Hydrology and Water Use for Salmon Streams in the Chilcotin Habitat Management Area, British Columbia

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HYDROLOGY AND WATER USE FOR SALMON STREAMS IN THE CHILCOTIN HABITAT MANAGEMENT AREA, BRITISH COLUMBIA

by

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ABSTRACT

The Fraser River Action Plan (FRAP) is developing plans for environmentally sustainable salmon production in streams of the Fraser River watershed. This report focuses on the Chilcotin Habitat Management Area (HMA). The HMA contains the Chilcotin River watershed, on the west side of the Fraser River near the town of Williams Lake. The report discusses hydrology and water use on five salmon streams.

The Chilcotin HMA includes two physiographic regions with distinct climate and flow regimes, the Chilcotin Plateau and the east side of the Coast Mountains. The drainage basins are larger than 2000 km^2, except for Elkin Creek. The Chilcotin River flows through the Chilcotin Plateau, which has gently rolling uplands with steep escarpments along creeks and river valleys. The Chilko and Taseko watersheds drain the steeper Coast Mountains, and their flow regimes control the flow regime on the lower Chilcotin River. Precipitation is much greater along the Coast Mountains (1000 mm per year) than on the Chilcotin Plateau (up to 450 mm per year). The major sources of precipitation are winter snowfall and summer rainfall. Snowmelt produces peak stream flow on the upper Chilcotin River between mid-April and mid-June. Flows are low by September. Peak flows occur from mid-May to August on the Taseko, Chilko, and lower Chilcotin Rivers. Late summer flows are moderate.

The hydrologic regimes and the effects of human development on the regimes are emphasized. Ten indices use hydrologic, water use, and land use data to rank habitat sensitivity of the streams. Some indices express the level of human activity. Some express the state of the stream and its ability to resist change. The most useful indices reflect summer water use, compare low and peak flows to mean flow, and indicate the extent of forest harvesting in the watersheds. The most sensitive streams are those that are most affected by human activity and those naturally sensitive to human impact.

Forestry and agriculture cause the most significant impacts on stream flow. On the upper Chilcotin River and Elkin Creek, low summer stream flows are reduced further by withdrawals for irrigation (10 to 15% of the average monthly flows in August and September). Forest harvesting affects less than 4% of any watershed. Most harvesting occurred in the last ten years, so there has been limited hydrologic recovery. Proposed cut rates are 2 to 3%, and include salvage of beetle-killed timber. There are concerns about road encroachments on streams and slope failures on small tributaries. The main streams show little evidence of sedimentation or altered stream flow attributable to forest harvesting. Placer mining occurred in the past, but there is no activity currently. B. C. Hydro has land and water reserves on Chilko and Taseko Lakes, and has considered diverting flow from Taseko Lake for power generation. The Taseko River contributes glacial sediments and turbidity to the Chilcotin River. Upstream of Elkin Lake, Elkin Creek has an unstable streambed, low flow problems, and a proposed mine development.

The report recommends improving stream flow measurement, monitoring and controlling water use, and developing water management plans for the most sensitive streams. Stream flow requirements of fish should be better studied. A formal system should be developed for reporting incidents of erosion. The report also recommends distributing proposed forest harvesting over the various tributary basins, to maintain flow regimes, and organizing five-year harvesting plans by watershed. These measures will allow more accurate prediction of the impacts of harvesting on hydrology.

RÉSUMÉ - ZGH DE LA CHILCOTIN

Le Plan d'action pour le Fraser (FRAP) vise la production de saumon, dans une perspective de développement durable, dans les cours d'eau du bassin hydrographique du Fraser. Le présent rapport porte sur la zone de gestion de l'habitat (ZGH) de la Chilcotin, qui couvre le bassin de la Chilcotin, sur la rive ouest du Fraser, près de la ville de Williams Lake (C.-B.). Ce rapport examine l'hydrologie et l'utilisation de l'eau sur cinq rivières à saumon.

La ZGH de la Chilcotin couvre deux régions géomorphologiques présentant des caractéristiques climatiques et hydrologiques distinctes, le plateau Chilcotin et le flanc ouest de la chaîne Côtière. Les bassins versants dépassent 2 000 km^2, sauf celui du ruisseau Elkin. La Chilcotin traverse le plateau, qui est constitué de hautes terres faiblement ondulées coupées d'escarpements abrupts le long des ruisseaux et des vallées. Les bassins de la Chilko et de la Taseko drainent le versant escarpé de la chaîne Côtière, et leur régime hydrologique commande celui du cours inférieur de la Chilcotin. Les précipitations sont beaucoup plus fortes le long de la chaîne Côtière (1 000 mm par an) que sur le plateau (jusqu'à 450 mm par an). Les principales formes de précipitations sont les chutes de neige en hiver et la pluie en été. La fonte des neiges produit des débits de pointe de la mi-avril à la mi-juin sur le cours supérieur de la Chilcotin. Le débit est bas dès septembre. Le débit est au plus haut de la mi-mai à août sur la Taseko, la Chilko et le cours inférieur de la Chilcotin. Il est modéré à la fin de l'été.

Les travaux mettent l'accent sur les régimes hydrologiques et les effets de l'activité humaine sur ces régimes. Dix indices font appel aux données sur l'hydrologie, l'utilisation de l'eau et l'utilisation des terres pour classer les cours d'eau selon la vulnérabilité de leurs habitats. Certains indices expriment le niveau de l'activité humaine; d'autres indiquent l'état du cours d'eau et son aptitude à résister au changement. Les indices les plus utiles reflètent l'utilisation de l'eau en été, comparent les débits minimaux et maximaux au débit moyen, et indiquent l'ampleur de l'exploitation forestière dans les bassins versants. Les cours d'eau les plus vulnérables sont ceux qui sont les plus affectés par l'activité humaine et ceux qui sont naturellement sensibles à l'impact de cette activité.

Ce sont la foresterie et l'agriculture qui ont les effets les plus forts sur le débit des cours d'eau. Sur le cours inférieur de la Chilcotin et dans le ruisseau Elkin, les faibles débits de l'été sont encore réduits par les ponctions d'eau destinée à l'irrigation (10 à 15 % du débit mensuel moyen en août et septembre). L'exploitation forestière touche moins de 4 % des bassins. La plus grande partie de cette exploitation a eu lieu dans les dix dernières années, de sorte que le rétablissement hydrologique est faible. Les taux de coupe sont de 2 à 3 %, et couvrent la récupération du bois tué par les ravageurs. On s'inquiète de l'effet du tracé des routes sur les cours d'eau et des glissements de terrain sur les petits affluents. Les principaux cours d'eau présentent peu de signes de sédimentation ou de modifications du débit attribuables à la foresterie. On a pratiqué dans le passé l'exploitation des placers, mais ce n'est pas le cas présentement. La B.C. Hydro and Power Authority possède des terres et des réserves d'eau aux lacs Chilko et Taseko, et a envisagé de détourner l'eau du lac Taseko pour produire de l'électricité. La rivière Taseko apporte des sédiments glaciaires et de la turbidité à la Chilcotin. En amont du lac Elkin, le ruisseau Elkin présente un lit instable et des problèmes de faible débit et fait l'objet d'un projet d'exploitation minière.

Le rapport recommande d'améliorer les mesures du débit, de surveiller et de régir l'utilisation de l'eau, et d'élaborer des plans de gestion de l'eau pour les cours d'eau les plus vulnérables. Il est nécessaire de mieux étudier les besoins du poisson en matière de débit. Il serait bon d'établir un système officiel pour signaler les cas d'érosion. Le rapport recommande aussi de répartir les projets d'exploitation forestière sur les divers bassins tributaires, de maintenir les débits et d'établir des plans quinquennaux d'exploitation forestière par bassin. Ces mesures permettront de prédire plus précisément les impacts de l'exploitation forestière sur l'hydrologie.

FOREWORD

This report was commissioned by the Fraser River Action Plan (FRAP). It contains hydrology and land use information that will be useful in reviewing salmon habitat quality and assessing habitat sensitivity.

The Hell's Gate landslide in 1913 decimated sockeye and pink stocks from the upper Fraser River. Habitat degradation and marine exploitation rates have affected some salmon stocks as well. Measures to rebuild salmon stocks began several decades ago, and the stocks have been rebuilding slowly. Stock rebuilding became a higher priority after the signing of the 1985 Canada-U.S.A. Pacific Salmon Treaty. Canada's Green Plan recognizes the importance of good habitat quality in rebuilding stocks. The Department of Fisheries and Oceans incorporated habitat considerations in the Fraser River Green Plan initiative in 1990. This program is now called the Fraser River Action Plan. One of its goals is developing and maintaining sustainable fisheries resources in the Fraser River Basin.

Under FRAP, the Department of Fisheries and Oceans is developing an integrated fisheries resource management plan for the entire Fraser River Basin. The plan provides direction to governments and stakeholders for conserving and restoring habitat and rebuilding salmon stocks. The basin was divided into fifteen Habitat Management Areas (HMAs), based on major river systems and salmon stocks. Within each HMA, the status of salmon habitat, stocks, and habitat restoration and protection priorities will be defined. This information will be used to establish a database and the framework for discussing sustainable development, to which Canada is committed.

Sustainable development is based on two principles: maintaining ecological diversity and maximizing the net economic benefits of the resource. Specific goals are incorporated into Habitat Management Plans and associated DFO decisions and activities. These goals are:

1) **Avoiding irreversible man-made changes to fish producing habitats.**
Habitat alterations that reduce fish production capacity will be avoided if they cannot be reversed within one human generation.

2) **Maintaining the genetic diversity of fish stocks.**
No fish stock will be written off arbitrarily, and small or remnant stocks will be conserved and rebuilt wherever possible.

3) **Maintaining the physical and biological diversity of fish habitats.**
Habitat diversity encourages genetic diversity, alternate life history strategies, and the capacity to survive natural variation in environmental conditions.

4) **Providing a net gain in the productive capacity by habitat management.**
Natural and self-sustaining methods of increasing productive capacity are preferred to those that require human intervention and maintenance.

5) **Maximizing the value of commercial, sport, and aboriginal fisheries.**
Competing uses of the fisheries resources will be quantified by considering tangible and intangible market and extra-market values.

6) **Maximizing the non-consumptive values of fishery resources.**
Intangible and cultural values of the fishery resources will be considered when allocating fishery resources.

7) **Distributing fishery net benefits in a fair and equitable manner.**
Local communities should help make decisions about habitat conservation and restoration, stock enhancement, distribution of benefits, and cost-sharing arrangements.

This report is intended to contribute to effective land use planning. In turn, this should protect and manage aquatic habitat successfully and result in sustainable development.

1. INTRODUCTION

1.1 Purpose of the Study

The Fraser River Action Plan, of the Department of Fisheries and Oceans Green Plan Program, is developing plans for environmentally sustainable salmon production. Planning is based on fifteen sub-basins -- called Habitat Management Areas (HMA) -- within the Fraser River watershed (Figure 1). This report examines the Chilcotin HMA which includes the watershed of the Chilcotin River and lies on the west side of the Fraser River near the town of Williams Lake.

An understanding of the hydrologic regimes of the salmon streams, and their response to land and water use, is an important aspect of habitat management planning. This report describes both the regimes themselves and the effect of human development on those regimes. Within the Chilcotin HMA, agricultural, municipal and industrial extractions from surface waters, and the effect of forest harvesting on floods, are the main anthropogenic issues affecting the hydrology of the salmon streams.

The main objective of the report is to express the habitat sensitivity of the salmon streams through various indices that are calculated from the hydrologic, water use and land use data collected for the streams. In this report, we use "sensitivity", in a very broad sense, to refer to a level of concern for those aspects of the hydrologic regime that affect habitat and are altered by human activities (ESSA 1992). The indices are used to rank the streams within the combined West Road and Chilcotin Habitat Management Areas. The most sensitive streams include those that are most affected by human activities as well as those that, because of their hydrologic regime, have the least ability to resist human impact.

1.2 Scope of the Study

Our study examines 5 salmon streams within the Chilcotin HMA, including two reaches of the Chilcotin River, that are listed in the Stream Information Summary System (Table 1). Our analysis is based on information obtained from the Ministry of Forests, Water Survey of Canada, the Ministry of Environment, Lands and Parks and from interviews with staff of the various government agencies. Information available prior to 1993 has been summarized in this report. The following tasks were completed during our study:

1. Summarize and describe those aspects of the climate, physiography, surficial geology and soils that affect the hydrology of the salmon streams;

2. Describe the local hydrologic regime and prepare estimates of mean annual flows, mean annual floods, mean monthly flows and seasonal 7 day low flows for each of the salmon streams from Water Survey of Canada records, Water Management Branch records or from regional analysis for ungauged streams;

3. Use Water Rights Branch records to calculate licensed demand on surface waters in each of the salmon streams;

4. Review the impact of forest harvesting on hydrology and determine the portion of the watersheds of the salmon streams that are harvested;

5. Use the hydrologic, water use and land use data to calculate sensitivity indices and rank the various salmon streams according to water withdrawals, high flows, low flows and forest harvesting.

6. Summarize the main issues in the salmon streams and discuss technical or management alternatives for the salmon streams based on interviews and discussions with government personnel.

The main task was predicting flow characteristics for the 5 salmon streams. Although the quality of information varied greatly from stream to stream, our approach focused on predicting flow characteristics that permitted comparison and ranking of streams within the study area. Predicted flows, given in this report, are not necessarily the best estimate for any individual stream and should not be used for design of structures or evaluation of projects without further, detailed study of that particular stream.

1.3 Report Structure

The report describes each task separately and presents the overall results of the study in the final chapter. Chapter 2 describes the characteristics of the study area; Chapter 3, the methods used to estimate flow characteristics; Chapter 4, the effect of land use on hydrology and the measurement of the areas of forest harvesting; and Chapter 5, the calculation of licensed demand for surface flows. Table 4 summarizes the data for these investigations for each of the salmon streams.

The sensitivity indices are described in Chapter 6. Table 6 presents the 10 sensitivity indices calculated for each of the salmon streams. Chapter 7 presents the results of the study and describes technical and management alternatives for the salmon streams.

1.4 Acknowledgements

A number of individuals agreed to interviews and provided an overall perspective on land and water use and hydrology in the Chilcotin Habitat Management Area, as well as information on the salmon streams. We would like to thank Ken Soneff, Bill Klopp, Jack Leggatt, Greg Ashcroft and Marcel Demers of the Williams Lake office of the Ministry of Environment, Lands and Parks; Uwe Finger, Glen Davidson, Dennis Abelson, Don Cadden and Dave Stevenson of the Prince George Office of the MOELP; and Bruce Mac Donald, Pat Harvey, Ray Finnegan, George Nielsen, Mel Sheng and Ed Woo of the Department of Fisheries and Oceans. Final preparation of the report for publication was made by Karen Munro.

2. OVERVIEW OF THE SALMON STREAMS IN THE CHILCOTIN HMA

Physiography and geology act to influence the behaviour of soil and water and, consequently, the hydrologic characteristics of the salmon streams. Terrain and surficial deposits help determine storm runoff characteristics, infiltration rates, and the susceptibility of stream channels to erosion. Subsurface geologic materials influence the recharge, movement and re-emergence of ground water.

Climate, in combination with physiography and geology, can be used to define broad regions of similar hydrologic behaviour. As is discussed in the following sections, the Chilcotin HMA includes two physiographic regions, which have different hydrologic regimes, and, as a result, the salmon streams exhibit a range of flow characteristics depending on their location.

2.1 Physiography

The Chilcotin HMA includes the watershed of the Chilcotin River (Figure 3) and lies on the western side of the Fraser River near the town of Williams Lake. The HMA includes two separate physiographic regions (Matthews 1986). While most of the Chilcotin River watershed lies on the Chilcotin Plateau the drainage basins of the Taseko and Chilko Rivers extend into the eastern side of the Pacific Ranges of the Coast Mountains (Table 1). The Chilcotin Plateau consists of gently rolling, undissected uplands. Elevations are generally between 1,300 and 1,600 m and rise to the west, reaching around 2,000 m near the Coast Mountains. Much of the plateau is underlain by volcanic flows, though the bedrock is mostly covered by glacial drift and drumlins and eskers provide local relief. The gently rolling surface has steep escarpments along creeks and major river valleys.

Highlands on the plateau include the Rainbow, Ilgachuz and Itcha Ranges, which reach about 2,500 m. These ranges are the dissected remnants of shield volcanoes of Miocene Age.

The upper portions of the Taseko and Chilko watersheds extend into eastern side of the Pacific Ranges of the Coast Mountains. The drainage areas of Chilko and Taseko Lakes lie entirely within these ranges. Summit levels are near 3,000 m and the higher peaks have typical alpine glacial features, such as cirques and sharp, saw-toothed peaks. Considerable portions of the Pacific Ranges are covered by small icefields and glaciers.

2.2 Climate and Streamflow

Climate varies within the Chilcotin HMA and precipitation decreases from east to west across the region. The variation of precipitation, temperature and elevation produces distinct climate and hydrologic regimes in the two physiographic regions (Table 2).

Chilcotin Plateau: Temperature and precipitation measured at the Alexis Creek Tautri Crk, Kleena Kleene, and Tatlayoko Lake climate stations, operated by the Atmospheric Environment Service (AES), are representative of the climate on the Chilcotin Plateau. Average normal temperature at these stations is typically near 1° Celsius. July and August are the months with the highest temperatures, averaging near 13°, though maximum daily temperatures reach 37°. January has the lowest average temperature at about -13°, and minimum winter temperatures are about -50°.

Annual normal precipitation ranges from 350 to 450 mm of which roughly 40% falls as snow at the climate stations (which are mostly at lower elevations). The greatest monthly totals are in December and January (almost entirely snow), and June, July and August (entirely rain). In the eastern side of the HMA, June, July and August have the greatest totals. About 40% of the total precipitation falls in these three months. Near the Coast Mountains, at Kleena Kleene, greater totals are recorded in the fall and winter, as Pacific storms spill over the Coast Ranges. Minimum monthly precipitation generally occurs in March or April.

The greatest daily rainfalls (about 40 mm) are recorded in June, July or August in the eastern portion of the basin. Near the Coast Mountains, the greatest daily rainfalls are recorded in October and November reaching a maximum of 70 mm at Tatlayoko Lake.

Mean annual flow from basins on the Plateau increases with drainage area. When the annual discharge is expressed as a **mean annual runoff** (i.e. expressed as the equivalent depth of water over the basin area) the values range from 10 to 200 mm with the lowest values recorded in the upper Chilcotin Basin. Annual runoff from the Chilanko River (*Chilanko River near Redstone 08MB004*) is near 10 mm and apparently the entire upper Chilcotin has very low runoff. The highest mean annual runoff is found near the eastern edge of the Coast Mountains in Lingfield Creek. Subtracting mean annual runoff from normal precipitation indicates that annual evapotranspiration and losses to groundwater amount to about 350 to 400 mm.

Maximum monthly discharges on the Plateau occur in May or June, though annual maximum discharges may occur at any time between mid-April and mid-June in response to snowmelt or rain on melting snow. Near the Coast Mountains, spill-over of pacific storms may produce floods in the late fall.

Mean monthly flows decline over the summer, reaching a minimum in September. On average, flows increase in October and November and then decline throughout the winter, reaching a minimum in February or March. Annual 7 day low flows are usually recorded between December and March though in some years the annual 7 day low flow also occurs in the late summer.

Coast Mountains: There are no AES stations on the east side of the Coast Mountains near the Chilcotin HMA and little is known the temperature and precipitation regime in this region. Mean annual precipitation is expected to exceed 1,000 mm.

Mean annual flow from basins in the Coast Mountains increases with drainage area. When the annual discharge is expressed as a **mean annual runoff** (i.e. expressed as the equivalent depth of water over the basin area) the observed values are between 500 and 700 mm. Subtracting mean annual runoff from normal precipitation indicates that annual evapotranspiration and losses to groundwater amount to about 350 mm.

Maximum monthly discharges occur in June though annual maximum discharges generally occur at any time between mid-May and August and annual maximums occasionally occur in the early fall in response to large rainstorms. Mean monthly flows decrease slowly over the summer because of contributions to streamflow from snowmelt at high elevations, glacier melt and release from storage in large lakes. Minimum monthly flows are usually recorded in February. Annual 7 day low flows usually occur between December and March.

3. FLOW CHARACTERISTICS OF THE SALMON STREAMS

The following average flow characteristic, for the period 1981-1990, were estimated for the mouth of each salmon stream and are defined in more detail on Table 3:

- **Mean Annual Flow**, expresses the total yield of water from the drainage basin and is useful for reservoir design;

- **Mean Annual Flood**, when combined with channel slope, is related to the potential for scour of gravel in the stream and the potential for channel erosion and enlargement. Peak flows at greater return periods are used for design of instream structures;

- **Mean Monthly Flow** for August and September expresses the average flow of water available during the driest portion of the summer when salmon rearing, adult migration and early spawning may occur. These months also have the greatest removals for irrigation. Low flows in these months reduce rearing habitat, strand juveniles and are associated with high temperatures that reduce habitat quality. Mean monthly discharge in February expresses the average flow of water available during the driest portion of the salmon egg incubation period. Low flows in this month affect incubating eggs through freezing in de-watered or exposed redds;

- **Mean 7 day low flows** for the summer express the average minimum flows during the summer rearing season and are used for fish habitat evaluations, calculating water allocations and water quality prescriptions. Mean 7 day low flows for the winter express the average minimum flow experienced during the winter and are associated with de-watering of redds.

There is a large range in the quality and availability of records on the salmon streams. Some streams have long-term gauging records at stations that continue to operate; other streams have short-term or seasonal records of moderate quality from the 1960's and 1970's; while other streams have little or no information available. The average flow characteristics in the above list, as well as other characteristics, can be very reliably estimated for salmon streams with long-term records. Less reliable estimates are available for streams with limited records and the least reliable estimates are for streams with no records.

3.1 Reference Point for Flow Characteristics

All flow characteristics, as well as water licence summaries, were prepared for the mouth of each stream as this was a representative and easily-identified point. Flows at the mouth are representative of the length of the lower reach of the stream downstream of any major tributaries.

The Water Survey of Canada report their data for a specific point on the stream which may be near the mouth of the stream, or a considerable distance upstream. The sites are generally selected for accessibility and for their suitability as gauging sites, rather than for other criteria. When the gauging site is near the mouth of the stream we have assumed that the recorded flows also describe flows at the mouth. However, if a major tributary enters between the gauge and the mouth, or if the gauge is well upstream of the mouth, the flows recorded at the gauge were adjusted to obtain flow estimates at the mouth, either by adding measured tributary flows or by increasing flows based on the ratio of drainage areas at the mouth and at the gauge (Appendix A).

On ungauged streams, flow characteristics were calculated for the drainage area to the mouth of the stream.

3.2 Period of Record for Calculating Flow Characteristics

In much of British Columbia, there is a consistent pattern of declining annual flows in the late 1940's and 1950's, above average annual flows in the 1960's and 1970's (Barrett 1979) and below average annual flows during the 1980's. Mean annual flows, as well as other flow characteristics, vary from decade to decade and it is important, when comparing records at different stations, to limit flow data to a common period, so that variation between gauges reflects the character of the particular station rather than differences in the period of record. Alteration of water demand and water utilization may also mean that records from the 1960's or 1970's may not be representative of the current regime.

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. This period includes a moderate drought from 1987 through 1989 in the Chilcotin basin and a large flood in June, 1990 with a return period of about 25 years.

3.3 Hydrometric Data in the Chilcotin HMA

The Water Survey of Canada is the prime agency collecting and reporting flow data in British Columbia. Gauging stations in the Chilcotin HMA are described in *Surface Water Data Reference Index: Canada 1991* published by Environment Canada. There are 16 active and abandoned stream gauging stations in the Chilcotin watershed and four of the salmon streams have at least some miscellaneous flow measurements (Table 1). However, only three salmon streams (Chilcotin River (lower), Chilko and Taseko Rivers) have complete, or nearly-complete, flow records for 1981 to 1990 at stations that are reasonably close to their mouths. For these streams, flow characteristics may be calculated from Water Survey of Canada records, as discussed in Section 3.5 and Appendix A.

The remaining salmon streams typically have either 1) partial records between 1981 and 1990, 2) partial records from earlier decades, such as the 1960's or 1970's, or 3) no discharge records from the Water Survey of Canada (Table 1). Procedures for estimating flows on these streams are discussed in Section 3.6 and Appendix A.

There are also gauging stations on streams that are not salmon streams. These stations provide useful information on the hydrologic regime of watersheds in the Chilcotin HMA and are used in estimating flow characteristics (Appendix A).

3.4 Other Sources of Hydrometric Data

The Water Management Branch of the Ministry of Environment operates some gauging stations (whose data are reported by the Water Survey of Canada), collects miscellaneous measurements to establish flows for approving licensed extractions, and carries out occasional (regional) data collection programs during droughts. Their drought programs (Nyhof 1987, Richards 1977) measured low flows on small streams on the eastern edge of the Chilcotin Plateau. Where possible, these measurements, as well as miscellaneous records, were used to corroborate regional estimates of low flows.

3.5 Gauged Salmon Streams

Gauged salmon streams are those whose flow characteristics can be calculated directly from Water Survey of Canada records. (Data for gauged salmon streams are shown shaded in Table 4.) Table 3 provides definitions of the flow characteristics used in this report and more detailed descriptions follow in Sections 3.5.1 and 3.5.2.

The gauging stations either measure natural flows or regulated flows, where regulated flows are those affected by upstream storage or water extractions. **Natural flows** -- those that occur in the absence of all regulation or extraction -- are best-suited for the sensitivity indices so that licensed extractions can be expressed as a percentage of the total available flow, rather than the measured flow.

3.5.1 Water Extractions and Flow Characteristics

For streams affected by water extractions, the characteristics calculated from the flow records were adjusted to represent the natural regime in the stream by added potential water extractions, as calculated from summaries of water licences, to the flow recorded at the gauge (Figure 4). We have referred to these adjusted flows as **naturalized flows** to distinguish them from measurements of the natural regime.

This approach provides a reasonable estimate of the natural flows in the Chilcotin HMA in that developed storage in most watersheds consists of small, independently-operated reservoirs. The total storage is small in comparison to irrigation requirements (Table 5) and licensed demand is often low in comparison to flows. In these circumstances, it is reasonable to ignore the contribution of storage to low flows, and naturalized flows may be assumed to represent the natural regime. The naturalized flows are close to the natural flows, but are expected to over-estimate these flows, because of differences between actual and licensed water use upstream of the gauge, flow enhancement by releases from small storage projects and return flows from irrigation diversions. The degree of over-estimation is small for the gauged streams and can be evaluated by comparing storage volumes to irrigation demand and to typical flows in August and September.

3.5.2 Storage and Flow Characteristics

There are no large reservoirs in the Chilcotin HMA.

3.5.3 Calculation of Annual Flow Characteristics

The historic period for the **mean annual flow** is 1981 to 1990, inclusive (see Table 3 for definitions). No adjustments were needed for the effect of regulation. The historic period for the **mean annual flood** is 1981 to 1990, inclusive. No adjustments were made for the effect of regulation, though it is recognized that natural flood flows are slightly reduced by storage in small reservoirs.

3.5.4 Calculation of Seasonal Flow Characteristics

The water year was divided into two seasons: summer (May 1 to October 31) and winter (November 1 to April 30). This division was chosen to include all irrigation within one season and separate low flows into two distinct seasons corresponding to different parts of the salmon life cycle. Summer low flows are affected by storage and release of water, irrigation diversion and domestic and waterworks withdrawals. Low flows in the summer reduce rearing habitat, strand juveniles and are associated with high water temperatures. They also affect late summer/fall migration of adults and early spawning.

Winter low flows are only affected by storage and release of water (in a few circumstances) and domestic and waterworks withdrawals. Low flows in the winter affect incubating eggs by de-watering redds and increasing the incidence of freezing of eggs.

Table 4 reports mean August and September flows for the gauged streams. Measured flows were adjusted to naturalized flows by adding potential licensed demands for each month, following the procedures discussed above.

Summer and winter 7 day low flows were extracted from Water Survey of Canada records, covering 1981 to 1990, and mean seasonal seven-day low flows calculated as an average of all observations. The mean low flows do not necessarily correspond with the two-year return seven-day low flows. This is because the mean low flow is affected by extreme seven-day low flows occurring within the period of record.

Where necessary, summer 7 day low flows were naturalized by adding the calculated potential demand for September, as these flows typically occur in September. This is a crude adjustment as low flows may occur during periods of limited or no irrigation and the adjustment will over-estimate the natural flows that would occur. Winter 7 day low flows were not adjusted.

3.6 Gauging Records on the Stream Summary Sheets

The gauging records were used to calculate detailed flow characteristics, such as mean annual hydrographs, monthly distributions of annual 7 day low flows, and 7 day low flow frequency curves for the Stream Summary Sheets (Appendix B). These flow characteristics are based on all available, complete years of data at the gauge sites, rather than 1981-90 -- in order to best estimate the flow characteristics at the gauge -- and are not adjusted for upstream storage or water use.

All data are included on the Stream Summary sheets attached as Appendix B. The mean annual hydrographs are calculated from all available complete, continuous years of record at the gauge. All years were used because these gave the best representation of the annual pattern of flow.

The distribution, by month, of the annual 7 day low flows, is based on all complete years of record at the gauge. Seven day low flow frequency curves are also included on the Summary Sheets.

Floods with various return periods were calculated with the CFA-88 program, prepared by the Water Survey of Canada, as adapted for micro-computers. Floods of 2, 10, 20, 50 and 100 year return periods are reported.

3.7 <u>Ungauged Salmon Streams</u>

The ungauged salmon streams include all those streams where average flow characteristics for 1981 to 1990 must be estimated rather than calculated from Water Survey of Canada records. A variety of techniques were used to estimate the flows and these are discussed in detail in Appendix A.

Flows were estimated for the ungauged streams by transferring measured flow information from nearby, similar streams, by adjusting incomplete records on the individual stream or by regional equations that relate flows to basin characteristics. Mean annual flows, mean annual floods, mean monthly flows and mean summer and winter 7 day low flows are estimates of values appropriate for 1981 to 1990.

4. LAND USE

The natural hydrologic regime of the salmon streams in the Chilcotin HMA is altered, to some extent, by land use. Urbanization, agriculture and forest harvesting have the potential to alter the hydrologic regime. Urbanization and agriculture mostly affect hydrology by extracting surface and ground water for stock watering, domestic use and irrigation. These land uses also have some limited impact on flood discharges through conversion of forest lands. Surface water extractions are discussed in detail in Section 5 "Water Licensing".

The removal of timber during forest harvesting eliminates transpiration; and the cut blocks alter the distribution of snow and may increase the rate of snowmelt. These changes in the watershed, coupled with road construction and soil changes during logging tend to increase water yield (mean annual flow), mean annual floods and summer base flows.

There are secondary effects on stream channels associated with increased flood flows. In susceptible materials, channels often enlarge through bank erosion and channel incision and they may degrade their bed. These processes, along with sediment released from harvesting activities, may greatly increase the quantity of sediment transported through the stream.

This section describes the measurement of impact of forest harvesting on the hydrology of salmon streams through estimation the rate of cut, or estimation of the clearcut equivalent area (CEA), within the watersheds; and further discusses the changes in hydrological and sedimentological regimes typically associated with forest harvesting in the interior of B.C.

4.1 Forest Harvesting

Maps and databases maintained by the Ministry of Forests were used to provide information on the following parameters for each salmon stream. Note that the information is compiled from compartment records, which are a large unit used by the Ministry to store silviculture, inventory and harvesting information.

- **Non-Forested Areas:** Includes exposed bedrock, icefields, treeless biogeoclimatic zones, etc. (Extracted from Inventory Branch, Standard Inventory Reporting (SIR) System and includes non-forest and non-productive classifications.)
- **Older Harvested Area:** Includes those cutblocks that are older than 10 years as recorded in the Licence Silvicultural Information System (which contains summaries for the major licence holders and the small business program). There are few cutblocks older than 10 years in the Chilcotin HMA.
- **Recently Harvested Area:** Includes those harvested areas that are less than 10 years old as identified from the Licence Silvicultural Information System (which contains summaries for the major licence holders and the small business program).
- **Proposed Harvest:** Identified from five-year plans and current to 1992. The data was extracted from the comprehensive plan prepared by the Chilcotin and Quesnel Forest Districts that incorporates all five-year plans submitted by the various logging companies. Salvage logging for beetle-kill is additional to the five-year plans and is also incorporated in the proposed harvest.

4.2 The Effect of Logging on Hydrology

Haul and skidder road construction compact the surface and increases runoff from the road surface and increases the rapidity of runoff. Ditching along roads concentrates water, generally into fewer channels, and intercepts subsurface flow, increasing the speed of flow to drainage channels. The removal of trees severely reduces or eliminates transpiration, in the short-term. Tree removal also increases air movement and changes soil temperature which tend to increase evaporation from the soil surface, but the overall effect is to reduce evapotranspiration from the soil. In British Columbia, tree harvesting also affects the distribution of snow and the timing of its melt.

4.2.1 Forest Harvesting and Streamflow Quantities

Well-designed experiments generally show increased water yield as a response to forest removal, and the increase is generally proportional to the amount of canopy removed (Bosch and Hewlett 1982). The increased flow of water results from increased storage of water in the soil as the result of reduced transpiration following the removal of forest cover. Increases are observed during the summer low flow season and also during the wet, or high flow season, particularly early in the season when soil storage differences are greatest between the forested and clearcut areas.

Clearcut logging in Camp Creek near Penticton, B.C., following Pine Beetle infestation, produced results similar to those recorded in experiments from the western and southeastern United States. Both annual and March to November monthly water yields increased in the clearcut stream with the greatest increases recorded in the months of August and September (Cheng 1989). There was no consistent evidence of increased streamflow in the winter months.

4.2.2 Forest Harvesting and Flood Flows

Many studies have demonstrated increased storm volumes and peak flows following forest removal, though there are few results appropriate to the Interior of British Columbia where snowmelt is the dominant mechanism for flood generation. Cheng (1989) found increased, and earlier, peak flows in Camp Creek after clearcutting of 30% of the basin area. His finding of a 20% greater, and two weeks earlier, flood peak are roughly comparable with studies in other snowmelt-dominated systems. King (1989) examining streamflow responses in northern Idaho, found increases of 15 to 35% in maximum instantaneous discharges.

Forest harvesting also affects flood flows generated by rain on snow, though studies have generally been conducted in the transient snow zone of the Pacific Coast and their conclusions may not be entirely transferable to the interior. Generally, greater melt rates of shallow, warm snowpacks are expected following forest harvesting because of increased transfer of convective energy from increased wind speed and turbulence. However, a number of variables, such as antecedent snow conditions, storm characteristics and climate affect the results and few studies have demonstrated increased peak flows (Harr 1986). Beaudry (1985), based on studies in Jamieson Creek in the Seymour watershed, shows that air temperature and the presence of snow in the canopy in the forest affect the relative melt rates and runoff from clearcut and forested sites.

The Ministry of Forests has prepared guidelines for the Kootenay Lake Forest District to control rate of cut in such a manner as to minimize changes to the annual hydrograph in snowmelt-dominated hydrographs (Toews 1990). Changes to the freshet hydrograph are minimized by distributing the cut over a range of elevations and aspects and by controlling the clearcut equivalent area (CEA) within the watershed. The CEA is calculated from the product of the total cut area and a regeneration recovery factor, which ranges from 90% for 3 m regeneration to 0% for 7 m regeneration on the block. This procedure assumes that 7 m regeneration represent full recovery and that intermediate regeneration reduces the hydrologic effect of the clearcut. Maximum allowable clearcut equivalent areas vary with basin type, but range from 25% to 35%.

4.2.3 Forest Harvesting and Sedimentation

Watershed disturbance during forest harvesting often causes increased fine (suspended) and coarse (bedload) sediment delivery to streams, through erosion of roads and cut-banks, soil disturbance or landsliding. Elevated suspended sediment loads and deposition of this material on fans or in low-gradient sections of streams may have greater impact than changes in the hydrologic regime resulting from logging.

The relative importance of various erosion processes, and the various forestry activities, to the total sediment budget of a disturbed watershed depend on the precipitation regime, character of the watershed, soils and logging practices. Details may only be resolved after extremely detailed study. However, a general appreciation of the nature of sediment sources and sediment delivery processes may be obtained from aerial photographs and reconnaissance studies.

4.3 Agricultural Land Use

Areas of agricultural land use were not measured as part of this study.

4.4 Physiography

The following parameters were used to describe each of the watersheds:

- **Drainage Area:** Drainage areas upstream of stream gauging sites were extracted from Water Survey of Canada publications. Drainage areas above the mouths of salmon streams were extracted from WSC publications or measured on 1:50,000 or 1:250,000 maps.
- **Relief:** Defined as the difference between the maximum and minimum elevations in the basin, measured from 1:250,000 topographic maps.
- **Surface Area of Lakes:** The surface area of lakes and reservoirs within each drainage was measured from 1:250,000 topographic maps.

5. WATER LICENCES

The Water Rights Branch of the Ministry of Environment maintains a computerized data base of water licences in British Columbia. Summaries (by licence type) were produced for all salmon streams, as well as streams with long-term Water Survey of Canada gauging stations.

5.1 Classification of Water Licences

Figure 5 reproduces the water licence classification system used by the Water Management Branch. Water licences are classified into consumptive and non-consumptive uses and further classified by the type of user. Computer-generated summaries, obtained from the Water Rights Branch, Victoria, utilize the main classification shown in Figure 5, but provide more detail on the type of user, producing a total of 73 sub-categories (including non-consumptive uses).

5.1.1 Consumptive Licences

The computer-generated classification provides more detail than is required so we have reported consumptive licensed extractions from the salmon streams (Table 4), under the categories of Domestic, Waterworks, Irrigation and Industrial. Pulp Mills, Land Improvement and Mining licences, which are classified separately by the Water Management Branch, are included under our Industrial category as there are few of these licences in the Chilcotin HMA. Table 4 reports the sum of all licences, of each type, above the mouth of each salmon stream.

5.1.2 Non-Consumptive Licences

Non-consumptive water use includes Power Generation, Storage (nonpower and power) and Conservation. Conservation licences are totalled and summarized on Table 4. Nearly all the storage licences are non-power licences.

The total non-power storage licences for each salmon stream are listed in Table 5. The total includes all storage for domestic, waterworks, irrigation, industrial and conservation licences; though, in most streams, the majority of the licences are for irrigation. Table 5 also compares the irrigation licences to the non-power storage in each salmon stream. Storage affects discharge by being accumulated during the spring freshet and released during low flows, or during the irrigation season. In many watersheds, licensed storage volumes are matched to some irrigation licences, and the net reduction in low flows resulting from diversion for irrigation is, theoretically, less than the total licensed irrigation diversion. This does not work in practice as the upstream storage facilities trap incoming flows during low flows as well as high flows -- reducing downstream flows in addition to extractions -- and leaky dams and evaporative and transmission losses reduce the storage quantity available to compensate for licensed extractions.

5.2 Licensed Versus Actual Water Use

5.2.1 Domestic and Waterworks Licences

Domestic use is only partly consumptive. In summer, although a large portion of the domestic use is for watering of lawns and gardens, some of this water re-enters the stream as return flow.

Waterworks are also only partly consumptive; but in organized areas, water may be diverted out of the basin and return flows may not end up in the same stream, producing a true loss to streamflow. Typically, waterworks are licensed for amounts well in excess of actual extractions. Because licence-holders for large waterworks projects pay a fee based on actual water use, rather than the licensed amount, records are available of the annual volumes of water extracted from streams. We have not obtained these records because waterworks and domestic extractions in salmon streams in the Chilcotin Basin are mostly insignificant when compared to irrigation use or to streamflow.

5.2.2 Irrigation Licences

A certain percentage of the water diverted for irrigation re-enters the stream as return flow. When flood irrigation (by ditches and flumes) was prevalent it was assumed that roughly 30% of the diverted volume returned to the stream. Sprinkler and drip/trickle irrigation, which are now the dominant methods of irrigating, use less water and are expected to produce less return flow.

Water applied to the land on a particular day will cause return flow some days, weeks or months later. The Okanagan report assumes about 12% of the annual return flow occurs in September and 9% in October; and also allows for a small percentage (about 4% per month) through the winter months. Return flow in August and September may reduce the impact of irrigation diversions in those months if the flow is returning to a reach of the stream supporting fish.

Actual irrigation demand can be estimated from the area of irrigated land and a calculated or estimated water duty. However, the area of irrigated land in the salmon streams in the Chilcotin HMA is not known. The duty -- the water needed for the irrigation season expressed as a depth -- which is used to calculate the total amount of water needed for irrigation is also not known. As well, the theoretical duty and the actual amount applied can differ, as a result of farming practices. The duty can also vary with location and elevation, and from year to year. Year-to-year variations are significant: from 1975 to 1988, duty in the Vernon Irrigation District varied from 31 to 48 cm (Rood 1989), with the greatest amount required during low flow, dry years.

We have used water licence summaries to estimate irrigation demand, for several reasons. First, areas of irrigated land within the watersheds of the salmon streams are not known and, second, the required duty is not known for the Chilcotin HMA. Finally, the water licences represent, as discussed in the next section, a maximum demand on the salmon streams and provide a comparable standard of comparison from stream to stream.

5.3 Calculation of Licensed Demand

Calculation of licensed demand has the advantage of providing a consistent measure of demand from each stream and, in many instances, the licensed amount may be close to actual use: extractions are greatest in dry years and overuse of some licences may compensate for licences that are only partly used, or not used at all.

The demand calculated from all licences is the maximum demand that may be exerted on the stream, if all licences were fully utilized. Some streams are fully recorded and the calculated demand will not increase; on other streams additional licences may be issued. (Those salmon streams with reserve notices or restrictions, issued by the Water Management Branch, are indicated in Table 6.)

The water licences summarized in Table 4 are expressed in various units, ranging from acre-feet for irrigation licences, to gallons/day for waterworks and domestic licences and ft^3/s for conservation licences. Licensed amounts expressed as a discharge were converted to litres per second (L/s) using appropriate conversion factors: 1 L/s is equivalent (approximately) to 19,000 imperial gallons/day; 1 L/s is equivalent (approximately) to .035 ft^3/s.

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decameters (dam^3), where 1 dam^3 is equivalent (approximately) to 0.81 ac-ft. In any time period, the total demand is calculated by adding the demand from waterworks, domestic and industrial licences, which are assumed to be constant throughout the year, to the irrigation demand. Irrigation volumes are assumed to be distributed in the Chilcotin HMA as follows: May (15%), June (25%), July (25%), August (25%) and September (10%). (These percentages were used in the Okanagan Basin Report (1974) and correspond reasonably well with the seasonal distribution of water use by the Vernon Irrigation District (Rood 1989).) Monthly irrigation volumes (in dam^3) were converted to discharges (L/s) by multiplying by 10^6, and dividing by the number of seconds in the month.

The total demand varies from month to month as a result of irrigation extractions. Table 4 presents calculated licensed total demand, in L/s, for August, September and February. These months were chosen because August and September are months when low flows commonly occur during the irrigation season and February is the winter month with the minimum monthly discharge.

6. SENSITIVITY INDICES FOR THE SALMON STREAMS

We have expressed the habitat sensitivity of the salmon streams through various indices that are calculated from the hydrologic, water use and land use data collected for the streams. The sensitivity indices used here describe the level of concern for those aspects of the hydrologic regime that affect habitat and are also potentially altered by human activities. The indices are of two general types:

- Indices that express the level of human activity in the watersheds of the salmon. These include expressions of the proportion of the basin of the salmon streams that has been harvested and the degree of utilization of water for irrigation, industrial and waterworks; and

- Indices that express the state of the particular stream and its ability to resist further change. These indices express peak flows and low flows as a ratio or percentage of the mean annual flow; extreme values indicate stressed systems with a limited ability to withstand further hydrologic alteration.

It was felt that the most useful indices for assessing habitat sensitivity would indicate the magnitude of water use during low flows in summer, compare the magnitude of low flows to mean flows, compare peak flows to mean flows and indicate the extent of logging in the watershed.

The indices are expressed as percentages of mean annual flow, except for peak flows, which are expressed as a ratio of the mean annual flow. The use of percentages and ratios permits easy comparison of streams of different watershed areas and allows ranking of the streams. The most sensitive streams were defined as those with the most extreme indices or those whose indices exceeded some critical value. On Table 6 the most sensitive streams are shaded: the rationale for selecting the most sensitive streams is discussed separately for each index in the following sections. The following table summarizes the indices:

Index	Definition	Interpretation
1	potential demand in August as a percent of the 7 day average low flow	expresses the maximum portion of flow during the rearing season that is used for water demand
2	as above for September	as above
3	potential demand in August as a percent of mean August discharge	expresses the typical portion of flow during the rearing season that is used for water demand
4	as above for September	as above
5	actual summer 7 day average low low as a percent of mean annual flow	expresses the ability of the system to resist water removals; low values indicate streams with low actual 7 day low flows
6	as above for winter 7 day lows	as above
7	mean annual flood as a ratio of mean annual flow	expresses the peakiness of the stream hydrograph and the potential for scour and erosion
8	recent logged area as a percent of total basin area	roughly expresses the clearcut equivalent area and indicates the extent of hydrograph changes from logging; values exceeding 20% indicate potential changes
9	total logged area as a percent of total basin area	as above
10	recent and proposed logging as a percent of total basin area	as above

6.1 Summer Water Demand

Indices 1, 2, 3 and 4 express potential demand in August and September as percentages of various measures of low flow and indicate the total portion of the natural low flows devoted to irrigation and other water uses. Indices 1 and 2 compare potential water demand to mean 7 day summer low flows, which typically occur in August or September. The 7 day low flows used in calculating the indices are naturalized or are estimates of the natural low flow and, consequently, the indices indicate the percentage of the available low flow that could, potentially, be required to meet water demand. Indices 1 and 2 represent extreme demands that may occur during the irrigation season. Indices 3 and 4 compare potential demand in August and September to average flows in these months and are a measure of typical or normal portion of flows devoted to irrigation during the late summer.

Large values of Indices 1 through 4 indicate streams with great potential demand, primarily from irrigation, on summer low flows. On Table 6, those streams whose indices are the top 25% of the values are shaded.

The potential water demand is calculated from the total licences and probably over-estimates the actual water use. The indices also do not account for storage and release in the watershed. Also, small errors in measurement or calculation of 7 day low flows can make large differences in the value of the indices.

6.2 Summer and Winter 7 day Low Flows

Indices 5 and 6 compare seasonal 7 day low flows to mean annual flow, expressing the 7 day low flows as a percentage of mean flow and indicate the ability of the stream to accept water extractions. Low values of the index indicate streams where 7 day low flows are small and where further reductions may significantly affect habitat.

Actual 7 day low flows as opposed to naturalized flows were used in the indices so that the indices reflected current conditions in streams with licensed demand and those without licensed demand. The 7 day low flows used in calculating the indices are the recorded low flows on gauged streams, prior to adjustment to reflect upstream storage and diversion of waters. On ungauged streams, with licensed demand, the predicted natural flows were adjusted to actual flows by subtracting the (September) potential water demand. Low values of the indices indicate streams with large water demand or steep recession curves during summer drought.

On Table 6, those streams whose indices are in the lowest 25% of the values are shaded. Most of the streams with low indices have small drainage basins which tend to have more extreme response to drought. On the Chilcotin and Cariboo Plateaus, measurements by the Water Management Branch indicate that drainage basins up to 50, or more, km^2 may have zero discharge during moderate droughts (Richards 1977; Nyhof 1987).

6.3 Peak Flows

Index 7 compares the mean annual flood to mean annual flow, expressing the mean annual flood as a ratio of the mean annual flow. Higher values of the index indicate streams with a greater range of flow, and, potentially, lower channel stability. This ratio does not vary significantly for stream to stream, partly because in some instances both mean annual flows are transferred to the ungauged streams from a nearby gauged stream. Consequently, ratios on the ungauged streams are the same as those on the gauged streams, and there is no correction for variation of unit annual flood with basin area. (Larger basins have lower unit values because of storm coverage effects.) On Table 6, streams with values of 10 or more for Index 7 are shaded.

Large values of the index may not indicate unstable streams because stability is also affected by the materials in the streambed and the gradient of the stream. Neither of these variables are included in the index.

Extreme floods also affect channel stability. Appendix B includes tables showing floods of various return periods for gauged salmon streams in the Chilcotin HMA.

6.4 Logging

Indices 8, 9 and 10 express the area of logging as a percentage of total basin area. Index 8 is the percentage of the watershed that has been recently logged (less than 10 years old based on silvicultural records); Index 9 is the percentage of total logging (all cutblocks including those blocks with some hydrologic recovery). Index 10 expresses the area of recent and proposed logging as a percentage of total basin area and reflects the area of clearcut with little or no hydrologic recovery expected by the end of 1997. The "older logging" includes cutblocks in varying stages of hydrologic recovery, ranging from those with limited or no hydrologic recovery that were recently harvested to some blocks that may be near 7 m green-up which is accepted to represent full hydrologic recovery. The percentage that have not recovered and the clearcut equivalent areas of both the recent and older logged areas are not known.

The Ministry of Forests often uses limits of 25 to 35% clearcut equivalent area in watersheds. This degree of clearcutting is expected to produce changes in the hydrologic regime (Section 4.2). Indices 8, 9 and 10 are not CEA values because they are not adjusted for hydrologic recovery of cutblocks and, as a result, may slightly over-estimate the clearcut equivalent area of recent logging and certainly over-estimate the CEA of total logging.

We have selected recent harvesting covering more than 20% of the watershed, which may correspond to a CEA of up to 20%, to indicate that management concern should be raised for fish habitat. A cut of 20% represent the point where effects on the hydrologic regime often become apparent and where changes in the sediment regime of the stream may result. We have also selected a low value so that those streams where changes in the hydrologic regime may be anticipated with further cutting are identified and management options may be considered. Those streams with recent logging greater than 20% of the basin area are shaded on Table 6.

Total basin area was used rather than forested area for several reasons. The effect on the hydrologic regime depends on the portion of the total basin whose hydrologic response is altered. If the forested area is only a small portion of the basin area, clearing a large percentage of the forest will have an undetectable influence on the hydrologic regime. Also, the Ministry of Forests uses total basin area in calculating these indices and we have followed their practice.

7. DISCUSSION OF THE SALMON STREAMS

Table 6 identifies the most sensitive salmon streams in the Chilcotin Habitat Management Area. Some of these streams have been the subject of studies and reports and have been, or currently are, managed in one fashion or another to benefit salmon. They are a source of on-going concern to Fisheries & Oceans Canada (DFO) or the Ministry of Environment, Lands and Parks (MoELP). As part of our study we reviewed existing reports and studies and discussed the salmon streams with Provincial and Federal government personnel. Our acknowledgements provide a summary of individuals contacted during the study.

7.1 <u>Sensitive Streams</u>

The streams that are shaded on Table 6 are those identified as sensitive as a result of high water demand, low flows, high peak flows or recent logging covering more than 20% of the basin.

The upper Chilcotin River and Elkin Creek have the greatest water demand in the Chilcotin HMA. Irrigation uses about 10 to 15% of the average monthly flows in August and September and up to 40% of the predicted summer 7 day low flows. The lower Chilcotin River has the greatest total volume of water extracted for irrigation (38,318 acre-feet; Table 4) but also has much higher average monthly and summer 7 day low flows so only a small percentage of the monthly flows is utilized for agriculture. The other salmon streams have insignificant water demand.

Peak flows, resulting from snowmelt occur from June to August except in the upper tributaries which have peak flows in May or June. They are usually less than 5 times greater than mean flows in the larger salmon streams. In both Taseko and Chilko Rivers large lakes store water and moderate annual floods. Release from storage, as well as glacier melt and melt of high elevation snowpack maintain discharges in the Taseko and Chilko Rivers into the late summer.

Total cut is less than 4% of the land area for all the salmon streams. Much of the total cut is less than 10 years old and, as a result, has limited hydrologic recovery. Proposed cut over the next five-year development plan ranges from 2 to 3% of the land base for most of the salmon streams, and includes large areas which will be cut for salvage of beetle-killed timber.

7.2 <u>Discussion by Stream</u>

Our discussions are not comprehensive appraisals of the various sensitive salmon streams but, rather, summarize previous studies or personal communications from knowledgeable individuals familiar with the streams. On some of the streams we have further distilled the available information into recommendations for management of individual streams (Section 8). The recommendations are in no particular order and the streams are not listed in priority order. In some instances, we felt there was insufficient information to develop general recommendations and these were not included for all streams. We recommend further study and investigation of all sensitive salmon streams.

Chilcotin River: Summer flows in the Chilcotin River remain high because of contributions from melt of glaciers and the high elevation snowpack as well as natural storage in Taseko and Chilko Lakes. Summer low flow problems are recorded on Alexis Creek and other tributaries. Some problems are noted with trapping of fish in unscreened ditches. There are 3 Finnigan screens reported to be in operation along the Chilcotin.

No problems are reported with winter low flows on the Chilcotin River. The flooding in 1990 produced some silt from bank erosion and failures along the river. Most of the spawning is upstream of the junction with the Chilko River and no sediment problems are reported for this area.

The Chilcotin River upstream of Chilcotin Lake was illegally diverted in 1975 so that it entered the lake much nearer its outlet, reducing flow circulation and causing concerns about eutrophication. The Habitat Conservation Fund contracted with Northwest Hydraulic Consultants Ltd (NHC) to develop channel restoration options and prepare costs for the various options (NHC 1992). It is believed that no construction has been carried out.

Chilko River: B.C. Hydro maintains land and water reserves on both Chilko and Taseko Lakes. Chilko Lake has an ample supply of water, no development, and, as a result, considerable storage potential.

There is a proposal for a park on Chilko Lake (Ms Kris Kennet, Parks Coordinator, Prince George) and for a development corridor plan along the Chilko River from Brittany Creek to Chilko Lake (Duncan Watson, Crown Lands) that would control development. There are a number of private docks near the outlet of Chilko Lake that could be a problem for future corridor plans.

There is a gravity feed groundwater supply near the confluence with the Chilcotin River that is sufficient to support a moderate-sized chinook incubation and rearing facility (Ginetz and Nielson 1980). A spawning channel was built on the Chilko River, about 4 km from the lake, in 1988.

Taseko River: There is little development in the watershed above Taseko Lake. Glacial sediments, generated in the upstream basin, pass through the lake, raising turbidity and limiting habitat.

A gravity groundwater supply of about 100 to 150 L/s has been identified about 3 km upstream of the mouth of Taseko River and could be developed for hatchery purposes (Ginetz and Nielsen 1980). There is no access to this site.

Elkin Creek: Upstream of Elkin Lake, in the Nemimiah Valley, the creek is unstable and actively transports a large bedload. The Ministry of Transportation and Highways channelized several kilometres of the creek upstream of the Nemimiah Valley road. The 1991 flood also produced some log jams near the mouth of Elkin Creek which have since been removed. There also has been beaver activity along the lower river and near the lake.

Low flow problems are reported on Elkin Creek upstream of Elkin Lake. There are a number of licences in the Nemimiah Valley. The Water Management Branch notes that there is not much more developable land in the valley. There is no storage development within the basin though there are several small lakes that could provide limited storage.

There is a proposed mining development for Fish Lake in the Elkin watershed.

8. RESULTS AND CONCLUSIONS

8.1 The Effect of Water and Land Use on Hydrology

The Chilcotin HMA includes two physiographic regions with distinct climate and flow regimes. Annual runoff is much greater from the eastern slopes of the Coast Mountains than from the Chilcotin Plateau; 500 to 700 mm compared to less than 100 mm. Annual runoff is lowest from the upper Chilcotin River, particularly the Chilanko River, where it may be as low as 10 mm. Most of the water in the lower Chilcotin River is from the Chilko River watershed.

The drainage basins of the Chilcotin HMA salmon streams are large and all exceed 2,000 km^2, except for Elkin Creek. The Chilko and Taseko Rivers extend into the Coast Mountains and have similar regimes. Because they are the main tributaries to the lower Chilcotin River it also has a similar regime. Peak monthly flows occur in June, July, or August as a result of snowmelt. Flows remain moderately high during August as a result of release of natural lake storage, melt of high elevation snowpack and glacier melt. Evapotranspiration demand is also highest during these months. Monthly flows decrease rapidly through September and October, reaching minimum monthly flows in March. The annual 7 day low flows typically occurs between December and April. Summer 7 day low flows exceed 30% of the mean annual flow. Irrigation extractions are at a maximum in July and August and provide the main human impact on summer streamflow.

On the Chilcotin Plateau, peaks flows occur in May or June as a result of snowmelt. Flows decline until September. In some years, fall rainfall raises discharges in October and November. Flows decline after November and remain low until March. Annual 7 day low flows occur in the late summer (September and early October) and in the winter and, in Lingfield Creek, are recorded in all months from September to April.

The following sections provide a summary of the main issues affecting the hydrologic and sediment regime of the salmon streams and discusses future developments in land use:

Water Use: Most of the irrigation licences are on small tributaries to the salmon streams. A number of the tributaries to the lower Chilcotin River have restrictions on further licensing though there are no restrictions on the main stem of any of the salmon streams. Neither the Water Management Branch nor the Ministry of Agriculture prepare forecasts of agricultural expansion and concomitant requirements for irrigation. However, local personnel report that very few applications for irrigation licences are received for the Chilcotin River basin and they do not anticipate much expansion of agricultural activity within these basins. The Water Manager (MoELP) in Williams Lake reports that the number of irrigation licence applications received generally increases following a moderate drought: snowpack has been adequate for a few years prior to 1991/92 and this, coupled with a substantial increase in licence fees, has reduced the number of applications received. However, there is a large backlog of unprocessed applications.

Storage Developments: B.C. Hydro maintains land and water reserves on Chilko and Taseko Lakes. As part of their Homathko Development, B.C. Hydro proposed to divert flows from Taseko Lake into the Homathko River basin to enhance power development. This is on hold.

There are some small storage projects on tributaries to the Chilcotin River, such as Alexis and Riske Creeks. These are primarily native developments.

Forestry: Logging began in the mid-1960's and most cutblocks have been harvested in the last 10 years. Total cut in the salmon streams is less than 4% of their watershed area. During our interviews, the Ministry of Environment expressed concern about specific logging-related issues -- such as road encroachments on streams and slope failures -- that mostly affect small tributaries to the salmon streams. As of 1993, there is little evidence for or concern about direct sediment- or hydrology-related forestry impacts on the larger mainstem salmon streams.

The proposed cut over the next five years ranges from 2 to 3% of the watershed area in the salmon streams. Proposed cuts are 3% (Chilko River) and 2% (Chilcotin River (upper and lower), Taseko River and Elkin Creek). At the end of the five year plan, the recent cut will range from 2 to 6% of the watershed area in the salmon streams. The proposed cut includes several areas of beetle-killed pine that are proposed for salvage logging. The salvage logging increases the rate of cut in some watersheds but most of the logging is distant from streams and does not pose a concern.

Placer Mining: Both the Chilcotin River and Big Creek have had historical placer mining activity (Holland 1986) but there is no evidence of renewed activity.

Flooding, Erosion and Sedimentation: There is little evidence or discussion of long-term sedimentation in any of the larger salmon streams, despite the 1990 flood that resulted from an unusually large winter snowpack. However, this issue has not been studied in detail. The Taseko River is the main source of turbidity to the Chilko and Chilcotin Rivers; the turbidity results from glacial flour passing through Taseko Lake and down the river.

In 1990 there was flooding on many tributaries, channel shifting and erosion of agricultural land along the Chilko River, and damage to a bridge crossing on the Taseko River. The flood on Elkin Creek produced some major changes. Above Elkin Lake, the creek diverted into Connie Lake and to the Chilko Lake drainage. The Ministry of Transportation and Highways returned the creek to its normal channel.

8.2 Technical and Management Recommendations

A number of general recommendations arise from this study that apply to management of the Habitat Management Areas as well as to the individual streams. These include legislative, policy and technical issues. Instream flow needs for fish are not addressed in existing legislation and changes are required to ensure that these needs are considered during licensing of waters in salmon streams.

8.2.1 Estimation of Flows and Demands in the Salmon Streams

Flows for all salmon streams were estimated from complete gauging records, partial gauging records, transfer from nearby stations or regional analysis. As discussed in previous sections the estimated flows are of variable quality and additional hydrologic studies are warranted, particularly for the most sensitive streams, to confirm the flow estimates.

We recommend that estimated flows on ungauged salmon streams, particularly low flows, should be confirmed by measurement programs, perhaps in conjunction with the Water Management Branch and the Water Survey of Canada. On gauged streams, further analysis of additional gauging records on tributaries or the upper mainstem is warranted, where the records are available.

Gaps in technical information limit our ability to adequately manage, and priorize, the salmon streams. These include:

1. The relationship between actual and licensed withdrawals, for various licence types, is not known. As well, demand varies from year-to-year, based on a number of factors. Management of the salmon streams requires some knowledge of the annual variation of demand and we recommend regular monitoring of withdrawals to establish actual demand on the most sensitive streams.

2. Instream flow needs for fish, or other uses, have not been established for the salmon streams. If instream flow requirements are better known, these can be used as critical values for the various indices, which will improve their interpretation.

8.2.2 Water Licensing and Water Use

The salmon streams in the Chilcotin HMA mostly have moderate to large watersheds, limited storage, and, in a few instances, moderate licensed water demands. Storage development, riparian zone management, and control of erosion by cattle are important issues.

Elkin Creek and (upper) Chilcotin River

The salmon streams listed above have a moderate portion of summer flows potentially utilized by licensed demand, principally irrigation, and are under the greatest threat from water use. Further water withdrawals from these stream systems -- even with compensating storage -- should be opposed until actual licensed demand is established and water management options for the stream system are reviewed. Opportunities for storage development within these systems -- particularly Elkin Creek -- should be reviewed.

The other salmon streams have summer and winter 7 day low flows that exceed 30% of the mean annual flow. Lake storage, delayed melt of high elevation snowpack, and glacier melt all contribute to maintaining high discharges in the Taseko, Chilko and (lower) Chilcotin River. Summer 7 day low flows in these streams typically range from 10,000 to 40,000 L/s. Winter 7 day low flows are typically about one-half of the summer flows.

There may be technical options for improving those streams with the greatest potential water demands. In some basins additional reservoirs may be used to supplement minimum flows in the stream. Studies of storage potential, instream flow needs and investigation of losses along the channel should precede agreements on management of instream flows (Hamilton 1992). Fisheries & Oceans Canada may participate in developing extra storage, or improving existing storage, to provide additional water for release during periods of low flow. In both instances, it should be ensured that some contractual relationship clearly spells out the reservoir operator's obligations.

The Water Management Branch classifies streams and restricts further water use in some streams. We recommend that Fisheries & Oceans Canada review the basis for decisions on restricting or not restricting water use and participate in revising the list of reserved streams.

8.2.3 Forest Harvesting

Most of the salmon streams (except Elkin Creek and upper Chilcotin River) have insignificant or zero licensed demand and are not likely to experience increased agricultural or water supply demand in the near-future. In these streams, logging is the main land use with the potential to alter the hydrologic or sediment regimes or alter channel morphology. It is generally felt that the hydrologic regime may be preserved or managed by controlling the rate of clearcutting, and consequently, controlling the portion of the basin that is in hydrologic recovery. It is not so easy to control or manage the sediment regime, and individual failures or poorly designed roads may alter downstream suspended sediment concentrations and deteriorate gravel quality. These must be investigated on a site by site basis and managed by following road construction and harvest prescription guidelines provided by the responsible agencies.

Managing the rate of clearcutting poses a number of technical difficulties, which are discussed below:

1. It is difficult to manage the rate of cut because the Ministry of Forests does not present their existing and proposed cut data by watershed. We recommend that DFO arrange with the Ministry of Forests to have the proposed cut on five-year plans sorted by watershed. A yearly breakdown of total previous and proposed cut within each of the watersheds should also be established.

2. The relationship between re-growth and hydrologic recovery is not known for the watersheds. Consequently, it is difficult to assess the effective clearcut area of watersheds with cut blocks of varying ages, and varying levels of regrowth, and the potential impact on the hydrologic regime; we recommend that further studies be undertaken. Research underway in the Stuart-Takla Fisheries/Forestry Interaction Project (Macdonald et al 1992) is examining rate of cut and cumulative impact issues.

   Until the issue of hydrologic recovery is resolved, a conservative position on the total cut permitted within individual watersheds should be maintained.

3. Within the basins of the individual salmon streams, the proposed cut should be distributed over the various tributary basins, to maintain the regime of the tributaries, as well as the main stem. Ultimately, a GIS database that includes logging history could be used to calculate clearcut effective area within the tributaries and main stem and to monitor forest harvesting.

8.2.4 Placer Mining

Overall, the existing system for managing placer mining in B.C. is acceptable.

8.2.5 Sedimentation and Sediment Sources

The Ministry of Forests has prepared a policy document on prevention, reporting and mitigation of erosion events (MOF 1992). This document includes the establishment of Erosion Control Teams, a formal system of reporting and inventorying erosion events and remedial planning for past and present events. Fisheries & Oceans Canada should ensure that they receive erosion reports and have an opportunity to participate in planning of remedial works, particularly in selecting those sites with highest priority.

Ultimately, the erosion events should be mapped or incorporated into a GIS database for display with respect to habitat along the streams.

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TABLES

Table 1: Salmon Streams in the Chilcotin HMA.

Stream Name	*SSIS Number*	*Water Survey of Canada Gauging Records*			*Region*
		Station	*Number*	*Area (km~u2$)*	
Chilcotin River	05	below Big Creek	08MB005	19,300	CP/PR
		near Redstone	08MB003	6,220	
		above Clusko River	08MB010	1,490	
Chilko River	05-3835	near Redstone	08MA001	6,940	CP/PR
		at outlet of Chilko Lk	08MA002	2,110	
Taseko River	05-3835-115	at outlet Taseko Lks	08MA003	1,520	CP/PR
Elkin Creek	05-3835-115-290				CP

1. CP, Chilcotin Plateau; PR, Pacific Ranges (Coast Mountains)

Table 2: Hydrology of the Various Physiographic Regions

	Chilcotin Plateau	Eastern Coast Mountains
Mean Annual Runoff (mm)	50 to 200	400 to 800
Month with Average Maximum Discharge	May or June	June; remains high in July and August
Timing of annual maximum discharge	late April to early June; affected by storage in lakes in some streams	late May to August; occasionally in October
Month with Average Minimum Discharge	February or March; sometimes September in smaller streams	February
Timing of annual minimum discharge	from October through March	December to March
Typical Stream	Lingfield Creek near the mouth 08MA006	Big Creek below Graveyard Creek 08MB007
Basin Area of Typical Stream (km2)	98	1,020

Table 3: Definitions of Flow Characteristics

Annual flood - Maximum or "peak" daily flow of the year.

Annual flow - Average of the daily flows between January 1 and December 31 for a particular year.

Annual 7 day low flow - The lowest average flow for 7 consecutive days between January 1 and December 31. Same as "7 day mean low" used in Appendix C.

Daily flow - Average flow for the period midnight to midnight.

Mean annual flood - Average of the annual floods for a stated historic period.

Mean annual flow - Average of the annual flows for a stated historic period.

Mean annual 7 day low flow - Average of the 7 day low flows for a stated historic period.

Mean August flow - Average of the August flows for a stated historic period.

Mean September flow - Average of the September flows for a stated historic period.

Mean summer 7 day low flow - Average of the summer 7 day low flows for a stated historic period.

Mean winter 7 day low flow - Average of the winter 7 day low flows for a stated historic period.

Naturalized flow - Measured flows, adjusted with upstream water licences, to represent the flows that would occur in the absence of regulation and extraction.

Summer 7 day low flow - The lowest average flow for 7 consecutive days between May 1 and October 31.

Water demand - Sum of all the consumptive uses upstream of a reference point, as estimated from water licences.

Winter 7 day low flow - The average flow for 7 consecutive days between November 1 and April 30.

Unit flow - The flow at a reference point, usually a Water Survey of Canada station, divided by the basin area above that reference point.

Table 4: Hydrology of Salmon Streams in the Chilcotin HMA

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Forested Area (km2)	Logged Area			Improved Farmland (1990) (km2)	Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m3/s)					
																		Mean Monthly		Mean 7-day Flow	
				Recent (km2)	Older (km2)	Proposed (1992–97) (km2)		Domes-tic (g/day)	Irrig-ation (ac-ft)	Water-works (g/day)	Indus-trial (g/day)	Conser-vation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Aug	Sept	Summer	Winter
Chilcotin River	08MB005	19,700	16,120	587.88	90.22	389.82	–	184,710	38,318	5,000	1,444,043	440	4491	1801	7	95.5	326.5	220.89	127.53	40.80	22.10
Chilcotin R (upper)		6,220	5,460	226.71	13.7	175.71	–	30,500	9,836	5,000	259,121	0	1152	462	1	14.8	52	11	8.8	4.20	3.00
Chilko River	08MA001	6,940	4,213	71.95	20.55	175.7	–	3,500	2,285	10,000	8,002	0	267	107	0	81.5	287.0	197.77	114.71	26.51	15.10
Taseko River	08MA003	2,730	1,231	46.99	0.1	73.37	–	8,500	995	0	4,000	60	116	47	0	35.5	155.7	91.68	45.47	10.85	4.63
Elkin Creek		300	210	0.59	0.1	5.88	–	6,000	895	0	4,000	0	105	42	0	2.1	13.0	0.70	0.34	0.26	0.19

- Shading indicates gauged salmon streams.
- Forested and logged areas were calculated from records provided by the Ministry of Forests.
- Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
- Reference for all data in table is the mouth of the salmon stream.
- Licenced demands (L/s) calculated from total water licences as described in body of report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 5: Storage on Salmon Streams in the Chilcotin HMA.

Stream Name	*Basin Area (mouth) (km2)*	*Total Non-Power Storage (ac-ft)*	*Total Conservation Storage (ac-ft)*	*Total Irrigation Licences (ac-ft)*	*Percent with Storage (%)*
Chilcotin River	19,700	7,032	5,733	38,318	18
Chilcotin R (upper)	6,220	0	604	9,836	0
Chilko River	6,940	0	0	2,285	0
Taseko River	2,730	0	0	995	0
Elkin Creek	300	0	0	895	0

1. "Non-power includes all storage for domestic, waterworks, industrial, or irrigation licences. Conservation licences are noted separately and not included in non-power totals.
2. Irrigation licences for each salmon stream from Table 4.
3. Percent with storage calculated from by dividing non-power storage by total irrigation licences for each stream.

Table 6: Sensitivity Indices for the Chilcotin HMA

		SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
Stream Name	Status	Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin	Index 10 Recent & Proposed
Chilcotin River		11	4	2	1	43	23	3	3	3	5
Chilcotin R (upper)		27	11	10	5	28	20	4	4	4	6
Chilko River		1	0	0	0	33	19	4	1	1	4
Taseko River		1	0	0	0	31	13	4	2	2	4
Elkin Creek		41	16	15	13	12	9	6	0	0	2

- Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
- Aug and Sept Use are total demands in these months; Sum Q7L2 and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin, proposed logging refers to the 5 year plan; Basin is basin area above the mouth.
- Indices expressed as percentages except 7, which is a direct ratio.
- Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6; values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

FIGURES

Figure 1: Fraser River Habitat Management Areas

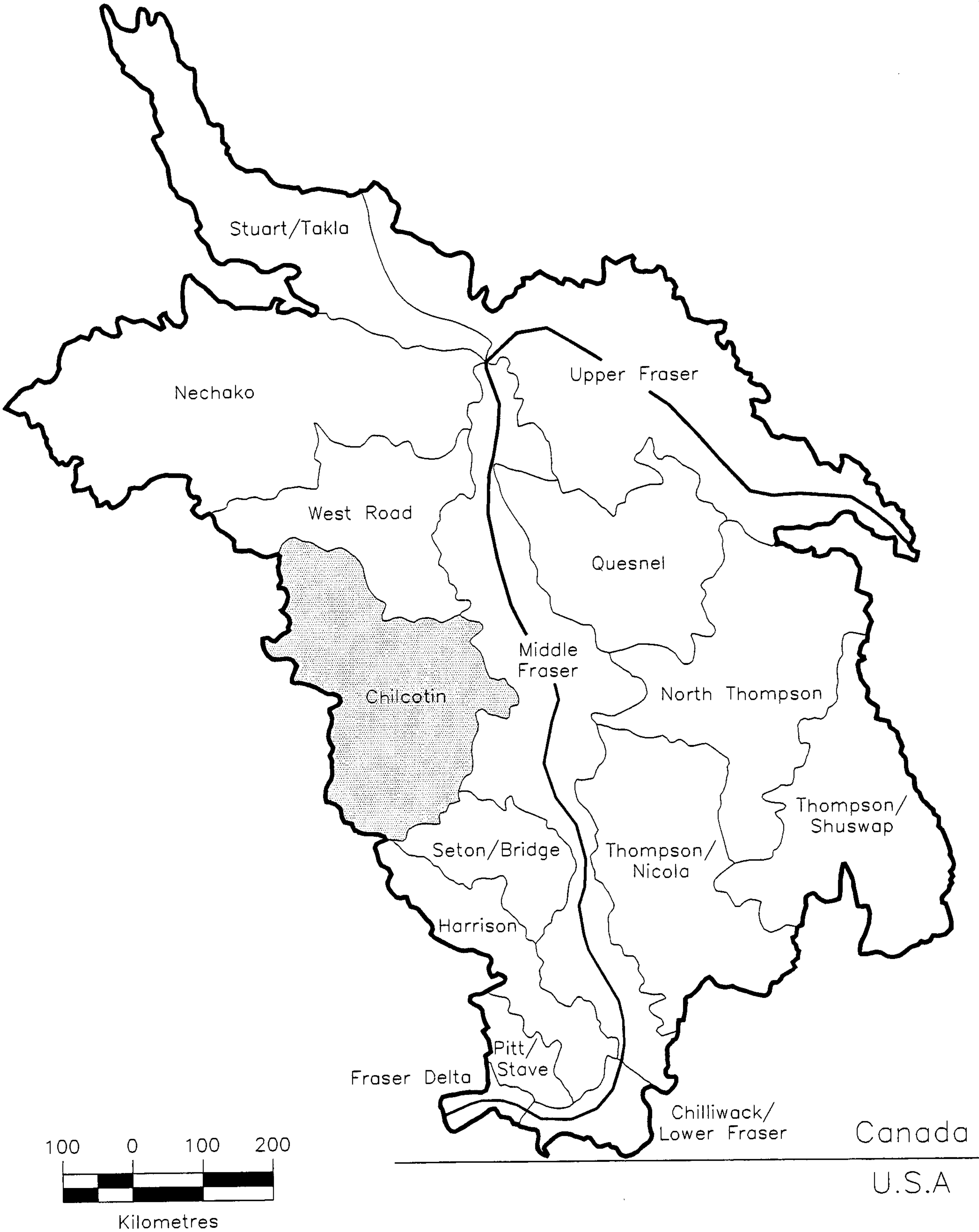

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Figure 2: Salmon Streams in the Chilcotin HMA

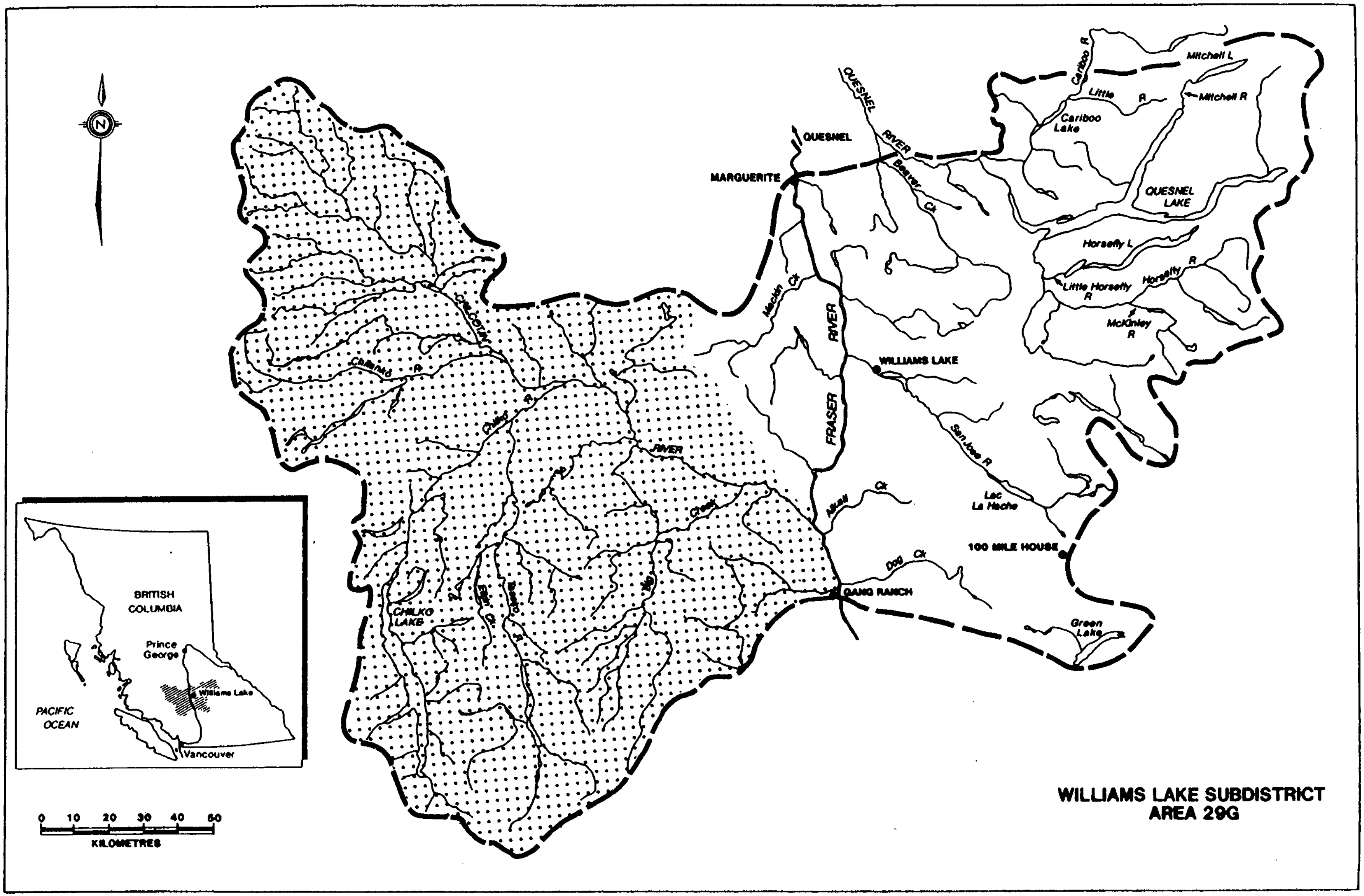


Figure 3: Physiography and Gauging Stations in the Chilcotin HMA

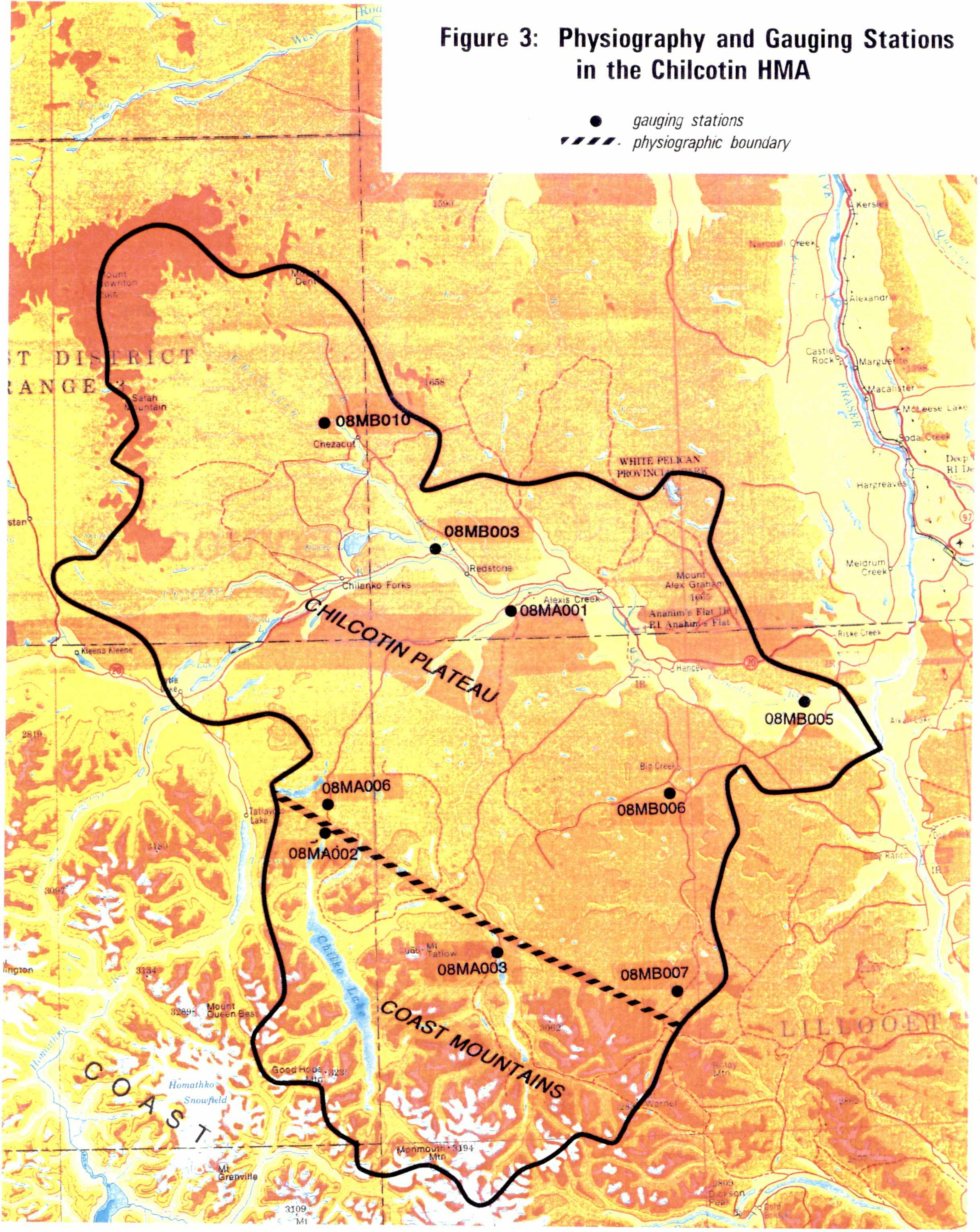


Figure 4: Calculation of Natural and Naturalized Flows for the Salmon Streams

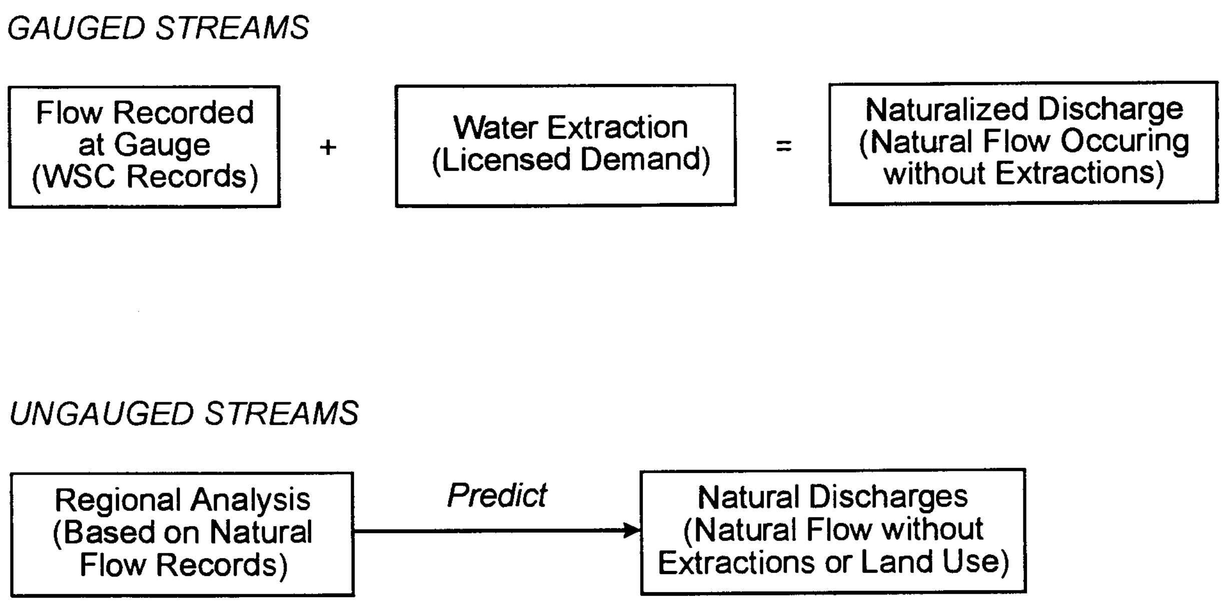


Figure 5: Classification of British Columbia Water Licences

No.	USE CLASS	DESCRIPTION (uses included)	UNITS
	CONSUMPTIVE		
1	Waterworks	- conveyed by local authority (munipality, regional or improvement district) - conveyed by others (individual, utility, Indian band)	gallons/day gallons/year
2	Domestic use		gallons/day
3	Pulpmills		cubic feet/second
4	Industrial	- processing (sawmills, food, manufacturing, etc.) - cooling - enterprise (hotels, motels, restaurants, etc.) - ponds - watering - bottling for sale - commercial bulk export - mineral water sold in containers and used in bathing pools - all other industrial uses	any
5	Irrigation	- conveyed by local authority (municipal) - private agricultural use	acre-feet
6	Land improvement	e.g. draining property, creating ponds	any
7	Mining	- hydraulic, washing coal, processing ore, placer	any
	NON-CONSUMPTIVE		
8	Power generation	- residential, commercial, general	cubic feet/second
9	Storage - nonpower		acre-feet
10	Storage - power		acre-feet
11	Conservation	- storage (e.g. waterfowl habitat enhancement) - use of water (e.g. hatchery) - construction of works in and around a stream (e.g. fish culture, fish ponds, personal)	any

APPENDIX A

PREDICTING FLOWS AT THE MOUTHS OF SALMON STREAMS

A. PREDICTING FLOWS AT THE MOUTHS OF SALMON STREAMS

The attached table A1 summarizes the source of data quoted in Table 4 for each of the salmon streams. Both the Chilcotin River (lower) and Chilko River have gauging stations at, or near, their mouths and the quoted data are derived directly from station records.

There are insufficient independent gauging stations on the Chilcotin Plateau to develop regional equations linking drainage basin characteristics to annual or seasonal flows (Rood 1988). Consequently, discharges at the ungauged streams were estimated by comparison with artificial records created by subtraction and adjustment of gauging records or by transfer from a nearby, similar stream. Procedures are discussed in the following paragraphs:

Chilcotin River (upper): The gauge near Redstone (08MB003) only has seasonal records from the late 1940's; thus flows recorded on Table 4 were estimated, in part, from the overall regime on the Chilcotin Plateau. Typical values for mean annual and mean monthly discharges on the Chilcotin Plateau were established by subtracting average 1981-90 discharges for the Chilko River near Redstone (08MA001) and Big Creek above Groundhog Creek (08MB006) from the average 1981-90 discharge for the Chilcotin River below Big Creek (08MB005). The calculated differences represents the discharge from 12,000 km^2 of the Chilcotin Plateau. These values were transferred to the Chilcotin River by prorating on drainage area (i.e. 6,220 km^2/12,000 km^2; or 0.52) and checked against the discharges recorded at the Redstone gauge (08MB003).

Mean annual floods were calculated as an average of all values recorded at the Chilcotin River near Redstone gauge and were not adjusted in any fashion.

An artificial record of daily discharges for the lower Chilko River drainage area was created for 1981 to 1990 by subtracting lagged daily flows at the outlet of Chilko Lake (08MA002) and Taseko Lake (08MA003) from those recorded at Redstone (08MA001). Mean winter and summer 7 day low flows were established for this record. Annual runoff is higher from the lower Chilko River watershed than from the upper Chilcotin and 7 day low flows transferred on the ratio of drainage areas were too large. Reducing the transferred flows by the ratio of runoff (i.e. 30 mm/58 mm; or 0.52) in the Chilcotin and lower Taseko watersheds produced values that seemed too low. An average of the two sets of numbers was recorded on Table 4.

Taseko River: The 08MA003 gauge provides a record of flows for 1981 to 1990 at the outlet of Taseko Lake. These records cannot be adjusted to the mouth using a ratio of drainage areas because runoff is much lower from the plateau than from the Coast Mountains. Instead, the artificial record established for the lower Chilko drainage area (see above) was adjusted, by ratio of drainage area, to represent the lower Taseko watershed and added to the recorded values at the outlet of Taseko Lake.

Elkin Creek: Elkin Creek has not been gauged. Lingfield Creek (08MA006) has complete records from 1981 to 1990, is near Elkin Creek and is of similar size. However, Lingfield Creek has no lakes and may have slightly higher runoff. Mean annual flows, mean annual maximums and mean monthly flows were transferred from the Lingfield Creek records on the ratio of drainage areas.

Summer and winter 7 day low flows on Elkin Creek were transferred from the artificial record created for the lower Chilko watershed, based on the ratio of drainage areas. These corresponded well with miscellaneous measurements by the Water Management Branch on this system.

Table A1: Establishing Flows for Salmon Streams in the Chilcotin HMA

Stream Name	SSIS Number	Water Survey of Canada Gauging Records			Source of Discharge Data at the stream mouth
		Station	Number	Area (km^2)	
Chilcotin R (lower)	05	below Big Creek	08MB005	19,300	use data from 08MB005 station
Chilcotin R (upper)	05	near Redstone above Clusko River	08MB003 08MB010	6,220 1,490	use difference between 08MA001 and 08MA002 stations. Compare to 08MB003
Chilko River	05–3835	near Redstone at outlet of Chilko Lk	08MA001 08MA002	6,940 2,110	use data from 08MA001 station
Taseko River	05–3835–115	at outlet Taseko Lks	08MA003	1,520	use data from 08MA003 and inflows from plateau
Elkin Creek	05–3835–115–290				prorate data from Lingfield Ck (08MA006)

APPENDIX B

STREAM SUMMARIES

B. STREAM SUMMARIES

A two page summary has been prepared for each salmon stream. Those streams with six or more complete years of records at a gauge have a detailed summary of hydrology, as described in Section 3 of the main text. Those salmon streams with limited or no gauging records have a less detailed summary.

The stream summary consists of 5 main elements each of which is explained in detail in the following sections. Some of the information is abridged.

B.1 Licensed Water Demand

Total licensed demand above the Water Survey of Canada gauge on the stream, or above the mouth for ungauged streams, are given in the units currently used by the Water Rights Branch. The monthly demand is calculated from the licensed amounts for the three characteristic months of February, August and September and is quoted in litres per second (L/s). The final separate row at the bottom of the table is the mean monthly flow of the stream during the three characteristics months.

B.2 Mean Annual Hydrograph

The mean annual hydrograph is an average of the flow recorded on each day for all complete years of record. For comparative purposes, the vertical scale is the same for all streams. The mean annual flow is included in a box on the hydrograph; this, together with the percent values on the vertical axis, allows estimation of the flows for various times of the year.

For ungauged streams, the mean annual hydrograph is transferred from a hydrologically-similar, nearby stream.

B.3 Sensitivity Indices

As described in the main text, each index is a ratio or percentage. For example, Index 1 is the ratio of the August water use to the Mean summer 7 day low flow. Index 3 is similar to Index 1 except that it shows the ratio of August water use to the mean August flow.

The bar graphs show how the indices for the stream compare with the indices for the other streams in the combined Chilcotin and West Road Habitat Management Areas. For example, if Index 7 is above the median it indicates that peak flows are more severe than average, relative to the other streams.

The bar graph provides a visual summary of the relative sensitivity of the stream to various land and water uses and is incorporated for both the gauged and ungauged streams.

B.4 7 Day Low Flows

Distribution, by month, of 7 Day Low Flow: This bar graph shows the months of the year when the annual 7 day low flow (the lowest consecutive 7 day flow in a calendar year) has occurred. The height of the bar shows the percentage of annual 7 day low flows that have occurred in that month. In general, it is apparent that in this HMA, the 7 day low flows typically occur in January to March and in August and September.

The bar graph may not provide a good indication of the distribution of annual 7 day low flows if there are only a few years of record at the gauging station. No distribution is provided for the ungauged streams.

7 Day Low Flow Frequency Curve

The frequency curve shows an Extreme Value Type III (Gumbel) Distribution fit to the annual 7 day low flows recorded at the gauging station. The curve shows the predicted annual 7 day low flow, in m^3/s, for return periods up to about 100 years. Note that the confidence in the estimated flow at a given return period depends on the length of record available at the gauging station. For streams with only a few years of record (as shown by the number of data points) the curve is an approximation. Also note that estimates beyond about 50 years are only approximate even when there is ten or twenty years of record. No distribution is produced for the ungauged streams.

Annual floods and **7 day low flows**, for various return periods, are given in a common table.

B.5 Summary Notes and Recommendations

This section provides an abbreviated summary of important activities in the basin, together with suggestions and recommendations where these can be provided.

CHILCOTIN RIVER

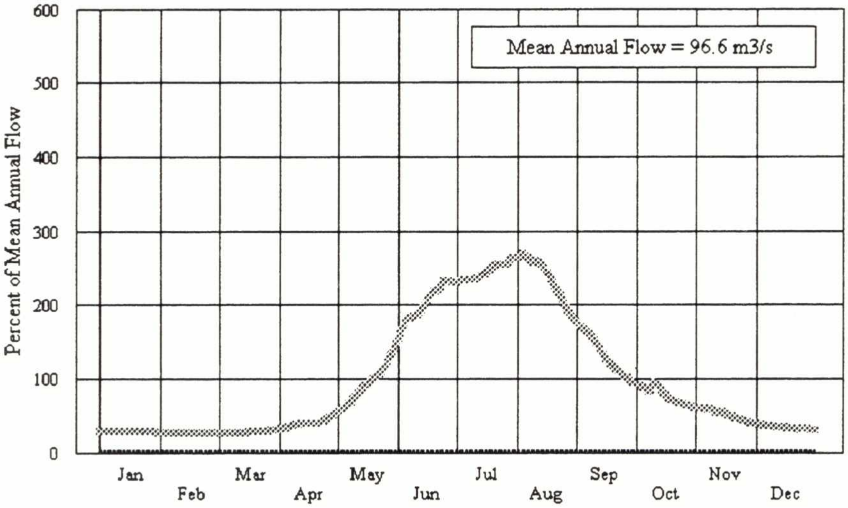
Stream number 05
*Water Survey of Canada Station **08MB005***
Chilcotin River below Big Creek
Records 1970 to 1992
Drainage Area = 19,300 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	184,710 g/d	9.7	9.7	9.7
Irrigation	38,318 ac.ft.	0	4,412	1,823
Waterworks	5,000 g/d	0.3	0.3	0.3
Industrial	1.444043 g/d	76.0	76.0	76.0
Conservation	440 cfs			

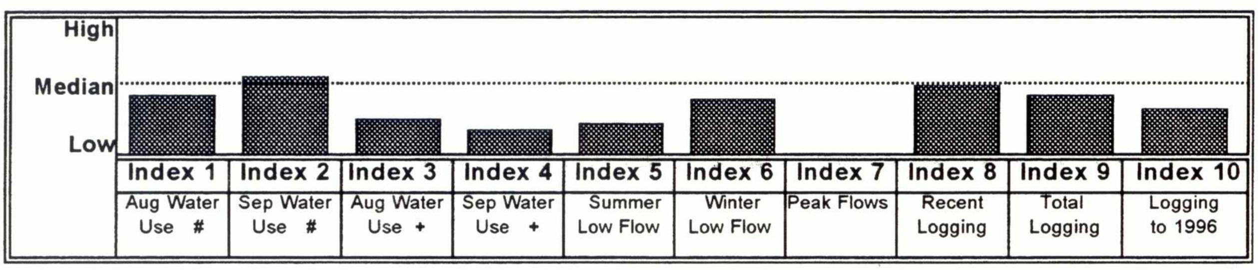
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	26000	226000	127000

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

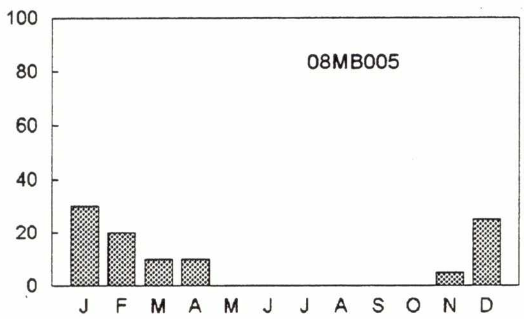
The following bar graph shows the sensitivity of this stream relative to others in the Chilcotin and West Road Habitat Management Areas. An index above median indicates a more severe problem; an index below median indicates a less severe problem.



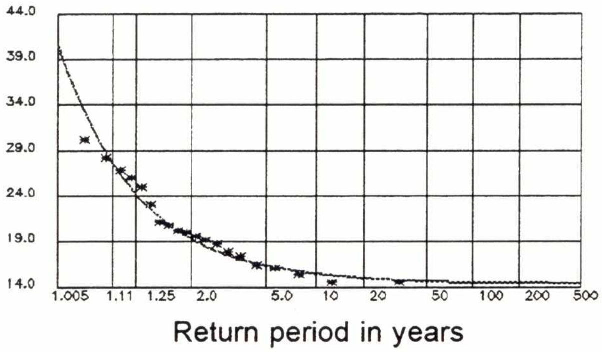
Water use as a proportion of the 7 day low flow
+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

Distribution , by month, of
7 Day Low Flow (in percent)



7 Day Low Flow Frequency Curve
(Flow in m^3/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	19.2 m^3/s	15.4 m^3/s	14.9 m^3/s	14.6 m^3/s	14.5 m^3/s
Annual Flood	319 m^3/s	377 m^3/s	413 m^3/s	445 m^3/s	512 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. Low flows in the mainstem Chilcotin River appear not to be a problem because of the contribution from glacier melt, but low summer flows are of concern in Alexis Creek.

2. There are some problems with trapping of fish in unscreened irrigation ditches. Approximately three Finnigan screens are in operation along the river.

CHILCOTIN RIVER
(UPPER)

Stream number 05
*Water Survey of Canada Station **08MB003***
Chilcotin River near Redstone
Seasonal records only
Drainage Area = 6,220 km²

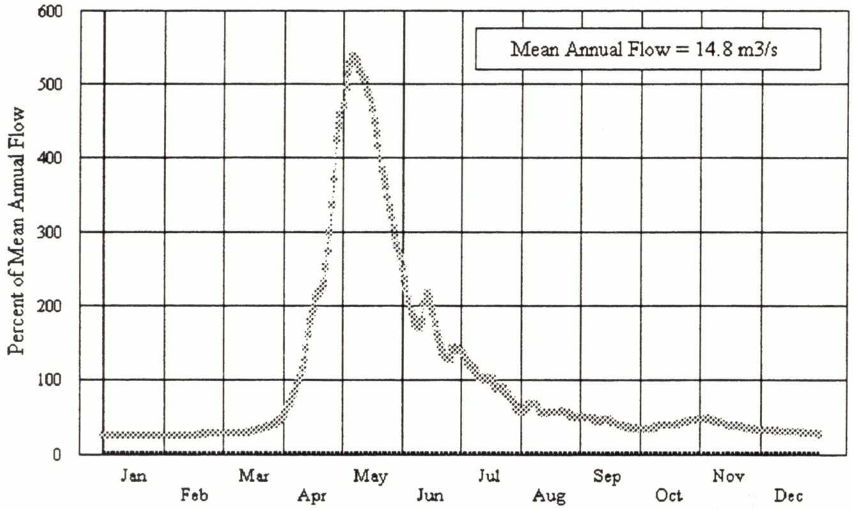
LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	30,500 g/d	1.60	1.60	1.60
Irrigation	9,836 ac.ft.	0	1,133	468
Waterworks	5,000 g/d	0.26	0.26	0.26
Industrial	259,121 g/d	13.6	13.6	13.6
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		11,000	8,800

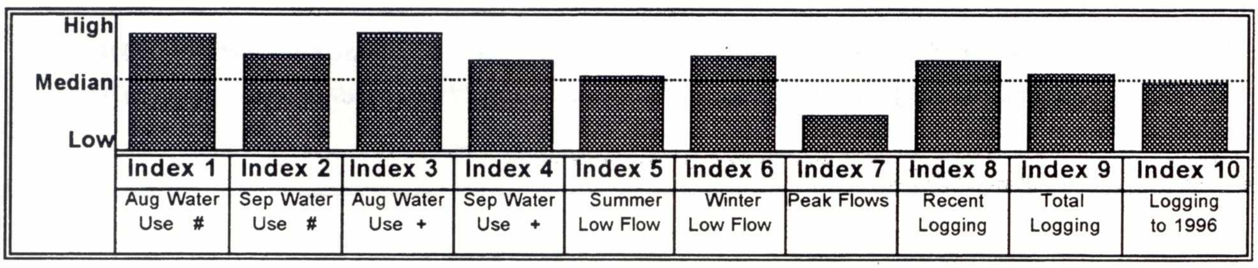
MEAN ANNUAL HYDROGRAPH

(Estimated, using Nazko River station 08KF001)



SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the Chilcotin and West Road Habitat Management Areas. An index above median indicates a more severe problem; an index below median indicates a less severe problem.



\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

CHILCOTIN RIVER
(UPPER)

SUMMARY NOTES AND RECOMMENDATIONS

1. Restoration options for the channel of the Chicotin River above Chilcotin Lake have been investigated by the Conservation Fund.

2.Licensed water demand is relatively high in the Upper Chilcotin area. Further licensing should be opposed until actual water use is established and water management options for the river are reviewed.

CHILKO RIVER

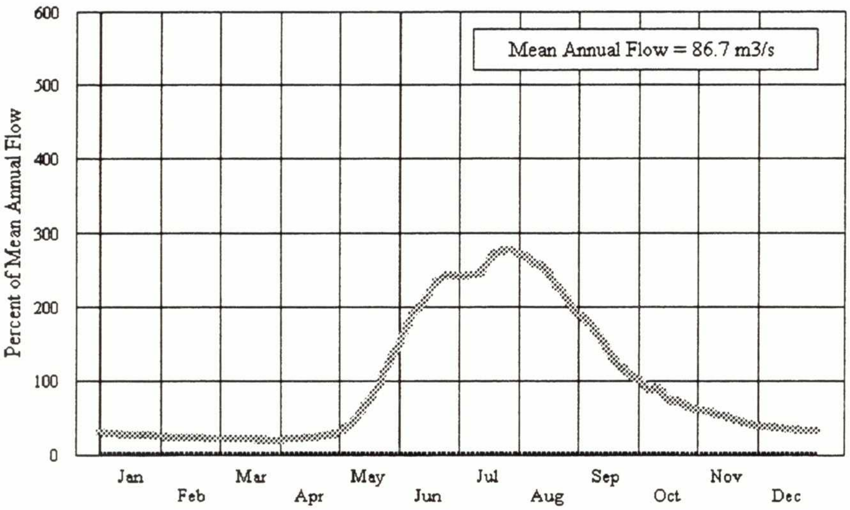
Stream number 05 - 3835
*Water Survey of Canada Station **08MA001***
Chilko River near Redstone
Records 1927 to 1992
Drainage Area = 6,940 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,500 g/d	0.2	0.2	0.2
Irrigation	2,285 ac.ft.	0	263.1	108.7
Waterworks	10,000 g/d	0.5	0.5	0.5
Industrial	8,002 g/d	0.4	0.4	0.4
Conservation	0 cfs	0	0	0

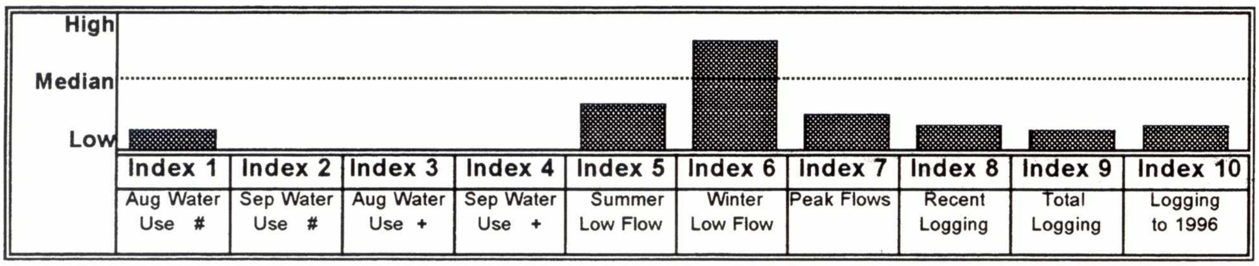
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	19,900	212000	132000

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

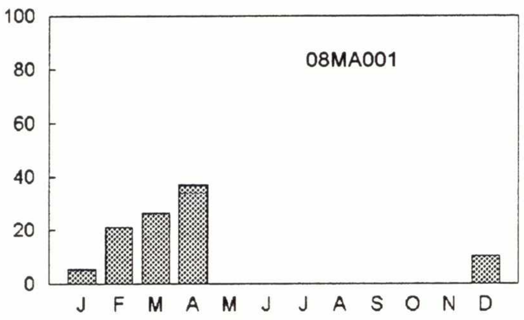
The following bar graph shows the sensitivity of this stream relative to others in the Chilcotin and West Road Habitat Management Areas. An index above median indicates a more severe problem; an index below median indicates a less severe problem.



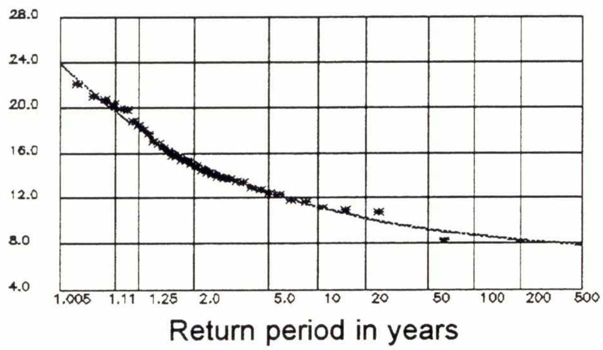
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

Distribution , by month, of
7 Day Low Flow (in percent)



7 Day Low Flow Frequency Curve
(Flow in m³/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	15.2 m^3/s	11.1 m^3/s	10.2 m^3/s	9.2 m^3/s	8.7 m^3/s
Annual Flood	291 m^3/s	372 m^3/s	401 m^3/s	439 m^3/s	466 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. B.C.Hydro maintains land and water reserves on both Chilko and Taseko Lakes, which have considerable storage potential, altho private docks impose some limitations on Chilko Lake.

2. There are proposals for a park at Chilko Lake and a development control corridor along the river from Chilko Lake down to Brittany Creek.

TASEKO RIVER

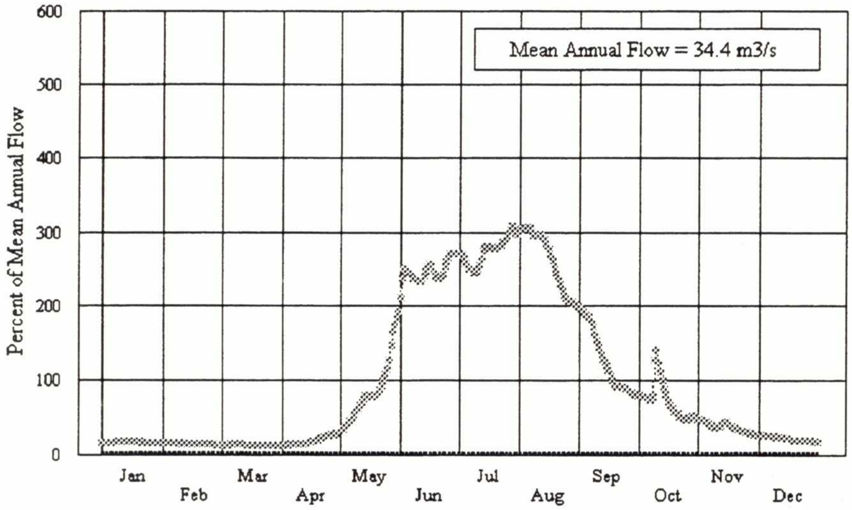
Stream number 05 - 3835 - 115
*Water Survey of Canada Station **08MA003***
Taseko River at outlet of Taseko Lakes
Records 1983 to 1992
Drainage Area = 1,520 km^2

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	6,500 g/d	0.34	0.34	0.34
Irrigation	995 ac.ft.	0	114.6	47.4
Waterworks	0 g/d	0	0	0
Industrial	4,000 g/d	0.21	0.21	0.21
Conservation	60 cfs			

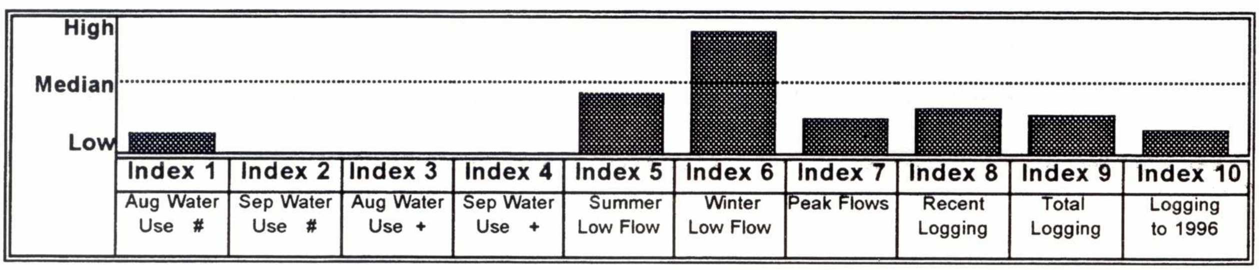
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	4,960	91,300	46,800

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

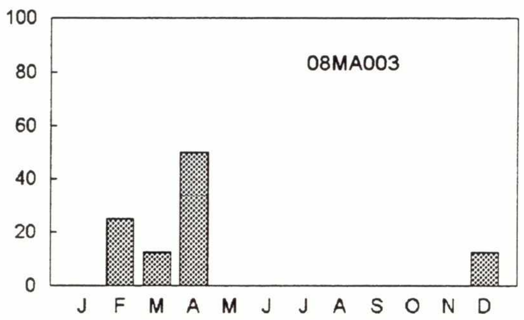
The following bar graph shows the sensitivity of this stream relative to others in the Chilcotin and West Road Habitat Management Areas. An index above median indicates a more severe problem; an index below median indicates a less severe problem.



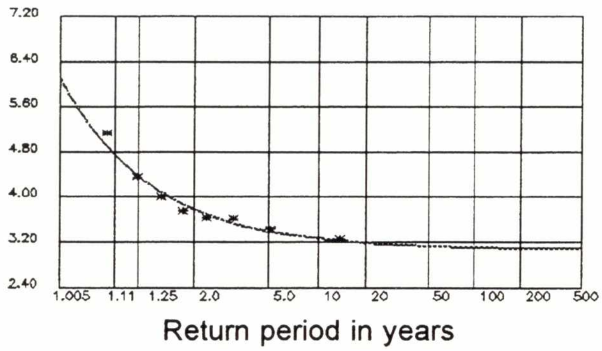
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

Distribution , by month, of
7 Day Low Flow (in percent)



7 Day Low Flow Frequency Curve
(Flow in m³/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	3.77 m^3/s	3.25 m^3/s	3.18 m^3/s	3.12 m^3/s	3.10 m^3/s
Annual Flood	150 m^3/s	210 m^3/s	241 m^3/s	286 m^3/s	326 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. There is little development in the watershed above Taseko Lake. Glacial sediment causes turbidity in lake and river, limiting habitat.

2. A groundwater source, for a possible hatchery, of 100 to 150 L/s, about 3 km upstream from the mouth of the Taseko River was identified in the 1980 report by Ginetz and Nielsen.

ELKIN CREEK

Stream number 05 - 3835 - 115 - 290
Ungauged
Tributary to Taseko River

Drainage Area = 300 km²

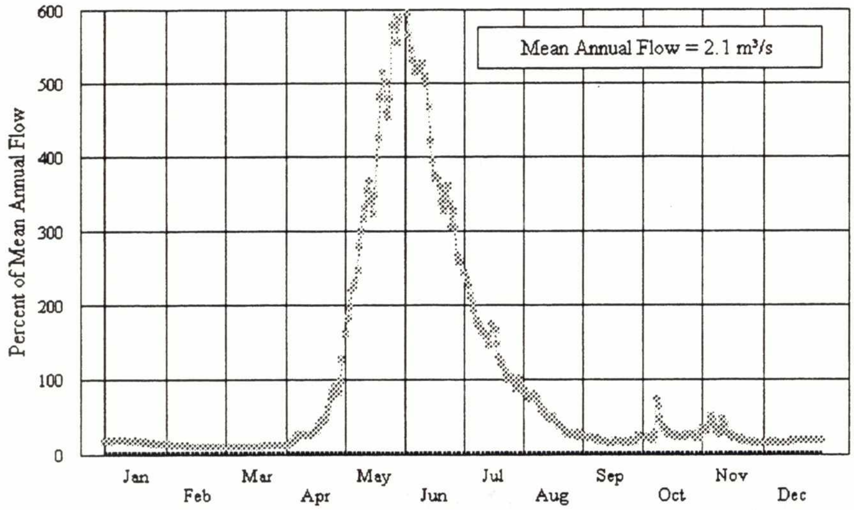
LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	6,000 g/d	0.3	0.3	0.3
Irrigation	895 ac.ft.	0	103	42.6
Waterworks	0 g/d	0	0	0
Industrial	4,000 g/d	0.2	0.2	0.2
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		700	340

MEAN ANNUAL HYDROGRAPH

(Estimated, using Lingfield Creek station 08MA006)



SENSITIVITY INDICES

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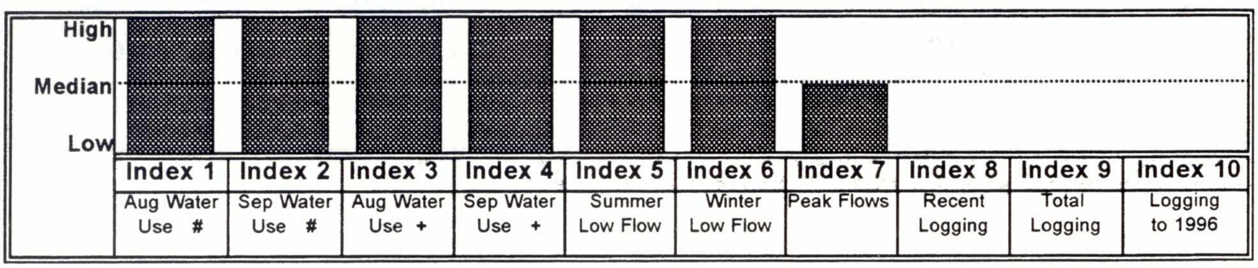

\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

ELKIN CREEK

SUMMARY NOTES AND RECOMMENDATIONS

1. Elkin Creek upstream of Elkin Lake is unstable, actively transporting large bedloads. Several kilometres above Nemimiah Valley Road have been channelized.

2. Low flow problems upstream of Elkin Lake have been reported. There are a number of water licences in the Nemimiah Valley, but the amount of additional developable land is limited. There are several small lakes that could provide limited storage.

3. As licensed water demand is relatively high, further licensing should be opposed until actual water use is established and water management options are reviewed.

4. A mining development for Fish Lake has been proposed.