows for rearing for fish nor for the sorely needed spring freshet that is used by recently emerged juvenile fish, adult steelhead migration and spawning, and the flushing of sediment. Furthermore, the 2003 predictions of a forecast of a snowpack that is well below normal levels does not bode well for flows this year. How these conflicts between fish and irrigation will be adjudicated is not clear.

Table 4.8 Proposed fish-periodicity chart for the Nicola River at Nicola Lake dam and suggested flows to protect fish.

Note the similarity in Nicola Dam Operating Plan rule curve hydrograph (McNeil 1987) and the BC Modified Tennant proposed flows (%mad) (current fisheries agency proposal, A. Caverly, pers. comm.). The Nicola Dam Operating Plan flows are similar to the currently proposed flows for some, but not all, months.

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Ecological Function												
Flushing Fine Sediments					xxxx	xxxx						
Reduce Icing (egg freezing)	xxxx	xxxx										xxxx
Wetland/trib/sidechannel link				x	xxxx	xxxx						
Channel Maintenance flood once every 5–10 y (~400% MAD)					xx	xx						
BC Modified Tennant proposed flows (%mad)	20	20	20	50	100	150	50	45	30	20	20	20
BC Modified Tennant proposed flows (cms)	1.18	1.18	1.18	2.94	5.88	8.82	2.94	2.65	1.76	1.18	1.18	1.18
1987 Nicola Dam Operating Plan rule curve hydrograph	1.20	1.20	1.20	1.20	2.32	1.84	3.20	2.89	1.78	1.78	1.78	1.20
Chinook Salmon												
Smolt Emigration and Fry movement	xxxx	xxxx	xxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
Adult Migration				x	xxxx	xxxx	xxxx	xxxx	xx			
Spawning								x	xxxx	xx		
Incubation	xxxx	xxxx	xxxx	xxxx	x			xx	xxxx	xxxx	xxxx	xxxx
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Coho Salmon												
Adult Migration									xxx	xxxx	xxxx	xx
Spawning										xx	xxxx	xx
Incubation	xxxx	xxxx	xxxx	xxxx						x	xxxx	xxxx
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Smolt migration				xx	xxxx	xxxx	x					
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Steelhead and Rainbow Trout												
Adult passage into mainstem and tributaries				xxxx	xxxx	x						
Spawning				xx	xxxx	xx						
Incubation				x	xxxx	xxxx	xxxx					
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Pink Salmon-Lower Nicola R												
Spawning									xx	xxxx	x	
Incubation	xxxx	xxxx	xxxx	xxxx	xxxx						xxx	xxxx

Estimated pre-diversion natural MAD = 5.88 cms or 207.65 cfs.

4.5.2 Refusal of Guichon Creek Water License Application and Appeal to the Environmental Appeal Board

One of the important actions that occurred recently in the Nicola River basin subsequent to the development of the Nicola Basin Strategic Plan was the upholding by the Environmental Appeal Board of the Province's decision to refuse water to applicants on the Guichon Creek watershed (Fig. 4.1).

The British Columbia Environmental Appeal Board was established in 1981 under the Environment Management Act as an independent agency to review administrative decisions including water allocations, and provide a final quasi-judicial access point for the public and industry.

The case in point related to the application for the diversion of water for irrigation from the Guichon Creek watershed into the Tunkwa/Durand watershed, a completely different drainage. From the point of diversion to Nicola River there is a distance of 50 km with a multitude of tributaries flowing into Guichon Creek downstream. The application was for 250 acre-feet of water to be diverted from Guichon and stored in Tunkwa Lake. The applicants wanted water to be allocated in order to expand their agricultural capacity through irrigation of croplands. The ranch applied for the water and after more than eleven years, the license was finally turned down in July of 1998. Despite stated explanations, it is not clear why the decision took so long.

The applicants appealed this decision to the Environmental Appeal Board and the Board upheld the original decision by the Assistant Water Manager. This decision can be viewed at: http://www.eab.gov.bc.ca/water/1998wat23.htm

4.5.3 Non-Compliance Monitoring

One of the more sensitive issues affecting fish and flows in this and other watersheds throughout British Columbia relates to non-compliance of water licensees who extract more water than is stipulated in their license. Hubert et al. (1990) showed that water license diversion rates for agriculture are often not adhered to, and this has probably been the case as well in the Nicola River basin. While the Nicola Basin Strategic Plan recommended that audits or compliance measurements of water extraction take place, for the most part this activity was limited in the watershed. A recent and rare exception to the lack of compliance water monitoring in the Nicola River basin involved the Regional Water Engineer directing a ranch on the Coldwater River (Fig. 4.1) to attach a cumulative-flow-recording device on their irrigation pump in 2001. Because the intake structures for many of these agricultural-water intakes are relatively crude, and do not normally have technologically-accurate flow-measuring devices attached to them, it is difficult to know if a license holder is in compliance with the amount of water permitted for withdrawal from the stream. Furthermore, compliance monitoring by the provincial government agency responsible for ensuring observance of the *Water Act* in the Nicola River basin has been almost non-existent. It should be noted that over-extraction of water impacts not only on instream fisheries resources but on water-license holders in the downstream areas.

Over the years a number of individuals in the Coldwater Valley had complained that a particular license holder had been diverting more water than was allowed by the water licenses. When Ministry of Environment, Lands and Parks water management staff began to investigate the complaint in 1991, it became clear that the water extraction taking place was substantially more than the diversion volume allowed by the water licenses. However, the practice was allowed to continue

Then in 1994 a further investigation again determined that the diversion of water at this ranch was significantly out of compliance as per the conditions set by the license; the non-compliance estimate was about double that of the permitted volume. Subsequently, in 1995 there was a public request that enforcement personnel investigate the same license holders, and in 1998 a Ministry of Environment, Lands and Parks memo described the situation as a gross over-use of water. The matter still continued to remain unresolved.

Finally, in 2001 the Province's Water Engineer met with the license holder and sent a letter stipulating that a cumulative-flow-measuring device be attached to the facility and that the licensee submit records of water use to the Water Management Branch. The data provided by the measuring device showed that by August 1, 2001 almost 160 acre-feet had already been pumped and by August 29 over 250 acre-feet had been used; the license only allowed 115 acre-feet per annum. A subsequent flow measurement at the point of diversion estimated that almost 500 acre-feet would have been extracted per year when extrapolated over the season.

The license holder appealed the requirement for measuring extraction of water by the Water Engineer to the Environmental Appeal Board, and took the position that local groundwater contributions to the diversion flows were substantially greater than that determined by the agency. The license holder felt that the amount of river water being used was within the limits of the license; note that groundwater extractions do not require licensing in British Columbia. The counter argument by water management staff was that the groundwater contribution was small. The Environmental Appeal Board upheld the Water Engineer's position based on the evidence provided in the hearing.

http://www.eab.gov.bc.ca/water/1998wat23.htm
http://www.eab.gov.bc.ca/water/2001wat009.htm

This case points to the difficulty in monitoring and enforcing compliance with licensed diversions in the Nicola River basin. Monitoring is expensive, time consuming, technically difficult, and fraught with inconsistencies. What is probably more remarkable is the fact that the water management agency took so long to enforce the *Water Act* despite evidence that the license holder was significantly diverting more than allowed by license for more than ten years.

As a result of this and other experiences, it is the view of various fisheries professionals in the Thompson-Nicola region that over-extraction of water in the Nicola River basin is probably common and significant in terms of occurrences and volumes, and that a comprehensive review and audit are needed. The experience also points to the need for a careful review in terms of the current expectations by the public and governments for setting standards, monitoring and tough and appropriate penalties for non-compliance.

4.6 First Nations Interests

Finally, there must be due consideration of First Nations interests in the issue of water allocation and opportunities to protect traditional resources such as fish. There are a number of First Nations communities in the Nicola Basin watershed that rely on accessibility to water for domestic, agricultural and fisheries needs. Also, since the Plan was implemented, a number of relevant court cases have been heard including the *Delgamuukw* decision whereby the Supreme Court has directed resource managers to consult in actions that may infringe on aboriginal rights and title. First Nation's land claims in this geographic area may well have water allocations incorporated into the settlement, although this has still to be determined.

4.7 Summary and Recommendations

Despite commitments to undertake a more protective approach to water since the implementation of the Nicola Basin Strategic Plan, significant fisheries and water related issues remain to be resolved. A positive sign is notable in the declining rate at which water licenses have been issued for this watershed over the 20-year period since the Plan was established. Yet, there still have been licenses and allocations approved since that time, and there is currently intense pressure to allocate more water to non-fish uses.

It is the view of the fisheries professionals dealing specifically with the situation that the original plan was good for its time, but is now in need of revision in light of new knowledge and changing circumstances.

Consequently, government agencies and the public should engage in a commitment to protect and restore fish flows in the Nicola basin through a variety of means:

1. The moratorium on new license allocations recommended by the Plan should be entrenched and they should be applied to the perceived existing water surpluses in the Nicola Lake that are currently being considered for licensing. Since 1983 research has enabled a greater understanding of the instream fisheries needs in the Nicola River basin and it has become increasingly clear that even if the legal allocation limits are adhered to, the extraction of water now taking place is to the detriment of salmon and steelhead under some flow conditions. A moratorium on licensing further water for diversion or extraction is required if commitments by the federal and provincial government to protect fish stocks are to be upheld. This is reinforced by the fact that coho salmon in this watershed are now listed as endangered by the Committee on the Status of Endangered Wildlife in Canada and this species may be affected by low flows in the Nicola River basin.

2. The 20-year old Nicola Basin Strategic Plan now requires an update. Despite some gains resulting from the plan, new scientific (habitat modeling, fisheries assessments) and engineering information reveals significant technical deficiencies in the Plan. This must be rectified through a public-consultative review process, possibly using the Fraser Basin Council as an appropriate body through which this is conducted. Consideration should be given to using water use planning protocols developed by the province of British Columbia, the federal government and BC Hydro (Rosenau and Angelo 2000).

3. As part of the Plan, an updated hydrological budgeting process must be undertaken in order to determine the true water availability and drought-return periods in order to properly allocate water to fish and agriculture in a fair, balanced and legal manner; to date, many would argue there has not been a balanced approach, and that this has been at the expense of fish.

4. Regulatory agencies should undertake a license-compliance and beneficial-use audit of existing water licenses and water use in the basin. The water management and fisheries protection agencies have failed to ensure that only the licensed water is being diverted and that valuable water supplies are not being used beneficially as per the British Columbia *Water Act*.

5. The Nicola Lake dam-operation plan and flow releases must be updated. At present, there is considerable uncertainty with respect to the best flow regime to provide protection for fish and meet water license requirements. The joint Nicola Dam Committee is currently working on an appropriate rule curve which must be developed that takes all aspects into consideration and does not unfairly exclude fish and fish habitat.

6. Opportunities should be explored to buy back water licenses for fish and ecosystem values similar to what is now being undertaken in parts of the western United States. (This concept is discussed further in this report.)

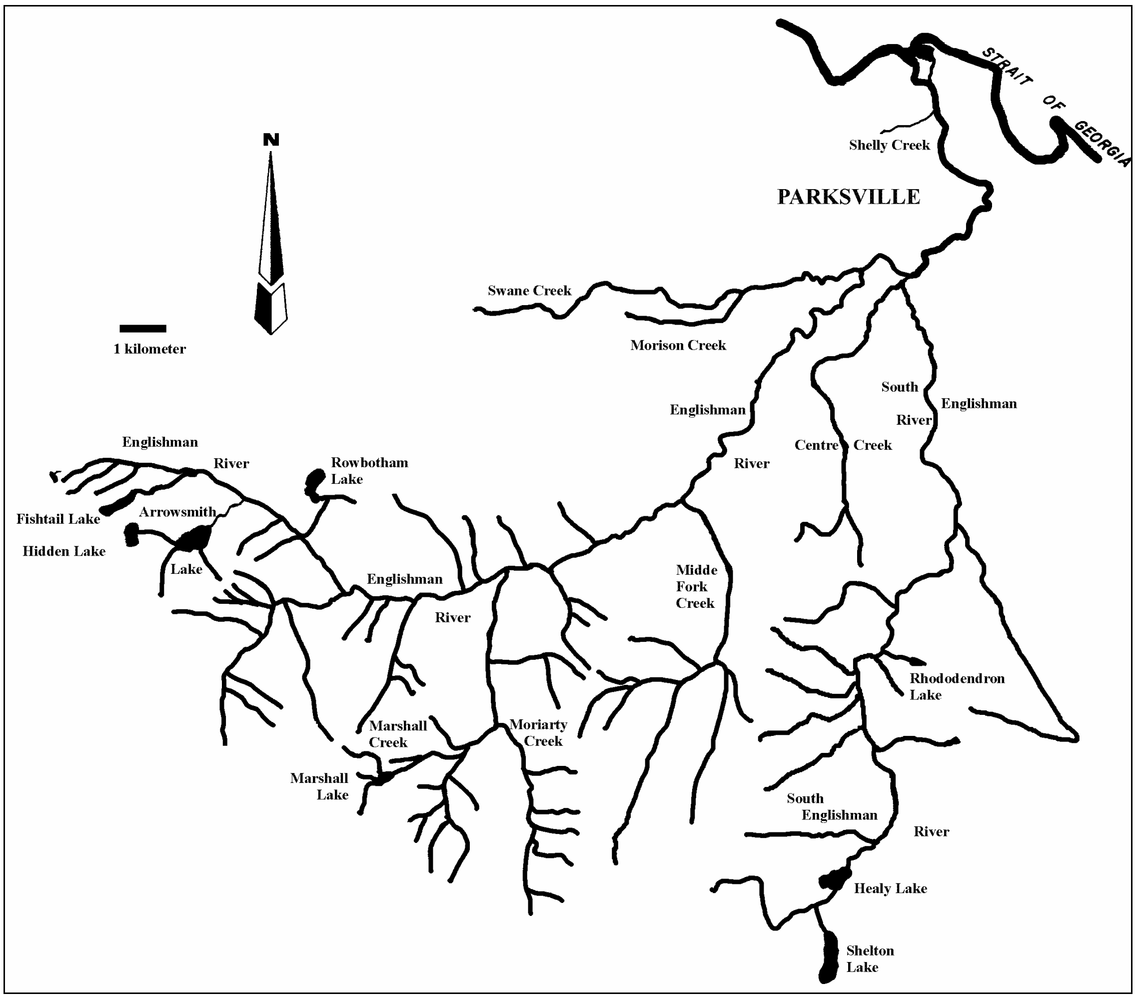
Rood and Hamilton's analysis of naturalizing the discharge suggest that there should be sufficient flow left in the mainstem Nicola River, but empirical observations indicate that this is not based on other, more current, analyses. Also note that even in this analysis all of the streams excepting the Nicola River are less than 20% of mean annual discharge during this critical flow period.

5.0 A COASTAL EXAMPLE: THE ENGLISHMAN RIVER WATERSHED

5.1 Geography and Hydrology

Another watershed in southern British Columbia where low-flows and human extraction of water have come into conflict is the Englishman River on Vancouver Island (Fig. 5.1). The Englishman River drainage accumulates from mountains Moriarity, Arrowsmith and De Cosmos and it flows in a north-east direction to the Strait of Georgia at Parksville. Urbanization and agriculture comprise the landscape of the lower river, while the upper river is primarily forested.

Figure 5.1 The Englishman River basin.



The Englishman River is a 4th order stream (Fig. 5.2) and has a mean annual discharge of 13.1 cubic meters per second. Its length is 39 km and it has a drainage area of 324 km^2 (Canadian Hydrological Data © 1997, Environment Canada, Station 08HB002 at Parksville) with an section accessible to anadromous fish comprising the lower 22.7 km. The discharge regime of the Englishman River is typical of coastal streams with the large flows occurring in the late-fall and winter period (Figs. 2.3, 2.4). This means it has a very different hydrograph than the Nicola River, which is a snowmelt-dominated stream with peak flows during the spring-early summer period (Fig. 2.1, 2.2). The Englishman River tends to have a relatively small spring freshet and large winter floods (Fig. 5.3), with its lowest flows occurring during the late summer/early autumn. The annual maximum is usually between November to February while the annual minimum 7-day low flow is in late August, September or early October.

Figure 5.2 Looking upstream along the left bank of Englishman River.
Photo of the stream at Site 8+960 m from Gaboury (2003).

The Englishman River is a coastal stream that flows in an eastward direction under the rain shadow of the mountain range running down the spine of central Vancouver Island. Hence, there are normally exceptionally low flows during the summer period, and these are probably lower relative to the mean annual discharge of other similar-sized most coastal streams because of the leeward orientation of the basin against the mountains. These river flows were historically low during drought even prior to human water withdrawal.

A multitude of other impacts have also affected the Englishman River watershed salmon and steelhead stocks, including effects due to logging, urbanization and agriculture (Bocking and Gaboury 2001). Excessive extraction of water is also thought to have contributed to these declines to the point where in a dry year no flow remains in some of the tributary streams.

Major tributary streams to the Englishman River (Fig. 5.1) include the South Englishman River as well as Swane, Morison and Marshall creeks. The South Englishman River has a length of 26 km and is a 3rd order stream, Morison Creek is 3.7 km in length and is a 2nd order stream tributary to Swane Creek, which in turn is 12.3 km long and is a 3rd order stream. Another tributary, Marshall Creek, is a 3rd order stream of 4 km in length.

There are no large lakes in the Englishman River (Fig. 5.1) watershed, but small stillwater habitats include Arrowsmith, Shelton and Healy lakes. Arrowsmith Lake is located on the headwaters of the Englishman River proper and has been developed into a 35.3 ha reservoir for the purposes of domestic waterworks, and to augment flows for fisheries purposes since 1999. The reservoir has a live storage of 9,000,000 m^3 of water and about one-half of this is to be allocated for fisheries purposes. The water license for this facility requires that at least 1.6 m^3/s of flow must be maintained in the Englishman River at a point near Parksville between June 1 and October 31

Figure 5.3 Late winter flood in the Englishman River, March 2003.
Photo courtesy of Craig Wightman.

Other water bodies in the drainage include Shelton Lake which has an area of 36 ha and is located at the headwaters of the South Englishman River. Healy Lake is 29 ha and is adjacent to Shelton Lake.

In terms of water licenses, the Englishman River has the most in the basin including 28 for storage and diversion. The largest licenses on this stream are for domestic use by the Nanaimo Regional District and City of Parksville local waterworks authorities. The South Englishman has no issued water licenses while Morison Creek has three diversion licenses for 70 acre-feet per annum, of which 10 acre-feet are backed up by storage. Swane Creek has 13 water licenses of which all but 2000 gallons per day are backed by storage.

5.2 Human Settlement

The areas of Parksville and the Englishman River basin were historically settled by the Coast Salish First Nations peoples. With the arrival of European, humans began altering the natural environment of the area in the early 1870's when 65 ha of the west half of the Englishman River were diked and then farmed. By 1890 the community of Parksville was established. As the community began to grow, much of the area was tilled by agriculture, although by 1904 the logging industry came into full force.

The Englishman River watershed has seen a wide range of impacts to both instream and riparian habitats, particularly over the last three decades as a result of human activity and growth patterns that have paralleled these changes. Many of those impacts included intensive logging of the old-growth forest on private land. Much of this watershed was logged in the early part of the previous century and much of the second rotation was cut again in the 1950's and 1960's (Wright 2003).

The two primary forestry owners of the watershed include TimberWest Forest Ltd. and Weyerhaeuser Canada Ltd. and these companies are now harvesting second-growth stands in the river valley. Some of the logged parcels are being sold to developers for new residential subdivisions administered by the Regional District of Nanaimo.

Morison Creek, considered to be one of the key tributaries of the Englishman River, has an altered landscape surrounding this watershed that is primarily comprised of small hobby farms. This agricultural activity involves what are considered to be poor land use practices (e.g., tilling of peat bogs) that have resulted in major sediment-loading of fish habitats within this sub-basin.

Much of the above information was derived from the web site:
http://www.steelheadrecoveryplan.ca/focus7.htm

5.3 Fisheries Values

The Englishman River basin is habitat for a variety of anadromous and non-anadromous species of fish including salmonids and non-salmonids. These include chinook salmon, chum salmon (*Oncorhynchus keta*), coho salmon, sockeye salmon (*O. nerka*), pink salmon, both anadromous and resident cutthroat trout (*O. clarki*), rainbow trout and the sea-going steelhead, Dolly Varden (*S. malma*), sculpins (*Cottus sp.*), and threespine stickleback (*Gasterosteus aculeatus*). Atlantic salmon (*Salmo salar*) have also been recorded in this watershed and brown trout (*S. trutta*) have been stocked in Arrowsmith Lake.

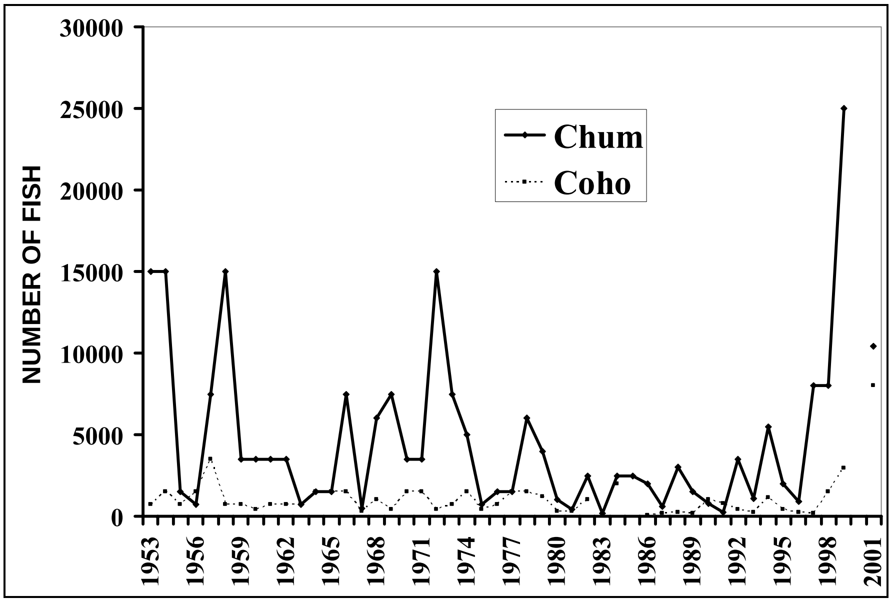
This coastal watershed has far fewer species of fish than the Nicola River basin, presumably due to the different zoogeographical history and glaciation patterns between them. Chum salmon are numerically the most abundant adult salmonid (Fig. 5.4) and the escapements of adults have averaged almost 5,000 fish over the last 50 years. Notably, this species is not readily affected by rearing low-flows because the juvenile fish migrate from the stream within days or weeks of emerging from the gravel. High winter flows are thought to be most damaging to this species, however, due to scour from the gravel while the young embryos and alevins are incubating in the gravel redd (see Fig. 5.3).

The sockeye salmon escapement into the Englishman River comprise trivial numbers (usually 25 fish or less) and it is not clear whether these fish are strays from another population or a true native Englishman river-run population. Likewise, chinook salmon numbers have been very small in this stream over the last 50 years, although a run of 1,200 fish was recorded in 2001. Pink salmon recorded numbers have also been typically low (i.e., less than 2–3,000 adults) during that time frame, but an aggressive recovery program resulted in a return of 13,500 fish in 2001.

Both resident and anadromous cutthroat trout are also present in the Englishman River basin and a few thousand hatchery smolts have been stocked per year.

Figure 5.4 Chum and coho adult salmon escapements to the Englishman River.

Data from http://iwww.bcfisheries.gov.bc.ca/lakes/SearchResultsStreams.asp?InternalID=307267#nuseds



5.3.1 Steelhead

The Englishman River was well known for its steelhead angling and was considered to be one of the more important streams on the east coast of Vancouver Island (Fig. 5.5). Excessive harvest of wild fish during the 1960's and 1970's resulted in a kill restriction for these steelhead. Around that time, the Province of British Columbia embarked on a hatchery program in the Englishman River in order to enhance numbers of fish for harvest by anglers. By the mid-1980's the legal harvest was comprised only of hatchery fish, often reaching a couple of hundred steelhead. The long-term average yearly effort from 1968–1996 was just over 2,000 angler days with an average annual catch of about 1,000 fish (Lill 2002).

In the late 1990's the numbers of steelhead returning to the Englishman River and other east-coast steelhead streams declined dramatically. The declines are thought to have been due to a drop in productivity for both freshwater and marine environments. In recent years the steelhead run has been about 100–200 fish with an observed mean peak of 5.6 fish/km from 1998–2001. As a result, since 1997, the stream has been closed to angling.

Based on the available habitat, fisheries biologists estimate that 4,600 smolts and 598 adults can be produced by the Englishman River. Their opinion is that a conservation concern occurs below 30% of capacity, or 180 adults (Lill 2002)

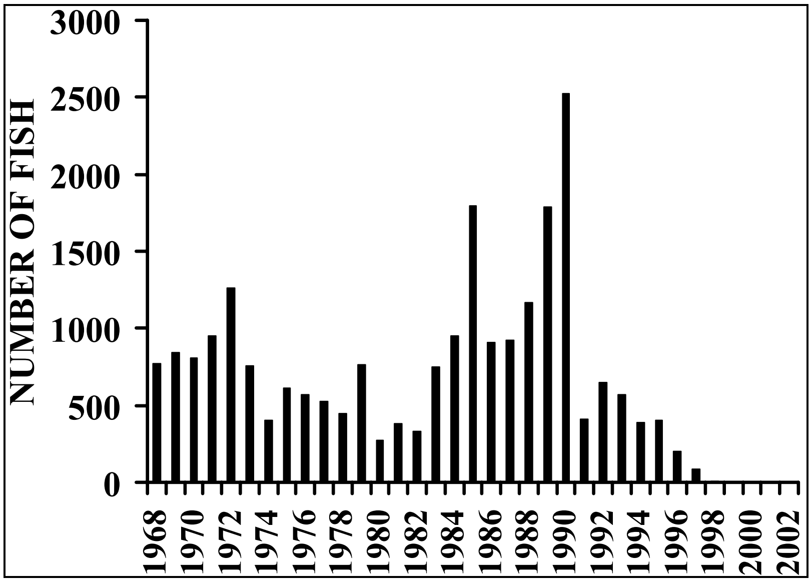
5.3.2 Coho

Coho salmon adult escapement numbers have fluctuated considerably over the past 50 years (Fig. 5.4). These stream-rearing fish prefer slower waters and side-channels during the juvenile phase of their life history. In particular, small tributary streams comprise some of the best habitat for the young coho and the northern part of the lower Englishman River watershed has consisted of some the most highly productive of these streams (e.g., Morison Creek). Much of the off-channel enhancement project work by Fisheries and Oceans Canada has targeted juvenile coho rearing.

The harvest of coho in southern British Columbia has been radically curtailed over the last decade and some of the reductions in harvest were evident in the relatively large escapement to the Englishman River in 2001 (Fig. 5.4).

Figure 5.5 Numbers of steelhead caught by angling in the Englishman River.

These data are from the British Columbia Ministry of Water, Land and Air Protection steelhead angler harvest analysis. Note that in recent years (1997–2003) the stream has been closed to angling.



5.3.3 General Habitat Values and Issues

One of the issues regarding habitat declines in the Englishman River is the extensive channel widening and chronic sedimentation induced by past logging practices (Lill 2002). Under such circumstances, channel widening can have the effect of reducing the habitat capacity of a stream during low-flow conditions where the discharge is spread too thinly across the broad stream bottom. Furthermore, in some instances, the deposition of coarse material on a widened floodplain can cause discharges to go sub-surface, resulting in losses of fish habitat when the stream appears to dry up during extreme low flows.

It is also felt that there is a limited amount of summer rearing habitat capacity in parts of the Englishman River due to reduced complexity resulting from human activity over the years (Lough and Morley 2002). Lough and Morley (2002) looked at the tributaries and noted that pool-type habitat often did not meet the minimum depth criteria as recommended by Johnston and Slaney (1996) and also suggested that there was a shortage of pool habitat for summer rearing conditions.

In the Englishman River, much of the large woody debris, an important component of instream salmonid rearing habitat, has been deposited on elevated gravel bars and does not function during low summer flows. In contrast, tributaries with stable flows, such as Centre Creek, had much more functional wood cover (Lough and Morley 2002). Lough and Morley (2002) took the position that the amount of wood cover in pools for much of the watershed was also less than the minimum 5% recommended by Johnston and Slaney (1996).

To counter some of the impacts to fish habitat on the mainstem, two semi-natural side channels have been constructed by Fisheries and Oceans Canada off of the Englishman River near Parksville (Lough and Morley 2002). These have been highly complexed with large woody debris. These off-channel habitats are more protected during high-winter floods than main-channel habitat construction sites. Large floods tend to be particularly damaging to such structures in mainstream channels due to the elevated flow velocities encountered during these high-discharge events. The target species for these channels are chum and coho salmon, although there may be ancillary benefits to steelhead through some rearing capacity, as well as the marine-derived food and nutrients arising from the spawned-out adult carcasses and eggs and fry.

Regardless of the technical problems of restoring the mainstem Englishman, pool and cover habitat enhancement on the main river was still put forward by Lough and Morley (2002) as a reasonable and viable option. Construction of anchored woody debris habitat was also suggested by NHC (2002). As a result, Gaboury (2003) recently completed a series of fish-habitat restoration designs for the Englishman River and recommended a number of locations where these could be implemented over an assessed length of stream of about 5.7 km and at 16 sites.

Problems arise in this watershed due to sediment loading from headwaters and eroding streambanks. Existing suitable parr habitat in boulder-cascades are highly embedded with sand and small gravel. Volatile flows during the winter, which facilitated sedimentation and downstream movement of bed material during the mid-1990's, may have contributed to a reduction in the number and depth of pools in the study area (Rood 2001). Some of these sediment-erosion problems may be addressed by capping the exposed eroded stream banks with a non-erodable cover.

The Georgia Basin Steelhead Recovery Action Plan (Lill 2002) also suggests that there should be efforts to achieve a reduction of sedimentation from land development in the Morison Creek watershed, and the Plan recommends activities to improve public awareness through habitat stewardship. Furthermore, Lill (2002) suggests that it is important to ensure that private land logging practices meet or exceed standards required by provincial regulations. This is because the Englishman River watershed has such a large base area that is still subject to logging.

While summer rearing flows and habitat are an issue with respect to habitat capacity, the lack of over-winter refuge in the Englishman River mainstem is also a problem during harsh winters with extreme flood events. Indeed, the lack of quality winter refuge habitat appears to be a major factor that undermines total survival and smolt production from the system (Lough and Morley 2002). To counter this, side channels and tributary streams probably function as refugia for these fish.

Nutrient levels are also considered to be less than adequate for a complete restoration of the instream salmonid habitat in this watershed. There is a general lack of nutrients (e.g., phosphorus) which sustain primary productivity and are required for fish to take advantage of available physical habitat. This is thought to be due, in part, to the small numbers of anadromous salmonids that have returned in recent years, which in turn provide marine derived nutrients when their bodies decompose after death. Artificial enhancement of nutrients has been suggested as an option, but this could conflict in the mainstem Englishman River as water-quality contaminants if placed in the water near the Parksville waterworks intake.

In summary, the Georgia Basin Steelhead Recovery Program (Lill 2002) has identified a number of physical recovery options such as:

- installing anchored large woody debris habitat structures and building off-channel refuge alcoves on the mainstem, and adding habitat complexity to Center Creek (a south fork tributary)—Gaboury (2002) recommended 73 sites at a total cost of approximately $193K.

- stabilizing exposed, fine deleterious sediments using re-vegetation techniques to halt eroding mainstem clay banks and reduce the inputs of these harmful sediments.
- extending the existing Timber West side-channel by 2.5 km at a cost of $200K—Fisheries and Oceans Canada—(This engineered project was delayed indefinitely due to development approval problems with the landowner.)

5.4 Flow Issues in the Englishman River Basin

For all of the habitat concerns that exist in the Englishman River watershed, the most overarching issue is that of flows. Without adequate amounts of water in the basin's streams, even high-quality structural habitat is of little use. While this flow issue is relatively simple compared to the extreme complexities of those in the Nicola River Basin, low flows in the Englishman watershed are still thought to have significant impacts on its instream-rearing fish-production capacity.

5.4.1 Tributaries

Lough and Morley (2002) suggested that a primary factor that limits the capability of summer rearing habitat in the tributaries to the Englishman River are the low flows and channel dewatering that occur during the late summer in Centre, Morison and Shelly Creeks, and to a lesser degree in the South Englishman River. Thus, water flows, largley define the productive capacity of this watershed.

Flows in the tributary streams are of special concern because, compared to the main river, these habitats have a much higher per-unit-area productive capacity. The effects of low summer flows in these smaller streams appear to be even more pronounced as some sections of these tributary stream channels become completely dewatered. This leaves fish stranded, or subject to artificially high densities in the limited and isolated pockets of habitat, which in turn can leave the fish vulnerable to predation, disease and death due to high temperatures.

During low-flow events in the tributaries, young coho and steelhead may also be forced downstream into the Englishman River where the habitat is of lower quality and can also be limited by low flows and the rearing habitat may already be operating at fully capacity. Thus, the overall contribution of juveniles from the tributaries can be low during the summer-rearing component of drought years.

Morison Creek can be viewed as an example as it is considered to be a productive stream, yet its discharges have been seen to routinely fall to near zero during the late summer. This phenomenon is apparently due to a combination of low natural inflows and water extraction for agriculture (Rood 2001). A considerable amount of water "disappears" during the critical flow period in the summer in this stream , possibly due to excessive water withdrawals. Recent October observations found that upper Morison Creek had also dewatered, and it has been speculated that this may have been due to altered drainage patterns that occurred when the natural channel was ditched through the agricultural area that surrounds this stream.

It should be noted that there are often high abundances of juvenile salmonids, primarily coho, observed in the lower Morison Creek during water-rich times of the year which suggests that the rearing habitat has relatively high capacity if adequate flows are available (Lough and Morley 2002). As a result, Lough and Morley (2002) suggest that augmented flows during the summer might significantly increase the amount of wetted rearing habitat and reduce dewatering and stranding of Morison Creek.

Centre Creek is another stream in the Englishman River drainage subject to minimal flows, and it dewaters during very dry summers. Even when there has been water in the stream, low flows resulted in inadequate wetted width. Therefore augmentation of discharges would also help this stream (Lough and Morley 2002).

Finally,the South Englishman River has been considred by some to be the tributary stream with the highest quality juvenile steelhead habitat (Lough and Morley 2002) but it also suffers from low flows in the summer. Winter discharges are thought to be volatile, but less so than the Englishman River mainstem and that provides some benefits to fish production. Unfortunately, the opportunities for headwater storage of water, which could alleviate some of the summer low flow issues, seem unlikely since the relatively large channel of the South Englishman River requires a substantial volume of water and a large reservoir would need to be constructed in order for this concept to work. Thus, at first glance this option of constructing and operating a reservoir on this tributary does not appear to be technically feasible.

Despite the need for augmented flows, Lough and Morley (2002) suggested that opportunities for flow augmentation in most of the other small Englishman River tributary streams appear to be limited. Still, even marginal increases in discharge are expected to support substantial fish production and any small amount of water may provide very large gains. Their suggestions for flow augmentation included headwater storage projects in the tributaries or off-channel storage using dugouts on the private agricultural land adjacent to Morison Creek. This water could be pumped or drained into the stream.

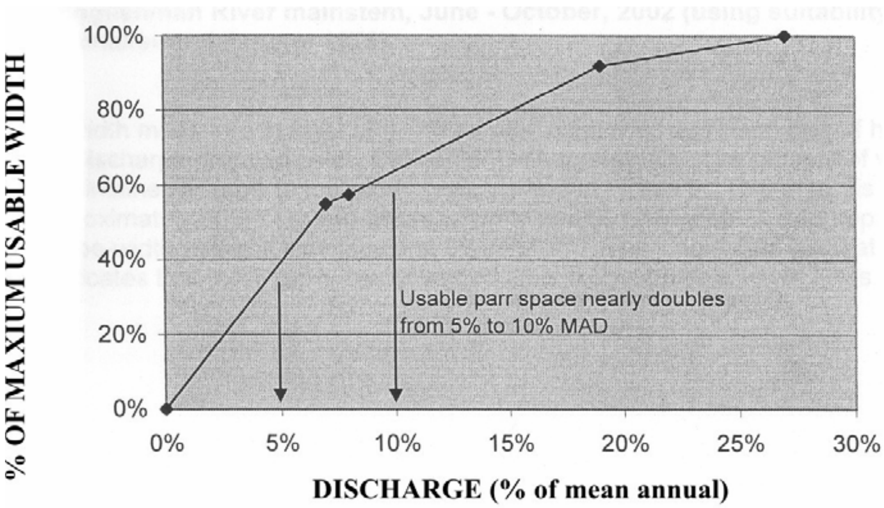
Another observation is that water appears to go sub-surface in Centre Creek and some of its small tributaries downstream of the anadromous fish barrier during low inflows. A suggested technical solution to rectify this is to use anchored large organic debris to facilitate the scour of deep holes in the stream, during high discharge, so that this sub-surface water could then be exposed and would remain available for fish during late summer, even though the connections between such pools may be still be dewatered during a drought.

Finally, another alternative to storing water for fish releases would be to determine whether or not the current water license holders are actually operating within their allocated storage and diversion amounts. Some increased flows for fish may be available through the recovery of unlicensed water.

5.4.2 Mainstem Englishman River

Bocking and Gaboury (2001) reviewed spawning-habitat assessments undertaken by Blackburn and Hurst (unpublished) and determined that coho and steelhead production in the mainstem Englishman River is not spawning-habitat limited. In the anadromous section of the Englishman River, production of juvenile fish is thought to be limited by the amount of available juvenile-rearing habitat during the lowest of summer flows (Lough and Morley 2002). Informed opinion is that prior to the development of the Arrowsmith Lake reservoir, flows were often below optimum levels for fish production, that being less than 20% of mean annual discharge. Wright (2003) investigated the relationship between flows and habitat, and he suggested that 20% of mean annual flow would be ideal (Fig. 5.6), although there was a recognition that it may have to drop to 10% for short time periods during drought.

Figure 5.6 Relationship between percent maximum useable width and discharge for steelhead parr in riffles in the Englishman River mainstem.
Taken from Figure 7 of Wright (2003).



A primary limiting factor in the production of stream-rearing salmonids in the Englishman has been the conflict between use of water between humans and fish. Historically, the Englishman River has been the primary source of water for the local community in the area. During the summer the lower river discharge often fell to levels that were clearly unacceptable for fish-production purposes due to these water extractions. To resolve this issue, in the late 1990's the Arrowsmith Lake reservoir (Fig. 5.1), situated in the upper reaches of the Englishman River, was designed and built to provide flows for fish in this stream with the recognition of the requirement for licensed extraction in the lower river for domestic water use. The objective was to store discharge during the winter water-rich months and then release it slowly throughout the latter part of the summer for both fish and human consumption.

Arrowsmith Lake reservoir has a live storage volume of 9,000,000 m3 and the agreement between the fisheries agencies and the local community requires that 1.6 cubic meters per second, or about 10% of the mean annual discharge, be maintained at the highway bridge near the confluence of the river with the ocean. This operating regime is stipulated in the water license for this facility. While a 10% mean annual discharge, below the water district intake, is thought to be an improvement that should limit loss of rearing habitat during extreme dry summers, this is still less than the 20% MAD required for ideal summer flows based on BC fisheries standards (Bocking and Gaboury 2001). Unfortunately, opportunities to increase the minimum flows are apparently limited by the small size of the reservoir storage capacity needed to maintain higher flows (K. Rood pers. comm.).

The first releases of water for fish from the Arrowsmith Lake reservoir into the Englishman River occurred in 1999. Unfortunately, it soon became apparent that despite the development of this reservoir, flows were not always being maintained to the agreed-upon target discharges. For example, in 2001 flows at the highway bridge dropped below the mandated 1.6 m3/s discharge and continued even lower (to below 0.93 m3/s), where it was last measured in October of that year (Wright 2003).

It is not clear where the problems lies but the situation now requires rectification, if technically possible. Wright (2003) suggests that there may be a problem with regards to the estimation of flows released from the dam versus domestic water-use requirements. An incomplete data set with regards to low flow patterns means that the expectation of what minimum flows are likely to be in the mainstem Englishman River on an average year may be incorrect.

Thus, it is incumbent on those in charge of the dam operations to determine if the reservoir can be operated in a more efficient manner to optimize flows towards the fish-flow targets for fish habitat, and still provide the licensed water to communities. The system operations and the rule curve (an engineering term for the guidelines for releasing water) need to be reviewed and clarified and there is now a commitment by the affected parties to resolve this issue.

5.5 Summary and Recommendations

The Englishman River basin historically sustained healthy populations of salmon and steelhead but habitat damage and loss of water has adversely impacted the capacity of this watershed. Still, there may be opportunities to partially redress some of these losses through physical restoration. Other options to restore habitat capacity include the augmentation of flows in either the main stem Englishman River or its tributary streams. Recent preliminary assessments suggest that the agreed-upon flows that are required to be released from the Arrowsmith Dam have been less than expected and this situation should be reviewed and rectified if needed.

In summary, the following flow recommendations should be implemented for this watershed, some of which were recently put forward by Wright (2003):

1. Stored water from the Arrowsmith Lake reservoir should be used when needed in an effort to keep the flows in the mainstem Englishman River at a minimum of 20% of mean annual discharge (MAD) (equal to 2.76 cubic meters per second) while ensuring that short term flows do not fall below 10% of MAD. This may involve developing a more accurate operational “rule curve” for the new Arrowsmith Lake dam/reservoir in order to provide appropriate flow augmentation between the dam and regional district’s water intake in Parksville. The system operations of this dam require updating in order to maximize the efficiency of the water being stored and released.

2. Initiate a compliance assessment of existing water licenses. Water in some of the tributaries seems to disappear unaccountably and this may be due to unauthorized extractions.

3. Facilitate a complete hydrological budgeting exercise for the watershed. Like the Nicola River basin, discharge patterns are still not clearly understood and a more precise understanding of flows over the seasons and among years would be highly beneficial in managing the flow resource. This would involve more flow measurment (hydrometric stations) and may help resolve reaching flow-release targets in the Englishman River from Arrowsmith Lake reservoir.

4. Restrict further water licenses unless supported by off-channel storage. The current discharges throughout the watershed during the low-flow periods are simply not sufficient to satisfy acceptable levels of fish production and no new licenses should be issued without appropriate storage to replace withdrawals during the low-flow periods.

5. Investigate new or innovative options to provide more water in tributary streams, including storage of water for release during dry periods.

6.0 Concluding Remarks

6.1 Some Thoughts on Low-Flow Issues in British Columbia

Much debate has occurred in British Columbia over the last two decades focussing on the need to protect, restore and nurture the salmon and steelhead stocks and their associated habitats. There has also been a great deal of media profile on the perilous state of some fish stocks and the need for decisive action if they are to be saved.

The efforts to protect and restore our salmon and steelhead populations seem to be failing despite all of the passionate rhetoric. Notwithstanding some spectacular recoveries of spawning runs in recent years, including the enormous run of pink salmon returning to the Fraser River in 2001 and the return of the almost-extinct Horsefly River sockeye throughout the 1990's, there is considerable evidence to suggest that fish habitat in British Columbia is undergoing slow-net-loss rather than no-net-loss.

Furthermore, a growing population in British Columbia will result in continuing increases in the demand for water, often at the expense or exclusion of fish. As a result, the best efforts to protect fish habitat in the face of increasing pressures often fall short of success.

This report has dealt with the issues of salmon and steelhead rearing in two watersheds in seasonally dry parts of this province that, even in the absence of human extraction, were naturally subject to low flows during critical times of the year. The Nicola and Englishman river basins typify many of the problems surrounding conflicts between the extraction of water for human uses and fish where the water resource is already limited. What is notable, but often forgotten, is that even before significant extractions began to occur from these streams, the stocks of salmon and steelhead in these watersheds were probably already living on the ecological fringe. The water removal simply exacerbated the problems associated with their survival. This would support the view that, for some streams in British Columbia, that no flow should be removed if the objective of ecological integrity is to be maintained.

So, what can fisheries management and regulatory agencies and the public do about the issue of low-rearing flows, extraction of water and the protection of salmon and steelhead?

As a summary to this report, it is appropriate to consider some crucial questions that are relevant to this issue:

1. If water withdrawals have adversely impacted salmon and steelhead populations, would returning flows to a stream restore the stock of fish to its former abundance?

In British Columbia there are few examples of streams with salmon or steelhead populations where flows have been restored for the benefit of fish. Furthermore, there are even fewer instances where the return of water has been conducted in an experimental way so that scientists could detect an empirical response. Most of the discussion surrounding flows and fish production in this province have been theoretical and based on computer modelling exercises. There has typically been a lack of clear or sufficient data.

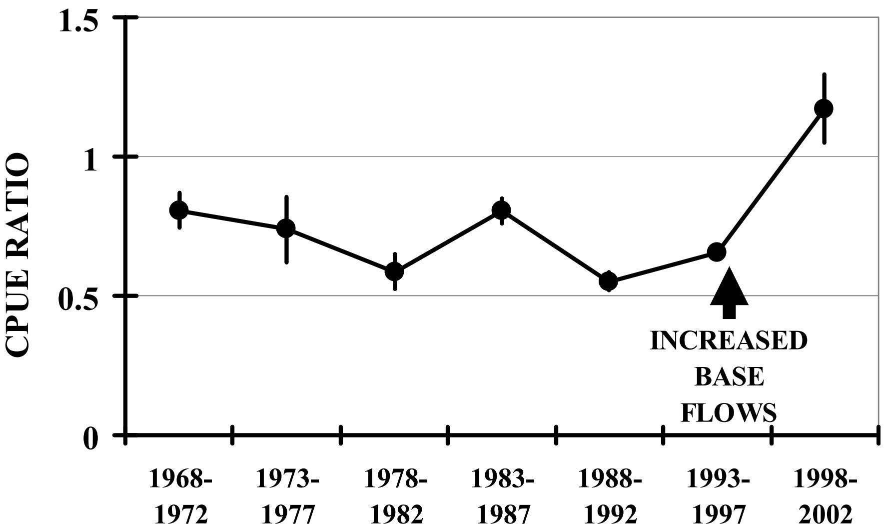
An exception to this seems to have been the recent response of steelhead in the Alouette River where base flows that were blocked by a dam in the early part of the century were restored in the latter half of the 1990's. In 1928 the Alouette River near Maple Ridge was dammed and a reservoir formed from two lakes in the upper watershed. Most of the water in this reservoir was diverted out of the Alouette River into another drainage. Thus, there remained limited-to-non-existent flows for rearing steelhead, subsequent to impoundment, in areas downstream of the dam.

Over the succeeding years various public groups and individuals called for more water with the expectation that fish populations in this stream would benefit as a result. Then in the late 1990's, BC Hydro embarked on a public water use planning process and the computer habitat-modelling exercise suggested that significant increases in flows in the river downstream of the dam would result in major increases in juvenile rearing habitat capacity. BC Hydro subsequently increased flows into the lower river, from a lower maximum of two or three percent of the mean annual discharge, to greater than 10% of mean annual discharge after the new flow regime was implemented.

Fortuitously, a large data set of wild-steelhead angler catches had been accumulated since the 1960's for both the Alouette River and other streams in the lower mainland as part of the provincial government's steelhead angler harvest analysis. A comparison of pre- and post-flow catch-per-unit effort of wild steelhead, among the Alouette River and other streams in the lower mainland (Fig. 6.1), strongly suggests that subsequent to the increased releases of water into the lower Alouette River, the abundance of wild steelhead in this stream increased substantially over a relatively short time period (1998–2002).

Figure 6.1 Catch-per-unit-effort (CPUE) trend for wild steelhead in the Alouette River

Pre- and post-flow release from the Alouette Reservoir dam. Alouette River wild-steelhead angler CPUE is divided by the Region 2 (lower mainland) wild-steelhead angler CPUE to produce ratios for blocked periods from 1968 to 2002; with variance. CPUE is used as a proxy for relative adult steelhead abundance for these streams. The CPUE data for the rest of the lower mainland steelhead catch was used as an experimental control to account for changes in ocean survival and variability in angling conditions and instream habitat conditions due to year-to-year changes in water conditions and flows. Data from the Ministry of Water, Land and Air Protection Lower Mainland steelhead angler harvest analysis.



We believe this relative increase in steelhead catch rates has been the result of the increased base flow regime. Furthermore, there is no reason to think that this situation would be unusual for steelhead, and other stream rearing salmonids, given the appropriate circumstances where productivity has been restricted by un-naturally low flows.

2. Recognizing that, at least in the short term, the human population of the province will continue to increase and result in unavoidable water extractions, the question must be asked, how much water should be left in streams in order to maintain ecological functions as well as salmon and steelhead rearing and spawning capacity?

The question of how much flow fish need to survive and thrive have been pondered for decades in British Columbia, across western North American, and around the world. The Nechako River fish-flow debate in the 1990's turned out to be one of the most acrimonious and divisive environmental discussions this province had seen in some time. The issue was essentially a question of how much water needed to be left in the Nechako River in order to protect fish.

The painful social divisions that the Nechako River flow debate caused were due, in part, to the inadequate information (both scientific and traditional knowledge) and an insufficient basis for understanding the relationship between flows and the instream needs of fish. The situation also suffered from a lack of clearly-defined and agreed-upon standards that water withdrawals, such as those proposed for the Nechako/Kemano power-project, can be measured against.

As a consequence, as long as water allocation conflicts continue to occur within British Columbia, there must be a commitment by the federal and provincial governments to conduct the research that is essential to determine the optimum instream flow needs of salmon and steelhead for streams in this province.

Secondly, there needs to be a commitment to develop scientifically defensible standards for Instream-Flow-Needs that all can agree upon and use in a practical way. It is our understanding that the senior fisheries agencies are currently engaged in the development of British Columbia Instream Flow Standards for fish and these efforts should be encouraged and hastened.

Finally, as an adjunct to these initiatives, there needs to be a commitment by senior governments to redress historic flow imbalances for the sake of salmon and steelhead where egregious impacts have occurred as a result of the over-extraction of water. We think that turning back the clock is both achievable and realistic, in some circumstances, given our increasing understanding of the functional relationship between fish production and flows.

3. Will government agencies and the public embrace new working arrangements whereby historic fish-flow issues can be addressed through the re-assignment of water rights?

There are areas in North America, and even some examples in British Columbia, where fisheries agencies and the public have been able to restore fish flows. In British Columbia the water use planning process (Rosenau and Angelo 2000), currently engaged in by BC Hydro, has achieved some remarkable successes with regards to fish and water in streams. This is exemplified by the Alouette River initiative described above whereby flows were released by BC Hydro through the efforts of a water use planning process. There have also been some other recoveries of flows by government agencies in the central interior region, such as a recent initiative on the Bonaparte River where base flows were augmented for fish through the construction of a storage dam and licensing agreements.

Nevertheless, outside of these limited efforts, current federal and provincial legislation and initiatives do not seem to be sufficiently addressing the issue of fish flows in salmon and steelhead streams where lack of water is clearly impacting on fish production. Furthermore, the Nicola Basin Strategic Plan, while forward-thinking for its day, is in need of an update. Perhaps the current provincial Living Rivers Strategy will move this province towards the objectives of providing water for salmon and steelhead in streams that have chronically suffered from low flows.

We point out that an alternative method of restoring fish flows might be to re-acquire the rights to water currently held by individuals or groups with the intention of returning water back to the original stream. A number of U.S. states are now embarking upon on the purchase of water rights for fish. For example, the Oregon Water Trust has been able to convert extractive rights into stream flows in order to restore some of the lost capacity (http://www.cei.org/gencon/025,01354.cfm). Despite the western water law prior-appropriation and beneficial-use-of-water concepts that Oregon and other west-coast states and British Columbia adhere to, this became possible when the state of Oregon revised its legislation to include fish as beneficial users of water. The Trust's Board of Directors and Advisory Board consists of ten individuals representing varied interests from around the state. The Trust's 1998 operational budget totals $264,000, and its funding for acquisition of water rights between 1994 and 1998 totaled $284,000. Additionally, the Trust has also acquired $370,000 worth of donated water rights.

Oregon is not the only state purchasing water rights for fish. Since 1990, throughout the Pacific Northwest, more than $36 million US was spent in Washington, Idaho, Montana, California and Oregon to acquire 1.7 million acre feet of water for instream use (Landry 1998). Purchase and lease prices averaged $151 and $30 per acre-foot, respectively.

Perhaps similar initiatives could be applied in British Columbia to protect and conserve its fisheries resources in the face of sometimes excessive but legal extraction in low-flow streams where salmon and steelhead are affected through over-licensing.

4. The effects of climate change are now being superimposed on the complex issue of water extraction and fisheries impacts. In light of this, what should be an appropriate response by fisheries agencies and the public regarding the management of flows for salmon and steelhead?

The current change in the Earth's climate appears mainly to be the result of human activities. The Kyoto protocol, now ratified by Canada, acknowledges that human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, resulting in a warming of the earth. The world's temperature is becoming warmer, with the 1980's and 1990's being the warmest decades on record while the ten warmest years for those where records have been kept have all occurred in the past 15 years. Also, the Twentieth century was the warmest in the last 600 years.

As a result, change in the historical hydrological cycle is predicted to occur with the expectation that overall global precipitation will increase. It is also expected that there will be regional disparities in the distribution of temperature and precipitation changes.

It is probable that climate change will negatively impact salmon and steelhead production in British Columbia watersheds and across western North America. Aquatic organisms will be affected more acutely in higher latitudes during fall winter and spring seasons (Hengeveld 1990). The expected effect on salmon and steelhead in streams such as the Nicola and Englishman river basins will include both water temperature increases and further decreases in summer low flows.

Decreased seasonal instream discharges, due to global warming, and increased human withdrawals, have the potential of causing impacts to instream rearing of juvenile fish in a variety of ways. Levy (1992) stated that:

> *…within freshwater fish habitats, anticipated climate warming effects on water temperature, water quantity, are summarized by Regier and Meisner (1990) who point out that in general, the size of stream fish populations should follow the*

changes in streamflow with climate change, since streamflow is a measure of habitat space. In one model for trout standing crop (Binns and Eiserman 1979), the effects of water temperature and water quantity act multiplicatively with respect to trout standing crop… Many species of salmonids will be negatively impacted by climate warming, particularly those which rely on freshwater habitats for juvenile rearing near the southern margin of their geographical range.

What this means is that the loss of water in conjunction with increased water temperatures resulting from global warming has the potential for impacting fish populations such as those found in the Nicola and Englishman river basins that are already stressed as a result of low flows.

Various scientists have looked at particular aspects of global warming in various parts of British Columbia. For example, the trend resulting from this shift in climate for the Fraser River watershed indicates that there will be more total precipitation, increased runoff during winter months, lower snowpacks, earlier and reduced peak-of-flow spring runoff, and subsequent lower base-flows during critical fish rearing low-flow periods in late summer. This trend was similar to one postulated for large western North American rivers which are dominated by spring/summer snowmelt runoff (Lettenmaier and Gan 1990). Foreman et al. (2001), Moore (1991) and Morrison et al. (2002) also indicate that there have been, and may continue to be, increases in water temperature and shifts in the flow regime in the Fraser River as a result of global warming.

Levy (1992) reviewed the impacts of global warming on Fraser River salmon production and provided the following comments:

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

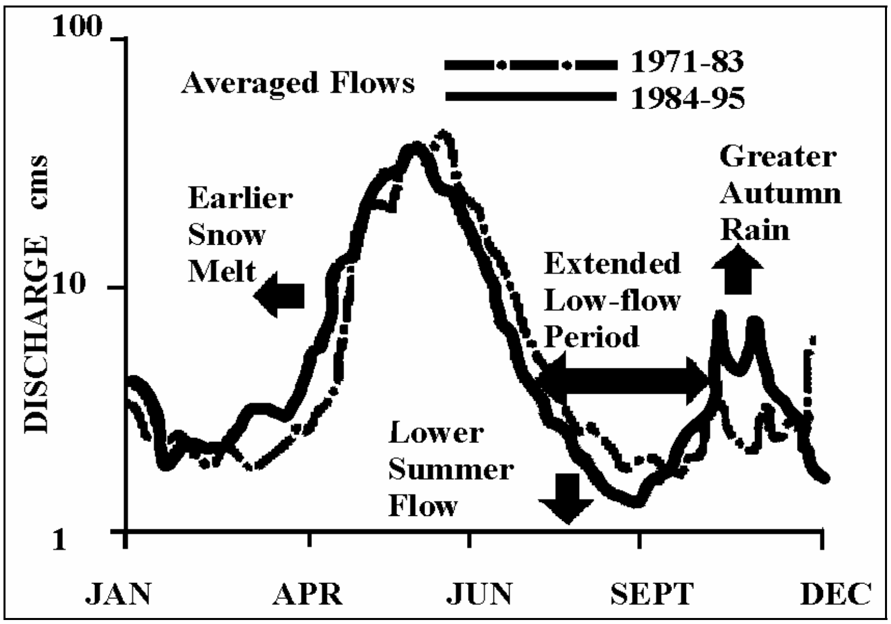
There is also other scientific evidence that is particular to the Nicola and Englishman river basins. Leith and Whitfield (1998) suggest that the Upper Similkameen River, a watershed immediately adjacent to the Nicola River basin, has shown an earlier shift in snow melt, extended low-flow period, and reduced low-flow period in summer due to climate change (Fig 6.2). Levy (1992) suggests that the likely result of gobal warming is that summer runoffs would likely be reduced in the Thompson-Nicola watersheds and that the freshet would occur several weeks earlier than it currently does. Weston et al. (2003) suggest that, for the Englishman River, climatic change will result in increased flow levels and frequency of winter floods, but decreased summer low flows.

So what can fisheries managers do about global warming and impacts to streams like the Nicola and Englishman watersheds? It is unlikely that any behavioral change at the local level is going to directly affect global warming in a substantial material sense. However, in addition to thinking globally while acting locally as individuals to reduce global warming, there are some actions that fisheries managers can take.

To begin with, greater care must be taken regarding the use and allocation of instream flows. It is unlikely that there are any surpluses of water for extractive demands in either the Nicola or Englishman watersheds at this time. Secondly, harvest levels for such stocks must be maintained at cautious, risk-averse levels in order to ensure adequate seeding of the remaining available habitat. Thirdly, protecting and maintaining the physical habitat (which has started to occur in both watersheds by groups such as the Pacific Salmon Foundation and others) and recovering any available water is key to ensuring that these stocks avert extinction. Finally, as Levy (1992) suggests, proactive and adaptive management fisheries policies must be developed in order to provide the best opportunities to respond to climate induced alterations in fisheries productivity.

Figure 6.2. Change in hydrograph in the Upper Similkameen River, British Columbia

Between 1971–83 and 1984–95. Note that the spring run-off is earlier, there is an extended and exacerbated low-flow period during the late summer, and a higher discharge due to greater autumn rains in the fall. Adapted from Leith and Whitfield (1998) and the Natural Resources Canada website: http://www.adaptation.nrcan.gc.ca/posters/articles/bc_08_en.asp?Region=bc&Language=en



6.2 Why Do Fish-Flows Matter?

In the final analysis, perhaps it comes down to what is really valued in a society and culture. In this regard, it is evident that British Columbians are not willing to easily write off their environmental and cultural heritage, and that salmon and steelhead stocks in streams such as the Nicola and Englishman river basins are important to all British Columbians.

As a result, the protection and enhancement of salmon and steelhead in these watersheds must be given the utmost attention and their protection must be adequately considered in any decisions relating to water allocation and extraction. In addition, every effort must be made to restore and recapture flows while continuing to protect and restore fisheries habitat. British Columbians would not expect anything less.

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7.1 Personal Communications

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GLOSSARY

Anadromous	Migrating up rivers from the sea to breed in fresh water.
Alevin	A hatched, but not-yet-free-swimming or foraging, salmon or steelhead that is still in the spawning gravel of a stream and feeding off of its yolk sac
ft3/s—or cfs	Cubic feet per second
Embryo	A fertilized egg in development
Fingerling	A small, young salmon or steelhead that is larger and older than a fry and is usually about the length of a human finger
Freshet	High run-off flows in a stream, as in during snowmelt periods in the interior part of the province
Fry	A very small free-swimming young salmon or steelhead, usually less than one year old
Incubation	The development of a salmon or steelhead embryo or alevin in the spawning gravel of a stream
m3/s—or cms	Cubic meters per second
Mean annual discharge: (MAD)	Instantaneous flow volume of water in a stream averaged over the period of a year, usually in cubic meters per second (cms), or cubic feet per second (cfs)
Salmonid	Belonging to thefamily Salmonidae, which includes the salmon, trout, and whitefish.
Smolt	A young steelhead or salmon at the stage after the parr when it becomes covered with silvery scales and first migrates from fresh water to the sea
Stream order	The smallest permanent streams are called “1st order streams”. Two first order streams join to form a larger, second order stream. Subsequently, two second order streams join to form a third order, etc. Smaller streams discharging into a higher-ordered stream do not change its order number.

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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 Order of Canada and 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.

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