


Nechako Fisheries Conservation Program

Technical Data Review 1988—2002

BRITISH COLUMBIA | Ministry of Environment

ALCAN

Fisheries and Oceans Canada / Pêches et Océans Canada




July 2005

Nautley River
Tatsutnai Cr
FORT FRASER
Fraser L.
Diamond Island
RIVER
Smith Cr.
Tanuitzu Cr
NECHAKO
Greer Cr.
Bungalow Cr.
Forge Cr
Ranch River
Bert Irvine's Lodge
Swanson Cr.
Twin

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PREFACE

THE TECHNICAL COMMITTEE OF THE NECHAKO FISHERIES CONSERVATION PROGRAM (NFCP) HAS PREPARED THIS REPORT TO DOCUMENT AND SUMMARIZE THE WORK WE HAVE UNDERTAKEN SINCE OUR INCEPTION IN 1987. While the work of the committee is available to the public in a series of individual published reports, this review has been prepared to synthesize all of these materials into one document which provides the program rationale, its history, direction and the key findings.

The NFCP was created by a 1987 legal agreement between the Canadian Federal Government (Department of Fisheries and Oceans), the British Columbian Provincial Government (Ministry of Environment and Parks), and Alcan Inc. to ensure the conservation of the Nechako River salmon. The NFCP Technical Committee is comprised of individuals representing these three agencies and one independent member who chairs the Committee. The 1987 agreement provided a mandate for the NFCP to ensure the conservation of Nechako salmon during the planned Kemano Completion Project (KCP) which would have further reduced flows in the Nechako River. In 1995 the KCP was cancelled by the province and in 1997, legal arrangements between the province and Alcan resulted in the generation of a number of independent working groups within the watershed community.

One such group, the Nechako Environmental Enhancement Fund (NEEF) was created in 1998 to evaluate options for the enhancement of the Nechako watershed. In 2001 NEEF members presented their final report and recommendations for the watershed. At the same time, concern regarding fish species other than salmon in the Nechako was garnering much attention from other stakeholder groups in the watershed. Concurrent with these activities, the NFCP Technical Committee continued to focus on its mandate for conserving Nechako salmon, however our efforts were informed by these other activities by virtue of the participation of NFCP Technical Committee members and their agencies in these other working groups.

This report reflects the efforts of a large number of individuals who have worked on the Technical Committee since 1988. It summarizes the body of work that the NFCP has completed in the context of conserving and protecting the chinook and migratory sockeye of the Nechako River. The information which provides the basis for this review includes twelve years of data representing almost three life cycles of chinook. It incorporates the results of more than 150 reports which are referenced throughout, cited in the appendices and available on the NFCP website (http://www.nfcp.org).

We have presented our work to address the clearly defined objectives of the NFCP, emphasizing our evaluation of the status of Nechako River salmon for the period of 1988 – 2000. The committee recognizes that new concerns in the watershed and the evolving social context may require re-evaluation of the NFCP mandate. We have identified the need for a discussion of both recommendations for future work and the changing role of the NFCP. The Technical Committee looks forward to addressing these issues now that this report has been completed.

Sincerely

Ellen Petticrew

Dr Ellen Petticrew
NFCP Independent Member

June 30, 2005

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Section 1
Introduction

The Nechako Fisheries Conservation Program was established by the *1987 Settlement Agreement,* signed by Alcan Aluminium Ltd. (now Alcan Inc.), the Province of British Columbia and the Government of Canada. Administered by a Steering Committee[1] and implemented by a Technical Committee, the program's mandate is to annually plan and implement a program of monitoring, research and, if required, remedial measures to conserve:

- the chinook salmon that use the Nechako River year-round; and
- sockeye salmon that migrate through the Nechako River to tributary river systems.

Since its inception, the program has collected biological and physical data on the Nechako River watershed (**Figure 1-1**). These data—now spanning almost three complete life-cycles of the Nechako River chinook salmon (1987 to 1998 with selected data to 2002)—have been regularly documented in Technical Committee project reports. [*See Appendix I – List of NFCP Reports.*] The purpose of this report is to summarize and integrate the data collected by the Technical Committee, discuss the outcomes of the various projects[2], and provide conclusions.

The report is in ten sections. Section 1, *Introduction*, provides background information, including information on historical developments on the Nechako River and the implementation of the program. Section 2, *Kenney Dam Release Facility Approval Process*, describes the review of the design for the Kenney Dam Release Facility. The next six sections of the report are organized according to the program mandate. Each section includes the purpose and objectives addressed by the section, and a review of the work completed and of the results. Section 3, *Conserving Sockeye Salmon*, discusses issues pertinent to sockeye salmon, while issues relevant to chinook salmon can be found in:

S. 4 *Conserving Chinook Salmon*
S. 5 *Chinook: Primary Monitoring*
S. 6 *Chinook: Secondary Monitoring*
S. 7 *Chinook: Tertiary Monitoring*
S. 8 *Remedial Measures*

Section 9, *Applied Research*, describes the research carried out by the federal Department of Fisheries and Oceans[3] to address gaps in knowledge identified by the Technical Committee. Section 10, *The Nechako Fisheries Conservation Program: Results and Considerations*, summarizes and evaluates the individual components of the program. Where appropriate, the report recommends other analytical work that could be done in the future.

The Technical Committee expects that this document will provide a scientific basis for future decisions on the direction of the NFCP.

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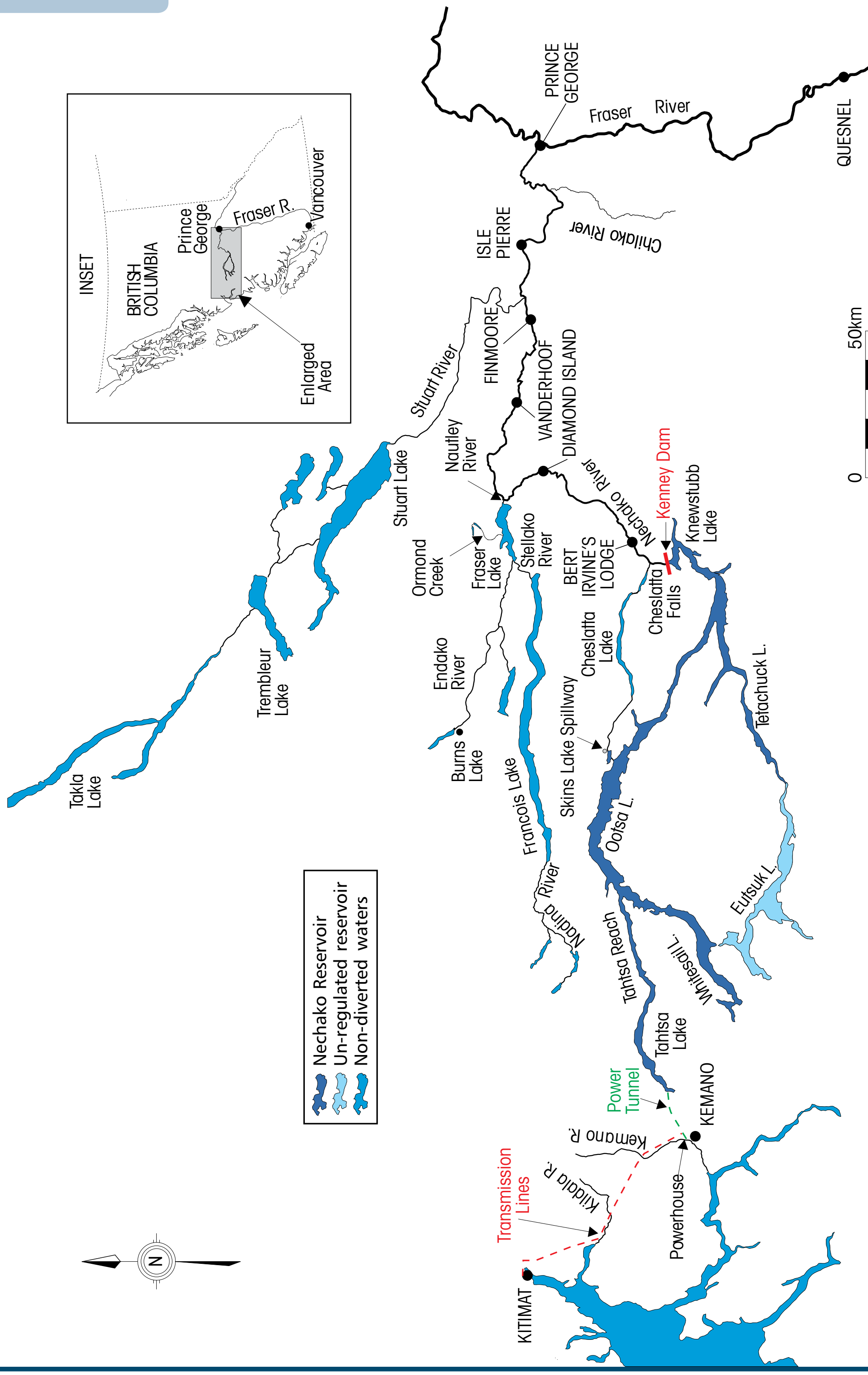
[1] The Steering Committee includes senior representatives of the three parties to the Agreement. The Technical Committee includes one independent member plus one technical representative and one alternate from the federal government (represented by Fisheries and Oceans Canada), the provincial government (represented by the Ministry of Environment) and Alcan Inc.

[2] This review summarizes all the data collected by the NFCP from 1988 to 1998. Where indicated, more recent analysis extends the data, in some cases to 2002.

[3] The Department of Fisheries and Oceans has been renamed "Fisheries and Oceans Canada." This report uses the older name as that was the department's designation throughout the study period.

Figure 1.1-1 **The Nechako River Watershed**



1.1 BACKGROUND

The Kemano Power Project originated in 1941 when the British Columbia government invited Aluminium Company of Canada Limited (now Alcan Inc.) to investigate developing a hydroelectric power project and establishing an aluminum industry on Canada's West Coast. The Second World War interrupted these discussions; however, the government approached the company again in 1947, asking it to further consider a project in the province.

Alcan carried out preliminary engineering studies in 1948 and 1949. These resulted in a proposed development that would include:

- a dam in the Grand Canyon of the Nechako River;
- a reservoir in the Tahtsa/Eutsuk drainage;
- a spillway at Skins Lake;
- two new communities (Kitimat and Kemano);
- a tunnel through Mt. DuBose to a powerhouse in Kemano;
- a transmission line from Kemano to Kitimat; and
- an aluminum smelter and deep-water port at Kitimat.

In 1949, the provincial government passed the *Industrial Development Act*, allowing the province to enter into an agreement with Alcan that the parties signed in 1950. Among other things, this agreement granted Alcan a conditional water licence for power generation.

Construction began in 1951, ending in 1954; river flow was diverted in 1952 and the reservoir took four years to fill. In the interim, Nechako River water levels were regulated using a temporary weir in the Murray-Cheslatta system. Water releases from the reservoir began in 1956 with water entering the Cheslatta River through the Skins Lake Spillway[4].

The Kemano powerhouse was completed in stages paralleling the construction of the aluminum smelter; installation of the last of the powerhouse's eight generators was completed in 1967. The Kemano powerhouse supplied power to the Kitimat aluminum smelter and neighbouring communities (*i.e.,* Kitimat, Terrace and Prince Rupert) until 1978 when the British Columbia Hydro and Power Authority (B.C. Hydro) inter-tie reached Terrace from Prince George. The inter-tie linked Kemano to the provincial power grid, allowing Alcan to sell power to B.C. Hydro. Throughout the 1970's and early 1980's Alcan continued to investigate ways to use all of the water rights granted in the 1950 agreement.

The 1950 agreement and conditional water licence allowed Alcan to reduce releases at the Skins Lake Spillway during periods of below-average inflows to the Nechako Reservoir. However, in June 1980 the Department of Fisheries and Oceans expressed concern over the volume of water released. The department anticipated sockeye salmon (*Oncorhynchus nerka*) migrating through the Nechako River system would be exposed to high summer water temperatures resulting from low water flows and for low spring, fall and winter flows to possibly affecting chinook salmon.

Although Alcan was committed to releasing water to protect the fish, the company and the Department of Oceans and Fisheries had differing opinions on the timing and level of the required flows. This difference in opinion led the department to seek and receive an interim injunction from the B.C. Supreme Court setting out the flows to be released until the issue could

[4] Significant changes occurred in the Cheslatta river channel following the initiation of releases from the Skins Lake Spillway.

be resolved. In granting the injunction, the court noted that a genuine difference of scientific opinion existed between the parties and urged the department and Alcan to work together to reach a consensus.

A series of studies carried out between 1980 and 1984 attempted to resolve the issues, Alcan voluntarily agreeing to a renewal of the 1980 injunction in each of these years. Considerable progress was made during this period on methods to be used for the conservation of migrating sockeye salmon. However, by 1985, a consensus still had not been reached — particularly on the water releases required to conserve chinook salmon — and Alcan returned to court to seek resolution.

While preparing for the court case, the Nechako River Working Group, a task force comprised of scientists from the Department of Fisheries and Oceans, the provincial environment ministry and environmental consultants from Alcan, was asked if there was a technical basis for reaching an out-of-court settlement that could — with an acceptable level of certainty — conserve the chinook salmon that use the Nechako River. The Working Group's *Summary Report* (1987) became the basis for the *1987 Settlement Agreement* (Anonymous 1987), the legal settlement of the dispute. [*see Appendix II - Settlement Agreement*]

The terms of the Agreement provided Alcan the certainty it needed to start work on the Kemano Completion Project (commonly referred to as Kemano II). Under the terms of the 1950 agreement with the province, the Completion Project could divert additional water from the Nechako Reservoir to an expanded powerhouse at Kemano.

The Agreement also created the Nechako Fisheries Conservation Program. The immediate focus and much of the early work of the program (1988 – 1994) was based on the premise — stated in the Agreement — that the Nechako River flow regime would change from the then-current "Short-Term Annual Water Allocation" to a "Long-Term Annual Water Allocation" once a water release facility (part of the Kemano Completion Project) was constructed by Alcan at Kenney Dam. [*see Appendix II - Settlement Agreement, Clause 2.1B (a)*]

Accordingly, the Nechako Fisheries Conservation Program developed projects to collect baseline data and carry out research on the Nechako River basin. The objective of this research was to fill important gaps in knowledge in anticipation of lower water flows resulting from construction of the project. However, following the signing of the Agreement, a number of unforeseen events occurred that affected the program's activities (**Table 1.1-1**).

Table 1.1-1 **Events affecting NFCP program activities – 1991 to 1997**

May 1991	Federal Court Trial Division decision requires further environmental review of the Kemano Completion Project under federal guidelines.
May 1992	Federal Court of Appeal reverses lower court decision.
January 1993	Province issues terms of reference for a review of the Kemano Completion Project by the B.C. Utilities Commission (BCUC).
February 1993	Supreme Court of Canada refuses Kemano Completion Project opponents leave to appeal the Court of Appeal's May 1992 decision.
November 1993	BCUC public hearings begin.
December 1994	BCUC panel submits report to provincial Cabinet.
January 1995	Province releases BCUC report. Province rejects recommendations of the BCUC and cancels Kemano Completion Project.
August 1997	Alcan and the province reach a settlement on issues arising from the cancellation of the Kemano Completion Project. The *B.C.-Alcan Agreement* affirms the terms of the *1987 Settlement Agreement*, including the requirement to release the Short-Term Water Allocation in perpetuity to conserve Nechako River salmon stocks.

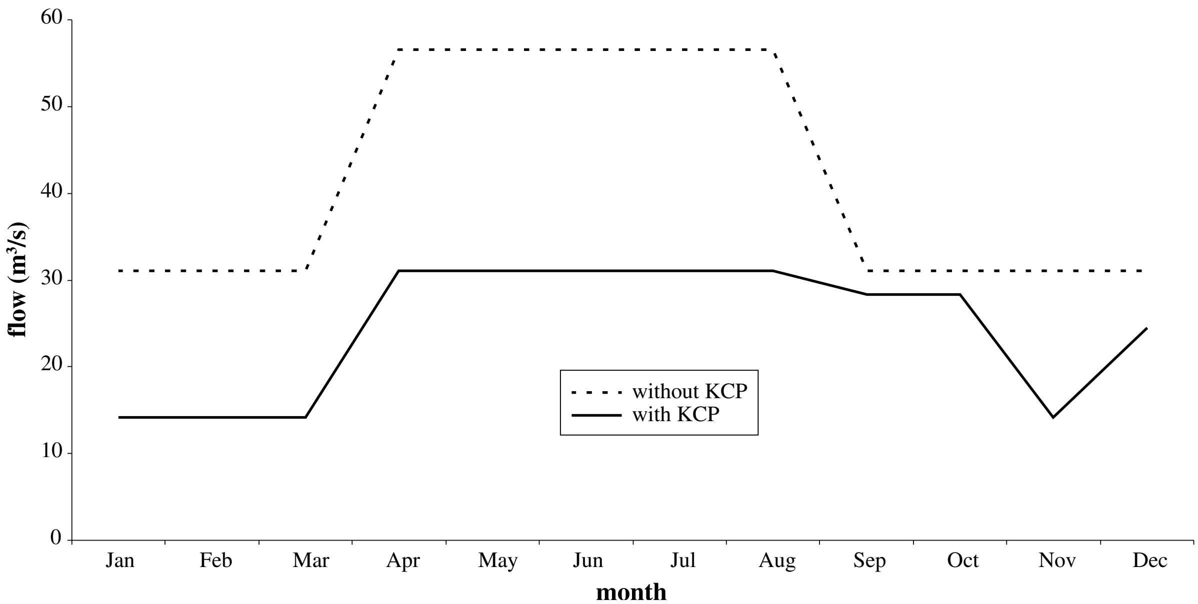
Despite the uncertainty created by the court challenges and the province's cancellation of the Kemano Completion Project, the Technical Committee continued to fulfill the mandate for the Nechako Fisheries Conservation Program set out in the 1987 Settlement Agreement. This work has continued to the present.

1.2 THE *1987 SETTLEMENT AGREEMENT*

The *1987 Settlement Agreement* defined a program of measures—including water releases from the Nechako Reservoir—intended to ensure the conservation of Nechako River chinook salmon (*Oncorhynchus tshawytscha*) and to protect migrating sockeye salmon (*O. nerka*) populations. The Agreement provided direction to the parties for the periods prior to and following construction of the Kemano Completion Project and the Kenney Dam Release Facility. For example, the Agreement specified a schedule of short-term water releases to be carried out until the completion of the project, as well as a schedule of long-term releases to be carried out once the release facility was operating (**Figure 1.2-1**).

The Agreement did not specify the volume of water to be released from the Nechako Reservoir to protect migrating sockeye. However, it did specify the continued use of Alcan's computer model and associated protocols to be used in reaching daily decisions on he volume of water to be spilled for this purpose during the summer months. These were developed and implemented in the early 1980s to predict water temperatures and to release cooling water from the Skins Lake Spillway.

Figure 1.2-1 **Nechako River: approx. flows below Cheslatta Falls – with and without KCP**



1.2.1 Conservation Goal

The *1987 Settlement Agreement* sets out a "Conservation Goal," defined as:

> *… the conservation on a sustained basis of the target population of Nechako River chinook salmon including both the spawning escapement and the harvest as referred to in paragraph 3.1 of the Summary Report….*

Paragraph 3.1 of the *Summary Report*, appended to the Agreement, states that:

> *[T]he total population of chinook to be conserved is that represented by the average escapement to the river plus the average harvest during the period 1980-1986. Department of Fisheries and Oceans escapement records during this period averaged 1,550 with a range of 850-2,000. In view of the known inaccuracies in spawner count data the working group recognizes that the estimated escapement is on average 3,100 spawning chinook, but ranges from 1,700 to 4,000. This number is referred to as the target population.*

1.3 THE NECHAKO FISHERIES CONSERVATION PROGRAM

1.3.1 Goals and Objectives

The Nechako Fisheries Conservation Program (NFCP) has two general goals.

- Develop and implement a program of remedial measures, monitoring and applied research projects as deemed necessary to ensure the conservation and protection of the chinook fisheries resource of the Nechako River (the Conservation Goal);
- Manage the operation of the computer models and protocol necessary to reach decisions on the daily release of water from the reservoir to control water temperature in the Nechako River to protect migrating sockeye salmon.

According to an annual plan approved by the Steering Committee, the objectives of these goals are to:

- Ensure that changes to instream habitat conditions do not jeopardize the population of chinook in the Nechako River;
- Reduce temperature-related risks to returning sockeye in the Nechako River by releasing cooling water flows during July and August.

A decision framework developed by the Technical Committee between 1987 and 1990 (NFCP 1991a) had three objectives.

- Establish the rationale for the various components of the program.
- Identify key monitoring parameters and data requirements.
- Provide a format for data presentation and a framework for decision-making.

An Early Warning Monitoring Program was also implemented in anticipation of the lower flows that would have resulted from the proposed Kemano Completion Project. The program used data from annual juvenile chinook monitoring projects to assess trends and would be used to trigger remedial activities post-Kemano if those trends suggested that adult chinook returns four to five years later would be significantly lower. An Early Warning Monitoring Program flow chart (**Figure 1.3-1**) allowed hypotheses to be tested. For example, according to the chart, if a significant decrease in the index of juvenile chinook out-migrants is accompanied by a significant decrease in the index of fry emergence, then tertiary monitoring results would be examined to identify the reason for the decrease. Appropriate action would then be taken and subsequent monitoring used to measure the response of the juvenile chinook population.

Figure 1.3-2 presents the assessment framework for assessing the Technical Committee's success at meeting the terms of the Conservation Goal.

Figure 1.3-1 Early Warning Monitoring Program

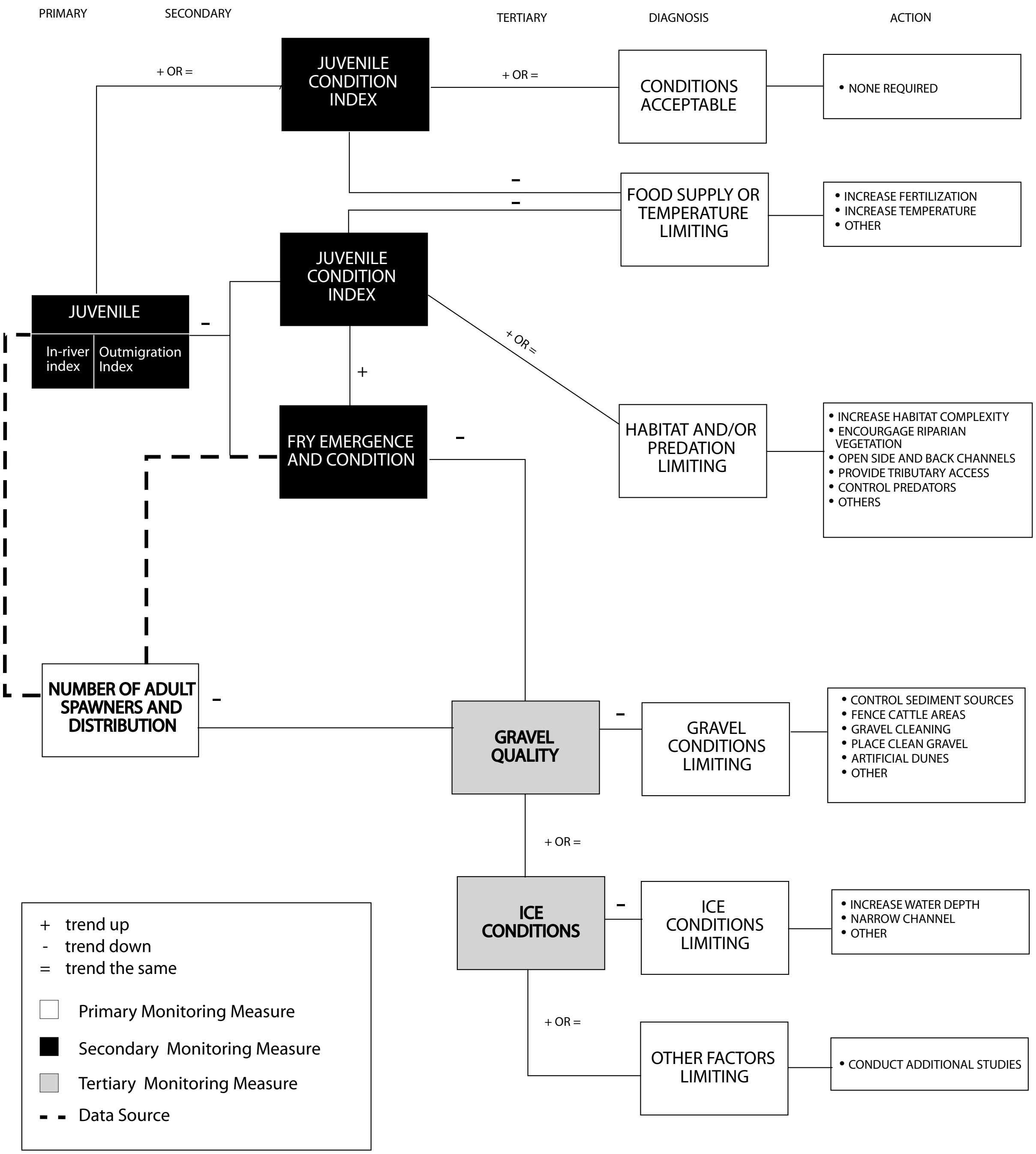
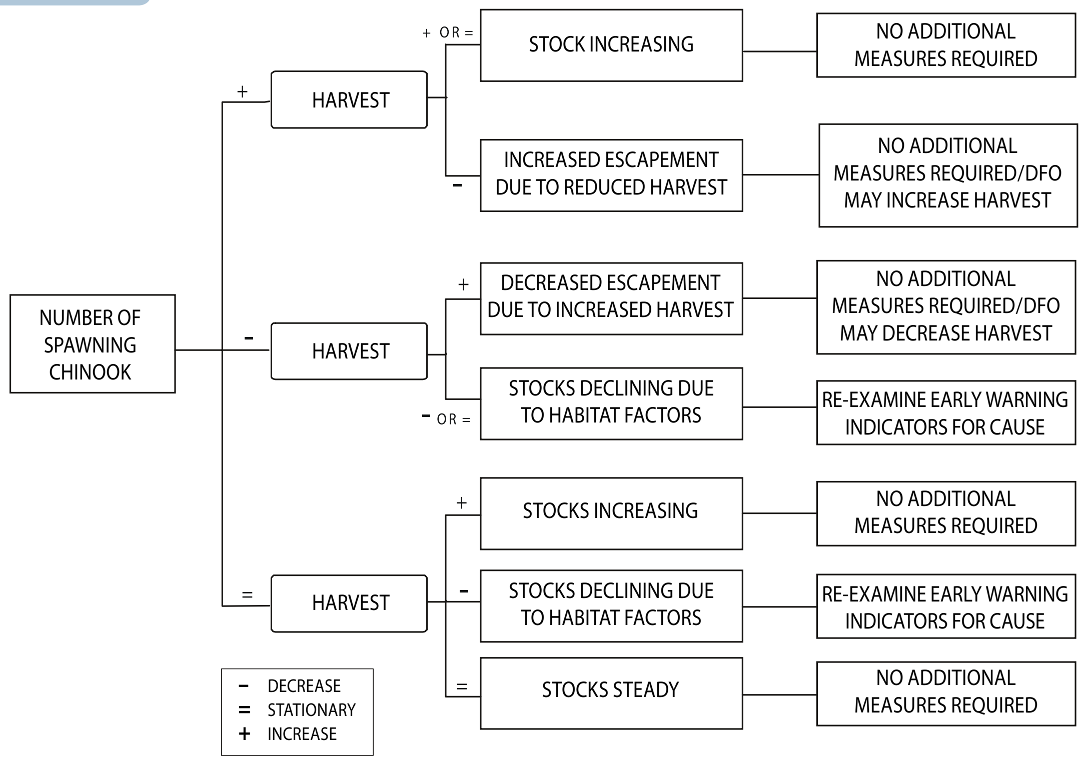


Figure 1.3-2 **Conservation Goal assessment framework**



1.3.2 Primary Activities

Since 1997, the Technical Committee has focused on three primary activities.

- Managing water releases from the Nechako Reservoir into the Nechako River. This includes both the Annual Water Allocation (AWA) and releases made during the summer months to protect migrating sockeye. The Short-Term releases are the basis for the AWA. This regime is defined by an annual average minimum flow of 36.8 m^3/s of water (not including additional cooling releases) released from the Skins Lake Spillway into the Nechako River. Based on an estimated average natural inflow into Cheslatta and Murray Lakes of 4.9 m^3/s, this provides a mean annual flow of 41.7 m^3/s at Water Survey of Canada Data Collection Platform Station 08JA017, near Bert Irvine's Lodge (km 19[5]), downstream of Cheslatta Falls.
- Collecting chinook utilization data in the upper Nechako River.
- Compiling and analyzing data to complete a technical review of the program and establish the basis for future NFCP-related activities.

1.3.3 Project Overview

The NFCP includes projects in three areas originally set out in the Nechako River Working Group's *Summary Report* (**Table 1.3-1**):

[5] Unless otherwise noted, all longitudinal distances in this report are expressed as kilometers from the centerline of Kenney Dam. The first nine kilometers of the river are within the Nechako River Canyon, which was dewatered when Kenney Dam closed in October 1952.

- **remedial measures**: four projects annually, six periodically;
- **monitoring**: five projects annually, four periodically; and
- **applied research**: five projects.

Reports detailing the findings of most of these projects have been prepared. A summary of the findings is included in Sections 3 to 9 of this report.

1.3.4 Technical Data Review

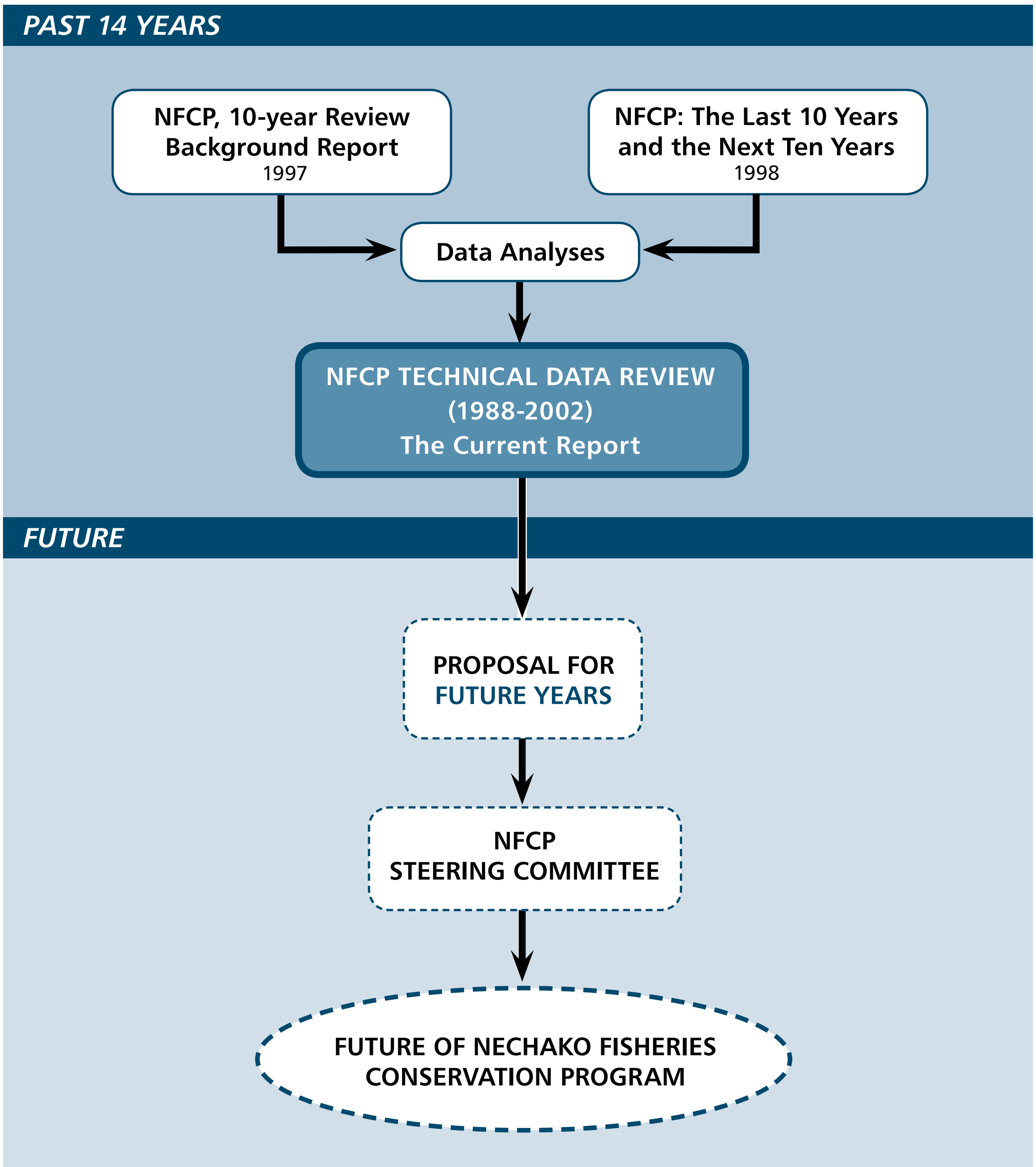
Following the province's cancellation of the Kemano Completion Project (1995) and the subsequent signing of the *B.C.-Alcan Agreement* (1997), the Technical Committee decided to carry out a thorough review of its activities and to consider how the NFCP should be modified to meet current and future needs (**Figure 1.3-3**). Accordingly, the committee brought together much of the data collected by the NFCP in a background report entitled *Nechako Fisheries Conservation Program, 10-Year Review Background Report* (NFCP 1997). This was followed in February 1998 by a two-day workshop in which 25 participants from the Department of Fisheries and Oceans, the B.C. Ministry of Environment, Lands and Parks, academia and the private sector reviewed the background data and made recommendations on further analyses. The workshop report is

Table 1.3-1 NFCP Project Overview

project	# of years implemented
Remedial Measures	
Cheslatta Murray Data Collection	6
Summer Temperature Management	13
Instream Habitat Modification	10
Biological Assessment of Habitat Complexing	9
Fertilization	5
Inventory of Habitat	2
Inventory of Sediment	1
Flow Control	13
Winter Remedial Measures	1
Riparian Bank Stabilization	3
Monitoring	
Adult Chinook Spawner Enumeration	13
Chinook Carcass Recovery	13
Juvenile Outmigration Monitoring	13
Winter Physical Conditions	5
Physical Data Collection	13
Fry Emergence	12
Gravel Quality	3
Dissolved Oxygen Monitoring	7
Applied Research	
Ecology of Juvenile Chinook Salmon	2
Chinook Life History Model	2
Predator Prey Studies	6
Temperature Effects	4
Chinook Overwintering	6

entitled *Nechako Fisheries Conservation Program (NFCP): The Last 10 Years and the Next 10 Years* (NFCP, 1998). Since 1998, while continuing its responsibilities under the *1987 Settlement Agreement*, the committee has been completing the data review that forms the basis of this report.

Figure 1.3-3 **NFCP: flow chart of activities, past and future**



Section 2
Kenney Dam Release Facility Approval Process

The *1987 Settlement Agreement* indicated that, should Alcan wish to change releases from the Nechako Reservoir from the Short-Term Water Allocation protocol to the Long-Term Water Allocation protocol, it first had to design and construct a multi-level water release facility at Kenney Dam. The purpose of the facility would be to:

- release cooler, hypolimnetic water[6] from the Nechako Reservoir during the summer months: and
- release the Long-Term Water Allocation year round.

The design of the water release facility—to be approved by the Technical Committee—was to be reviewed against criteria derived from objectives set out in the Nechako River Working Group's *Summary Report*. According to the *Summary Report*:

- flow releases were to be maintained at satisfactory year-round volumes;
- the rate of change of water levels could not cause stranding or premature out-migration; and
- the rate of temperature change was to be controlled.

Anticipating a reduction in flow once the Long-Term Water Allocation protocol was implemented, the Technical Committee added the following criteria:

- cooling water releases were to be at a mean daily temperature of no less than 10.0˚C with an instantaneous temperature of no less than 9.5˚C; and
- total gas pressure in river water was to be less than 103% within 1 km of Kenney Dam.

[6] The layer of water in a thermally stratified reservoir that lies below the thermocline, is noncirculating, and remains perpetually cold.

2.1 KENNEY DAM: REVIEW PROCESS, 1988 TO 1993

Between 1988 and early 1991 the Technical Committee worked with the Kemano Completion Project Design Team to develop criteria related to the fisheries aspects of the Kenney Dam Release Facility. The process involved informal meetings and exchanges of information. The committee would request, review and comment on studies and supporting documents prepared by the Design Team as part of the design's development, forwarding comments for consideration to the team if:

- the committee felt there was a design procedure, or an alternate type of design that could better achieve the design criteria;
- there was a misunderstanding or misinterpretation of the design criteria, or an error perceived in any analytical procedure; and
- there were areas in the documentation that needed clarification.

Recognizing that there were design aspects that were beyond the committee's interests (*e.g.,* dam safety and structural requirements), the committee separated design approval—represented by plans and specifications—from the review and approval process associated with operating the structure.

The Kemano Completion Project Design Team issued its design report in March 1991, including a summary of the design criteria and the design concepts for the Kenney Dam Release Facility. A second review by the Technical Committee and the Design Team was subsequently initiated through a combination of correspondence and meetings. The committee suggested that this more formal review be undertaken in six modules designed to address the various components (**Table 2-1**).

Table 2-1 **Review of design components — Kenney Dam Release Facility**

component	examples
Design Criteria	• Are the design criteria addressed? • How are they monitored? • Did the designers give assurances for achieving the design criteria?
Cold Water Releases	• How much cold water is required? • Is cold water available? • Can cold water be delivered?
Water Quality	• What will be the total gas pressure? • What measures will be undertaken to control sediments, both during construction and resulting from re-watering the canyon and passing water across Cheslatta Fan?
Structure Operation	• How will the structure be operated relative to changing flows and water levels?
Flood Releases	• Will flood releases through the water facility adversely affect the *1987 Settlement Agreement*'s Conservation Goal?
Construction Activities	• Will construction activities adversely affect the *1987 Settlement Agreement*'s Conservation Goal?

Also in March 1991, in response to initiatives from the Technical Committee, the Steering Committee drafted a memorandum on the *1987 Settlement Agreement's* description of the Technical Committee's approval function[7]. The memorandum established that design responsibilities for the Kenney Dam Release Facility rested with Alcan and its design consultants. The committee was to:

- act as a review board that:
  - participated actively and rigorously in the review process;
  - made suggestions to the Design Team;
  - challenged the team to consider various issues that could adversely affect both the structure's performance and its ability to achieve the design criteria; and
- raise questions and offer comments for Alcan and its designers to consider prior to the Kemano Completion Project Design Team concluding that the structure would meet the design criteria specified by the committee.

The Technical Committee's role did not include ensuring agreement on every point raised about the design.

In addition to copies of all the reports produced by Alcan's consultants in support of the Kenney Dam Release Facility design, a full set of plans and specifications for the structure (plus addenda) were forwarded to each committee member for review. The initial set of documents was received on May 27, 1991[8].

Few questions and little discussion resulted from the committee's second review of the plans and specifications as most issues had been discussed in the earlier process. The questions that did arise dealt with operational issues such as coordinating the acceptance tests for the spillway gates and with re-watering the Nechako Canyon after the dam was completed. The committee formally approved the Kenney Dam Release Facility plans and specifications on March 25, 1993. This approval was within the context of the policy direction set out by the Steering Committee in its memorandum.

2.1.1 Kenney Dam: Unfinished Business

2.1.1.1 Operating Issues

Aspects of the Design Team's work that require further review and discussion include issues about operating a release facility (*e.g.,* commissioning the structure, the allowable rate for opening and closing gates so as not to strand juvenile fish in downstream habitats, etc.). Draft reports on these issues were submitted by the Design Team, but were not fully reviewed or discussed by the Technical Committee.

2.1.1.2 Plans for the Cheslatta Fan Channel

Part of the review and approval of the design of the proposed water release facility included reviewing plans for a channel to convey water across Cheslatta Fan, an alluvial deposit at the downstream end of the Nechako Canyon, immediately upstream of Cheslatta Falls. Anticipating significantly reduced flows, the Nechako River Working Group's *Summary Report* stated that a channel should:

- allow water to pass across the fan without eroding the deposit and potentially moving it downstream to important spawning and rearing habitats; and
- maintain, as much as possible, the existing rearing habitat in the vicinity of the fan.

---

[7] A copy of Steering Committee's memorandum is included as *Attachment D*, to the March 25th, 1993 approval of the release facility plans and specifications in *Appendix III – KDRF Approval Letter*.

[8] See *Appendix III – KDRF Approval Letter* for the design criteria and the documents provided by the Design Team to the Committee. Reports under review at the time the Kemano Completion Project was rejected are also listed in *Appendix III*.

The Design Team proposed constructing an armoured channel across the fan to meet the design objectives. The Technical Committee reviewed the design and gave conditional approval. The most important condition was that the Design Team consider and provide information to the committee on potential regime or natural options for the design of the channel to determine if the options could meet the intent of the *Summary Report*.

The Design Team had not met this condition when the provincial government cancelled the Kemano Completion Project. That said, the investigations associated with the project will be useful in considering future designs for conveying water across the Cheslatta Fan if a release facility is constructed in the future.

2.2 DECISIONS OF THE NECHAKO ENVIRONMENTAL ENHANCEMENT FUND (NEEF) MANAGEMENT COMMITTEE

Among other things, the *B.C.-Alcan Agreement* (1997) established the Nechako Environmental Enhancement Fund, Alcan agreeing to contribute — on a matching basis — up to $50 million to the fund. A management committee was established and given the task of determining the best use of the funds within the parameters set by the 1997 agreement.

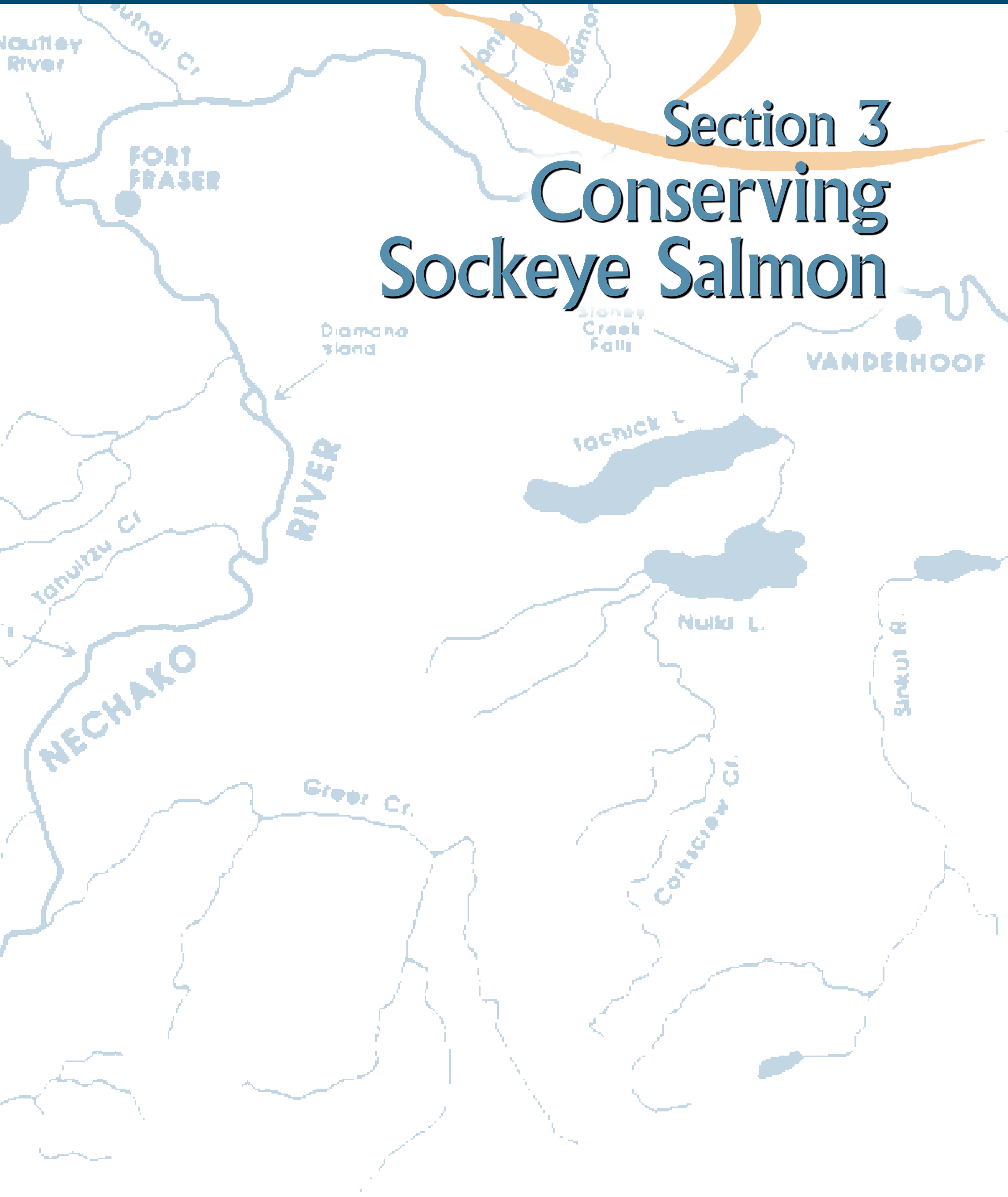
In 2001, the Management Committee issued its report. It included two decisions and five recommendations. One of the decisions was to use most of the NEEF to construct a particular form of water release facility at Kenney Dam.

2.3 KENNEY DAM: FUTURE CONSIDERATIONS

Many if not all of the design criteria referred to above should be revisited if a water release facility is constructed at Kenney Dam. The design capacities of many of the components will have changed since the Kemano Completion Project was cancelled in 1995. This could lead to different solutions to meet flow criteria.

Research into environmental criteria and processes will also have advanced in the years since 1995, possibly leading to different criteria than were used during the Technical Committee's review of the Kenney Dam Release Facility.

Section 3
Conserving Sockeye Salmon



THE *1987 SETTLEMENT AGREEMENT* MANDATED THE NECHAKO FISHERIES CONSERVATION PROGRAM (NFCP) TO MANAGE THE WATER temperature of the Nechako River for the benefit of sockeye salmon migrating through the river to their natal streams. Several runs of sockeye (*O. nerka*) use the river as a corridor to the Stuart (early and late runs), Nadina (early and late runs) and Stellako Rivers (late run). The fish usually move through the Nechako River to or from their natal streams at fairly regular intervals (**Table 3-1**). Individual fish spend two to four days in the river during migration.

A small number of sockeye spawn in the Nechako River. One group spawns near Targe Creek in the upper river, another spawns near bird sanctuary islands just upstream of the town of Vanderhoof. It is not known if these fish are strays from the more abundant runs that use the tributary systems, or if they are discrete sockeye stocks.

Table 3-1 **Nechako River Basin: timing of adult sockeye migrations**

	Nadina run				Stellako run		Stuart run			
	early		late				early		late	
Nechako River location	earliest date	latest date	earliest date	latest date	earliest date	latest date	earliest date	latest date	earliest date	latest date
Prince George	Jul 18	Aug 14	Jul 25	Aug 21	Aug 12	Sep 29	Jul 10	Aug 09	Aug 01	Sep 06
Stuart	Jul 20	Aug 16	Jul 27	Aug 23	Aug 15	Oct 02	Jul 12	Aug 11	Aug 03	Sep 08
Nautley	Jul 22	Aug 18	Jul 29	Aug 25	Aug 18	Oct 05				

3.1 SUMMER TEMPERATURE MANAGEMENT PROGRAM

Most sockeye stocks that move through the Nechako River are only briefly exposed to the river's environmental conditions; however, increases in river temperatures can increase stress on the migrating salmon, making them more susceptible to disease and pre-spawning mortality. Consequently, a river temperature control program, the Summer Temperature Management Program (STMP), was planned as part of the response to concerns about potentially higher water temperatures resulting from reduced water flows following the construction of the Kemano Completion Project.

Developing a cold-water water release facility at Kenney Dam—a recommendation of the Nechako River Working Group's *Summary Report*—ended with the cancellation of the Kemano Completion Project. However, the operating protocols for releasing cooling water—developed between 1980 and 1983—and the associated computer models needed to generate water temperature data, were referenced in the *1987 Settlement Agreement* and remain in use in their original form to the present[9]. The protocols—based on meteorological conditions over the watershed (**Figure 1-1**)—help Alcan operations personnel and the Technical Committee reach decisions on the need for water releases from the Nechako Reservoir via the Skins Lake Spillway to manage downstream water temperatures. The need for additional cooling water is determined daily using a mathematical water temperature model and real-time data. Release rates are based on the Decision Protocol described in *Appendix IV – STMP Decision Protocol.*

3.1.1 Operating Criteria

The criteria for conserving sockeye are defined in terms of water temperatures in the Nechako River measured upstream of its confluence with the Stuart River at Finmoore[10]. The goal of the program is to maintain mean daily water temperatures at, or below 20°C. This goal was established in the late 1970's (IPSFC 1979) and has been part of the STMP since the program's inception in 1983.

Limitations in infrastructure make it impossible to keep mean daily water temperatures <20°C at all times. Given that the time needed for flow changes to translate through the 40 km of lakes and 240 km of river between the Skins Lake Spillway and the confluence with the Stuart River is five to seven days, water temperatures at Finmoore will occasionally exceed 20°C. In fact, in some circumstances the amount of water needed to cool the river below 20°C could cause flooding. This necessitates managing releases so that flows in the river below Cheslatta Falls for the summer period range from 170 m^3/s to 283 m^3/s: the minimum flow ensures a timely response to forecasted warming over the basin; the maximum flow will mitigate most temperature increases while minimizing summer flooding along the upper Nechako River.

The early Nadina sockeye stock is the first stock that would be exposed to lower flow rates and consequent higher temperatures upstream of Stuart River. Typically, this stock migrates through the Nechako from the confluence with the Stuart River to the Nautley River at Fort Fraser after July 20 (IPSFC 1979). Consequently, the STMP

[9] Cooling water release decisions were reached between 1980 and 1982 using methods that differ with those in use since 1983.

[10] Although all Nechako River basin sockeye are potentially affected by increased water temperatures resulting from the construction of Kenney Dam, sockeye migrating past the confluence of the Stuart River in the Nechako River face the greatest potential effects as they are exposed for longer periods of time.

is initiated on July 10 (or a few days earlier, if warranted by the meteorological forecasts, or the possibility of an early-run), adjusting water flows to meet the target water temperatures at Finmoore from July 20 until August 20.

The river cools naturally by August 20. The advancing season and consequent decrease in solar energy gain reduces the potential for warm water temperatures and by early September the flow usually is changed to the winter release level of approximately 30 m^3/s (1,060 cfs) to maintain chinook fall spawning flows below Cheslatta Falls. [see *s.4 Conserving Chinook Salmon*]

3.1.2 Monitoring

The STMP depends on real-time water temperature and flow data, and observed and forecasted meteorological data. The water temperature data must include:

- observed river temperatures;
- predicted river temperatures; and
- changes in predicted temperatures day-to-day.

The following data is collected at the noted locations from early July to late August:

- water temperature:
  - Nechako River below Cheslatta Falls;
  - Nechako River at Fort Fraser (upstream of the Nautley River confluence);
  - Nautley River; and
  - Nechako River above the confluence with the Stuart River.
- river flow:
  - Skins Lake Spillway;
  - Nechako River below Cheslatta Falls;
  - Nautley River; and
  - Nechako River at Vanderhoof.

Meteorological data collected for the STMP include total solar (short-wave) radiation, mean daily air temperature, mean daily relative humidity and wind speed. This data is collected on the river at Prince George and at Fort Fraser where a portable weather station is set up each summer. Cloud cover is estimated by observers at each location and observed meteorological data from the Prince George Atmospheric and Environment Service station are used in the daily preparation of five-day meteorological forecasts to model water temperatures during July and August. The Fort Fraser data are used as backup in the event the Prince George data are unavailable.

3.1.3 Releasing Water

Operating the STMP was included in the mandate of the NFCP. Each day, water temperature, flow data and meteorological data are used to predict water temperatures in the Nechako River just above the Stuart River confluence five days into the future. When two of the three monitored trends indicate that additional cooling water is needed to manage downstream water temperatures, the Technical Committee passes the daily flow release decisions to Alcan's Power Operations staff. These staff make the necessary changes to the Skins Lake Spillway gates to increase the water release[11]. Due to the delays created as flows are translated through Murray and Cheslatta Lakes, the range in operating releases at the Skins Lake Spillway is necessarily larger (14.2 m^3/s to 453 m^3/s) than the flows recorded at Cheslatta Falls.

Figure 3.1-1 summarizes minimum, mean and maximum Skins Lake Spillway releases, July 10 to August 20, 1983 to 1998 (data are not available for 1999 and 2000). **Figure 3.1-2** summarizes minimum, mean and maximum discharges in the Nechako River below Cheslatta Falls from July 10 to August 20, 1983 to 2000.

[11] A protocol was developed in 1997 to ensure the appropriate exchange of information between Alcan staff and the Technical Committee and to check the necessary gate settings at Skins Lake. [see *Appendix V – Information Exchange Protocol*]

Figure 3.1-1 **Nechako River: Skins Lake Spillway releases, July 10 to August 30, 1983 to 2000**

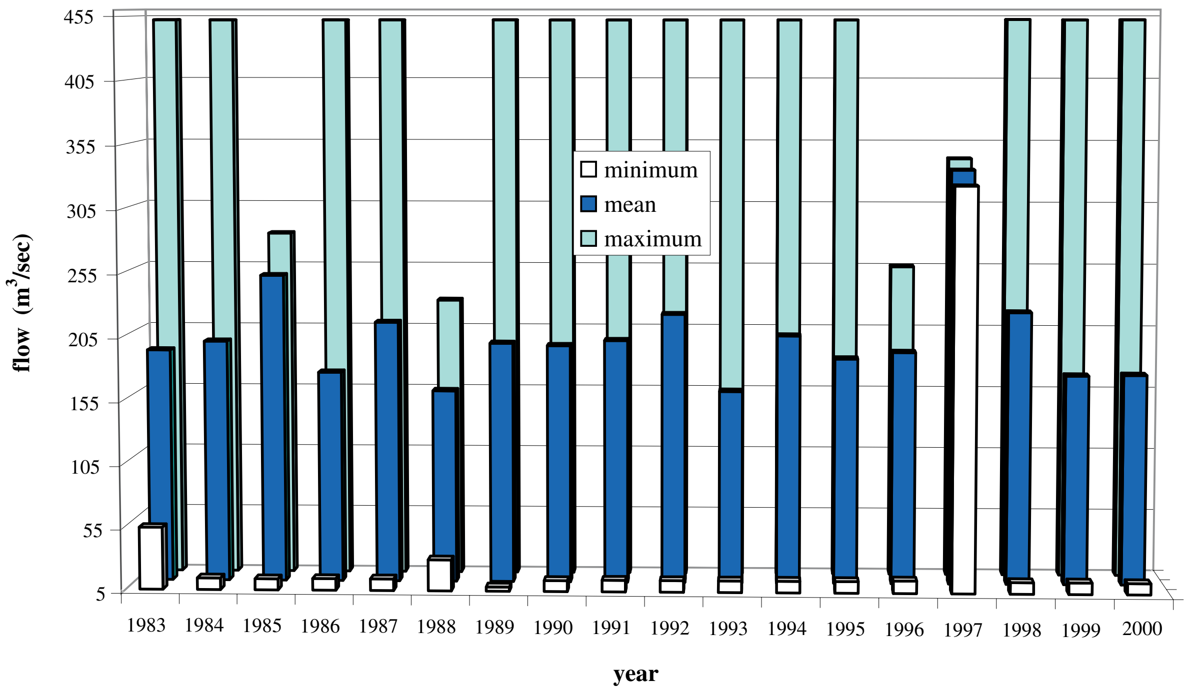
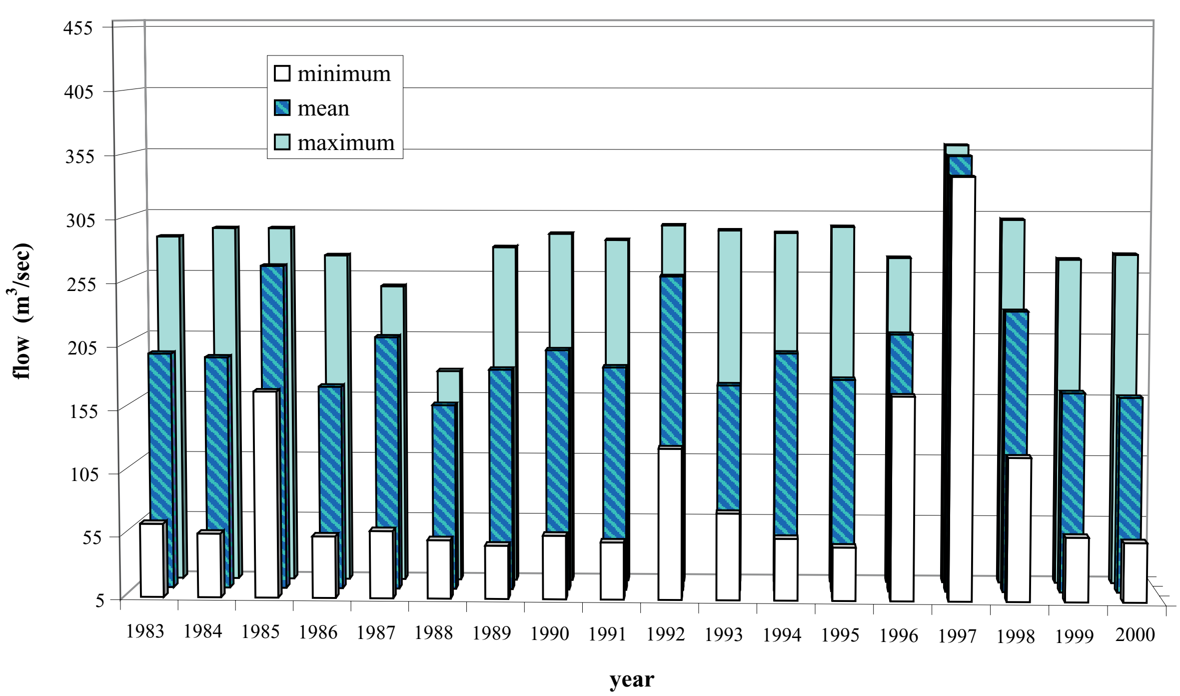


Figure 3.1-2 **Nechako River: annual flows below Cheslatta Falls, July 10 to August 30, 1983 to 2000**



3.2 REVIEWING THE STMP

Water temperatures have been monitored in both the Nechako and Stuart Rivers at their confluence since 1953. Consequently, water temperature and meteorological data included in this section are for two periods: pre-STMP (1953 to 1979); and post-initiation of the STMP (1983 to 2000). The years 1980, 1981 and 1982 have been removed from the data as the methods used to reach flow control decisions during these years were different from both the prior years and from the current STMP. The Nechako River water temperature data allows a comparison of can be compared to water temperatures in the unregulated Stuart River, which shares the same hydrological basin and biogeoclimatic influences and also supports large sockeye runs. However, care needs to be exercised when comparing the two systems; the fact that the temperature data set includes only flow-regulated Nechako River years restricts some comparisons. That said, with the given data set, the Stuart River system can be used as a control watershed to evaluate the effectiveness of the STMP in cooling Nechako River water.

3.2.1 Annual Release Regulation

Skins Lake Spillway releases during July and August have been regulated between a minimum of 14.2 m^3/s (500 cfs) and a maximum of 453 m^3/s (16,000 cfs) since 1983, as required by changes in observed river temperatures and meteorological forecasts. Recorded mean daily releases for the period July 10 to August 20, 1983 to 2000 averaged 204 m^3/s (7,200 cfs) and ranged from 158 m^3/s (5,580 cfs) in 1988 to 335 m^3/s (11,800 cfs) in 1997 (**Figure 3.1-1**). These data include releases (forced spills) in 1985, 1992, 1996 and 1997 beyond those needed to manage the downstream temperature for fisheries resources. In years when no spills in excess of normal releases occurred, recorded mean daily Skins Lake Spillway releases for the period July 10 to August 20 averaged 188 m^3/s (6,640 cfs) and ranged from 158 m^3/s (5,580 cfs) in 1988 to 213 m^3/s (7,520 cfs) in 1987. The annual releases of cooling water for the period 1983 to 2000 averaged 16 m^3/s (**Table 3.2-1**).

3.2.2 Summer Water Temperatures

Mean daily water temperatures recorded from July 20 to August 20 in the Nechako River at Finmoore for the years 1983 to 2000 are presented in **Figure 3.2-1**. The figure shows that water temperatures have generally remained between 15˚C and 21˚C and only infrequently exceeded 20˚C. This is within the pre-STMP range (*i.e.,* 1956 to 1982) of maximum and minimum mean daily values (**Figure 3.2-2**).

Table 3.2-1 **Summary: average annual frequency of mean daily water temperatures exceeding 20°C in the Nechako River above the Stuart River, and in the Stuart River, July 20 to August 20, 1953 to 2000***

A) Water Temperature Exceedances (days per year)

period	Nechako River >20.0°C	Stuart River >20.0°C
1953 - 1979	3.2	5.0
1983 - 2000	2.9	7.6

B) Average Annual Response Temperature (°C)

period	Temperature (°C)
1953 - 1979	20.0
1983 - 2000	21.2

* 1980, 1981 and 1982 have been removed from data — see text.

Figure 3.2-1

Nechako River: mean daily water temperatures recorded above the Suart River confluence, July 20 to August 20, 1983 to 2000

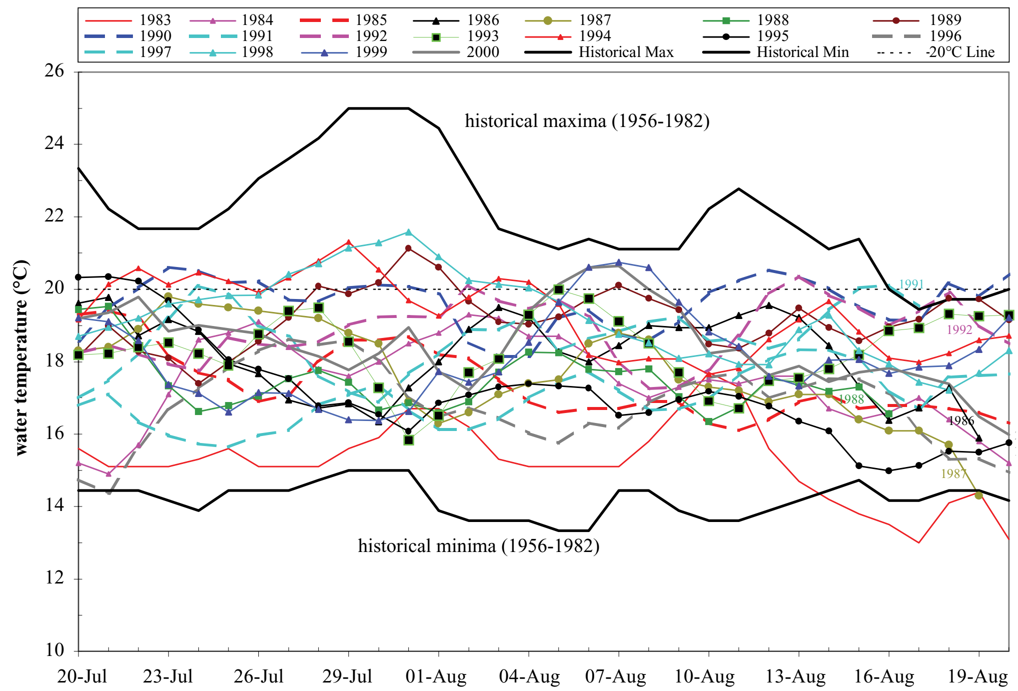
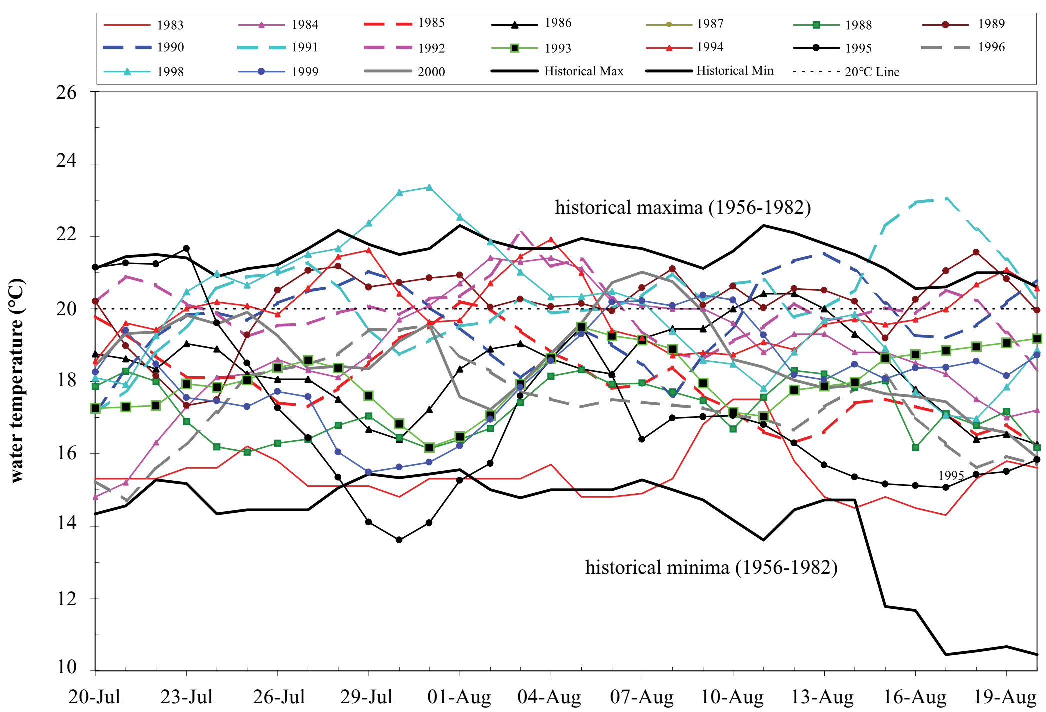


Figure 3.2-2

Stuart River: mean daily water temperatures, July 20 to August 20, 1983 to 2000



For comparative purposes, water temperatures in the Stuart River just upstream of the confluence with the Nechako River are presented in Figure 3.2-2. Since 1983, mean daily water temperatures did exceed 20°C in both rivers, but did so more frequently in the unregulated Stuart River than in the managed Nechako River. In fact, the average number of days with a mean daily water temperature >20°C per year has increased in the Stuart River since 1983 (5.3 to 7.4 days per year on average), while remaining relatively stable in the Nechako River where the STMP was in effect (3.0 days per year on average).

In 1985 and 1996, forced spills of at least 283 m^3/s were made from the reservoir and the STMP was not implemented. In 1987, Stuart River water temperatures were not recorded. As well, forced spills of 283 m^3/s or greater during part of the STMP period in 1992 and 1997 would have biased the comparison and have not been included in the analysis. Therefore, for 11 of the remaining 13 years (starting in 1983) in which the STMP was operated, the annual frequency of water temperatures in the Nechako River >20°C was less than in the Stuart River. Furthermore, mean water temperatures and maximum and minimum water temperatures tended to be lower in the Nechako River than in the unregulated Stuart River.

3.2.2.1 Effect of Meteorological Conditions on Reaching the STMP Objective

The objective of the STMP is to reduce the occurrences of water temperatures >20°C in the Nechako River above the Stuart River confluence. The ability to achieve this objective is limited by:

- the current location of the infrastructure; and
- restrictions on the maximum flow permitted during the summer to limit flooding to lands adjacent to the river.

This means that water temperatures can exceed the objective because meteorological conditions can warm the river to >20°C even in some cases when the maximum release has been made, or when weather forecasts may have been in error to a degree that delayed the timing of the increase in releases from the reservoir.

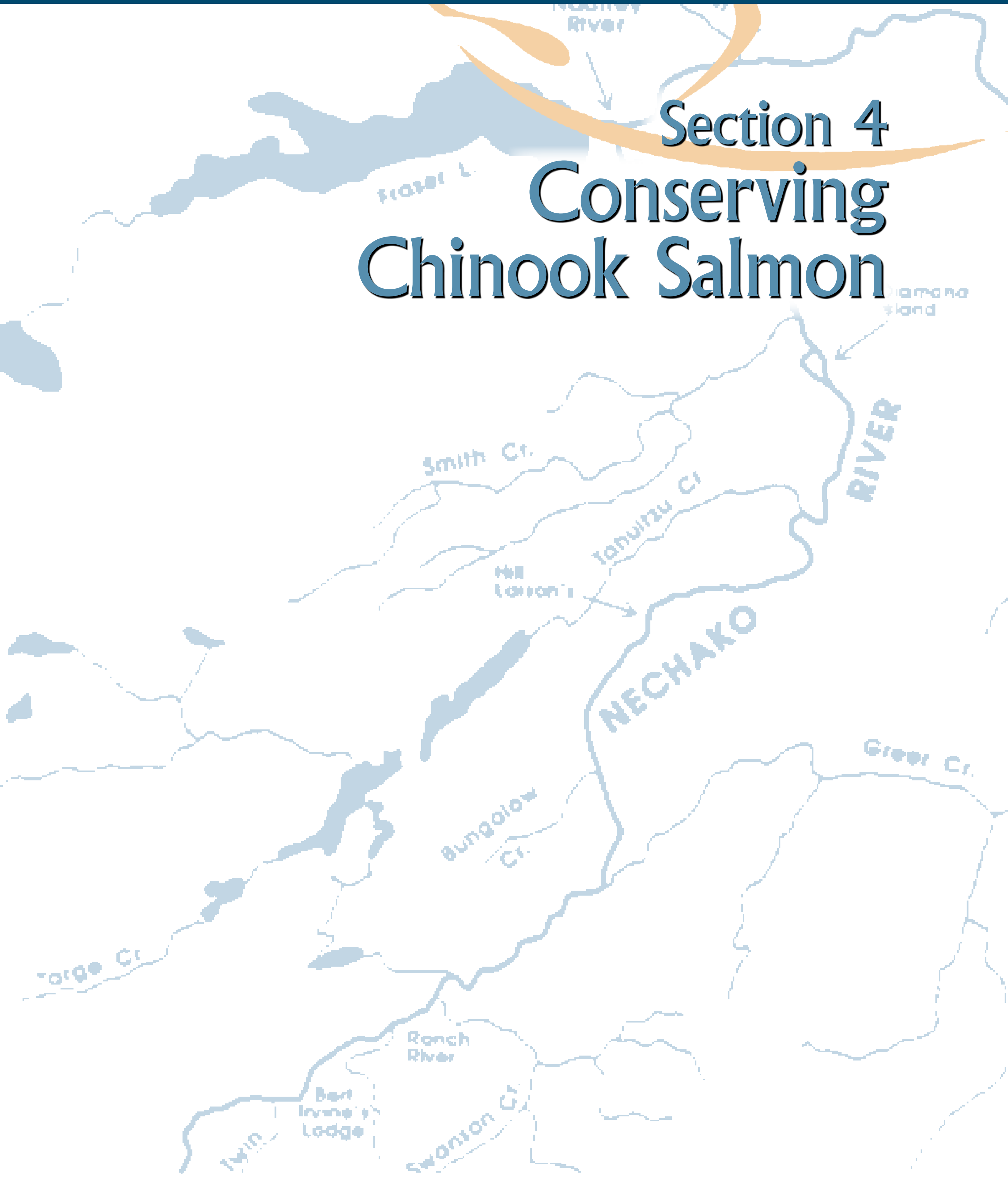
Meteorological conditions for the periods prior to 1980 and from 1983 to 2000 were compared to determine if the difference in water temperatures was due to management of the river. To do this, an index was adopted that integrated only the effect of meteorological conditions on water temperatures. This "response temperature" is the temperature that a column of water would theoretically rise to if acted on only by meteorological conditions. **Table 3.2-1** shows the index for 1953 to 1979, and 1983 to 2000.

Given the generally warmer meteorological conditions in the latter period (evidenced by increases in both the response temperatures and the Stuart River temperatures), it appears that meteorological conditions were responsible for the generally warmer water temperatures in recent years. This conclusion is supported by the fact that meteorological forecast errors are usually corrected within one day, whereas the warmer weather conditions that lead to water temperatures >20°C extend over a longer period (*i.e.,* multiple days to weeks).

3.2.3 Summary

Since it was implemented in its current form in 1983, the STMP has regulated the release of additional water from the Nechako Reservoir via the Skins Lake Spillway to limit the frequency of mean daily temperatures >20°C measured at Finmoore upstream of the confluence of the Nechako and Stuart Rivers. Nechako River temperatures have rarely exceeded 20°C, even though meteorological conditions have warmed over the study period. In fact, the frequency of occurrence of Nechako River water temperatures exceeding 20˚C during this warmer period is similar to that recorded in a cooler period prior to the STMP being implemented.

Section 4
Conserving Chinook Salmon



The *1987 Settlement Agreement* mandated the Nechako Fisheries Conservation Program (NFCP) to conserve:

> *… on a sustained basis [the] target population of Nechako River chinook salmon including both the spawning escapement and the harvest….*

The approach adopted by the NFCP's Technical Committee to meet this "Conservation Goal" is based on the Nechako River Working Group's *Summary Report*, which is appended to the *1987 Settlement Agreement*. The philosophy expressed in that report is that it is necessary to maintain both sufficient habitat quantity and quality to provide an acceptable level of certainty that chinook salmon will be conserved and protected in the Nechako River.

The committee's projects relating to the Nechako River chinook and its habitat fall into three main areas:

1. Collecting information on:
    a. life-history events; and
    b. stock performance

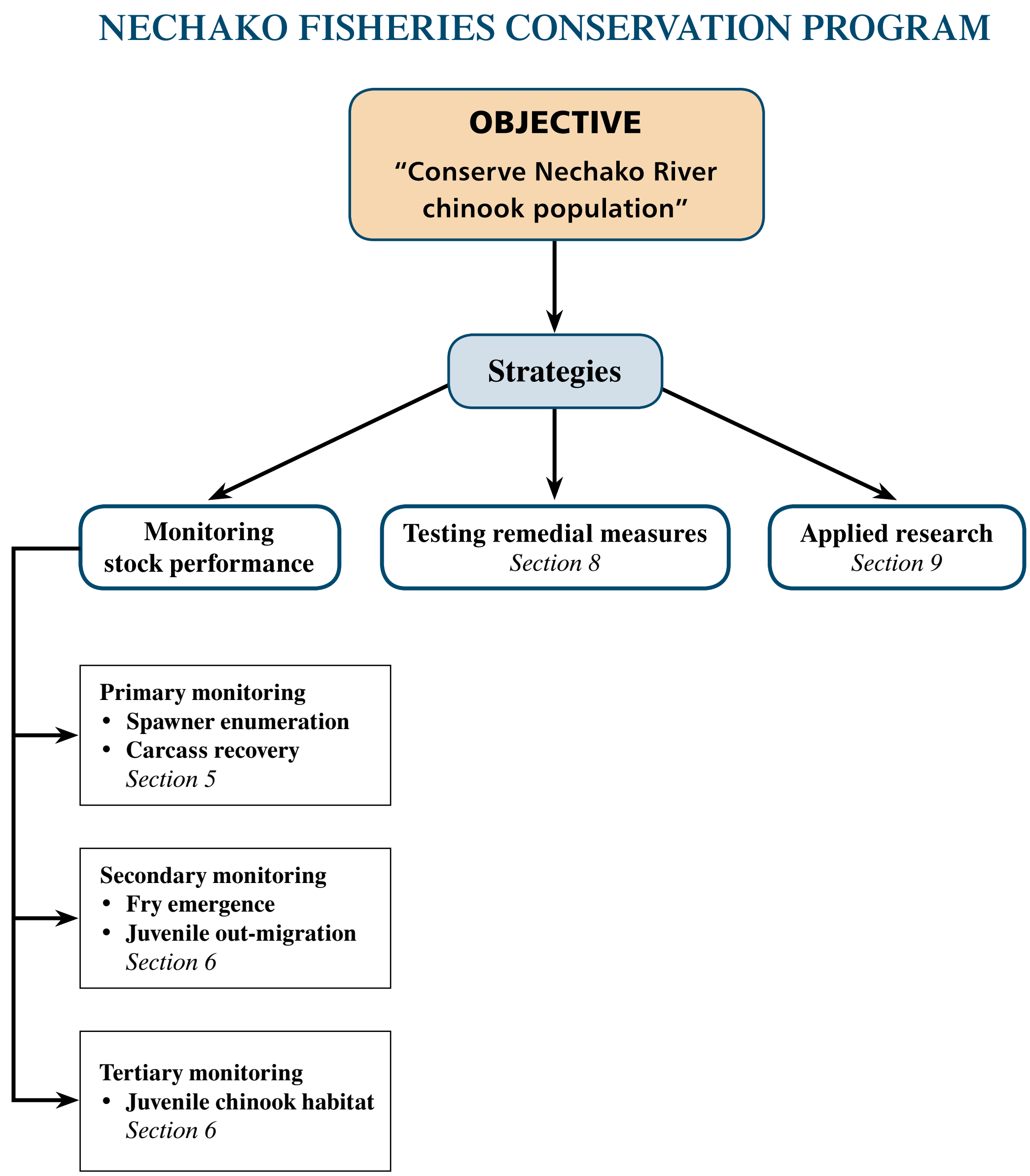
    to identify trends in Nechako River chinook.
2. Collecting information on:
    a. the use of natural and artificial habitats by juvenile chinook; and
    b. the status of in-river habitat.
3. Filling identified gaps in knowledge on Nechako River chinook ecology.

The Technical Committee recognized early in this project that physical and biological parameters vary both spatially and temporally and that not all of the possible parameters could be monitored with the same degree of rigour and precision. Consequently, the Technical Committee decided to measure primary parameters—those that allow assessment of the Conservation Goal (**Figure 1.3-2**) —with the greatest degree of rigour, and secondary (biological) and tertiary (physical) parameters with less rigour (**Figure 4-1**).

In addition, an Early Warning Monitoring Program (**Figure 1.3-1**) was developed by the committee to assess trends reflected by monitoring programs aimed at juvenile chinook life-histories, and to suggest timely and anticipatory actions that could be taken in response to these trends. Significant progress was made in implementing this multi-tiered approach prior to the province cancelling the Kemano Completion Project in 1995.

Sections 5 through 8 of this report summarize the findings of individual projects. Each section begins by describing the strategy adopted by the Technical Committee to ensure that a baseline of scientific information was collected prior to changes to the long-term flow regime resulting

Figure 4.1 NFCP Technical Committee: Objective and Strategies



from the construction of the Kemano Completion Project. It was necessary to collect this baseline information to establish a prioritized set of remedial measures that could be implemented in the event the Early Warning Monitoring Program identified a problem in chinook production. First stage remedial measures—including flow control, instream manipulations, and off-channel improvements—were generally expected to be sufficient to ensure the conservation of chinook. Second and third stage measures (Nechako River Working Group 1987) represented back-up positions in the event that the first stage measures proved inadequate.

4.1 MONITORING STOCK PERFORMANCE

The Technical Committee established projects to detect trends in important life-history stages of the Nechako River chinook stock. Primary monitoring projects gathered information on returning adult chinook. Among other things, this involved estimating adult chinook escapement to the mainstem of the Nechako River between Vanderhoof and Cheslatta Falls. [See *s.5 Chinook: Primary Monitoring*]

Secondary measures focussed on developing indices for two life-history phases: an index of fry emergence monitored the quality of the incubation environment in the Nechako River; and an index of juvenile chinook out-migration monitored the quality of the rearing habitat. [See *s.6 Chinook: Secondary Monitoring*]

Tertiary measures, which focussed on directly measuring physical habitat parameters, included:

- winter physical conditions;
- physical data collection (air and water temperatures; discharge);
- dissolved O_2; and
- substrate quality and composition. [See *s.7 Chinook salmon: Tertiary Monitoring*]

If a change was detected, results from tertiary monitoring could be examined to help isolate the cause for the trend and, if needed, assist in identifying the most appropriate remedial activity. Detecting a negative trend (*e.g.,* through the Early Warning Monitoring Program) would have resulted in either additional monitoring to determine the cause of the decline, or remedial measures to reverse the trend. For example, if the success of fry emergence (secondary monitoring) declined significantly, then gravel quality could be sampled (tertiary monitoring) to assess whether the decline was related to an increase in fine sediments.

4.2 GATHERING INFORMATION AND IMPLEMENTING REMEDIAL MEASURES

Remedial measures identified by the Technical Committee were based on information on in-river habitat including how juvenile chinook use natural and artificial habitats. The activities related to remedial measures undertaken by the committee included:

- collecting information on existing physical habitat conditions;
- creating an inventory of areas where mitigating activities potentially could be most effective;
- pilot-testing methods to offset potential habitat changes associated with the Kemano Completion Project; and
- developing Nechako River-specific habitat complex designs. [See *s.8 Remedial Measures*]

The information collected by the committee on habitat complexes came in part from years of pilot-testing both the complexes' effectiveness at providing acceptable habitat for juvenile chinook and the durability of different habitat types. The information included:

- an inventory of opportunities for establishing habitat cover in the Nechako River, including an inventory of the quantity and suitability of cover at different flow levels;
- a river slope profile/HEC-2 model to identify which sections of the Nechako River were suitable for placing habitat complexes (*e.g.,* where depths and velocities meet the criteria for habitat structure placement);
- data on sediment sources that may influence the design and placement of complexes;
- data from research projects that identified:
  - community structure;
  - predator/competitor/prey interaction;
  - juvenile chinook winter habitat use;

- temperature effects on food and fish growth; and
- integrating the available information to assess factors limiting Nechako River chinook productivity (NFCP 1999a).

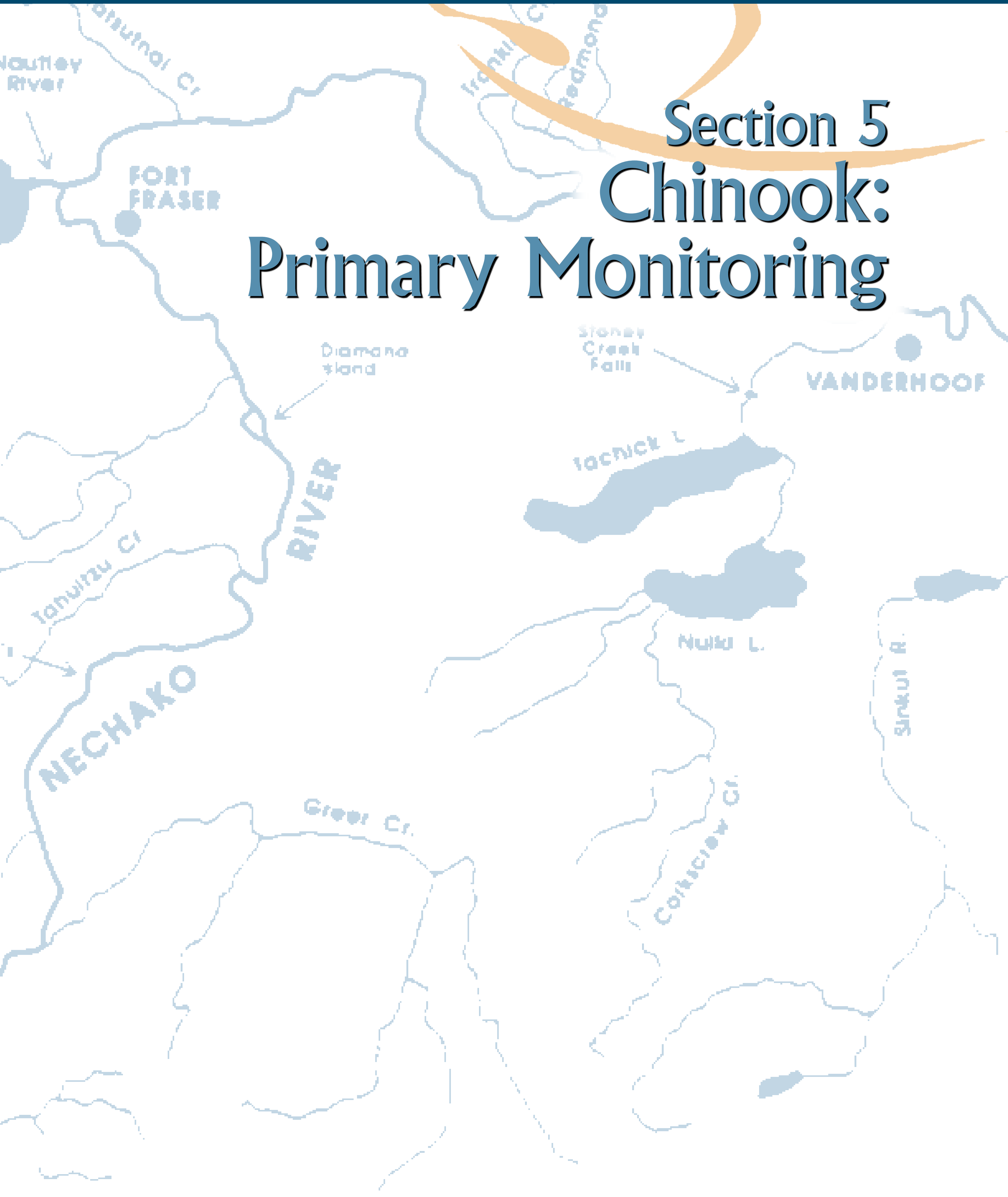
Habitat measures were to be implemented before any changes in flows resulting from the Kemano Completion Project occurred. This would make the habitats available to Nechako River chinook when the Long-Term Water Allocation was initiated. The initial design was to use debris as seed material. The material was to be flushed from the Nechako Canyon in advance of the Kenney Dam Release Facility being commissioned.

4.3 APPLIED RESEARCH

The Nechako River Working Group's *Summary Report* identified four areas where additional knowledge was needed on specific aspects of the ecology of Nechako River juvenile chinook. The objective of applied research projects in three of these areas — predator/prey interactions, winter habitat use by juvenile chinook salmon, and temperature effects on food and growth rates of rearing juvenile salmon — was to determine if factors relevant to these areas were significant enough to influence chinook production and possibly merit remedial activity. The research objective in the fourth area — a life-history model for Nechako River chinook — was to develop a single framework within which data from the various monitoring programs could be analyzed. The main results of these four research projects are summarized in Section 9, *Applied Research*.

In addition to activities in these four areas, the Technical Committee kept abreast of developments in the research community so that relevant information could be incorporated in the ongoing research.

Section 5
Chinook: Primary Monitoring



Nechako River chinook salmon use the Fraser and Nechako Rivers during all freshwater phases of their life-cycle. Spawning chinook migrate past Albion (near Langley) from late May to early August, with peak migration during June and July (Parken 2003, pers.comm.). These adult fish arrive on the Nechako River spawning grounds in late summer and early fall to spawn in the mainstem of the river between Vanderhoof and Cheslatta Falls (**Figure 1-1**), typically between August 25 and October 8. The eggs incubate in the river gravel until March of the following year and juvenile chinook emerge as free-swimming fry from March to May.

Fry rear in the river for varying periods of time. A large portion of the population leaves in late spring (May/June) to rear in the Fraser River mainstem. The remaining juveniles may rear in the Nechako River until the following spring when they typically migrate downstream to spend four years in the ocean before returning to spawn[12].

5.1 ESTIMATING CHINOOK SPAWNER NUMBERS

According to the *1987 Settlement Agreement*, a key measure of the Conservation Goal is whether the annual abundance of chinook spawners is within the target population. Consequently, the Technical Committee annually estimates the number of chinook returning to spawn in the mainstem of the Nechako River.

The Conservation Goal was established using the formula "2 X Peak of Spawn" (2XPOS)—a simple expansion of the number of fish recorded in the Department of Fisheries and Oceans database. However, the Technical Committee recognized that there is inherent variability in this number. For example, depending on the timing of the count, the peak could easily be missed on a given year. In addition, the magnitude of the variability could change on a year-to-year basis, affecting the committee's ability to accurately assess trends in Nechako River chinook stocks. Consequently, the methodology is not suitable for accurately monitoring long-term trends.

Based on information from Jaremovic and Rowland (1988), the largest chinook escapements to the mainstem of the Nechako River prior to the inception of the NFCP were recorded in 1951 (3,500) and 1952 (4,000) prior to construction of Kenney Dam and the regulation of the upper river. Escapements fell ten-fold with the closure of the dam (1952), but between 200 and 1,500 spawners were reported in the next four years (1953 to 1956) as the last progeny of the pre-dam era returned from the sea to spawn.

By the fifth year, 1957, no spawners were reported and none were observed in 1958 and 1959. Then in 1960 a total of 75 spawners were reported; escapements slowly increased thereafter. In recent years escapements have come near or exceeded the recorded pre-dam escapements. Recovery was entirely natural, unaided by transplanted eggs or fry. Estimates of chinook escapement to the mainstem of the Nechako River from 1980 to 2002, are included in **Table 5.1-1** and plotted by year in **Figure 5.1-1**.

[12] Nechako and Stuart River fry show common timing for migration through the lower Nechako River downstream of the Stuart River confluence during the May/June period. Recent research has shown that some juvenile chinook reside in the lower Nechako River, while perhaps a larger number travel through the lower river from natal areas in the upper Nechako and Stuart Rivers to take up residence in the Fraser River mainstem (DFO, unpublished data).

Table 5.1-1

Nechako and Stuart Rivers: escapements of chinook to tributaries and mainstem, 1951 to 1998*

Year	Nechako tributaries					mainstem	Nechako	mainstem
	Chilako River	Endako River	Ormond Creek	Stellako River	Total	Nechako River	tributaries and mainstem	Stuart [a] River
1951	[d]	[d]	[d]	25	25	3500	3525	400
1952	[d]	[d]	[d]	[d]	[d]	4000	4000	750
1953	250	[d]	[d]	75	325	400	725	1500
1954	350	[d]	[d]	25	375	1500	1875	75
1955	[d]	[d]	[d]	25	25	400	425	400
1956	175	[d]	[d]	75	250	200	450	200
1957	125	[d]	[d]	75	200	[b]	200	200
1958	200	[d]	[d]	1500	1700	[c]	1700	750
1959	[d]	25	25	460	510	[c]	510	200
1960	25	6	4	120	155	75	230	75
1961	50	[d]	[d]	127	177	350	527	750
1962	25	25	[d]	200	250	400	650	200
1963	40	25	[d]	400	465	400	865	350
1964	75	25	25	200	325	700	1025	400
1965	50	25	[d]	75	150	400	550	60
1966	40	25	25	150	240	450	690	55
1967	60	25	[d]	77	162	750	912	200
1968	75	25	[d]	75	175	400	575	200
1969	[d]	25	[d]	75	100	400	500	400
1970	75	25	[d]	90	190	750	940	750
1971	75	25	7	75	182	400	582	750
1972	75	25	25	54	179	400	579	75
1973	200	25	[d]	25	250	750	1000	200
1974	200	25	[d]	75	300	1424	1724	400
1975	75	25	[d]	75	175	1500	1675	750
1976	75	25	25	80	205	1200	1405	225
1977	200	25	[d]	140	365	2000	2365	225
1978	200	25	25	75	325	2600	2925	1000
1979	200	75	[d]	75	350	1800	2150	750
1980	200	50	[d]	50	300	2000	2300	1800
1981	150	32	0	25	207	1540	1747	140
1982	150	65	[d]	[d]	215	1448	1663	600
1983	75	50	0	0	125	850	975	475
1984	150	300	0	0	450	1300	1750	500
1985	175	300	0	30	505	2000	2505	3000
1986	150	300	0	75	525	2000	2525	3000
1987	175	500	[d]	50	725	1590	2315	5000
1988	250	300	[d]	50	600	2694	3294	3000
1989	50	200	[d]	[d]	250	2915	3165	1600
1990	425	75	[d]	0	500	2645	3145	6000
1991	150	200	[d]	[d]	350	2363	2713	7500
1992	150	10	[d]	[d]	160	2525	2685	15000
1993	25	20	[d]	[d]	45	673	718	1259
1994	119	200	[d]	10	329	1150	1479	2420
1995	200	125	[d]	[d]	325	1686	2011	3741
1996	624	167	[d]	20	811	2040	2851	7159
1997	186	43	[d]	[d]	229	1954	2183	5826
1998	39	191	[d]	15	245	1851	2096	4734
1999	126	131	[d]	18	275	1915	2190	3045
2000	22	160	[d]	[d]	182	3405	3587	6525
2001	[d]	[d]	[d]	[d]	0	5785	5785	7634
2002	232	235	[d]	[d]	467	3296	3763	4554
All Years								
mean	147	100	12	119	313	1567	1783	2054
SD	113	113	12	240	260	1170	1191	2887
n	46	42	13	41	51	49	52	52
1974-2002								
mean	171	138	7	45	329	2074	2403	3375
SD	121	122	12	37	186	977	979	3316
n	28	28	7	19	29	29	29	29
1988-2002								
mean	186	147	[d]	19	318	2460	2778	5333
SD	166	85	[d]	17	210	1182	1163	3403
n	14	14	0	6	15	15	15	15

* Nechako tributaries, all years, mainstem Nechako River, 1951-1987 and mainstem Stuart River, 1951-1990, from DFO nuSEDS V2.0 database accessed on-line January 7, 2004

[a] from Stuart Lake to the confluence of the Stuart and Nechako Rivers

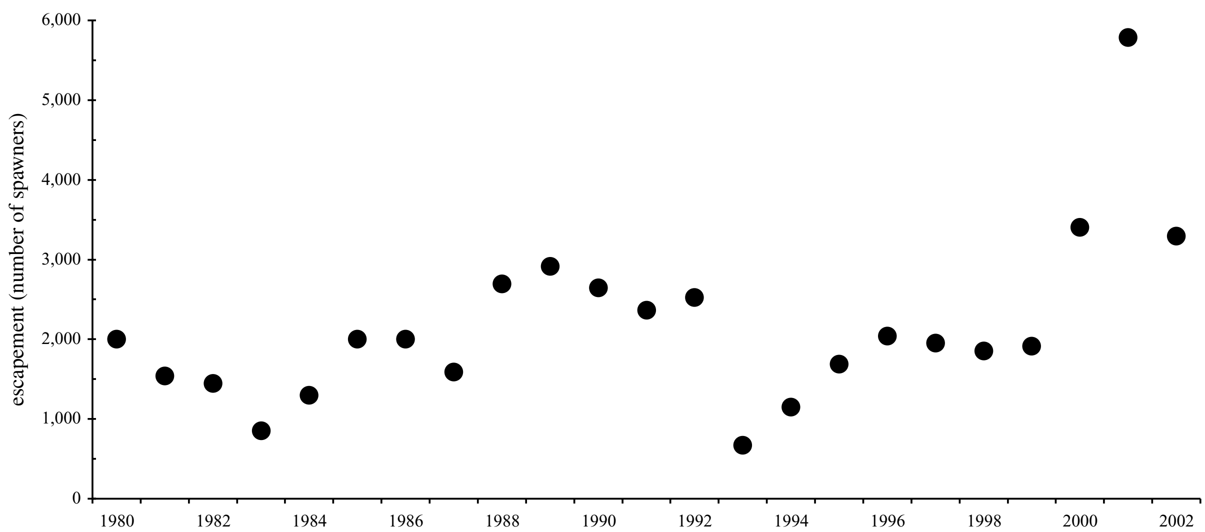
[b] in 1957 one gate of skins lake dam broke open, flooded the Nechako, and made visual observations impossible due to high, turbid water.

[c] in 1958-59, due to poor river spawning conditions (high silty water) chinook left the Nechako River and spawned in the Stellako River.

[d] no escapement records on file for this year; not included in statistical analysis.

NOTE: Many spawning estimates have been estimated (*e.g.,* on record sheet, an estimate of "A" represents 1-50 fish; therefore an average of 25 was recorded)

Figure 5.1-1 **Nechako River: escapements of chinook to the mainstem, 1980 to 2002**



Small numbers of chinook spawn in at least five streams in the drainage area other than the Nechako River including the Nadina, Chilako, Endako and Stellako Rivers and Ormond Creek. Escapement estimates for the Nadina River were unavailable. The combined escapements to the enumerated tributaries averaged 329 (SD = 186) each year between 1974 and 2002; the average escapement in these tributaries accounted for 13.7% of the combined mainstem and tributary escapements to the Nechako River.

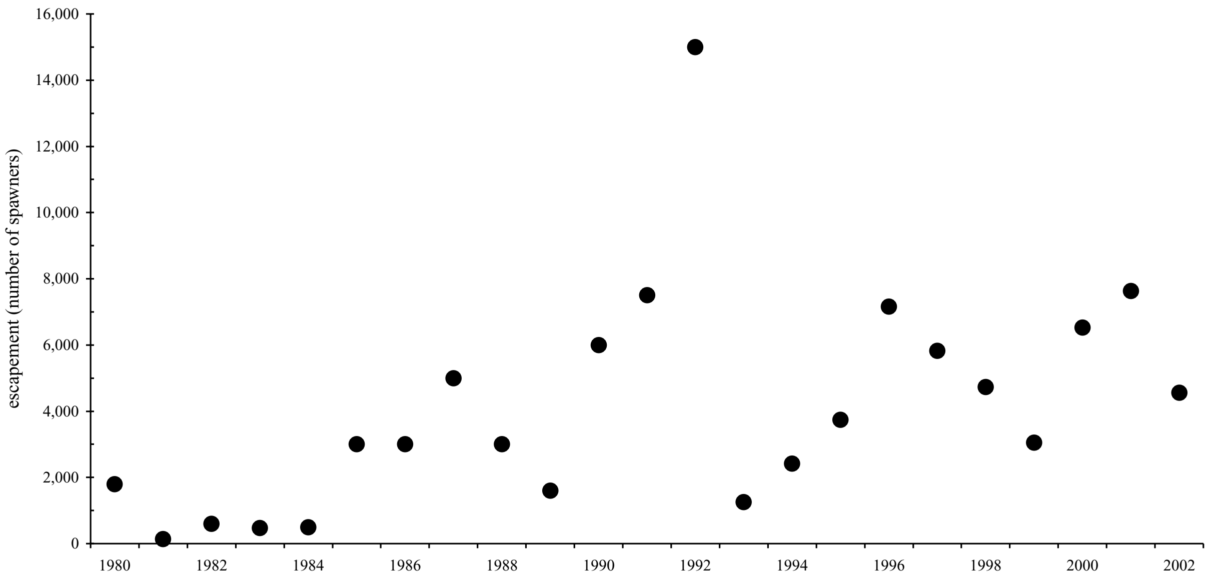
The number of spawners returning to the Stuart River was also estimated each year. This was done to assess the effect of factors outside the Nechako River (extrinsic factors) that influence the abundance of chinook on the river and on escapement. The Stuart River shares the same hydrological basin and biogeoclimatic influences as the Nechako River, but its flow is not regulated. The geographic proximity of the Stuart and Nechako Rivers means that the chinook that return to the Stuart River most likely experience similar migration timing, ocean conditions and harvest rates as Nechako River chinook making the Stuart River returns a reference against which to measure Nechako River returns.

The Stuart River system has seven locations known to support chinook spawning. The mainstem of the Stuart River from the outlet of Stuart Lake to the confluence of the Nechako and Stuart Rivers supports the great majority of spawners, while six tributaries north of Stuart Lake (the Driftwood, Middle and Tachie Rivers and Kazchek, Kuzkwa and Pinchi Creeks) support occasional, small numbers of spawners. Stuart River escapements are included in **Table 5.1-1** and are plotted by year in **Figure 5.1-2**.

5.1.1 Estimating Escapements: Methodologies

The historical methods of estimating chinook escapement in the Fraser River basin—including the Nechako and Stuart Rivers—are not well documented and the accuracy of the various

Figure 5.1-2 **Stuart River: escapements of chinook to the mainstem, 1980 to 2002**



methodologies is difficult to assess[13]. Jaremovic and Rowland (1988) reviewed the techniques used to estimate Nechako River chinook escapement up to 1986 (**Table 5.1-2**). They found that the counting methods, the type of counts (*i.e.,* spawners, redds[14] or carcasses), the areas of the river covered by surveys, and the expansion factors used to convert counts to escapement estimates were not standardized and varied among years. In addition, the counts and the calculations that converted counts to escapement estimates were not reported in sufficient detail to determine the sensitivity of estimates to variations in methodology[15].

Fraser *et al.* (1982) also reviewed the techniques used to estimate chinook escapement to the rivers and streams of the Fraser River basin. Prior to 1974, estimates were obtained mainly by foot and boat surveys, supplemented by counts of carcasses and redds. Counts were increased using undocumented expansion factors to account for reduced visibility and for unpredictable changes in the date of peak spawning in relation to survey dates. Essentially, this means that escapement numbers prior to 1974 are "best guesses" based on raw counts and the professional judgment of fisheries officers and regional biologists as to how much those counts underestimated the number of fish in a stream.

Helicopters were first used in the 1970s for visual counts of spawners. The first explicit record of an over-flight survey was in 1978 — two surveys were

[13] Counts reported in the 1950s and 1960s may have underestimated total escapement because fishery officers were still searching for tributary spawning sites (B. Rosenberger, Department of Fisheries and Oceans, Kamloops, pers. comm.). By the 1970s, most active spawning sites in the Nechako River basin had been located, and the list of sites to be surveyed each year had stabilized.

[14] A redd is a spawning nest made by a fish, especially a salmon or trout.

[15] Jaremovic and Rowland (1988) did not review the techniques used to estimate chinook escapements to the Stuart River, but it is reasonable to assume that similar methods were used in both the Nechako and Stuart Rivers.

Table 5.1-2 Nechako River: methods used to estimate chinook escapement 1951 to 2002*

year	method
1951	Spawner counts: Sep 4 to 7, Sep 20 to 22, Oct 5 to 7
1952	Redd count
1953	Redd count - spawner estimate = 2 times redd count. Two areas, upper Nechako River (above Nautley) and below Nautley - summed for spawner estimate
1954	Redd count - spawner estimate = 2 times redd count. Two areas, upper Nechako River (above Nautley) and below Nautley - summed for spawner estimate
1955	Redd count - spawner estimate = 2 times redd count. Two areas, upper Nechako River (above Nautley) and below Nautley - summed for spawner estimate
1956	Redd count - spawner estimate = 2 times redd count. Two areas, upper Nechako River (above Nautley) and below Nautley - summed for spawner estimate
1957	No estimate
1958	No estimate
1959	No estimate
1960	Counts by Fishery Officer
1961	By Fishery Officer - estimate based on 2 x redd count on Oct 23 to 24
1962	Counts by Fishery Officer
1963	Counts by Fishery Officer
1964	Specific numerical estimate by Fishery Officer
1965	Counts by Fishery Officer
1966	Counts by Fishery Officer
1967	Counts by Fishery Officer
1968	Counts by Fishery Officer
1969	Counts by Fishery Officer
1970	Counts by Fishery Officer
1971	Counts by Fishery Officer
1972	Fishery Officer and Habitat Staff - 2 x redd count - above Fort Fraser , Nov 15 (by boat)
1973	Counts by Fishery Officer
1974	Redd count
1975	By Fishery Officer - peak from Sept 18-25 - actual spawner counts - may be expanded (subjectively) to account for fish not seen
1976	By Fishery Officer - actual spawner counts - may be expanded (subjectively) to account for fish not seen
1977	By Fishery Officer - actual spawner counts - may be expanded (subjectively) to account for fish not seen
1978	By Fishery Officer - Flights on Sep 12 and 20 - actual spawner counts may be expanded (subjectively) to account for fish not seen
1979	By Fishery Officer - actual spawner counts - may be expanded (subjectively) to account for fish not seen
1980	Helicopter overflight - 8 surveys (AUC) - 1.23 times peak count
1981	2 x redd count - 2 counts
1982	2 x redd count - 1 count
1983	Helicopter overflight - Fishery Officer - Sep 19 - expanded count or rounded off to correct for missed peak
1984	Helicopter overflight - Fishery Officer -5 counts (Sep. 4 and 15) - carcass recovery (peak count) - counts expanded or rounded off by fishery officer
1985	Helicopter overflight - 4 counts during Sep - 2 observers (average) - peak counts expanded by similar factor as in 1980
1986	Helicopter overflight - 4 counts during Sep - 2 observers (average), 1 navigator - replicate counts compared and recounts if necessary - peak counts expanded by similar factor as in 1980
1987	Helicopter overflights - 5 counts - average of AUC and 2 X redd count
1988	8 helicopter overflights, conducted at 5 to 11 day intervals Aug 17 to Oct 7, 2 observers, max count used, AUC **
1989	8 helicopter overflights, conducted at 6 to 8 day intervals Aug 16 to Oct 4, 2 observers, max count used, AUC
1990	7 helicopter overflights, conducted at 7 to 8 day intervals Aug 22 to Oct 4, 2 observers, max count used, AUC
1991	9 helicopter overflights, conducted at 5 to 9 day intervals Aug 14 to Oct 9, 2 observers, max count used, AUC
1992	7 helicopter overflights, conducted at 7 day intervals Aug 21 to Oct 2, 2 observers, max count used, AUC
1993	7 helicopter overflights, conducted at 7 day intervals Aug 20 to Oct 1, 2 observers, max count used, AUC
1994	9 helicopter overflights, conducted at 3 to 7 day intervals Aug 19 to Oct 7, 2 observers, max count used, AUC
1995	7 helicopter overflights, conducted at 7 day intervals Aug 25 to Oct 6, 2 observers, max count used, AUC
1996	8 helicopter overflights, conducted at 7 day intervals Aug 21 to Oct 9, 2 observers, max count used, AUC
1997	6 helicopter overflights, conducted at 5 to 8 day intervals Aug 27 to Oct 1, 2 observers, max count used, AUC
1998	9 helicopter overflights, conducted at 4 to 7 day intervals Aug 14 to Sep 30, 2 observers, max count used, AUC
1999	7 helicopter overflights, conducted at 6 to 8 day intervals Aug 26 to Oct 5, 2 observers, max count used, AUC
2000	7 helicopter overflights, conducted at 6 to 8 day intervals Aug 23 to Oct 4, 2 observers, max count used, AUC
2001	7 helicopter overflights, conducted at 5 to 9 day intervals Aug 22 to Oct 3, 2 observers, max count used, AUC
2002	6 helicopter overflights, conducted at 6 to 8 day intervals Aug 27 to Oct 1, 2 observers, max count used, AUC

* Adapted from Jaremovic and Rowland (1988).
** Area-under-the-curve

performed in September of that year to obtain a peak count — although some of the earlier reported "counts by Fishery Officer" may have been performed partially or wholly by over-flights.

Multiple helicopter surveys were introduced in the 1980's to reduce the possibility of bias due to variations in run timing. Prior to 1988 more than two helicopter surveys were used to estimate abundance only in 1980, 1985 and 1986.

5.1.1.1 "Area-under-the-curve"

Spawner distribution is used to make comparisons between brood years and to attempt to relate differences in brood years to environmental events. In 1989 the Technical Committee decided that the most appropriate methodology for estimating the number of returning spawners in the Nechako River would be "area-under-the-curve" (AUC) (Neilson and Geen, 1981; English *et al.* 1992; Hill 1997). With the exception of a full-stream counting fence, which was judged infeasible, this technique was considered by the committee to be the most accurate and precise method available (Neilson and Geen, 1981). Hill and Irvine (2001) confirmed this supposition[16]. [See *ss.5.1.2.1 Sources of Bias and Imprecision*]

Almost all chinook spawning activity in the mainstem of the Nechako River occurs between Cheslatta Falls and the community of Vanderhoof. In order to help analyze spawner distribution, the committee divided this portion of the river into 16 sections[17] aggregated into three parts, the upper, middle and lower river **Figure 5.1-3** provides a map of the 16 sections in the study area. **Figure 5.1-4** provides mean chinook spawning distribution by section (1988 to 2002); **Table 5.1-3** aggregates the spawning distribution into the three parts. From 1988 to 2002, these sections were surveyed by helicopter at approximately seven day intervals from mid-August to early October. From 1988 to 1996 the flight schedule stayed much closer to the seven day interval than in more recent years (1997 to 2002) when the interval between surveys was allowed to vary so that the surveyors could choose days with good visibility.

Each survey began at Cheslatta Falls and finished at Vanderhoof. The helicopter flew at about 50 km/hour and between 30 and 35 m above the river, circling islands or bars where necessary, or reorienting its flight path to compensate for glare off the river surface. Two observers seated on the same side of the helicopter counted all the chinook spawners and carcasses they observed in each of the 16 sections. The observers wore polarized sunglasses to reduce glare off the river surface, and used hand-held counters to record their counts. They switched seats on alternate flights to avoid seating bias.

For each section of the river, each observer placed chinook counts in one of three classes:

- **on redds**: defined as chinook clearly associated with a redd, or just moving away from a redd as the helicopter approached. Redds were identified by their characteristic shape — particularly the long tailspill — and by their colour — gravel disturbed by spawners' digging is lighter in color than undisturbed gravel covered with periphyton[18]. In the upper and middle portions of the river, redds were

[16] Mark-recapture methods were used to estimate chinook escapement to the mainstem of the Stuart River where the AUC method cannot be used due to turbid water. [See *ss.5.1.1.2 Mark-recapture*]

[17] Some of the 16 sections were divided into sub-sections.

[18] Sessile organisms, such as algae that live attached to surfaces projecting from the bottom of a freshwater aquatic environment.

Figure 5.1-3 Nechako River: chinook spawning study area

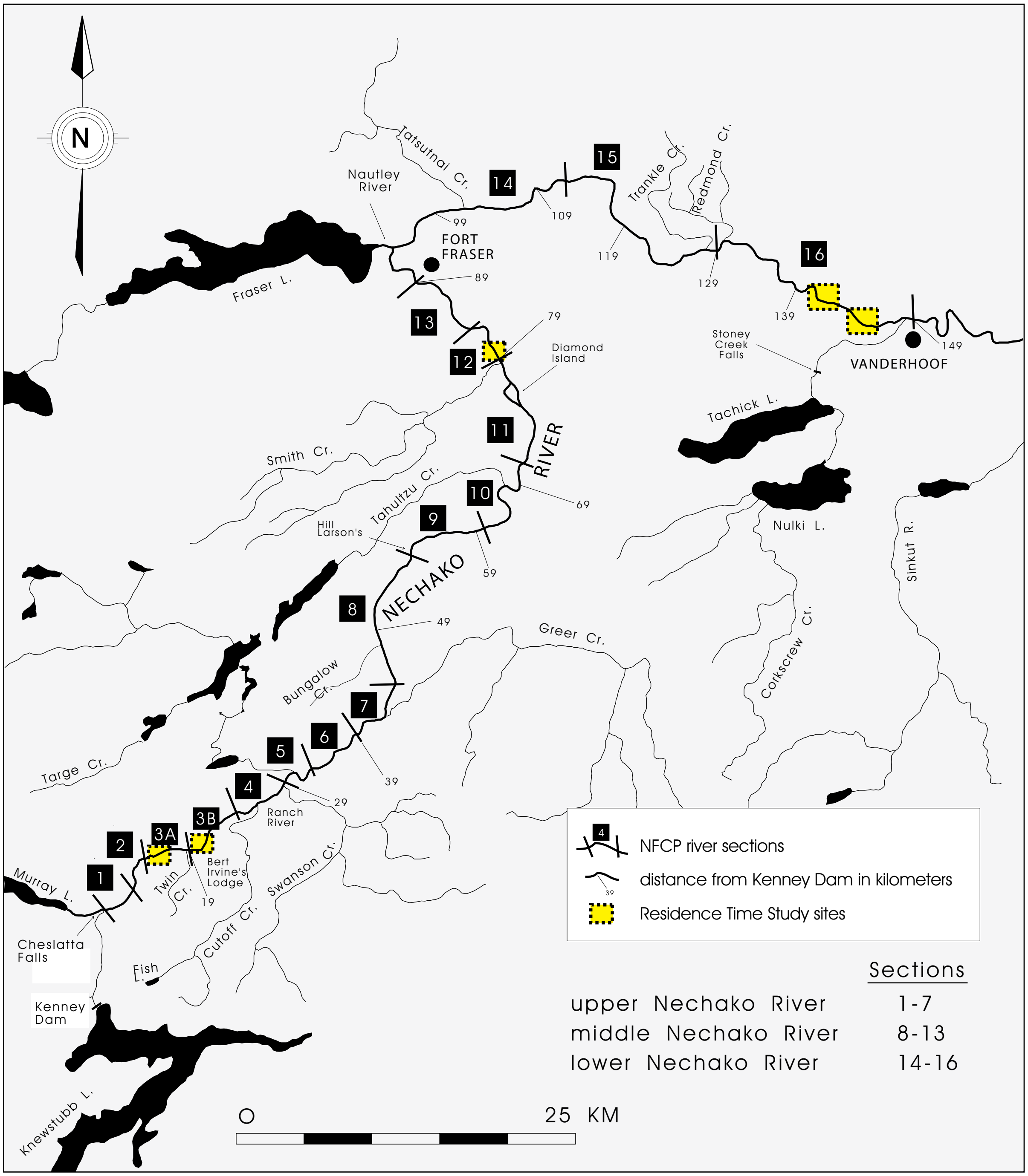


Figure 5.1-4	Nechako River: mean chinook spawning distribution by river section, 1988 to 1998

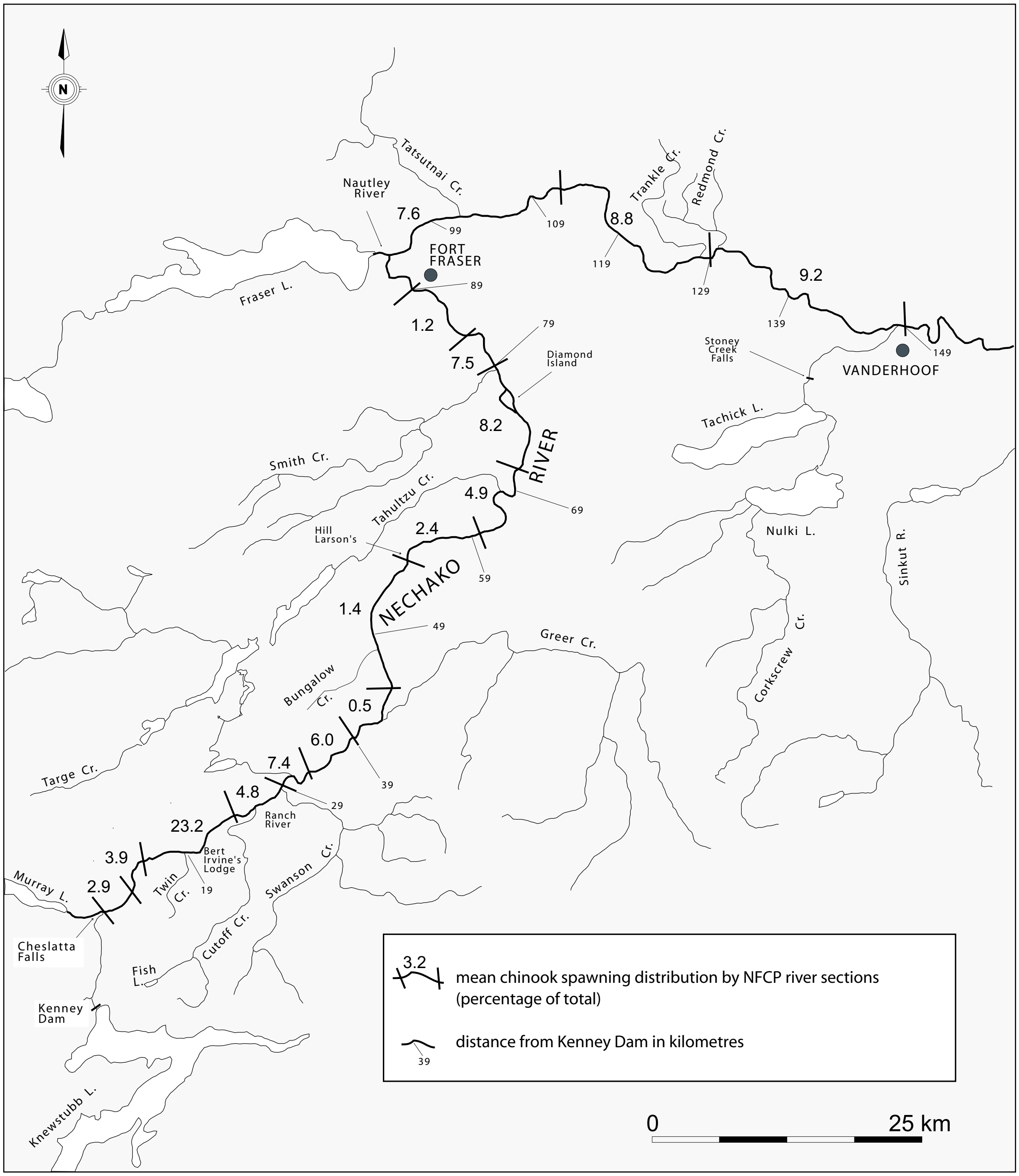


Table 5.1-3 **Nechako River: spatial distribution of chinook spawners, 1974 to 2002***

year	upper river (sections 1 to 7)	middle river (sections 8 to 13)	lower river (sections 14 to 16)	source	mean flow (m^3/s) at Vanderhoof during August 1-10
1974	35.0	9.9	55.1	1	272.8
1975	-	-	-	-	127.9
1976	-	-	-	-	566.0
1977	-	-	-	-	209.9
1978	88.9	0.0	11.1	1	60.2
1979	81.1	5.7	13.3	1	154.5
1980	78.2	14.7	7.3	1	63.7
1981	77.5	10.0	12.5	1	268.8
1982	58.8	32.0	9.2	1	289.2
1983	34.8	19.8	45.4	1	265.7
1984	26.8	13.0	60.2	1	284.6
1985	36.0	32.3	31.7	1	320.4
1986	44.4	20.9	34.7	1	229.8
1987	-	-	-	-	255.8
1988	56.5	17.2	26.3	NFCP	205.3
1989	47.9	24.3	27.8	NFCP	253.1
1990	48.7	25.3	26.0	NFCP	268.4
1991	40.9	20.9	38.2	NFCP	197.5
1992	29.8	21.5	48.7	NFCP	275.4
1993	30.9	29.3	39.8	NFCP	291.3
1994	39.7	26.1	34.2	NFCP	266.0
1995	47.7	27.3	24.9	NFCP	206.3
1996	54.9	26.2	18.9	NFCP	247.9
1997	56.8	30.5	12.7	NFCP	425.4
1998	42.9	30.1	27.1	NFCP	319.9
1999	58.8	23.4	17.9	NFCP	271.5
2000	59.2	29.1	11.7	NFCP	222.3
2001	57.4	27.3	15.3	NFCP	207.8
2002	58.7	25.5	15.8	NFCP	343.9
mean	51.7	21.7	26.6		
SD	16.7	8.6	14.9		
min	26.8	0.0	7.3		
max	88.9	32.3	60.2		
n	25	25	25		

* River sections are shown in Figure 5.1.3.
Distribution shown as percent of total spawners in river reaches
Dashed indicate no data was available
Sources: 1 = Jaremovic and Rowland (1988)

also associated with dunes (Neilson and Banford 1983; Tutty 1986);

- **migrating/holding**: defined as chinook in a deep pool or moving downstream or upstream at a distance from redds. This included moribund post-spawners drifting downstream or holding near a bank; and
- **carcasses**.

The two observers counted fish independently, but discussed their counts when groups of fish were present to ensure that all spawners were counted. Also, at the beginning of the season, some discussion and comparison of fish counts took place between the two observers to ensure consistency in counting methodology.

The observers compared counts after each flight. Since experienced observers count individual fish on the Nechako River, rather than estimate the number of fish in groups, lower counts were attributed to an observer having missed fish; the higher of the two counts in each class of each section of the river was assumed to be the most accurate and was chosen as the final count for the flight. A similar assumption has often been used during other surveys of Pacific salmon abundance (B. Rosenberger, Department of Fisheries and Oceans, Kamloops, pers. comm.).

To convert visual counts to an escapement estimate, the counts of spawners-on-redds were summed over each of the 16 sections for each survey flight. The summed counts were then plotted by date; joining the counts formed a curve. The total number of spawner-days was calculated by integrating the "area-under-the-curve" and dividing the total number of spawner-days by the average residence time (in days) of a female spawner on a redd to obtain an escapement estimate.

5.1.1.1.1 Residence Time of Female Chinook

Residence time is a component of total survey life[19]. Neilson and Geen (1981) define the residence time of female spawners as being from first defense of a redd by a female to the time she vacates the redd, based on a series of daily observations. However, residence time for the AUC on the Nechako River was defined as the number of days that an individual fish was observed at a redd site.

Estimates of residence time were made in 1980 at two sites in Reach 2 of the upper Nechako River (Envirocon Ltd. 1984a). No estimates were made in 1988; the average residence time estimated in 1980 was used to calculate the escapement in 1988. In 1989, residence time observation sites were established in the upper river at Bert Irvine's Lodge—referred to as the upper sites—and in the middle and lower river at Diamond Island, Engen and Vanderhoof—referred to as the lower sites. With the exception of 1992—when the lower sites were not occupied—and 1997—when data from the upper sites were rejected because of observer error—residence time from 1989 to 2002 was estimated at all of the sites established in 1989.

Observation sites for estimating residence time were about 100 m long. At each site, spawners were observed from elevated positions that allowed unobstructed views of the river. Polarized sunglasses and binoculars were used to enhance vision.

[19] Survey life—also referred to in scientific literature as stream life, breeding life, turnover time and average life span—is the number of days that a spawner is alive in a survey area (Perrin and Irvine 1990). This includes:

- the time a spawner takes to swim to a spawning site once it enters the survey area;
- the time a spawner is resident on a redd;
- the time between the abandonment of a redd by a spawner and death; and
- the time between the death of a spawner and discovery of the carcass.

The appearance and behaviour of female spawners on or near well-defined redds was recorded daily throughout the period of redd occupancy. Although females were not individually marked, it was assumed that any female occupying a position over a redd for a number of days was the same fish. Repeated observations of fish with unusual markings on the same redd over a period of days validated this assumption.

The residence times of males were assumed to be identical to those of females. Actual male residence times cannot be measured because males are too transient to be followed over the spawning period.

5.1.1.2 Mark-Recapture

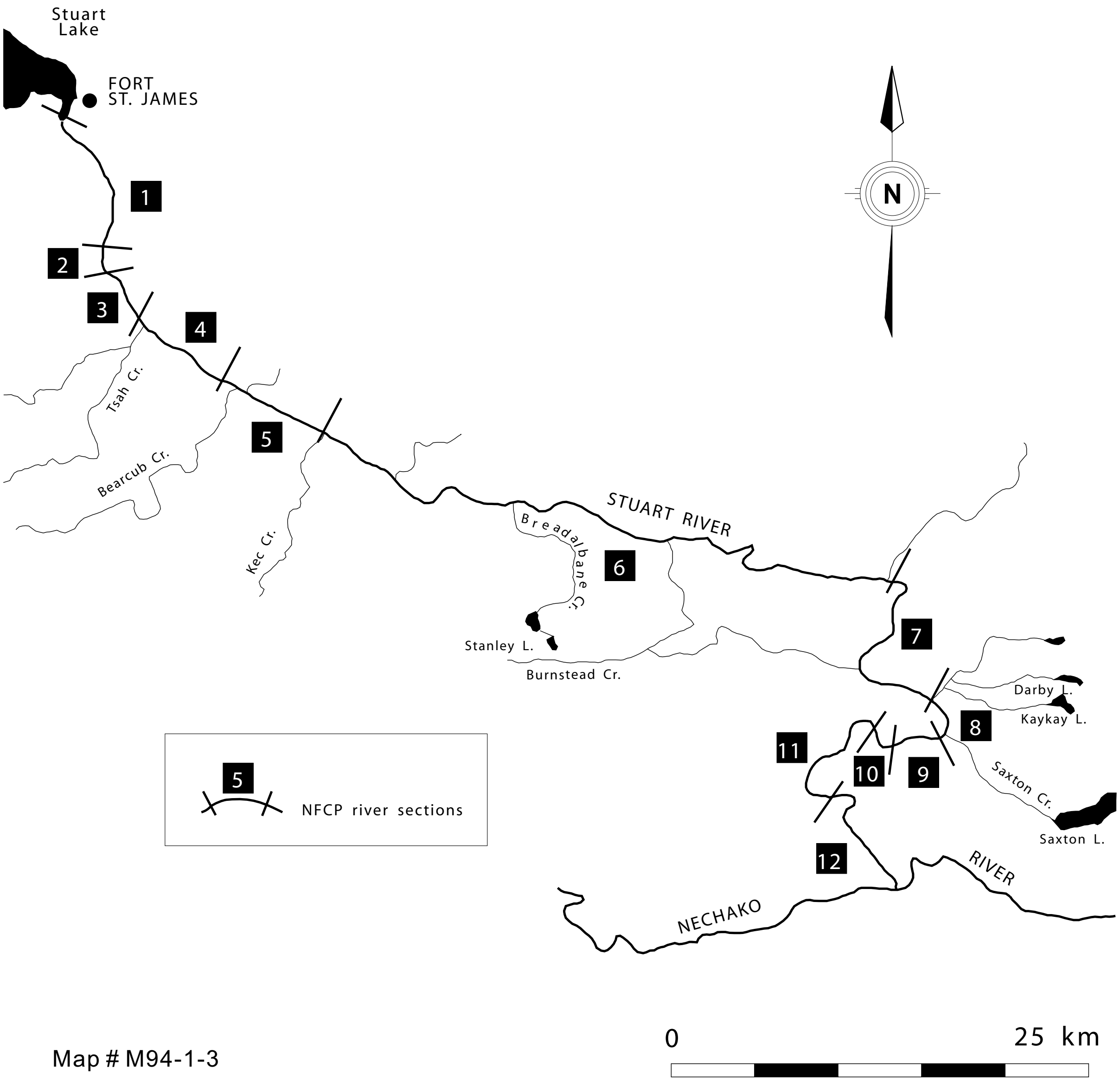
The AUC method was used in 1988 to estimate chinook salmon escapement to the mainstem of the Stuart River (**Figure 5.1-5**), although visibility was severely hampered by turbid water and the number of recovered carcasses (2,100) was more than twice the AUC estimate of spawners (994)[20]. No attempts were made to use the AUC to estimate escapement in either 1989 or 1990 and the Department of Fisheries and Oceans estimates of 1,600 and 6,000 (respectively) presumably were based on carcass surveys; however, the methods are undocumented.

From 1991 to 2002, escapement was estimated using a simple Peterson mark-recapture method (Ricker 1975) in which adult chinook downstream of Stuart Lake were marked with two types of tags (NFCP 1994b, NFCP 1994c, NFCP 1994d, NFCP 1994e, NFCP 1995a, NFCP 1995b, NFCP 1995c, NFCP 1995d, NFCP unpublished data 1995 to 2002). The primary tag was a numbered disc applied to the left operculum[21]; the secondary tag was a single (female) or double (male) punch of the right operculum. Double-tagging allowed researchers to estimate the incidence of tag loss. The marked and unmarked fish of each sex were counted during the carcass survey and separate Peterson estimates of the number of males and females were calculated from carcass counts and from the number of fish that had been tagged. The two Peterson estimates were summed to obtain a single escapement estimate.

[20] The official Department of Fisheries and Oceans escapement estimate of 3,000 spawners presumably was based on some combination of the number of carcasses and the AUC, but the methods used to obtain that number are not known.

[21] Gill cover.

Figure 5.1-5 Stuart River: chinook spawning study area



5.1.2 Results and Discussion

5.1.2.1 Sources of Bias and Imprecision

Table 5.1-4 summarizes sources of bias and imprecision relevant to AUC methodology and to calculating residence time. For additional detail, the reader is referred to the discussion of the sources of bias and imprecision in the area-under-the-curve method of estimating escapement in Appendix 1A of the NFCP Report – *10 Year Review, Background Report* (November 1997).

5.1.2.2 Timing and Spatial Distribution of Spawners: Nechako River

Spawning in the mainstem of the Nechako River begins in late August, peaks in mid-September and ends in early October (**Tables 5.1-5a** and **5.1-5b** and **Figure 5.1-6**). Except for 1992, the greatest percentage of spawning from 1988 to 2002 consistently occurred in Section 3 near km 19 in the upper river (**Table 5.1-6**). On average, the second and third greatest proportion of the spawning escapement occurred in the lower river, upstream of the community of Vanderhoof in Sections 16 and 15, respectively.

From 1974 to 2002, an average of 51.7% of spawning occurred in the upper river, 21.7% in the middle river and 26.6% in the lower river; however, substantial among-year changes have occurred in the percentage of chinook spawning in each part of the river. The percent spawning in the upper river fell from a high of 88.9% in 1978 to a low of 26.8% in 1984 (**Figure 5.1-7**). The percent spawning in the middle river was variable from 1978 to 1987, but has been fairly consistent since then (1988 to 2002). The percent spawning in the lower river showed a pattern almost directly opposite to the pattern of the upper river.

Table 5.1-4 **Nechako River: sources of bias and imprecision in the AUC***

	source of bias	significance
AUC	• not all fish are visible	• not likely significant as Nechako relatively clear and shallow.
	• not all visible fish are observed	• double-count reduces bias - photos showed bias is minimal
	• different observers in different years	• not expected to be significant as there is continuity in people counting from year to year.
	• only female residence times are estimated	• consistent annual bias would not affect trend
Residence Time	• residence times differ between early and late spawners	• historical estimate of escapement insensitive to use of overall mean estimate of res. time

	source of imprecision	estimation
AUC	• random observation error	• can be estimated because of two observers
	• random fish movement	• successive flights (unlikely to be significant)
	• overall precision of curve due to frequency of flights	• can simulate expected error from varying flight frequency
Residence Time	• uncertainty in estimate of mean residence time	• using standard error from large sample each year

* AUC = "area-under-the-curve"

Table 5.1-5a Nechako River: chinook spawners counts per date, 1988 to 2002

1988		1989		1990		1991		1992	
17-Aug	0	16-Aug	0	22-Aug	24	14-Aug	0	21-Aug	71
28-Aug	653	23-Aug	0	29-Aug	191	21-Aug	0	28-Aug	269
2-Sep	699	30-Aug	24	5-Sep	935	30-Aug	67	4-Sep	647
9-Sep	1299	6-Sep	638	12-Sep	1457	4-Sep	539	11-Sep	1495
15-Sep	1610	14-Sep	1850	19-Sep	766	11-Sep	1137	18-Sep	1320
20-Sep	1612	20-Sep	1179	26-Sep	158	18-Sep	1029	25-Sep	400
27-Sep	435	27-Sep	132	4-Oct	9	25-Sep	331	2-Oct	19
7-Oct	6	4-Oct	5			2-Oct	73		
						9-Oct	7		

1993		1994		1995		1996		1997	
20-Aug	0	19-Aug	0	25-Aug	21	21-Aug	0	27-Aug	0
27-Aug	3	26-Aug	0	1-Sep	47	28-Aug	62	3-Sep	575
3-Sep	175	2-Sep	4	8-Sep	703	4-Sep	430	10-Sep	1220
10-Sep	338	9-Sep	403	15-Sep	834	11-Sep	1342	18-Sep	1049
17-Sep	332	16-Sep	685	22-Sep	701	18-Sep	1023	23-Sep	465
24-Sep	109	20-Sep	540	29-Sep	175	25-Sep	275	1-Oct	32
1-Oct	23	23-Sep	253	6-Oct	24	2-Oct	45		
		30-Sep	50			9-Oct	0		
		7-Oct	16						

1998		1999		2000		2001		2002	
14-Aug	0	26-Aug	10	23-Aug	12	22-Aug	4	27-Aug	10
19-Aug	0	1-Sep	83	30-Aug	11	28-Aug	152	4-Sep	98
26-Aug	0	7-Sep	824	5-Sep	623	5-Sep	1116	11-Sep	1953
2-Sep	96	15-Sep	1066	13-Sep	2466	14-Sep	4807	18-Sep	1976
9-Sep	1045	21-Sep	686	21-Sep	1427	19-Sep	2853	24-Sep	1312
15-Sep	1044	29-Sep	257	27-Sep	432	26-Sep	669	1-Oct	143
21-Sep	838	5-Oct	123	4-Oct	59	3-Oct	72		
25-Sep	263								
30-Sep	55								

* Based on a maximum of two observers for fish on redds.

Table 5.1-5b Nechako River: average dates of beginning, peak and end of chinook spawning period, 1988 to 2002

	beginning	peak spawning	end
average	Aug 27	Sep 12	Oct 3
SD	4	3	3
range	Aug 21 - Sep 3	Sep 9 - Sep 18	Sep 30 - Oct 9

Figure 5.1-6 **Nechako River: counts of chinook spawners-on-redds, 1988 to 2002**

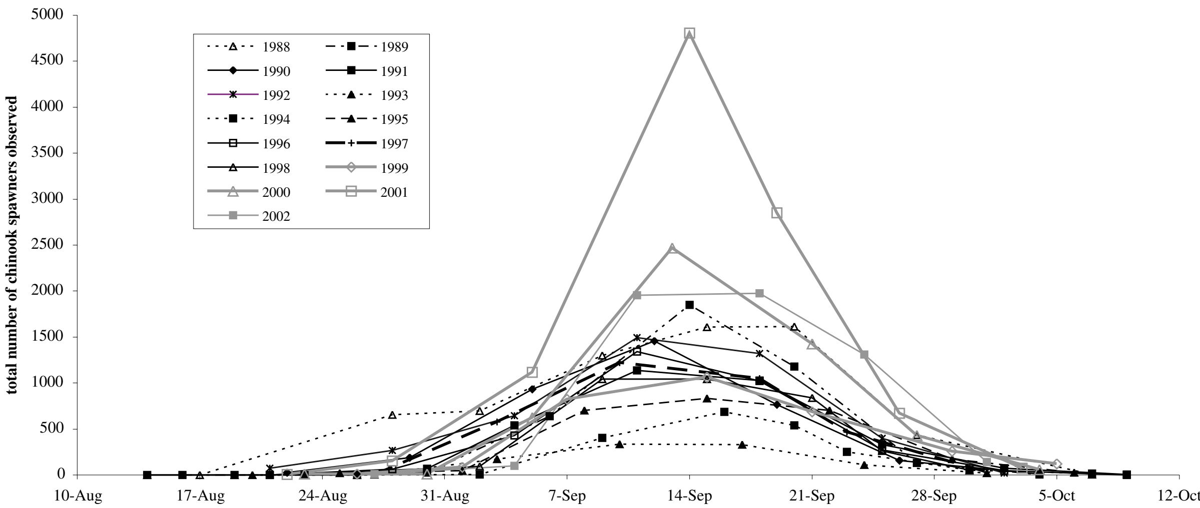


Figure 5.1-7 **Nechako River: percent of chinook spawning in the upper, middle, and lower river, 1978 to 2002**

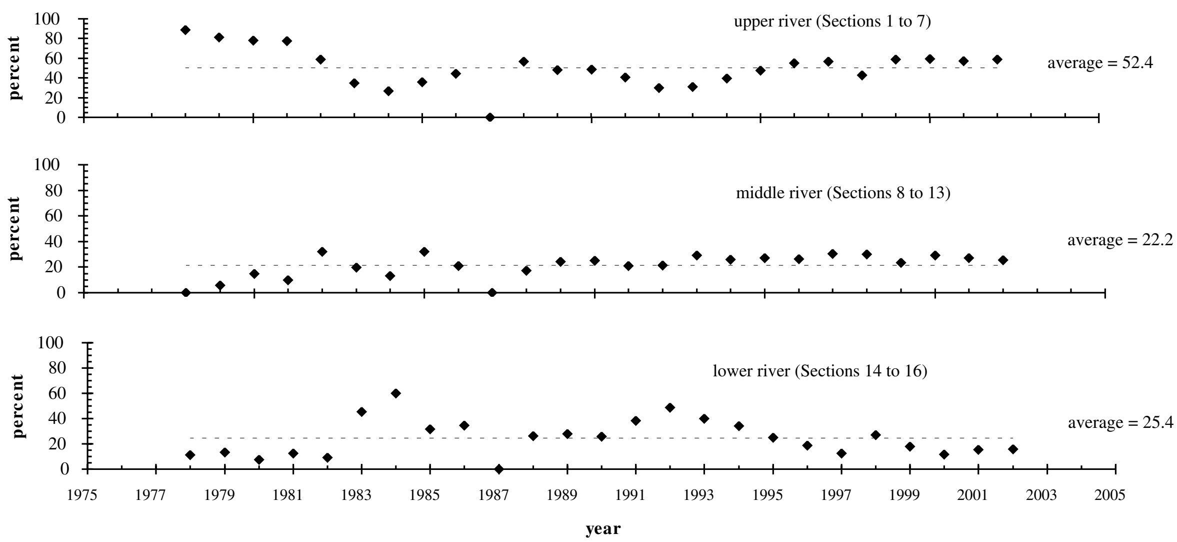


Table 5.1-6 Nechako River: percent chinook spawning by river section, 1988 to 2002

river section	midpoint* (km)	1988	1989	1990	1991	1992	1993	1994	1995
1	5.5	1.8	2.6	3.5	3.6	1.6	1.6	4.1	5.2
2	13.2	5.5	2.6	3.6	3.2	1.8	3.8	1.9	4.9
3A	17.0	26.6	21.6	22.3	8.9	4.8	5.6	6.9	8.4
3B	21.4	**	**	**	13.2	11.4	13.7	10.1	10.6
4	26.0	6.6	6.5	4.9	2.4	4.4	1.2	5.2	6.2
5	31.0	9.2	8.4	8.5	5.1	3.7	1.8	7.4	4.1
6	36.8	6.3	6.1	5.8	4.2	1.9	2.8	3.7	7.3
7	43.0	0.6	0.2	0.2	0.3	0.2	0.4	0.3	1.0
8	51.5	1.8	1.4	0.5	1.7	0.9	0.8	0.9	1.2
9	60.0	2.2	1.7	1.4	2.6	1.9	2.6	3.8	1.5
10	68.0	3.5	4.9	5.4	4.0	2.8	7.8	5.1	8.3
11	77.5	4.5	8.8	7.9	6.4	7.4	10.3	8.0	6.8
12	84.8	4.8	6.1	8.9	5.4	7.3	7.7	6.6	7.3
13	90.8	0.4	1.4	1.1	0.8	1.2	0.2	1.6	2.3
14	105.0	9.1	10.9	7.7	10.6	8.3	11.2	8.9	8.1
15	125.5	7.1	7.3	8.9	13.1	16.7	18.3	12.4	10.7
16	146.5	10.2	9.6	9.5	14.5	23.7	10.3	12.9	6.1

river section	1996	1997	1998	1999	2000	2001	2002	average 1988-2002	average 1991-2002
1	3.1	0.8	1.5	1.9	3.8	3.9	4.5	2.9	3.0
2	3.4	5.6	4.3	4.2	4.1	3.0	6.0	3.9	3.9
3A	13.9	10.3	7.6	13.6	11.7	12.7	13.5	23.2	9.8
3B	14.6	21.2	11.7	16.2	14.1	10.4	12.7	**	13.3
4	3.9	5.2	3.7	4.9	5.7	6.1	4.6	4.8	4.5
5	5.8	6.9	8.6	11.1	10.6	10.6	9.4	7.4	7.1
6	9.9	6.6	4.6	6.5	8.5	9.1	7.1	6.0	6.0
7	0.2	0.1	0.9	0.4	0.7	1.6	0.8	0.5	0.6
8	1.6	1.4	2.0	1.1	1.4	1.5	3.4	1.4	1.5
9	1.7	1.3	3.7	1.7	2.2	2.2	5.5	2.4	2.6
10	6.5	5.2	5.5	4.5	2.5	3.7	3.4	4.9	4.9
11	6.7	14.3	10.6	8.4	9.2	7.2	5.8	8.2	8.4
12	8.6	7.7	6.7	7.1	11.7	10.0	6.4	7.5	7.7
13	1.1	0.4	1.6	0.6	2.0	2.7	0.9	1.2	1.3
14	5.9	1.8	8.3	7.4	4.5	5.7	6.3	7.6	7.3
15	7.5	4.9	9.1	3.9	2.7	4.2	5.4	8.8	9.1
16	5.6	6.0	9.7	6.6	4.5	5.4	4.1	9.2	9.1

* defined as the downstream distance from the centerline of Kenney Dam.

** In 1988-1990 Section 3 was not broken into 3A and 3B. Values for Section 3 as a whole are reported in row 3A.

Two factors may influence the spatial distribution of chinook spawners in the Nechako River. The first is the annual variation in the summer flows. Bradford (1994) reported that the percentage of all Nechako River chinook spawners using the upper 35 km of the river between the years 1978 to 1990 was significantly negatively correlated with flows at Vanderhoof over the August 1st to 10th period. Re-examination of the data for 1974 and 2002 (**Figure 5.1-8**) showed that the regression coefficient remained statistically significant, but its significance still depended on three years of low flows (1978 to 1980) collected prior to the complete introduction of summer cooling flows.

A possible second factor is the propensity of offspring to return to the areas of the Nechako River where they hatched. However there does not appear to be any significant correlation between the spatial distribution of parent chinook and the spatial distribution of their spawning progeny (Bradford 1994).

Figure 5.1-8 **Nechako River: percent of chinook spawning in the upper river vs. mean flow of the river at Vanderhoof, August 1 to 10, 1974, and 1978 to 2002**

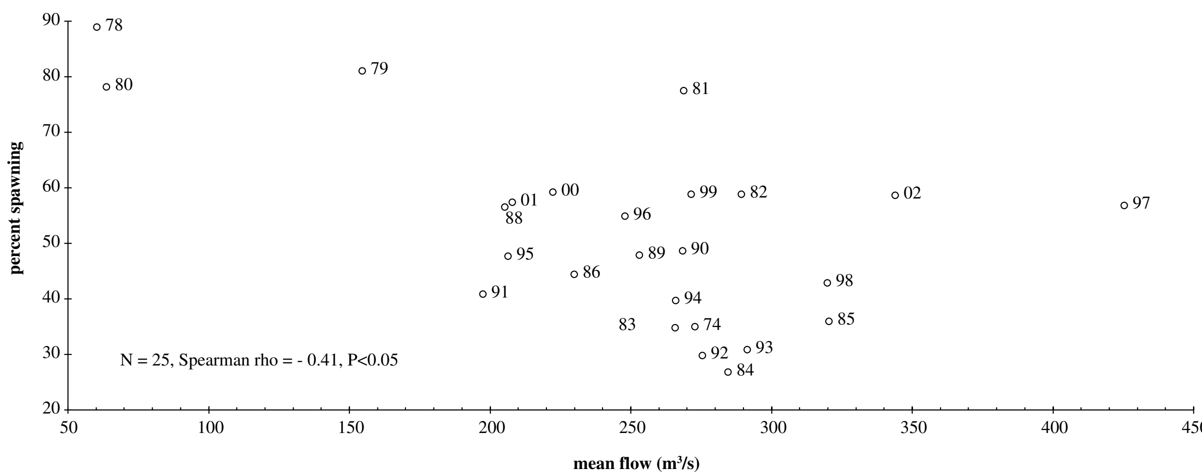


Figure 5.1-9 **Nechako River: residence times (±SE) of female chinook spawners at upper vs. lower observations sites, 1989 to 2002**

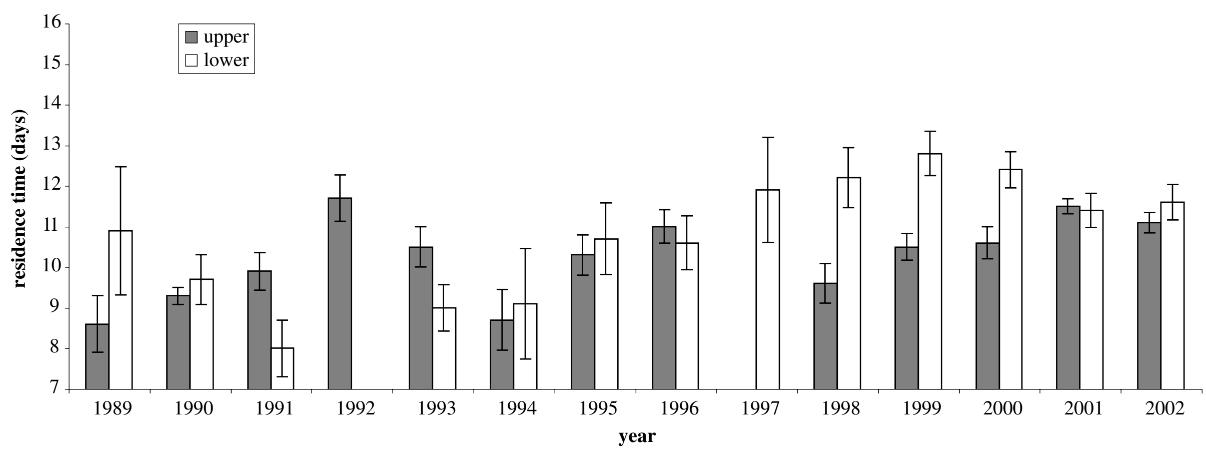


Table 5.1-7 **Nechako River: residence time (days) of female chinook s pawners, 1989 to 2002***

	lower river sites				upper river sites				combined sites			
year	mean	SD	N	range	mean	SD	N	range	mean	SD	N	range
1989	10.9	4.2	7	4 - 17	8.6	3.5	25	3 - 16	9.1	3.7	32	3 - 17
1990	9.7	2.6	18	5 - 14	9.3	1.9	75	5 - 13	9.4	2.1	93	5 - 14
1991	8.0	3.3	22	3 - 15	9.9	3.0	41	4 - 16	9.2	3.2	63	3 - 16
1992	-	-	-	-	11.7	3.4	35	4 - 16	11.7	3.4	35	4 - 16
1993	9.0	1.0	3	8 - 10	10.5	1.7	12	8 - 13	10.2	1.7	15	8 - 13
1994	9.1	3.6	7	4 - 14	8.7	2.5	11	5 - 12	8.9	2.8	18	4 - 14
1995	10.7	3.2	13	6 - 15	10.3	3.3	45	4 - 18	10.4	3.2	58	4 - 18
1996	10.6	2.9	19	5 - 15	11.0	2.7	43	5 - 18	10.9	2.8	62	5 - 18
1997	11.9	4.1	10	5 - 18	-	-	-	-	11.9	4.1	10	5 - 18
1998	12.2	3.4	21	8 - 21	9.6	3.1	40	4 - 17	10.5	3.4	61	4 - 21
1999	12.8	2.9	28	5 - 16	10.5	3.2	89	3 - 20	11.1	3.3	117	3 - 20
2000	12.4	2.7	36	6 - 19	10.6	4.8	141	4 - 23	11.0	4.5	177	4 - 23
2001	11.4	3.1	54	4 - 17	11.5	2.3	157	3 - 16	11.5	2.6	211	3 - 17
2002	11.6	2.4	29	5 - 16	11.1	2.6	108	4 - 17	11.2	2.6	137	4 - 17

* dashes indicate no data were collected

5.1.2.3 Residence Times: Nechako River

From 1989 to 2002, mean residence times ranged from 8.0 to 12.8 days at the lower sites and from 8.6 to 11.7 days at two upper sites (**Figure 5.1-9**) and (**Table 5.1-7**). The average residence time of 15 days reported for 1980 (Neilson and Geen 1981) could not be compared to estimates from 1989 to 2002, because they were collected using different observation protocols.

A two-way "analysis of variance" (ANOVA) was used to determine if there were statistically significant differences in residence time among the years 1989 to 2002 and between the lower and upper river observation sites. Residence times for 1992 and 1997 were excluded: the year-by-site interaction for these years could not be tested due to the fact that no data were available for the lower site in 1992 and for the upper site in 1997 (**Table 5.1-8**).

The interaction in the eight remaining years between year and site was significant:

$(F = 2.87, P = 0.001)$.

Residence times varied significantly among the twelve years,

$(F = 5.61, P = <0.001)$,

but not between the two sites,

$(F = 3.11, P = 0.078)$.

Table 5.1-8 **Nechako River: summary of residence time (days spent on a redd) for female chinook, 1989 to 2002**

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All spawners														
mean	9.1	9.4	9.2	11.7	10.2	8.9	10.4	10.9	11.9	10.5	11.1	11.0	11.5	11.2
SE	0.65	0.21	0.40	0.57	0.43	0.65	0.42	0.35	1.29	0.43	0.30	0.33	0.17	0.22
SD	3.7	2.1	3.2	3.4	1.7	2.8	3.2	2.8	4.1	3.4	3.3	4.5	2.6	2.6
N	32	93	63	35	15	18	58	62	10	61	117	177	211	137
range	3-17	5-14	3-16	4-16	8-13	4-14	4-18	5-18	5-18	4-21	3-20	4-23	3-17	4-17
Early spawners														
mean	10.0	9.7	10.3	11.0	10.7	9.2	10.1	10.9	12.8	14.0	12.0	12.1	12.1	11.8
SE	0.78	0.33	0.67	0.82	0.75	0.90	0.56	0.46	1.90	0.77	0.38	0.54	0.20	0.24
SD	3.6	2.3	3.1	3.7	2.0	3.0	3.2	2.7	3.8	3.0	3.0	4.9	2.2	2.5
N	21	47	21	20	7	11	32	34	4	15	61	82	116	103
range	4-17	5-14	6-15	4-16	8-13	4-14	5-16	5-16	8-17	10-21	5-20	4-23	4-16	4-17
Late spawners														
mean	7.5	9.1	8.7	12.7	9.8	8.4	10.7	10.9	11.3	9.4	10.1	10.0	10.7	9.6
SE	1.08	0.26	0.49	0.69	0.45	1.05	0.64	0.52	1.87	0.39	0.44	0.41	0.28	0.36
SD	3.6	1.8	3.2	2.7	1.3	2.8	3.3	2.8	4.6	2.7	3.3	4.0	2.8	2.1
N	11	46	42	15	8	7	26	28	6	46	56	95	95	34
range	3-11	5-12	3-16	8-16	8-12	5-11	4-18	5-18	5-18	4-14	3-16	4-22	3-17	5-14
Upper river sites														
mean	8.6	9.3	9.9	11.7	10.5	8.7	10.3	11.0	-	9.6	10.5	10.6	11.5	11.1
SE	0.70	0.21	0.46	0.57	0.49	0.75	0.49	0.41	-	0.49	0.33	0.40	0.18	0.25
SD	3.5	1.9	3.0	3.4	1.7	2.5	3.3	2.7	-	3.1	3.2	4.8	2.3	2.6
N	25	75	41	35	12	11	45	43	-	40	89	141	157	108
range	3-16	5-14	4-16	4-16	8-13	5-12	4-18	5-18	-	4-17	3-20	4-23	3-16	4-17
Lower river sites														
mean	10.9	9.7	8.0	-	9.0	9.1	10.7	10.6	11.9	12.2	12.8	12.4	11.4	11.6
SE	1.58	0.61	0.70	-	0.57	1.36	0.88	0.66	1.29	0.74	0.54	0.45	0.42	0.44
SD	4.2	2.6	3.3	-	1.0	3.6	3.2	2.9	4.1	3.4	2.9	2.7	3.1	2.4
N	7	18	22	-	3	7	13	19	10	21	28	36	54	29
range	4-17	5-14	3-15	-	8-10	4-14	6-15	5-15	5-18	8-21	5-16	6-19	4-17	5-16

5.1.2.3.1 Analysis and Results of Residence Times for Nechako River Chinook

Historical data on residence times for Nechako River chinook were assessed using both mean estimates and separate estimates for:

- early[22] vs. late spawners; and
- upper vs. lower river spawners.

Estimates of residence time in the Nechako River were compared to estimates of residence time for other chinook stocks. In addition, the AUC methodology for estimating spawner abundance was reviewed, as was the effect on spawner estimates of using different residence times for early vs. late and upper vs. lower river spawners.

The uncertainty in estimates of the number of spawners that results from uncertainty in mean residence times was also assessed, as was the possibility of further analysis of residence time data and its potential value.

5.1.2.3.2 Summary of Residence Time Data in the Nechako River

Residence time data for Nechako River chinook are summarized in **Table 5.1-8**. Residence time data were not collected in 1988, so the escapement estimated was generated using the data for the year 1980, taken from Neilson and Banford (1983).

In all cases, residence time was measured as the number of days spent by a female on a redd. Observations were made each year at a number of locations in the upper and lower Nechako River, except 1992, when no data were collected from the lower river, and 1997, when data from the upper river were rejected due to observer error.

Mean annual residence times in the Nechako River have varied over the period of record (**Table 5.1-9** and **Figure 5.1-10**). While not stating a reason, Perrin and Irvine (1990), as well as English *et al.* (1992) have noted that mean

[22] Early spawners are defined as spawners observed on or before the date of peak aerial counts.

Table 5.1-9

Nechako River: spawner estimates using separate residence times for chinook spawning in the upper (1-7) and lower sections (8-16) vs. estimates using mean residence times for whole river, 1989 to 2002*

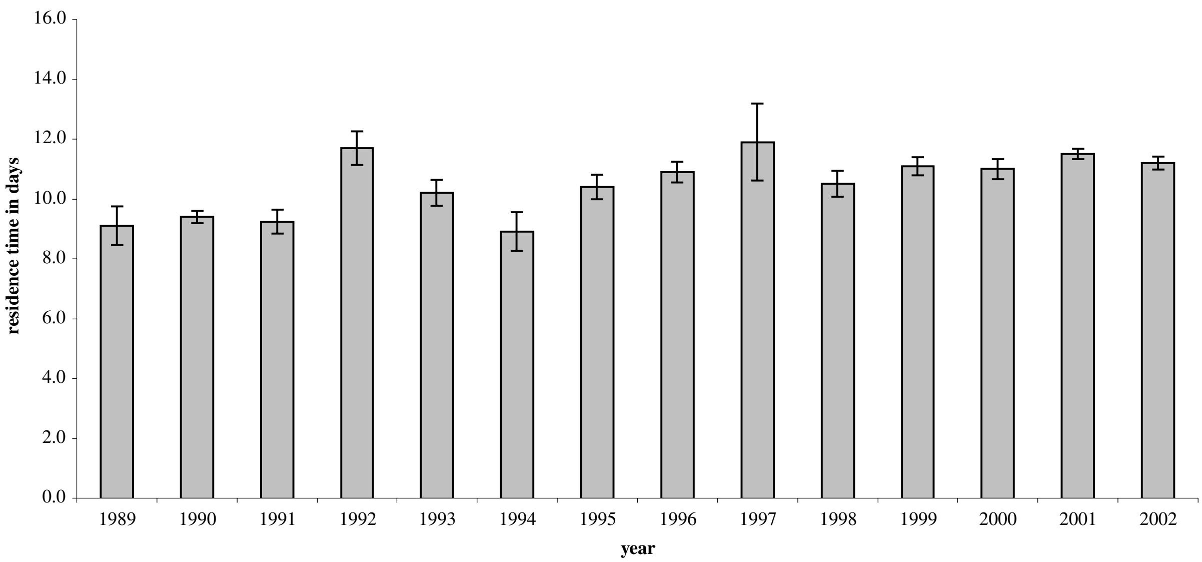
	1989	1990	1991	1993	1994	1995	1996	1998	1999	2000	2001	2002
Mean residence time for whole river (days)	9.1	9.4	9.2	10.2	8.9	10.4	10.9	10.5	11.1	11.0	11.5	11.2
AUC (total spawner days)[1]	26525.5	24859.0	21742.0	6860.0	10233.5	17535.0	22239.0	19432.0	21260.0	37454.5	66530.0	36920.5
Estimated spawners for whole river	**2915**	**2645**	**2363**	**673**	**1150**	**1686**	**2040**	**1851**	**1915**	**3405**	**5785**	**3296**
Percent spawners in upper sections	47.9	48.7	40.9	30.9	39.7	47.7	54.9	42.9	58.8	59.2	57.4	58.7
Upper reaches AUC (total spawner days)[2]	12705.7	12106.3	8892.5	2119.7	4062.7	8364.2	12209.2	8336.3	12500.9	22173.1	38188.2	21672.3
Mean residence time for upper section (days)	8.6	9.3	9.9	10.5	8.7	10.3	11.0	9.6	10.5	10.6	11.5	11.1
Estimated spawners in upper sections[3]	1477	1302	898	202	467	812	1110	868	1191	2092	3321	1952
Percent spawners in lower sections	52.1	51.3	59.1	69.1	60.3	52.3	45.1	57.1	41.2	40.8	42.6	41.3
Lower reaches AUC (total spawner days)[2]	13819.8	12752.7	12849.5	4740.3	6170.8	9170.8	10029.8	11095.7	8759.1	15281.4	28341.8	15248.2
Mean residence time for lower section (days)	10.9	9.7	8.0	9.0	9.1	10.7	10.6	12.2	12.8	12.4	11.4	11.6
Estimated spawners in lower sections[3]	1268	1315	1606	527	678	857	946	909	684	1232	2486	1314
New estimate of spawners (upper + lower)[4]	2745	2617	2504	729	1145	1669	2056	1777	1875	3324	5807	3266
Original estimate of spawners (for whole river)	**2915.0**	**2645.0**	**2363.0**	**673.0**	**1150.0**	**1686.0**	**2040.0**	**1851.0**	**1915.0**	**3405.0**	**5785.0**	**3296.0**
Difference	170	28	-141	-56	5	17	-16	74	40	81	-22	30
Percent difference	6.2%	1.1%	-5.6%	-7.7%	0.4%	1.0%	-0.8%	4.2%	2.1%	2.4%	-0.4%	0.9%

* data not available for 1992 and 1997.

Calculations

1. From available estimates of spawners and residence times, the area-under-the-curve (AUC) was derived as: spawners=AUC/residence time.
2. The AUC for spawners in the upper and lower sections was calculated by multiplying the AUC by the percentage of total observed fish-on-redds in the sections.
3. The estimate of the number of spawners in the upper and lower sections was derived as: upper spawners = upper AUC/upper residence time; lower spawners = lower AUC/lower residence time.
4. The new estimate of the number of spawners was derived by summing the estimates of spawners in the upper and lower sections.

Figure 5.1-10 **Nechako River: mean residence times (±SE) of female chinook, 1989 to 2002**



residence times of spawning salmon can differ significantly from year to year in the same river or among rivers in the same year. This appears to be true in the Nechako River.

Perrin and Irvine (1990) hypothesized that estimates of residence time vary among years and among streams because of undetermined site-specific factors. They concluded that estimates of residence time should not be extrapolated from one year to the next or from one stream to another.

Analysis of mean residence times in the upper and lower sections of the river did not reveal any obvious trends over time (**Table 5.1-9** and **Figure 5.1-11**). Residence times for early and late spawners also showed considerable variability among years (**Table 5.1-10** and **Figure 5.1-12**): early spawners had longer residence times than late spawners in eleven out of fourteen years. This finding is consistent with Neilson and Geen's findings that the residence times of early and late chinook spawners in the Morice River—the only available estimates of female residence time on redds on rivers other than the Nechako River—decreased linearly with a later date of arrival to the spawning grounds (Neilson and Geen 1981). Their calculations showed the mean residence time of early spawners in the Morice River to be 13.1 days (n = 126, SE = 0.13) and late spawners to be 7.7 days (n = 37, SE = 0.25).

Perrin and Irvine (1990) showed that rather than measuring residence time as the number of days spent by a female on a redd, most studies estimate survey life, the number of days that a spawner is alive in a survey area. Estimates of residence time at a redd will be less than estimates of survey life because the former does not account for either the time between a fish entering a stream and locating at a redd, or the time between a fish leaving a redd and dying. In addition, estimates of survey life generally refer to both sexes rather than only females.

Perrin and Irvine (1990) calculated a mean survey life (including the data for residence time on redds from Neilson and Geen (1981) and Neilson and Banford (1983)) of 12.1 days with a range

Figure 5.1-11 **Nechako River: mean residence times (± SE) of female chinook in the upper (1-7) and lower (8-16) sections, 1989 to 2002**

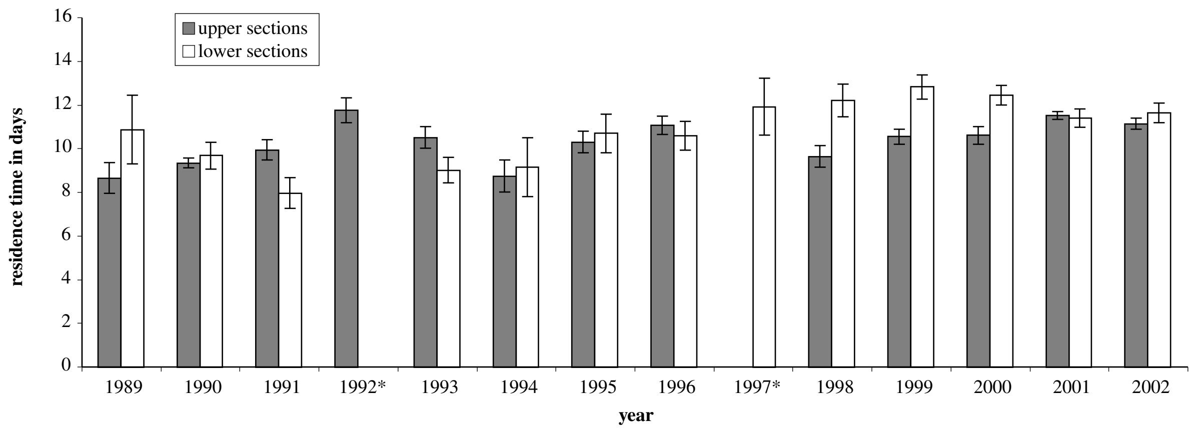


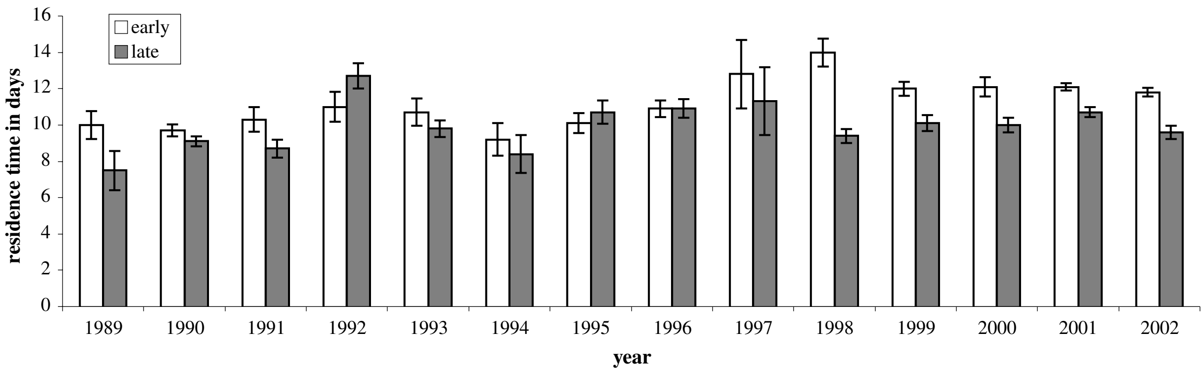
Table 5.1-10 **Nechako River: spawner estimates using separate residence times for early and late spawning fish vs. using mean residence times, 1989 to 2002**

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mean Residence Time	9.1	9.4	9.2	11.7	10.2	8.9	10.4	10.9	11.9	10.5	11.1	11.0	11.5	11.2
AUC	26525.5	24859.0	21742.0	29547.0	6860.0	10233.5	17535.0	22239.0	23256.0	19432.0	21260.0	37454.5	66530.0	36920.5
Estimated total spawners	**2915**	**2645**	**2363**	**2525**	**673**	**1150**	**1686**	**2040**	**1954**	**1851**	**1915**	**3405**	**5785**	**3296**
Percent early spawners	65.6	73.6	54.8	58.8	52.7	56.0	64.1	57.7	53.7	34.2	65.0	61.9	62.8	73.5
Early spawners AUC	17,401	18,296	11,915	17,374	3,615	5,731	11,240	12,832	12,489	6,646	13,819	23,184	41,781	27,137
Average early residence time	10.0	9.7	10.3	11.0	10.7	9.2	10.1	10.9	12.8	14.0	12.0	12.1	12.1	11.8
Estimated early spawner	1,740	1,886	1,157	1,579	338	623	1,113	1,177	976	475	1,152	1,916	3,453	2,300
Percent late spawners	34.4	26.4	45.2	41.2	47.3	44.0	35.9	42.3	46.3	65.8	35.0	38.1	37.2	26.5
Late spawners AUC	9,125	6,563	9,827	12,173	3,245	4,503	6,295	9,407	10,768	12,786	7,441	14,270	24,749	9,784
Average late residence time	7.5	9.1	8.7	12.7	9.8	8.4	10.7	10.9	11.3	9.4	10.1	10	10.7	9.6
Estimated late spawner	1,217	721	1,130	959	331	536	588	863	953	1,360	737	1,427	2,313	1,019
New estimate of spawners (late+early)	2,957	2,607	2,286	2,538	669	1,159	1,701	2,040	1,929	1,835	1,888	3,343	5,766	3,319
Original estimate of spawners	2,915	2,645	2,363	2,525	673	1,150	1,686	2,040	1,954	1,851	1,915	3,405	5,785	3,296
Difference	-42	38	77	-13	4	-9	-15	-0	26	16	27	62	19	-23
Percent difference	-1.4%	1.4%	3.4%	-0.5%	0.6%	-0.8%	-0.9%	-0.0%	1.3%	0.9%	1.4%	1.9%	0.3%	-0.7%

Calculations

1. The area-under-the-curve (AUC) was derived from available estimates of spawners and residence times, as spawners=AUC/residence time.
2. The AUC for early spawners was calculated by multiplying the AUC by the percentage of total observed early fish-on-redds.
3. The estimate of the number of early spawners was derived as: early spawners = early AUC/early residence time.
4. The new estimate of the number of spawners was derived by summing the estimates of early and late spawners.

Figure 5.1-12 **Nechako River: residence times of early* and late female chinook (± SE), 1989 to 2002**



*Early females are those observed on or before the date of the peak aerial counts

from 3 to 20 days[23]. Data for Nechako River chinook residence times on redds are not directly comparable, but assuming the errors are relatively small, they seem to be within the range typical of chinook populations. No information was found to explain why different stocks might have different residence times.

5.1.2.3.2.1 Sensitivity of Spawner Estimates to Mean Residence Time Estimates

Estimates of the number of spawners in a given year might differ if separate residence time estimates are used for upper vs. lower river spawners or early vs. late spawners. Prior to the analysis, it is important to understand exactly how residence time is used to estimate the number of spawners. Using the AUC methodology, the two inputs in the calculation of spawners are:

- the residence time of females on redds; and
- aerial estimates of the number of fish on redds.

When weekly aerial counts of the number of fish on redds are plotted, the AUC then represents the number of spawners per day, assuming a residence time of one day. In order to calculate the annual spawner escapement, the AUC is divided by the mean residence time observed for that year.

5.1.2.3.2.2 Using Separate Residence Times for Upper and Lower River Spawners

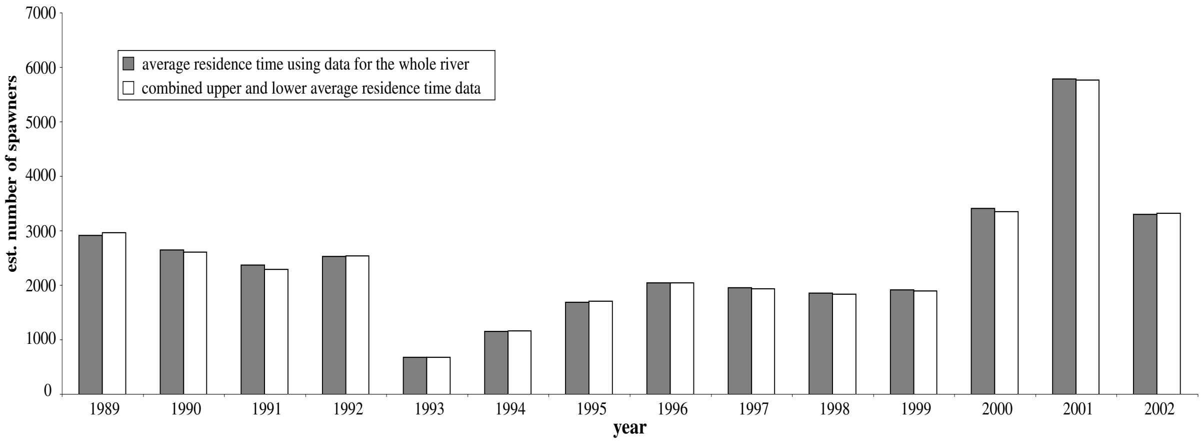
The Technical Committee used mean residence time for the whole river to calculate the AUC, even though separate residence time data is often collected at km 19.2 (upper-river sites), as well as km 83, km 131.3 and km 152.7 (lower-river sites). The committee tested the validity of this approach by calculating separate population estimates for upper- and lower-river populations using separate residence time data.

An AUC estimate was developed for Sections 1 to 7 of the river using the spawner curve from this area and the upper-river residence time as the divisor. A similar estimate was made for Sections 8 to 16. These two estimates were summed to obtain a total river population, which was then compared to the population estimated by using the mean residence time for the whole river.

The calculations and results are shown in **Table 5.1-10**. **Figure 5.1-13** shows the revised estimates of the number of spawners in comparison to estimates made using the mean residence times for the whole river. The difference in the two methods varied between 0.4% and 7.7% with no consistent

[23] Details of each study can be found in the references cited by the authors.

Figure 5.1-13 **Nechako River: comparison between estimates of chinook spawners calculated with average residence times for whole river and from a combination of separate residence times for the upper (1-7) and lower (8-16) sections* of the river**



*Data for 1992 lower sites and 1997 upper sites are missing.

direction in difference. The differences were deemed by the committee to be of a small enough magnitude that the use of a mean resident time for the whole river was acceptable for the annual AUC calculation.

5.1.2.3.2.3 Using Separate Residence Times for Early and Late Spawners

In an analysis similar to that stated above, the effect on spawner estimates of using separate residence times for early and late spawners showed that there was very little change (-0.8% to 3.4%) in the annual estimates of the number of spawners (**Table 5.1-10**). This result is not surprising: Neilson and Geen, (1981) found a linear relationship between residence time and date of arrival on the Morice River spawning grounds. If the relationship were truly linear, one would expect the residence times of early and late spawners to average out. The small observed differences in the spawner estimates would then be due to the error in the approximation of run timing (*i.e.,* the partitioning of spawners as either "early" or "late" spawners) that arises from weekly rather than daily aerial counts.

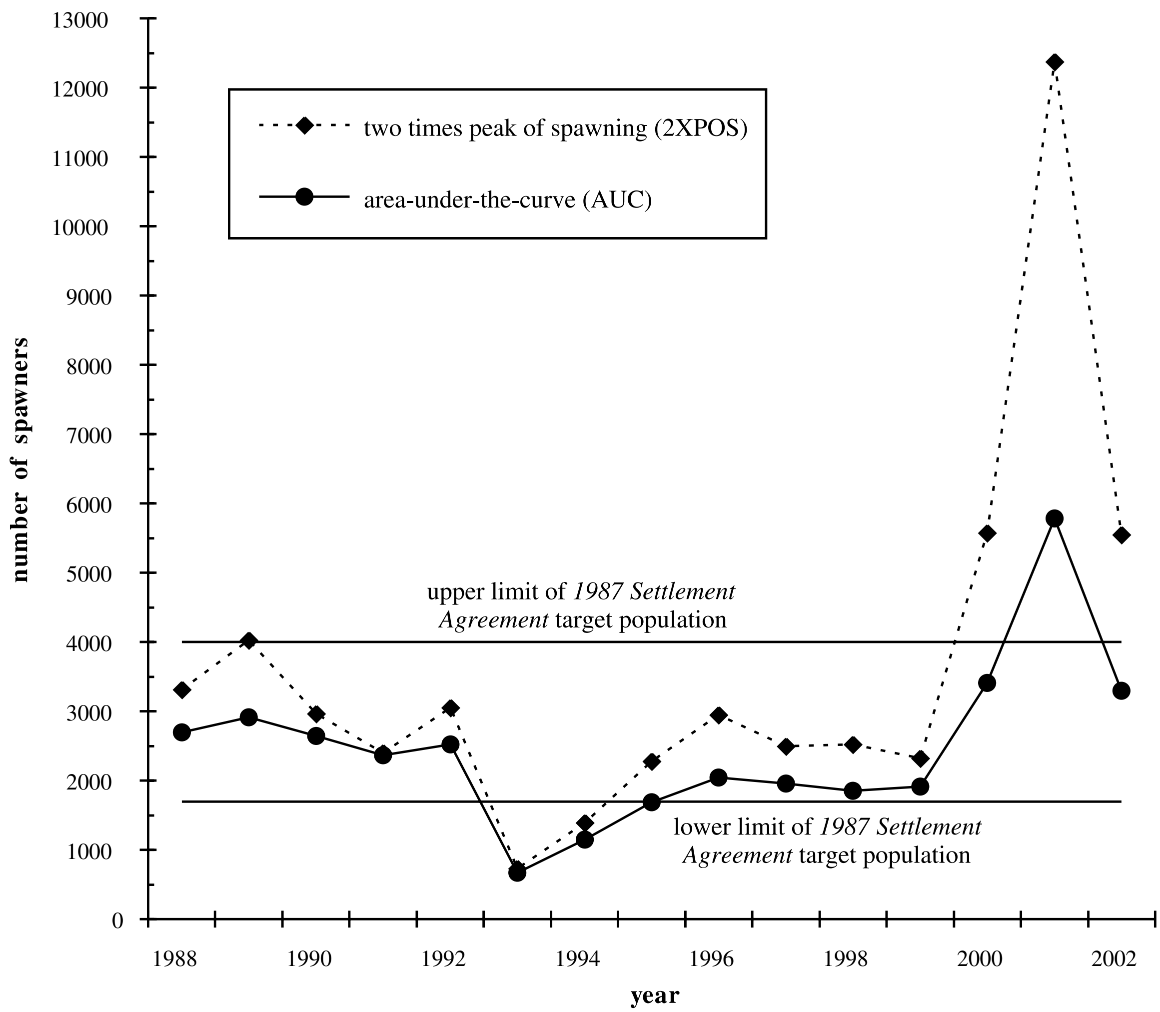
5.1.2.4 Escapement Estimates: Nechako River

The AUC estimates of chinook escapement for the Nechako River are shown in **Figure 5.1-14**. These estimates were reached by dividing the number of spawner-days calculated for each year from 1988 to 2002 by the average residence times for each of the years. The estimates ranged from a minimum of 663 in 1993 to a maximum of 5,785 in 2001, with an average of 2,042 (n = 11, SD = 687).

Figure 5.1-14 also shows estimates of escapement calculated by doubling the counts of live chinook made at the "peak of spawning" (2XPOS), the method used to define historical escapement in the *1987 Settlement Agreement.* Estimates derived with the 2XPOS method ranged from a minimum of 732 in 1993 to a maximum of 12,378 in 2001, with an average of 3,596 (n = 15, SD = 2,758).

The AUC method provides a lower, more conservative estimate than the 2XPOS. This is not unexpected given that the expansion of the POS was based on an arbitrary number with no scientific or statistical basis. An accurate expansion value would have to be developed by comparing POS

Figure 5.1-14 **Nechako River: chinook spawner estimates, 1988 to 2002**



counts to the actual population of fish spawning in the river, if that number could be ascertained.

While the average AUC estimate was 31.6% lower than the average 2XPOS estimate, AUC estimates (based on multiple counts) were also less variable than 2XPOS estimates (based on a single count) with a minimum/maximum difference of 5,112 compared to a minimum/maximum difference of 11,646 for 2XPOS (128% greater than the AUC difference). In addition, the coefficient of variation was lower for the AUC estimates than the 2XPOS estimates (48 vs. 77 respectively).

5.1.2.5 Escapement Estimates: Stuart River

From 1988 to 2002 the average escapement of chinook to the mainstem of the Stuart River was 5,333 (n = 15, SD = 3,403) (**Table 5.1-1** and **Figure 5.1-2**)[24], more than seven times greater than the

[24] While Stuart River escapements are theoretically comprised of wild and hatchery-reared fish, the Necoslie Hatchery escapement did not make a substantial contribution to the chinook population.

average escapement recorded from 1951 to 1987. The difference is largely due to the turbidity of the water, which caused visual methods to underestimate chinook escapements until 1987. At present, mark-recapture techniques are the only methods considered suitable for estimating Stuart River chinook escapements; these have been used for estimates since 1991.

5.1.2.6 Assessing Variations in Chinook Escapement: Nechako River

The causes of variations in Nechako River chinook escapement are poorly understood. One reason common to all Fraser River basin chinook stocks is the absence of information on the marine and freshwater harvest of chinook (NFCP 1998). A lack of harvest data means that it is not possible to be certain whether annual changes in escapement are due to variations in the survival of juvenile chinook in fresh or ocean water, or to variations in annual harvests. If the variations are due to the Nechako River habitat, then the Technical Committee has, in theory, the mandate to conduct remedial measures to increase the survival rate, or reduce annual variability. However, if the variations are due to factors outside of the Nechako River basin, the activities of the committee can have little effect.

Biological statistics on juvenile chinook were reviewed and compared among years to test the possibility that the variations in escapement outside of the target population were caused by events in the upper Nechako River. Since most Nechako spawners are four to five years old, in-river events and changes to in-river salmon fisheries management that may have affected the 1993 and 1994 returns (the two lowest escapement years) would have occurred in 1988 to 1990. [See *ss.6.1 Fry Emergence Project* and *ss.6.2 Juvenile Chinook Out-migration Project*]

With one exception, flows from 1988 to 1990 fell within the usual seasonal range for the years 1987 to 1999 and did not exhibit unusual early or late spills that may have had biological consequences. The sole exception was a large forced spill in the spring of 1990 when releases at Skins Lake Spillway rose to a peak of 264 m^3/s between April 7 and May 2. Although brief increases in spring or autumn flows due to heavy rains are common, the spring 1990 pattern was unusual for the Nechako River—264% higher than average April flows (1980-2000 data)—or for other unregulated rivers of the Interior Plateau of British Columbia due to the early timing (April) of these elevated flows. By comparison, Stuart River flows in April 1990, were only 15% higher than average April flows.

Possible effects of the 1990 forced spills that could affect fry survival include:

- **fish displacement –** Chinook fry are more vulnerable to downstream displacement by river flows during their spring emergence period than at any other time in their life. The 1990 forced spill event resulted in very limited near shore, low velocity emergent fry habitat due to bankful flows. Catch-per-unit-effort (CPUE) of juvenile chinook was lower throughout the 1990 May-November sampling period than in the years 1991 to 1998, which may indicate displacement. There was also a decline in fish diversity as measured by night electrofishing surveys in late spring of 1990 in the upper 100 km of the Nechako River. [See *ss.6.2.1.1 Index Sampling: Electrofishing Surveys*] This was due to a change in the relative abundance of juvenile chinook and largescale sucker (*Catostomus macrocheilus*) in the upper Nechako River from the first and third most abundant fish (respectively) to the third and eighth (**Table 5.1-11**). This may also indicate displacement.

Table 5.1-11 **Nechako River: rank in abundance of 14 species of fish captured in the upper river by night electrofishing in the month of June, 1990 to 1998***

		nonspill						spill		
Common Name	Scientific name	1992	1993	1994	1995	1998	**pooled**	1990	1991	1996
Chinook salmon	*Oncorhynchus tshawytscha*	1	1	2	1	1	**1**	3	1	1
Northern pikeminnow	*Ptychocheilus oregonensis*	3	2	5	2	2	**2**	1	2	2
Largescale sucker	*Catostomus macrocheilus*	2	4	3	4	3	**3**	8	6	4
Redside shiner	*Richardsonius balteatus*	4	3	1	3	4	**4**	4	3	3
Sculpin	*Cottus sp.*	5	5	4	6	6	**5**	2	4	6
Leopard dace	*Rhinichthys falcatus*	6	8	7	5	5	**6**	6	7	5
Longnose dace	*Rhinichthys cataractae*	7	7	6	7	7	**7**	5	5	7
Mountain whitefish	*Prosopium williamsoni*	8	6	10	8	8	**8**	9	8	8
Rainbow trout	*Onchorhynchus mykiss*	9	9	8	9	9	**9**	7	9	9
Peamouth chub	*Mylocheilus caurinus*	13	-	-	10	10	**10**	-	-	12
Burbot	*Lota lota*	11	10	9	11	11	**11**	10	10	11
Sockeye salmon	*Oncorhynchus nerka*	10	-	11	-	-	**12**	-	-	12
Coho salmon	*Oncorhynchus kisutch*	12	11	-	-	-	**13**	11	-	10
Bull trout	*Salvelinus confluentus*	-	-	-	-	-	**-**	-	11	13

Dashes indicate no specimens were captured in the upper river by night electrofishing that year.

* There were no data for 1997 as many sites were inaccessible because of high water levels.

- **reduced fish growth –** For each of the four spill-years, the average temperature difference from the mean (temperatures pooled over non-spill years between 1987 and 1998) was significantly different from zero. The larger the spill event, the larger the average drop in temperature. Juvenile chinook growth is directly proportional to average river temperature. However, although the 1990 spill caused a 0.4°C decrease in average annual temperature of the river (measured at km 19), the growth curve for juvenile chinook for 1990 was not significantly different from the curves for 1991 to 1998.

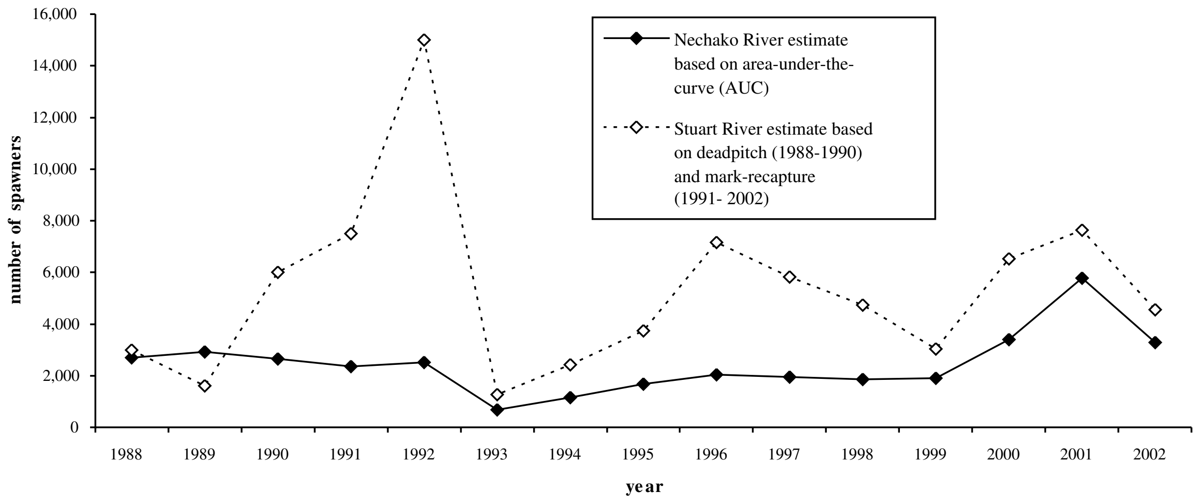
Comparing escapements for the Nechako and Stuart Rivers from 1993 to 2002 (**Figure 5.1-15**) shows that both populations followed similar trends. Since the Stuart River is not affected by regulating the Nechako River, it is unlikely that the low escapements of 1993 and 1994 were related to the 1990 forced spills and were most likely caused by extrinsic factors found in the Fraser River basin or the ocean[25].

Escapement trends differed between the Nechako and Stuart Rivers prior to 1993 by which time the escapement methodologies were standardized[26]. Escapements in 1993 were the lowest for both

[25] Although both Nechako and Stuart River chinook share common rearing in the Nechako River downstream of the Stuart River confluence, the magnitude of any flow variation is buffered by the contribution of Stuart River flows.

[26] The Technical Committee put considerable effort into assessing the biases and precision of the Nechako River AUC; however, there is little information on the robustness of the mark-recapture method applied to the Stuart River. In addition, data from the Stuart River was not as rigorously collected as data from the Nechako River. That said, the committee is comfortable with comparing the Nechako and Stuart Rivers' chinook escapements.

Figure 5.1-15 **Nechako and Stuart Rivers: comparison of chinook escapements, 1988 to 2002**



rivers, while escapements in both rivers from 1993 to 2002 followed a similar trend.

5.1.3 Summary: Estimating Chinook Spawner Numbers

Comparing the AUC estimates of chinook escapements with those from the 2XPOS rule found in the *1987 Settlement Agreement* shows that AUC estimates are more conservative than the 2XPOS estimates. In addition, there is less variability in the AUC methodology, which confirms the Technical Committee's position that it is the best methodology for use in trend analysis. Comparing the AUC estimates with mark-recapture estimates for the Stuart River shows that both populations have followed similar trends since 1993.

5.2 CHINOOK CARCASS RECOVERY PROGRAM

The Chinook Salmon Carcass Recovery Program (1988 to 1998) stemmed from the need to monitor chinook salmon population characteristics to provide support for estimating spawner numbers, particularly in the turbid Stuart River where the AUC methodology cannot be applied.

The program also gathered biological data on spawners, including age distribution, sex ratio, body size, fecundity and egg retention in order to:

- compare Nechako and Stuart River chinook populations to identify possible effects of river flows on population biology; and
- assess the degree of stress experienced by spawners during freshwater migration (BCUC 1994).

Data on recoveries in the Nechako and Stuart Rivers were published for the years 1988[27] to 1994 (NFCP 1989b, 1993c, 1993f, 1994c, 1994e, 1995b, 1995d, unpublished NFCP data, 1995 to 1998).

5.2.1 Chinook Carcass Recovery: Methodologies

Carcass recovery surveys were conducted each year from 1988 to 1998 during the period of chinook

[27] Information on carcass recovery surveys conducted between 1974 and 1988 were reported by Hickey and Lister (1981), Jaremovic and Rowland (1988) and Rowland (1988).

spawner die-off at the end of the spawning period. Surveys in the Nechako River began at Cheslatta Falls and ran downstream as far as Vanderhoof (**Figure 5.1-3**); the distribution of sampling among the 16 sections varied among years depending on escapement and the known distribution of spawners based on helicopter surveys. Surveys in the Stuart River began at the outlet of Stuart Lake and ran to the confluence of Kec Creek (**Figure 5.1-5**). Several complete surveys were done of each river to ensure that both early and late spawners were represented in the samples.

The surveys were conducted by running a jet boat downstream at low speed, recovering carcasses with a gaff, then processing the carcasses for biological information. Carcasses in water more than 3 m deep could not be reached with a gaff and were not recovered. All processed carcasses were cut in half to prevent re-counting and returned to the river.

Each carcass was assigned a number and its location and date of recovery recorded. If the carcass was too badly decomposed or eaten by animals to allow reliable measurements of body length or to obtain scale samples, it was cut in half to prevent re-counting and returned to the river.

The following information and samples were recorded for each fish:

- **scales and fin rays –** Samples were taken to establish age. Ten scales were taken from each processed carcass—five each side from the preferred area of the body, several rows above the lateral line between the posterior end of the dorsal fin and the anterior insertion of the anal fin—and stored in gummed, pre-numbered scale books. Care was taken to avoid regenerated, resorbed and irregular shaped scales. Dorsal fins from each carcass were removed with a knife, placed in pre-labeled paper envelopes and frozen.
- **sex and egg retention –** Fish were sexed based on their colour and morphology, and the body cavity of females was opened to check for eggs retained after spawning. All eggs were counted unless the number was greater than 600 to 1,000, in which case they were estimated volumetrically.
- **post-orbital hypural length** (POH) **–** The POH—the distance from the posterior margin of the orbit to the flexure of the hypural plate in the caudal peduncle—was recorded to the nearest millimeter. POH length is the principal measure of body size in spawning Pacific salmon. It is more easily measured than body weight due to the difficulty of weighing adult chinook with portable scales.
- **physical condition –** The presence of net scars and lamprey marks in particular was noted.
- **adipose fin –** A missing adipose fin is evidence of a hatchery raised fish with a coded-wire tag implanted in its head. If the fin was missing, the head was removed for subsequent analysis.

In 1994 and subsequent years, liver and muscle tissue samples were taken for genetic analysis by the Department of Fisheries and Oceans as part of a program to develop genetic markers for each major stock of chinook in British Columbia, and for contaminant analysis. The Technical Committee did not analyze these data.

Scales were examined at the department's Fish Morphology Laboratory in Vancouver, and scales and fin rays were examined at the Pacific Biological Station Fish Age Laboratory in Nanaimo. Station staff derived a "resolved" age for each fish by examining both scales and fin rays[28].

[28] Station staff has greater confidence in resolved age estimates than in ages derived solely from scales.

5.2.2 Results and Discussion

5.2.2.1 Age

The ages of Nechako River chinook spawners were determined by counting the number of annuli in both scales and thin-sectioned fin rays. Chinook scales are notoriously difficult to read due to resorption of scale margins (Healey 1991), so fin ray ages were compared to scale ages in 1984 and from 1988 to 1998 to develop a resolved age[29].

A total of 2,342 Nechako chinook spawners—1,370 females and 972 males—were assigned resolved ages between 1988 and 1998 (**Table 5.2-1**)[30]. Over 99% of these fish spent one summer and winter in freshwater before going to sea in their second year of life. That meant that age-at-smolting[31] could be ignored for the purposes of analysis and the fish could be pooled solely by their age at spawning (**Table 5.2-2**).

Five-year olds were the dominant age class in all eleven years, ranging from 50.5% to 86.4% of females and from 48.1% to 84.0% of males (**Figures 5.2-1** and **5.2-2**). Four-year olds were slightly more common than six-year olds. Three-year olds and seven-year olds together made up less than 1% of all aged fish.

The relative frequencies of four-, five- and six-year olds of both sexes changed little over the 1988 to 1998 period. This indicated little change in average age at maturation and average fry/adult survival of brood years over that time period. On average, 17.1% of all females and 18.3% of all males were four-year olds, 73.1% of all females and 65.8% of all males were five-year olds and 9.5% of all females and 14.6% of all males were six-year olds (**Figure 5.2-3**).

5.2.2.1.1 Age-comparison of Nechako and Stuart Chinook Stocks

The Stuart River chinook stock is the only other upper Fraser River basin chinook population upstream of the Thompson River for which there is as comprehensive a set of age-data as that collected for the Nechako River stock. Unfortunately, the two data sets are not strictly comparable. Resolved ages for Stuart River chinook are only available for 1988 and 1995 to 1998; 1989 to 1994 data for the Stuart River consists of scale-derived ages only.

Accepting that limitation, the data show minor differences in age structure (**Table 5.2-3** and **Figure 5.2-4**). Both populations are dominated by five-year olds, although the Stuart River population has a greater proportion of four-and seven years olds, and a lower proportion of six-year olds than the Nechako River population. That said, it cannot be determined whether these minor differences represent true population differences in age-at-maturation, or are simply artifacts of ageing methodology.

5.2.2.1.2 Age of Lower Fraser River Chinook Stocks

Until about 1990, the Department of Fisheries and Oceans did not regularly age chinook spawners in the Fraser River basin. Instead, most of the available age data were collected from samples obtained from the commercial fishery in the lower Fraser River (Fraser *et al.* 1982), and from opportunistic sampling of spawners in their natal streams conducted as part of department research programs not related to stock management (Shepherd *et al.* 1986, Jaremovic and Rowland 1988, and Bradford 1994).

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[29] Scale-derived ages for 1980 and 1988 to 1994 are presented in NFCP 1995d: Table 13.

[30] Although scale-derived ages are available as far back as 1980 (Jaremovic and Rowland 1988), resolved ages are only available for 1988 to 1998.

[31] Smolt is the name given to a juvenile salmon during their first seaward migration. Smolts are silver-coloured and have undergone physiological changes to enable them to withstand saltwater.

Table 5.2-1 **Nechako River: percent age composition of chinook spawners based on a combination of scale and fin ray analyses, 1980 to 1998**

year	resolved age at spawning - age at entry to sea												n*	method	sources**
	3-1	3-2	4-1	4-2	5-1	5-2	5-3	6-1	6-2	6-3	7-2	7-3			
							females								
1980	1	0	10	9	0	80	0	0	0	0	0	0	117	Scales	1
1981	1	1	3	28	1	65	0	0	1	0	0	0	99	Scales	1
1982	0	0	0	16	0	84	0	0	0	0	0	0	86	Scales	1
1983	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1984	0	0	1	67	0	30	0	0	3	0	0	0	78	Scales	1
1985	0	0	1	23	0	76	0	0	0	0	0	0	95	Scales	1
1986	0	0	0	38	0	60	0	0	3	0	0	0	74	Scales	1
1987	0	0	0	12	0	87	0	0	1	0	0	0	69	Scales	1
1988	0.0	0.0	0.0	4.8	1.6	81.6	0.0	0.0	12.0	0.0	0.0	0.0	125	Resolved	2
1989	1.0	0.0	0.0	28.2	1.0	49.5	0.0	1.0	18.4	0.0	1.0	0.0	103	Resolved	2
1990	0.0	0.0	1.6	2.5	0.0	81.1	0.0	0.0	13.9	0.0	0.8	0.0	122	Resolved	2
1991	0.0	0.0	1.8	14.4	0.0	55.9	0.0	0.9	25.2	0.0	1.8	0.0	111	Resolved	2
1992	0.0	0.0	0.0	5.1	0.0	86.4	0.0	0.0	8.5	0.0	0.0	0.0	118	Resolved	2
1993	0.0	0.0	0.0	11.3	0.0	79.2	0.0	0.0	9.4	0.0	0.0	0.0	108	Resolved	2
1994	0.0	0.0	0.0	10.9	0.0	79.3	0.0	0.0	9.8	0.0	0.0	0.0	172	Resolved	2
1995	0.0	0.0	1.6	12.7	0.0	84.9	0.0	0.0	0.8	0.0	0.0	0.0	126	Resolved	2
1996	0.0	0.0	0.8	42.4	0.0	49.2	1.5	0.0	6.1	0.0	0.0	0.0	132	Resolved	2
1997	0.0	0.0	0.8	20.6	0.0	77.0	0.0	0.0	1.6	0.0	0.0	0.0	126	Resolved	2
1998	0.0	0.0	0.0	25.2	0.8	73.2	0.0	0.0	0.8	0.0	0.0	0.0	127	Resolved	2
pooled	0.1	0.0	0.6	16.1	0.3	73.0	0.1	0.1	9.3	0.0	0.3	0.0	1370		
							males								
1980	0	3	11	16	3	67	0	0	0	0	0	0	63	Scales	1
1981	0	0	5	16	0	76	0	0	3	0	0	0	62	Scales	1
1982	0	0	0	8	0	90	0	0	2	0	0	0	90	Scales	1
1983	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1984	0	4	2	55	0	35	0	0	4	0	0	0	69	Scales	1
1985	0	0	0	40	0	60	0	0	0	0	0	0	47	Scales	1
1986	0	3	0	20	0	71	0	0	6	0	0	0	65	Scales	1
1987	0	0	1	19	0	76	0	0	3	0	0	0	69	Scales	1
1988	0.0	0.0	0.0	15.3	1.2	55.3	0.0	0.0	28.2	0.0	0.0	0.0	85	Resolved	2
1989	1.0	0.0	1.0	30.9	1.0	53.6	0.0	0.0	11.3	0.0	1.0	0.0	97	Resolved	2
1990	0.0	0.0	1.9	4.9	0.0	69.9	0.0	0.0	21.4	0.0	1.9	0.0	126	Resolved	2
1991	2.0	0.0	3.0	14.1	1.0	51.5	0.0	0.0	25.3	0.0	3.0	0.0	99	Resolved	2
1992	0.0	2.4	0.0	9.8	2.4	78.0	0.0	0.0	7.3	0.0	0.0	0.0	82	Resolved	2
1993	0.0	0.0	0.0	15.9	0.0	62.2	0.0	0.0	22.0	0.0	0.0	0.0	83	Resolved	2
1994	0.0	0.0	0.0	11.3	0.0	73.8	0.0	0.0	12.5	0.0	2.5	0.0	80	Resolved	2
1995	0.0	0.0	1.2	12.3	0.0	84.0	0.0	0.0	1.2	1.2	0.0	0.0	81	Resolved	2
1996	0.0	0.0	0.0	36.7	1.3	43.0	3.8	0.0	15.2	0.0	0.0	0.0	79	Resolved	2
1997	0.0	0.0	0.0	20.0	0.0	73.8	0.0	0.0	6.3	0.0	0.0	0.0	80	Resolved	2
1998	0.0	0.0	0.0	23.8	1.3	70.0	1.3	0.0	3.8	0.0	0.0	0.0	80	Resolved	2
pooled	0.3	0.2	0.8	17.2	0.7	64.8	0.4	0.0	14.6	0.1	0.9	0.0	972		

Dashes indicate no data available.
* n is the number of fish assigned an age based on either scales or fin rays or both.
** Sources: 1 = NFCP (1995b), 2 = NFCP (unpubl. data).

Table 5.2-2 **Nechako River: percent age composition of chinook spawners, pooled by age at spawning (resolved age), 1988 to 2002***

year	age at spawning (years) 3	4	5	6	7	N
females						
1988	0	5	84	12	0	125
1989	1	28	51	19	1	103
1990	0	5	81	14	1	122
1991	0	16	56	26	2	111
1992	0	5	86	9	0	118
1993	0	11	80	9	0	108
1994	0	11	79	10	0	172
1995	0	14	85	1	0	126
1996	0	43	51	6	0	132
1997	0	21	77	2	0	126
1998	0	25	74	1	0	127
1999	0	43	54	3	0	133
2000	0	62	35	3	0	159
2001	0	10	90	0	0	120
2002	0	23	75	2	0	111
pooled	0	23	70	7	0	1893
males						
1988	0	15	56	28	0	85
1989	1	32	55	11	1	97
1990	0	7	70	21	2	126
1991	2	17	53	25	3	99
1992	2	10	80	7	0	82
1993	0	17	61	22	0	83
1994	0	11	74	13	3	80
1995	0	14	84	3	0	81
1996	0	37	48	15	0	79
1997	0	20	74	6	0	80
1998	1	24	72	4	0	81
1999	0	47	46	7	0	70
2000	0	69	28	3	0	91
2001	2	13	84	2	0	61
2002	0	28	67	5	0	61
pooled	0	24	63	12	1	1261

*Data from DFO (Pacific Biological Station, Nanaimo) only available for 1988 to 2002.

Figure 5.2-1 Nechako River: percent age composition of female chinook spawners, 1988 to 1998

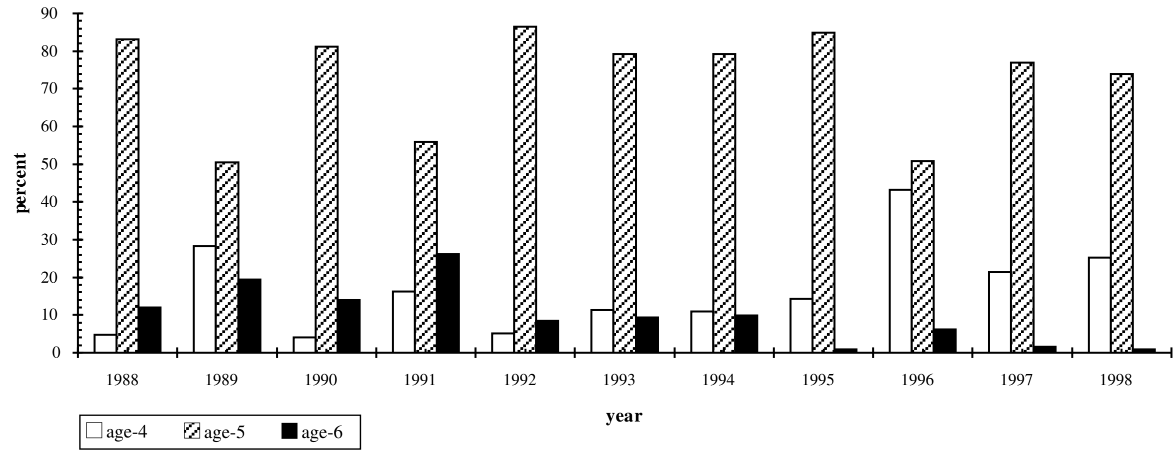


Figure 5.2-2 Nechako River: percent age composition of male chinook spawners, 1988 to 1998

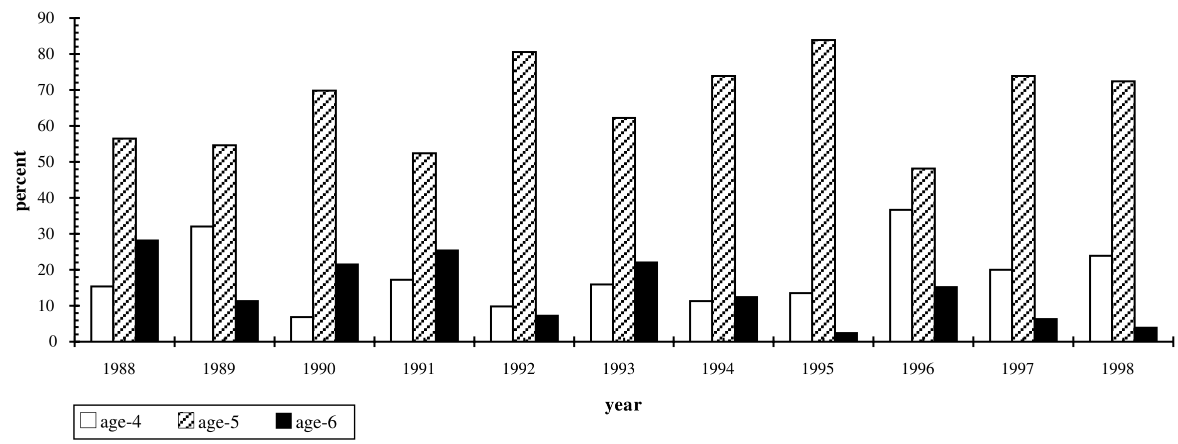
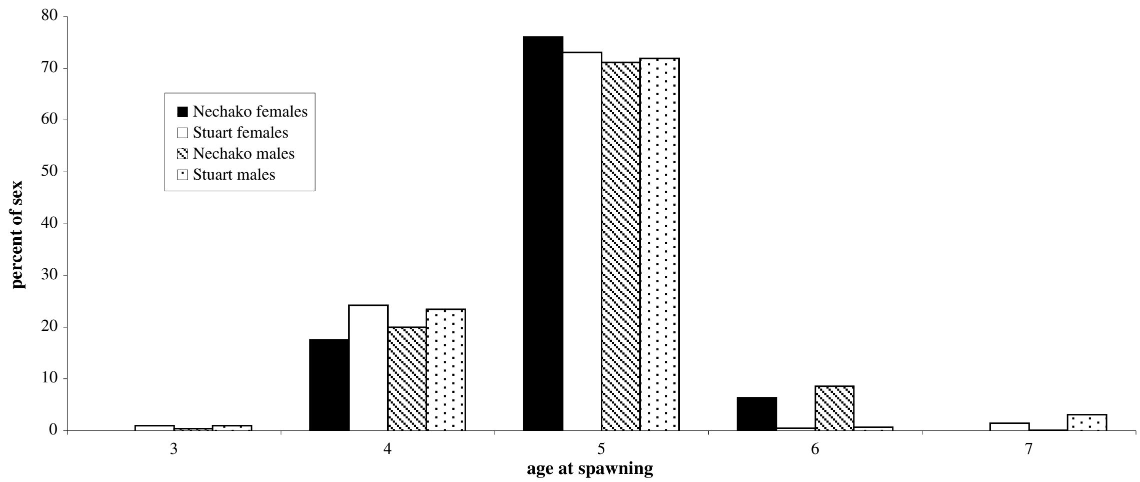


Figure 5.2-3 Nechako River: percent age composition of chinook spawners, 1988 to 1998

Table 5.2-3 Nechako and Stuart River: percent age composition of chinook spawners, based on a combination of scale and fin ray analyses (resolved age), 1988 to 1998

year	3	4	5	6	7	n	3	4	5	6	7	n
	age at spawning (years):						age at spawning (years):					
	Nechako (females)						Stuart (females)					
1988	0.0	4.8	83.2	12.0	0.0	125	0.0	27.5	67.5	5.0	0.0	40
1989	1.0	28.2	50.5	19.4	1.0	103	0.0	25.0	72.9	2.1	2.1	192
1990	0.0	4.1	81.1	13.9	0.8	122	0.0	11.9	88.1	0.0	0.0	202
1991	0.0	16.2	55.9	26.1	1.8	111	0.0	32.7	63.1	4.2	3.7	523
1992	0.0	5.1	86.4	8.5	0.0	118	0.0	5.3	93.8	0.9	0.9	433
1993	0.0	11.3	79.2	9.4	0.0	106	5.9	5.9	70.6	17.6	0.0	17
1994	0.0	10.9	79.3	9.8	0.0	92	0.0	24.7	75.3	0.0	0.0	97
1995	0.0	14.3	84.9	0.8	0.0	126	0.6	34.7	64.7	0.0	0.0	167
1996	0.0	43.2	50.8	6.1	0.0	132	0.0	38.7	58.5	2.8	0.0	106
1997	0.0	21.4	77.0	1.6	0.0	126	11.4	30.0	55.0	3.6	0.0	140
1998	0.0	25.2	74.0	0.8	0.0	127	0.7	38.5	60.8	0.0	0.0	143
pooled	**0.1**	**17.1**	**73.1**	**9.5**	**0.3**	**1288**	**0.9**	**24.2**	**72.8**	**2.1**	**1.3**	**2060**
	Nechako (males)						Stuart (males)					
1988	0.0	15.3	56.5	28.2	0.0	85	3.4	25.9	56.9	13.8	0.0	58
1989	1.0	32.0	54.6	11.3	1.0	97	1.1	17.2	75.3	6.5	0.0	93
1990	0.0	6.8	69.9	21.4	1.9	103	0.0	10.6	85.6	3.9	0.0	180
1991	2.0	17.2	52.5	25.3	3.0	99	0.4	29.9	63.0	6.8	0.0	281
1992	2.4	9.8	80.5	7.3	0.0	82	0.0	7.4	91.0	1.6	0.0	122
1993	0.0	15.9	62.2	22.0	0.0	82	5.9	41.2	47.1	5.9	0.0	17
1994	0.0	11.3	73.8	12.5	2.5	80	4.7	34.4	59.4	1.6	0.0	64
1995	0.0	13.6	84.0	2.5	0.0	81	0.9	34.2	62.4	2.6	0.0	117
1996	0.0	36.7	48.1	15.2	0.0	79	0.0	22.1	76.8	1.1	0.0	95
1997	0.0	20.0	73.8	6.3	0.0	80	2.7	22.5	72.1	2.7	0.0	111
1998	0.0	23.8	72.5	3.8	0.0	80	0.0	28.0	71.0	0.9	0.0	107
pooled	**0.5**	**18.3**	**65.8**	**14.6**	**0.8**	**948**	**1.0**	**23.1**	**71.7**	**4.2**	**0.0**	**1245**
total	**0.3**	**17.6**	**70.0**	**11.6**	**0.5**	**2236**	**0.9**	**23.8**	**72.4**	**2.9**	**0.8**	**3305**

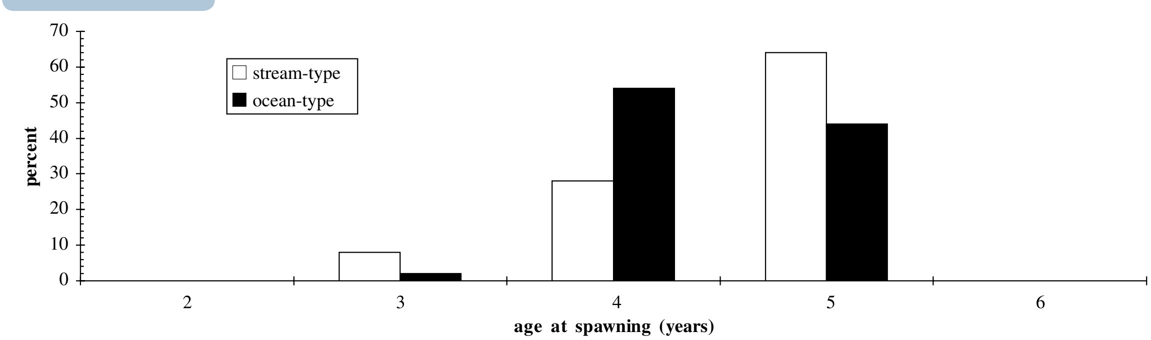
Figure 5.2-4 **Nechako and Stuart Rivers: percent age composition of chinook spawners, based on a combination of scale and fin ray analysis (resolved age), 1988 to 1998**



Fraser *et al.* (1982) summarized the age composition of over 16,000 chinook captured in the lower Fraser River gillnet fishery from 1957 to 1978. They were not able to determine the stock origin of their samples, although about one-third of the samples were known to be ocean-type fish[32] migrating to the Harrison River because of the late run timing of that stock. This mixing of ocean and stream-type age structures means that the data are not useful for assigning separate age structures for the two races of chinook.

Shepherd *et al.* (1986) compiled scale-derived ages from several studies on the chinook stocks that spawn above Hope. The sample of over 3,000 was collected mostly during 1980 and 1981 and, unlike the data reported by Fraser *et al.* (1982), could be used to assign separate age structures to stream- and ocean-type populations, although there was insufficient data to assign separate age structures to each of the 28 large chinook stocks in the Fraser River basin. Instead, Shepherd *et al.*'s (1986) age data on middle and upper Fraser River chinook stocks was pooled to estimate an average age-at-return for each race (**Figure 5.2-5**). The stream-type age structure is similar to the age structures estimated for the Nechako and Stuart River stocks.

Figure 5.2-5 **Fraser River Basin: average age structure of chinook, 1988 to 1998***



* Based on Shepherd *et al.* (1986)

32 Some chinook will migrate to sea during their first year (ocean-type) while others will rear in fresh water for a year or more before entering the ocean (stream type).

The average age structure for stream-type chinook based on Shepherd *et al.*'s (1986) data was supported by Bradford (1994), who reported that an average of 75% of chinook from the upper and middle Fraser River were five-year olds and 25% were four-year olds.[33]

5.2.2.2 Sex Ratio

Between 1974 and 1998, 4,994 Nechako River and 9,364 Stuart River chinook carcasses were sexed (**Table 5.2-4**). The average number of carcasses sampled in each river in each year was 238 and 936, respectively.

The sex ratio (number of female carcasses per male carcass) for the Nechako River population ranged from 1.00 to 1.92 with a mean of 1.37 (n = 21, SD = 0.27). The eleven years of data collected by the Technical Committee (1988 to 1998) fell within the range reported for the 1974 to 1987 period, indicating that there has been no obvious change in sex ratio between the pre-program period and the NFCP period (**Figure 5.2-6**).

The sex ratio of the Stuart River chinook population was on average somewhat lower that of the Nechako River population, ranging from 0.70 to 1.65 with a mean of 1.26 (n = 10, SD = 0.28). However, for any given year the sex ratio of the Stuart River population was not consistently less than sex ratio of the Nechako River population during the program period.

There are at least four possible reasons why more female carcasses than male carcasses are counted in the Nechako River:

- **bias in sampling –** Female carcasses may be more susceptible to collection than male carcasses because they may be more likely than males to be swept into shallow water where carcasses are easiest to collect. This may occur because females tend to reside near their redds, which are constructed in shallow water, whereas males may reside over a greater range of depths, including deep pools where their carcasses would never be seen.
- **variations in residence –** Males may have a different residence time on the spawning grounds than females.
- **sex-biased survival –** More females than males survive to enter the river and spawn. Sex-biased survival may occur if commercial, sport and aboriginal fisheries tend to select for male chinook rather than female chinook. Although Nechako River males are usually slightly larger than females, it is unlikely that the small differences in body size between sexes would be sufficient to produce skewed sex ratios as a function of fishing selection. Alternatively, females may be more likely than males to survive the migration up the Fraser River. This is also unlikely because of the small size differences between the sexes.
- **the ratio of "jacks" to "jills" –** A greater proportion of males mature as three-year olds (referred to as "jacks") than females (referred to as "jills"), thereby leaving fewer four- to five-year old male spawners than female spawners of the same age.[34]

[33] Bradford (1994) only reported the percentages of four and five-year olds.

[34] The ratio of jacks to adults in the Nechako River chinook population is very low.

Table 5.2-4 Nechako and Stuart Rivers: sex ratios of recovered chinook carcasses, 1974 to 1998.

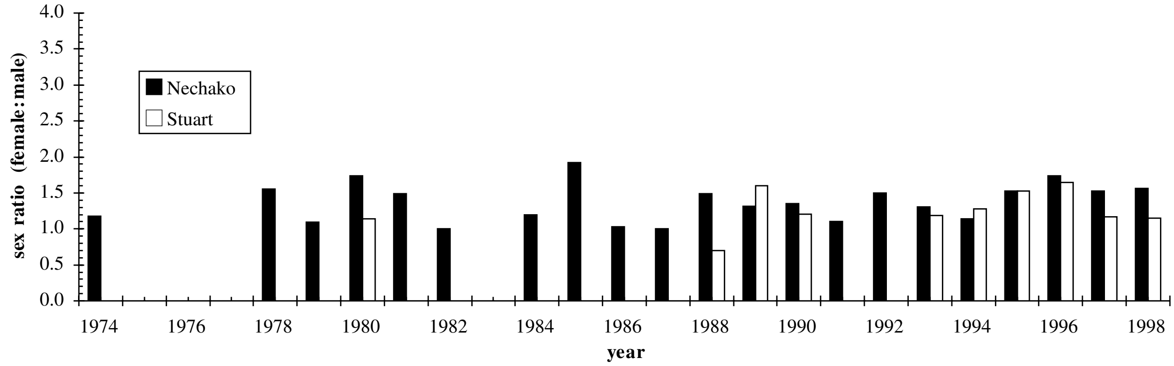
	Nechako			ratio	Stuart			ratio	
year	males	females	total	(F/M)	males	females	total	(F/M)	sources**
1974	75	88	163	1.17	-	-	-	-	1
1975	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-
1978	226	351	577	1.55	-	-	-	-	1
1979	21	23	44	1.01	-	-	-	-	1
1980	73	127	200	1.74	153	175	328	1.14	1, 2
1981	72	107	179	1.49	-	-	-	-	1
1982	100	100	200	1.00	-	-	-	-	1
1983	-	-	-	-	-	-	-	-	-
1984	81	97	178	1.20	-	-	-	-	1
1985	63	121	184	1.92	-	-	-	-	1
1986	101	104	205	1.03	-	-	-	-	1
1987	100	100	200	1.00	-	-	-	-	3
1988	85	127	212	1.49	60	42	102	0.70	4
1989	115	151	266	1.31	174	279	453	1.60	4
1990	170	230	400	1.35	236	285	521	1.21	4
1991	144	159	303	1.10	*	*	*	*	4
1992	149	224	373	1.50	*	*	*	*	4
1993	82	107	189	1.30	86	102	188	1.19	4
1994	81	92	173	1.14	291	373	664	1.28	4
1995	101	154	255	1.52	650	993	1643	1.53	4
1996	97	169	266	1.74	967	1591	2558	1.65	4
1997	86	131	217	1.52	954	1110	2064	1.16	4
1998	82	128	210	1.56	392	451	843	1.15	4
All Years									
sum	2104	2890	4994		3963	5401	9364		
mean	100	138	238	1.37	396	540	936	1.26	
SD	43	67	108	0.27	343	514	851	0.28	
n	21	21	21	21	10	10	10	10	
min	21	23	44	1.00	60	42	102	0.70	
max	226	351	577	1.92	967	1591	2558	1.65	
1988-1998									
sum	1192	1672	2864		3810	5226	9036		
mean	108	152	260	1.40	423	581	1004	1.37	
SD	32	43	73	0.19	352	528	874	0.29	
n	11	11	11	11	9	9	9	9	
min	81	92	173	1.10	60	42	102	0.70	
max	170	230	400	1.74	967	1591	2558	1.65	

Dashes indicate no data were available.

* data excluded due to potential sex biases in recovery methods for these years

** Sources: 1 = summary reported by Jaremovic and Rowland (1988), 2 = Hickey and Lister (1981), 3 = Rowland (1988), 4 = annual NFCP carcass recovery reports.

Figure 5.2-6 **Nechako and Stuart Rivers: sex ratios of recovered chinook carcasses, 1974 to 1998***



* Data unavailable for both rivers for 1975, 1976, 1977 and 1983.
Data unavailable for Stuart River for 1974, 1978, 1981, 1982, and 1984 to 1987.

5.2.2.2.1 Fecundity

The number of eggs Nechako River female chinook carry to the spawning grounds has only been counted for eight females over the last 20 years (**Table 5.2-5**). Mean fecundity was 5,769 eggs/female (n = 8, SD = 870, range = 5,000 to 7,200). Fecundity was not significantly correlated with POH length using either arithmetic or ln-transformed values of fecundity and length. This was due to the low sample size combined with the fact that female size typically explains only 50% or less of the variation in chinook fecundity within a population (Healey 1991).

All of the records of individual fecundity and size for Fraser River basin chinook were collected from the literature to provide a framework for comparing fecundity of Nechako River chinook to other stocks. Godfrey (1968) reported biological characteristics of chinook captured in test-fisheries at the mouth of the Fraser River from 1964 to 1966. The individual data were not included in the report: only the coefficients of the linear regression of $\log_{10}$ (fecundity) on $\log_{10}$ (fork length) for all 351 records combined were reported. Healey and Heard (1984) modified the equation by converting fork length to POH length and $\log_{10}$ to ln to obtain a relationship for all Fraser River basin chinook stocks combined:

$$\ln(\text{fecundity}) = -0.61 + 1.412 \ln(\text{POH length, mm})$$

The only other records on chinook fecundity were found in consultants' reports of bio-reconnaissance surveys of upper Fraser River basin streams conducted for the Salmonid Enhancement Program in the early 1980s (Shepherd *et al.* 1986). Data on five streams were available: Bowron, Quesnel, Stuart and Willow Rivers, and Slim Creek (**Table 5.2-5**).

Hickey and Lister (1981) reported that fecundities for the Stuart River stock might have been negatively biased because of eggs being extruded prior to sampling, so those data were not included in any comparisons. Following the recommendation of Healey and Heard (1984), both fecundities and POH lengths were ln-transformed prior to plotting because the fecundity of fish generally increases directly with the volume of a fish or the cube of its length.

Individual fecundities for the five upper Fraser River basin stocks, including the Nechako River, were slightly greater than predicted by the regression line reported by Godfrey (1968) for a mixture of Fraser River chinook stocks

Table 5.2-5 **Fraser River Basin: POH* length (cm) and fecundity of chinook**

stock	year	POH length (cm)	fecundity (eggs/female)	sources**
Bowron	1980	65.5	6,407	4
Bowron	1980	84.0	8,725	4
Bowron	1980	58.4	5,217	4
Bowron	1980	72.7	5,267	4
Bowron	1980	66.0	5,452	4
Bowron	1980	57.9	5,589	4
Bowron	1980	71.0	6,164	4
Bowron	1980	66.0	6,816	4
Bowron	1980	71.0	7,183	4
Nechako	**1978**	**68.4**	**5,250**	**1**
Nechako	**1978**	**66.3**	**6,305**	**1**
Nechako	**1979**	**70.3**	**7,200**	**2**
Nechako	**1979**	**61.1**	**5,313**	**2**
Nechako	**1979**	**61.1**	**5,284**	**2**
Nechako	**1980**	**71.0**	**5,000**	**7**
Nechako	**1980**	**71.0**	**5,000**	**7**
Nechako	**1985**	**76.0**	**6,800**	**8**
Quesnel	1979	63.3	5,584	2
Quesnel	1979	64.2	5,769	2
Quesnel	1979	67.2	5,234	2
Quesnel	1979	67.2	6,364	2
Quesnel	1979	67.9	6,042	2
Quesnel	1979	68.7	5,906	2
Quesnel	1979	70.2	7,377	2
Quesnel	1979	71.0	7,123	2
Quesnel	1979	71.5	5,779	2
Quesnel	1979	72.9	7,854	2
Quesnel	1979	73.2	7,844	2
Quesnel	1979	74.5	6,539	2
Quesnel	1979	67.0	5,262	5
Quesnel	1979	63.5	5,581	5
Quesnel	1979	71.5	5,747	5
Quesnel	1979	64.0	5,760	5
Quesnel	1979	68.5	5,900	5
Quesnel	1979	68.0	6,053	5
Quesnel	1979	67.0	6,346	5
Quesnel	1979	74.5	6,524	5
Quesnel	1979	71.0	7,098	5
Quesnel	1979	70.0	7,277	5
Quesnel	1979	73.0	7,850	5
Quesnel	1980	61.0	4,255	5
Quesnel	1980	73.0	5,836	5
Quesnel	1980	74.5	6,053	5
Quesnel	1980	65.0	6,435	5
Quesnel	1980	74.0	6,193	5
Quesnel	1980	72.6	6,320	5
Quesnel	1980	74.5	6,588	5
Quesnel	1980	72.7	7,264	5
Quesnel	1980	70.8	7,850	5
Slim	1980	67.5	5,953	4
Slim	1980	67.5	4,317	4
Slim	1980	69.5	5,612	4
Slim	1980	74.0	6,031	4
Slim	1980	67.0	6,044	4
Slim	1980	71.0	6,907	4
Slim	1980	71.0	8,526	4
Slim	1980	70.5	9,065	4
Slim	1981	62.3	5,620	6
Slim	1981	68.0	3,724	6
Slim	1981	73.1	3,822	6
Slim	1981	68.8	5,778	6
Slim	1981	70.1	9,807	6
Slim	1981	71.3	6,884	6
Slim	1981	73.3	6,745	6
Stuart	1980	73.5	6,710	3
Stuart	1980	74.0	4,332	3***
Stuart	1980	72.0	3,299	3***
Stuart	1980	73.5	5,652	3***
Stuart	1980	66.0	5,929	3***
Stuart	1988	76.0	8,800	9
Stuart	1992	76.0	5280	9
Stuart	1994	72.9	5,763	9
Stuart	1995	72.5	5,440	9
Willow	1980	71.5	6,656	4

* POH = postorbital hypural
** Sources: 1 = Fee and Sheng (1978), 2 = Olmsted *et al.* (1980), 3 = Hickey and Lister (1981), 4 = Murray *et al.* (1981), 5 = Olmsted *et al.* (1981), 6 = Rosberg and Aitken (1982), 7 = Russell *et al.* (1983), and 8 = Jaremovic and Rowland (1988).
*** possibly undercounted due to some eggs already extruded

(**Figure 5.2-7**). There was also substantial variation around that regression line. Healey and Heard (1984) reported that there is a great deal of variation in chinook fecundity that cannot be explained by body size, age at maturation or latitude.

A linear regression of fecundity on length for the upper Fraser River basin records (except the Stuart River samples) pooled was (n = 65, R^2 = 0.17, P<0.001):

$$\ln(\text{fecundity}) = 0.854 + 1.204 \ln(\text{POH length})$$

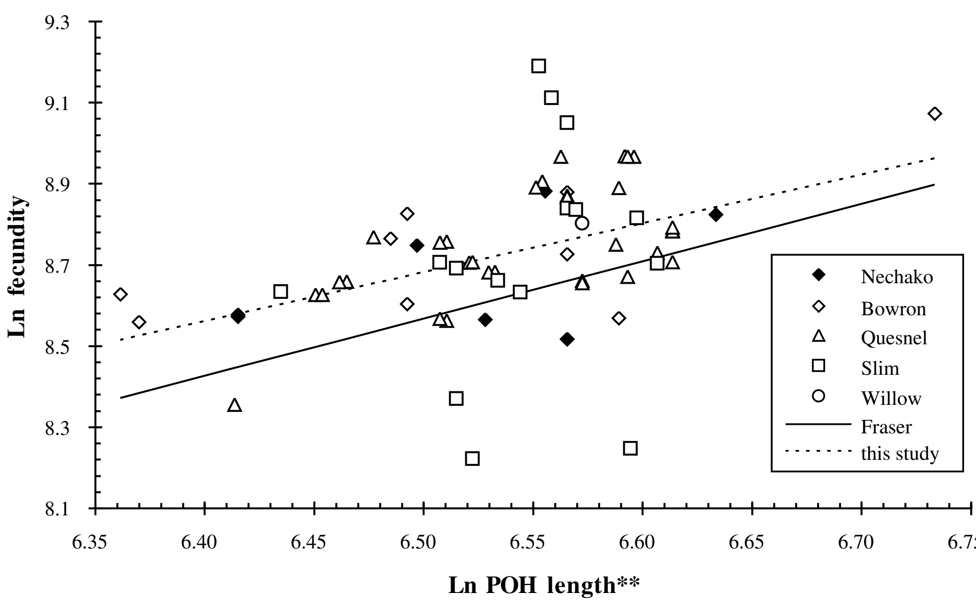
Neither the intercept nor the slope of that regression was significantly different from Healey and Heard's (1984) revision of Godfrey's (1968) regression (**Figure 5.2-7**).

5.2.2.3 Egg Retention

Not every chinook successfully releases, fertilizes and buries in gravel every egg; exhausted spawners may die before they have an opportunity to release all their eggs. Healey (1991) reviewed the available evidence and concluded that the percentage of eggs retained by female chinook was generally very low, ranging from 0.5% to 1.3%. However, diseased fish could retain up to 25%.

Between 1980 and 1998, female Nechako River chinook carcasses were examined each year for the number of eggs retained in the body cavity (**Table 5.2-6**). The number of female carcasses that retained all or a substantial portion of their potential fecundity—arbitrarily defined as >1,000 eggs/female in Technical Committee carcass survey reports—ranged from zero to seventeen, a maximum pre-spawning mortality of less than 2% of the total spawning population. The average number of retained eggs per female carcass ranged from 1 to 299. Based on the average Nechako River population fecundity of 5,769 eggs per female, that is equivalent to a range of retention of 0.02% to 5.18% of total potential fecundity.

Figure 5.2-7 **Fraser River: fecundity/length relationship of chinook stocks, 1974 to 1998***



* Fraser stock relationship from Godrey, 1968.
** POH = postorbital hypural

Table 5.2-6 Nechako River: mean egg retention in chinook, 1980 to 1998

year	number of retained eggs: mean	range	n	percent retained eggs	number of female carcasses with > 1,000 eggs	source*
1980	12	0 - 850	110	**0.21**	-	1
1981	1	0 - 6	107	**0.02**	-	1
1982	10	0 - 350	100	**0.17**	-	1
1983	-	-	-	**-**	-	-
1984	21	0 - 1200	97	**0.36**	1	2
1985	38	0 - 600	120	**0.66**	0	2
1986	30	0 - 1600	104	**0.52**	1	2
1987	185	0 - 6000	100	**3.21**	5	3
1988	91	0 - 4320	127	**1.58**	3	4
1989	239	0 - 6073	150	**4.14**	8	4
1990	146	0 - 8831	230	**2.53**	5	4
1991	168	0 - 7289	159	**2.91**	5	4
1992	125	0 - 7395	224	**2.17**	5	4
1993	284	0 - 6848	106	**4.92**	6	4
1994	52	0 - 2272	92	**0.90**	2	4
1995	290	0-6750	154	**5.03**	10	4
1996	34	0-3600	169	**0.59**	3	4
1997	126	0-4081	131	**2.18**	4	4
1998	299	0-10026	128	**5.18**	4	4

* Sources: 1 = Russell *et al.* (1983), 2 = Jaremovic and Rowland (1988), 3 = Rowland (1988), 4 = NFCP (unpubl. data).

5.2.2.4 Body Size

During the NFCP period, the pooled mean POH length between 1988 and 1998 fell within a narrow range of 67.9 to 73.0 cm (**Table 5.2-7**). This is very similar to the range of 67.0 to 72.7 cm reported for the 1974 to 1987 period. Jaremovic and Rowland (1988) compared mean lengths among the upper and lower river and did not find any significant differences.

The mean POH length of Nechako River chinook is greater for males than females (**Figure 5.2-8**), although the differences do not appear to be statistically significant for most years. The causes of these differences are not clear. Most likely they are related to the causes proposed above for sex ratio differences (*i.e.,* sex-biased sampling of carcasses and differences between the sexes in age and size at sexual maturation).

However, unlike sex ratios, mean POH lengths have been reported for at least 20 chinook spawning populations in the Fraser River basin (**Table 5.2-8**). The data were collected mainly by contractors working on salmonid enhancement projects in the upper and middle Fraser River in 1980 and 1981 (Shepherd *et al.* 1986); Nechako River spawners are the fourth largest chinook spawners in the basin[35] (**Figure 5.2-9**).

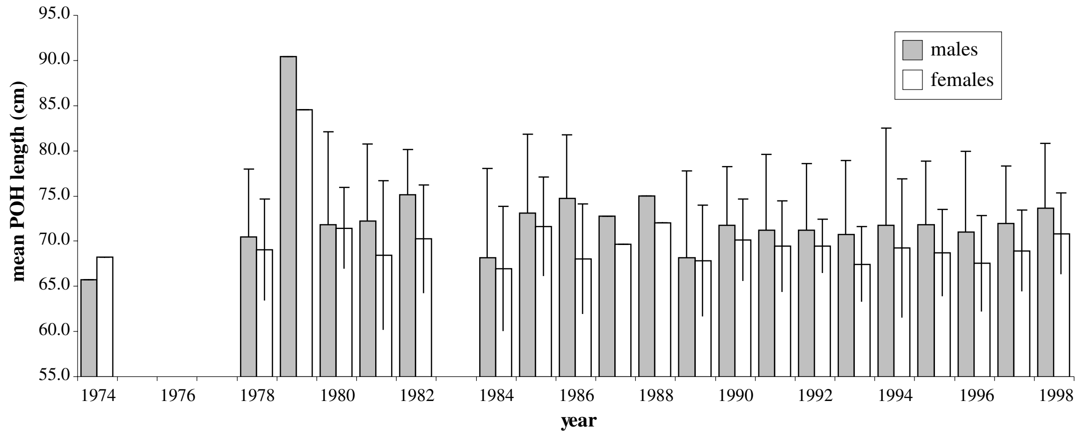
[35] This finding must be interpreted with caution because of the low sample sizes and short time periods over which data were collected for most non-Nechako River populations.

Table 5.2-7	Nechako River: mean POH* length (cm) of chinook, 1974 to 1998

	males				females				combined			
year	mean	SD	n	SE	mean	SD	n	SE	mean	SE	n	sources**
1974	65.7	-	75		68.2	-	88		67.0	-	163	1
1975	-	-	-		-	-	-		-	-	-	-
1976	-	-	-		-	-	-		-	-	-	-
1977	-	-	-		-	-	-		-	-	-	-
1978	70.4	7.5	226	0.50	69.0	5.6	351	0.30	69.7	-	577	1
1979* **	90.4	-	21		84.5	-	23		87.4	-	44	1
1980	71.8	10.3	73	1.20	71.4	4.5	127	0.40	71.5	0.5	200	1
1981	72.2	8.5	72	1.00	68.4	8.3	107	0.80	70.0	0.6	179	1
1982	75.1	5.0	100	0.50	70.2	6.0	100	0.60	72.7	0.4	200	1
1983	-	-	-		-	-	-		-	-	-	-
1984	68.1	9.9	81	1.10	66.9	6.9	97	0.70	67.4	0.6	178	1
1985	73.1	8.7	64	1.09	71.6	5.5	120	0.50	72.1	0.5	184	1
1986	74.7	7.0	101	0.70	68.0	6.1	104	0.60	71.3	0.5	205	1
1987	72.7	-	100		69.6	-	100		71.2	-	200	2
1988	75.0	-	85		72.0	-	127		73.0	-	212	3
1989	68.1	9.7	115	0.90	67.8	6.1	151	0.50	67.9	0.5	266	3
1990	71.7	6.5	170	0.50	70.1	4.5	230	0.30	70.8	0.3	400	3
1991	71.2	8.4	144	0.70	69.4	5.0	159	0.40	70.3	0.4	303	3
1992	71.2	7.3	149	0.60	69.4	3.0	224	0.20	70.1	0.3	373	3
1993	70.7	8.2	83	0.90	67.4	4.2	109	0.40	68.9	0.5	192	3
1994	71.7	10.8	81	1.20	69.2	7.7	92	0.80	70.4	0.7	173	3
1995	71.8	7.0	101	0.70	68.7	4.8	154	0.39	70.0	0.36	255	3
1996	71.0	8.9	97	0.90	67.5	5.3	169	0.41	68.8	0.42	266	3
1997	71.9	6.4	86	0.69	68.9	4.5	131	0.39	70.1	0.37	217	3
1998	73.6	7.2	82	0.80	70.8	4.5	128	0.40	71.9	0.51	128	3

Dashes indicate no data available
* POH = postorbital hyperal
** Sources: 1 = Jaremovic and Rowland (1988), 2 = Rowland (1988), 3 = NFCP (unpubl. data).
*** reported as “fork length”, which is longer than POH length

Figure 5.2-8 Nechako River: mean (±1SD) POH* length (cm) chinook spawners, 1974 to 1998**



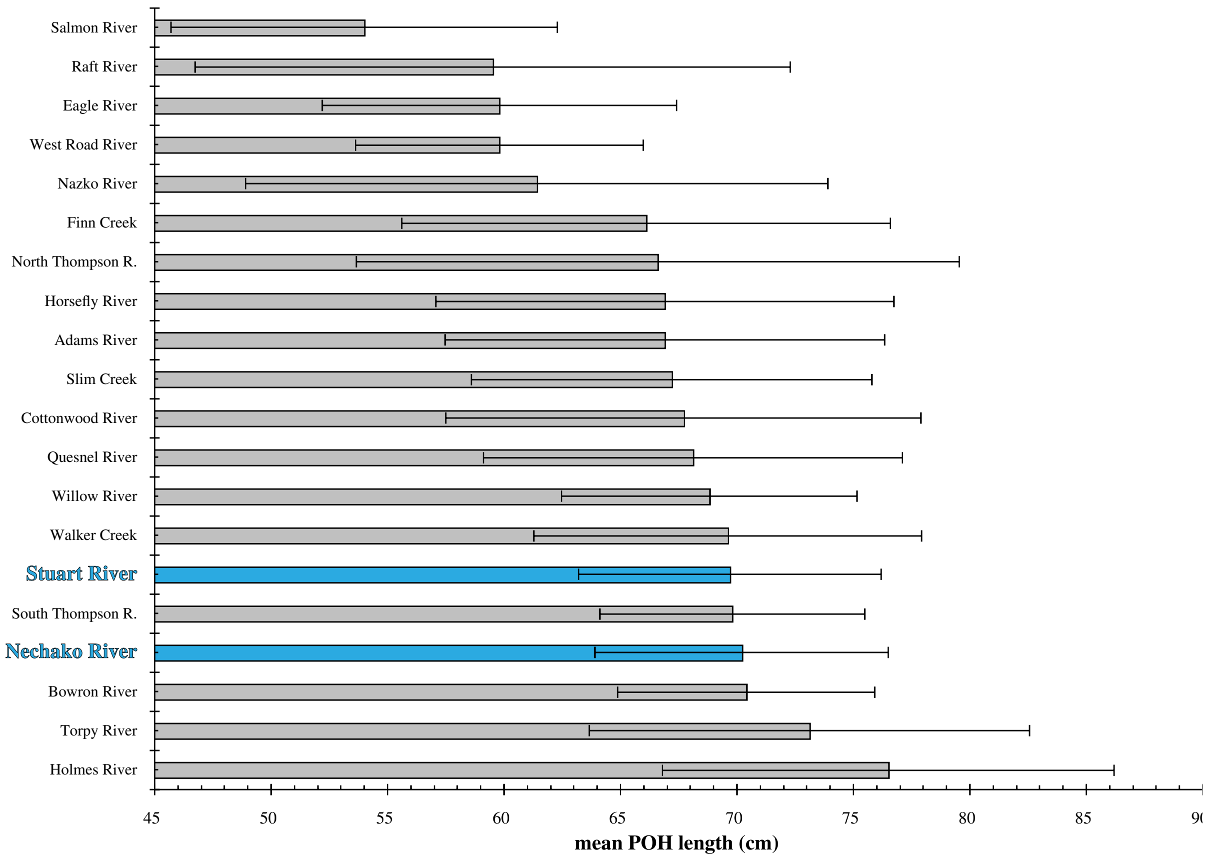
* POH = postorbital hypural
** Data unavailable for 1975 to 1977 and 1983

Table 5.2-8 Fraser River Basin: POH* length (cm) of chinook

	POH (cm)			
stock	**mean**	**SD**	**n**	**source****
Salmon River	54.0	8.3	95	6
Raft River	59.5	12.8	290	7
West Road River	59.8	6.2	17	5
Eagle River	59.8	7.6	118	6
Nazko River	61.4	12.5	10	5
Finn Creek	66.1	10.5	689	7
North Thompson R.	66.6	13.0	397	7
Adams River	66.9	9.4	123	6
Horsefly River	66.9	9.8	64	4, 5
Slim Creek	67.2	8.6	419	1, 2
Cottonwood River	67.7	10.2	9	5
Quesnel River	68.1	9.0	418	4, 5
Willow River	68.8	6.3	82	2
Walker Creek	69.6	8.3	63	1
Stuart River	69.7	6.5	4943	8
South Thompson R.	69.8	5.7	807	6
Nechako River	70.2	6.3	2864	8
Bowron River	70.4	5.5	190	2
Torpy River	73.1	9.5	81	1
Holmes River	76.5	9.7	12	1

* POH = postorbital hypural
** Sources: 1 = Rosberg and Aitken (1982), 2 = Murray *et al.* (1981), 3 = Hickey and Lister (1981), 4 = Olmsted *et al.* (1980), 5 = Olmsted *et al.* (1981), 6 = Whelen and Olmsted (1982), 7 = Scott *et al.* (1982), 8 = NFCP (unpubl. data).

Figure 5.2-9 **Fraser River Basin: mean POH* length (± 1SD) of chinook spawners**



* POH = postorbital hypural

5.2.3 Summary: Chinook Carcass Recovery Project

There were no notable differences in adult characteristics between the chinook from the Nechako River and those from the unregulated streams of the upper Fraser River basin. The age structure of Nechako River chinook closely resembled the age structure found on the unregulated Stuart River and was not markedly different from the age structure of combined Fraser River basin stream-type chinook. The sex ratios of the Nechako and Stuart River chinook populations were skewed towards females, but that may be the result of a bias towards sampling female carcasses, compounded by sex-related differences in age at sexual maturation. The fact that the Nechako River (regulated) and Stuart River (unregulated) populations have a similar range of sex ratios and age structure indicates that the observed ratios in the Nechako River were not related to regulating the river.

The fecundity of the Nechako River population appeared to follow the same general trend for body length observed for other Fraser River basin chinook stocks. Egg retention was low, indicating most females had the opportunity to release their eggs.

Section 6
Chinook: Secondary Monitoring

THE NUMBERS OF CHINOOK SALMON RETURNING TO THE NECHAKO RIVER ANNUALLY ARE AFFECTED BY BOTH INTRINSIC (*i.e.,* Nechako River) and extrinsic (*e.g.,* Fraser River, Pacific Ocean) factors. This means that the abundance of returning adult salmon alone cannot be relied on to indicate or detect changes in the quality of the Nechako River habitat.

To provide a more reliable indication of changes in habitat, the Nechako Fisheries Conservation Program's (NFCP) Technical Committee instituted two secondary monitoring projects. These projects were designed to monitor freshwater life-history components and to provide an early warning of changes in stock status or habitat variables. The Fry Emergence Project [see *ss. 6.1 Fry Emergence Project*] allowed an assessment of the success of fry emergence within the study area, as an indicator of chinook incubating habitat, while the Juvenile Chinook Out-migration Project [see *ss.6.2 Juvenile Chinook Out-migration Project*] allowed the development of an index of juvenile chinook migrating from the system, as an indicator of the condition of juvenile rearing habitat. Where possible, the data has been updated to 2002 to provide the most complete description of the spawner to emergent fry and spawner to out-migrant index relationships[36].

6.1 FRY EMERGENCE PROJECT

The Fry Emergence Project was a key element of the Early Warning Monitoring Program (BCUC 1994). The objectives of the project were to:

- acquire baseline information on the biological characteristics of emergent chinook fry in the upper Nechako River; and
- develop an index of emergence success to monitor the quality of the chinook incubation environment after completion of the Kemano Completion Project.

Specific tasks included monitoring:

- changes in the quality of the incubation environment in the upper Nechako River by developing an index for fry emergence timing and abundance;
- egg-to-fry survival using the fry emergence timing and abundance index; and
- the average size and condition of emerging chinook fry.

[36] Emergent fry per spawner and out-migrants per spawner relationships presented in this section are based on finalized Nechako River escapement data presented in *Section 5 Chinook: Primary Monitoring*. Consequently, the values differ slightly from data in individual project reports, which used preliminary escapement data.

Bert Irvine's Lodge (km 19) in the upper Nechako River just downstream of a known chinook spawning area and easily accessible by road was selected as the site for this project.

6.1.1 Inclined Plane Traps

The Fry Emergence Project began in the spring of 1990 with the installation of four inclined plane traps (IPT) to sample chinook fry as they emerged from the gravel. The traps were anchored by two cables across the river and positioned in pairs, with two traps on the right margin and two in mid-channel. In subsequent years (1991 to 2002) the four traps were placed approximately 8 m apart on a single cable spanning the entire channel, with one on each margin and two in mid-channel to provide a better estimate of fry distribution across the river.

The trap located on the left margin was approximately 20 m from the shore and the trap on the right margin was approximately 4 m from the shore. The floats of the margin traps were settled on the substrate and fished approximately 0.5 m of water. Mid-channel traps also sampled 0.5 m of water, but were supported by floats on the surface of the water.

From the beginning of the project, the margin traps were fitted with wings to increase the proportion of the river sampled[37]. The wings were constructed of wood frames with 63 mm mesh and were positioned between the trap and the upstream margin. The wings varied in length within and between seasons, depending on the river stage, but were approximately 35 m long on the left margin and 7 m long on the right margin.

As flows changed, the margin traps could be moved and/or the wings could be modified to maintain the traps' relative position in the river and water column. The traps and wings were cleaned as often as necessary to ensure proper functioning.

Average daily water temperatures and daily water flows were available from a datalogger—Water Survey of Canada (WSC) Data Collection Platform Station 08JA017 ("Nechako River below Cheslatta Falls")—installed at Bert Irvine's Lodge by the WSC. The station recorded water temperature on an hourly basis; mean daily temperatures were the average of 24 hourly measurements.

Daily water flows were also recorded by WSC Station 08JA013 at Skins Lake Spillway, while spot water temperatures, recorded to the nearest 0.1°C with handheld thermometers, and river stage measurements, were recorded daily at the IPTs throughout the sampling period[38].

The proportion of total Nechako River flows sampled by each trap was determined by measuring the cross sectional area of the trap and multiplying it by the average velocity through the traps. Several depth and velocity measurements were made for the wings along a line perpendicular to the shore upstream of the trap. The discharge was calculated for segments of the fence and summed. The total flow through the margin traps was determined as the sum of the flow through the IPT and the wings.

Velocities through the traps were recorded with a Marsh-McBirney velocity meter (1990 to 1994) or a Swoffer 2100 velocity meter (1995 to 2002).

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[37] Wings were installed in 1990 for only part of the sampling period (March 25 to April 12), but were attached to the margin traps for the duration of all subsequent sampling periods.

[38] The Department of Fisheries and Oceans maintains a separate set of temperature dataloggers at Bert Irvine's Lodge (km 19), Greer Creek and Fort Fraser, and in other locations in the lower Nechako River and in the Fraser River basin. This data has not been used in Technical Committee projects because they have not been available in time to prepare reports.

From 1990 to 1994, velocity measurements were taken daily during periods of changing flow, as indicated by staff gauge observations. At other times it was assumed that flows through the traps would remain the same at the same staff gauge level. From 1995 to 2002, velocity sampling was conducted at the traps every second day, when possible, to provide more accurate daily flows for index calculations.

6.1.1.1 Sampling the IPTs

Depending on ice conditions and river temperatures over the winter, sampling usually began in the second week of March of each year and continued until mid- to late-May when the number of fry was in decline (**Table 6.1-1**). The start date was based on accumulated thermal units (ATU) calculated from the peak of spawning in September of the previous year. Most chinook fry were expected to emerge from the gravel by approximately 900 to 1,000 ATU (March and Walsh 1987; Shepherd 1984).

Table 6.1-1 **Nechako Basin: dates of chinook fry emergence, sampled by inclined plane traps (Bert Irvine's Lodge)**

year	sampling period
1990	March 17 - April 30
1991	March 7 - May 22
1992	March 8 - May 13
1993	March 15 - May 20
1994	March 7 - May 20
1995	March 8 - May 25
1996	March 12 - May 22
1997	March 7 - May 20
1998	March 10 - May 15

Traps were checked twice daily for the duration of the sampling period. The morning sample included fry caught during the night; the evening sample included fry trapped during the day. All fish were identified to species, counted and then released live into the river. Chinook fry and other salmonids were sub-sampled (maximum = 15 per species per trap); fork length was measured to the nearest 1 mm with a measuring board, and wet weight was measured to the nearest 0.01 g with an electronic balance. Bam's (1970) development index (K_D, g/mm) was calculated for each measured chinook fry as,

$$K_D = 10(W^{1/3})/L$$

where:

- W = wet weight (g); and
- L = fork length (mm).

6.1.1.2 Index of Fry Emergence

The daily index of fry emergence from the substrate was estimated from the proportion of discharge sampled by each IPT and its wings, and the number of chinook counted in each IPT as,

$$N_I = n_i(V_i/v_i)$$

where:

- N_I = expanded number of fish;
- n_i = number of fish observed;
- V_i = total river flow;
- v_i = flow through trap; and
- i = the i^{th} sampling date.

Data for all IPTs were combined for each day because statistical independence among IPTs could not be assumed. Consequently, the index of fry emergence is the sum of all four IPTs' expanded daily catches weighted by the volume filtered by each trap. It is equivalent to an estimate weighed by the volume filtered:

$$\text{Index} = \Sigma\,(N_I v_i) \text{ of all traps}/\Sigma\, v_i \text{ of all traps.}$$

Implicit in the index is the assumption that the distribution of fry across the river is consistent among years and at different river flows. Any biases in estimates associated with concentrations of fry along the river margins or at the surface will be similar from year to year. As the program provides an index rather than a numerical value, comparison in trends between and among years is possible.

As sampling progressed through the season, the risk increased of including previously emerged fry (as opposed to newly emerged fry) in calculating the index. The concern was that previously emerged fry might have established residence along the banks in the vicinity of the IPTs; their inclusion in the calculation would overestimate the index.

To compensate for this risk, from 1991 to 1998 the date at which previously emerged fry started to make a significant contribution to the number of fry in the IPTs was inferred from variance in wet weight. This was based on an assumption that fry that had been feeding would be heavier than emerging fry, and their presence in the sample would result in an increase in the variance in wet weight of fry from the IPTs.

The date at which a significant difference in variance of wet weights occurred was determined by comparing the variance in weights with an F test after adding the next day's data. The mean plus one standard deviation of the wet weight of fry sampled before the "cut-off date" was then taken to be the upper limit of emergent fry weights. The proportion of fish sampled after the cut-off date which were heavier than this limit was determined and removed from the daily index calculations after the cut-off date. For example, if 30% of the fry sub-sampled after the cut-off date were heavier than the specified weight, only 70% of the daily catches were used in calculating the index of fry emergence after the cut-off date.

6.1.1.3 Index of Emergence Success

The index of emergent success (IES) is calculated as:

IES = (Index of fry emergence/number of eggs deposited upstream of the trap site) *100%

The numbers of chinook spawning upstream of the study site were estimated from the Nechako River over-flight spawner survey data to calculate the index of emergence success. Spawners located in river sections upstream of the trap site (*i.e.,* 1, 2 and 3a) were summed. The number of chinook spawners was calculated by multiplying the estimate calculated from the "area-under-the-curve" (AUC) method for the whole river by the percentage of spawners observed above the study site. [See *ss.5.1.1.1 "area-under-the-curve"*] The sex ratio of the chinook spawners was assumed to be 1:1[39].

A mean fecundity of 6,000 eggs per spawner obtained from Stuart River chinook stripped at the Necoslie Hatchery was used in 1990 (W. Patrick, pers. comm.). In all other years mean fecundity was assumed to be 5,769 eggs per female, based on the fecundity of eight Nechako River female chinook reported by Jaremovic and Rowland (1988). [See *ss. 5.2.2.2.1 Fecundity*] Using an average fecundity value was deemed to be appropriate due to the fact that fecundity is related to length and carcass recovery data indicated no significant differences in lengths of chinook spawners among years (**Table 5.2-7**) In addition, the number of eggs retained by Nechako River chinook was extremely low (**Table 5.2-6**)[40].

[39] Although carcass recovery data indicates a mean female to male ratio of 1.32:1, biases in behaviour may affect this ratio, therefore the NFCP decided to base egg deposition numbers on a 1:1 male to female ratio. [See *ss. 5.2.2.2 Sex Ratio*]

[40] A discussion of the estimated errors in the index of emergent success can be found in *NFCP 1998 (10 Year Review Background Report Appendix 2)*.

6.1.1.4 IPT Efficiency: Mark-Recapture Index

Mark-recapture trials were initiated in 1992 to determine trap efficiency and to develop a sound index of fry emergence. Captured chinook were retained in a live box until there were approximately 1,500 fish, or until the fish had been held for a maximum of four days. The fry were counted, marked with neutral red or Bismark brown dye and released 500 m upstream of the traps. The number of marked chinook fry recaptured in each trap was noted on subsequent days. Three to nine trials were conducted each year from 1991 to 2000, the trials separated by several days to ensure previously marked fish did not bias the trials.

Trap efficiency was calculated as the number of marked fish recaptured divided by the number released in the trial. This calculation may be used to compare among years; however, it cannot be used to estimate the true population of fry in the river because the river is not a closed system—fry are added to and subtracted from the system—and because fry do not have the same probability of being captured from time to time.

6.1.1.5 Length, Weight and Condition

The influences of time of day and trap location on the biological variables (fork length, wet weight and K_D) were determined each year through factorial analysis of variance (ANOVA). T-tests were also used in some years to test the effect of trap position, and Least Squared Difference tests were used for *a posteriori* testing of the effect of time of emergence. Linear regressions were used to determine the influence of emergence date on fry physical parameters.

From 1990 through to 1996, values of fork length, wet weight and K_D were transformed with the Box-Cox transformation. The data were not transformed in 1997 or 1998, since ANOVAs operate well under considerable deviations from normality and heterogeneity of variance when the sample size is large (Zar 1984).

6.1.2 Results and Discussion

6.1.2.1 Nechako River Temperatures

Daily water temperatures in the upper Nechako River varied only slightly among years during the study period. Consequently, the development and growth rates of chinook eggs and fry were also expected to be similar among years.

From 1987 to 1998 average daily temperatures declined rapidly during the chinook spawning period, from 16.8°C in late August to 9.2°C in late October. Temperatures continued to fall during the egg incubation period, reaching 3.5°C in late November, and remained <2.0°C until late March. During the fry emergence period (mid-April to early May), average daily temperatures ranged from 3.5 to 7.0°C.

Over the twelve years of recorded information, temperatures-at-date varied within a relatively small range. The difference between the maximum and minimum average daily temperatures at any date ranged from 0.9 to 7.8°C with an average difference of 3.1°C (n = 366, SD =1.4) (**Figure 6.1-1**). A plot of daily average temperature against date confirmed that temperatures followed similar trajectories in each year (**Figure 6.1-2**).

Figure 6.1-1 **Nechako River: mean, maximum and minimum daily water temperature of the upper river (Bert Irvine's Lodge), 1987 to 1998**

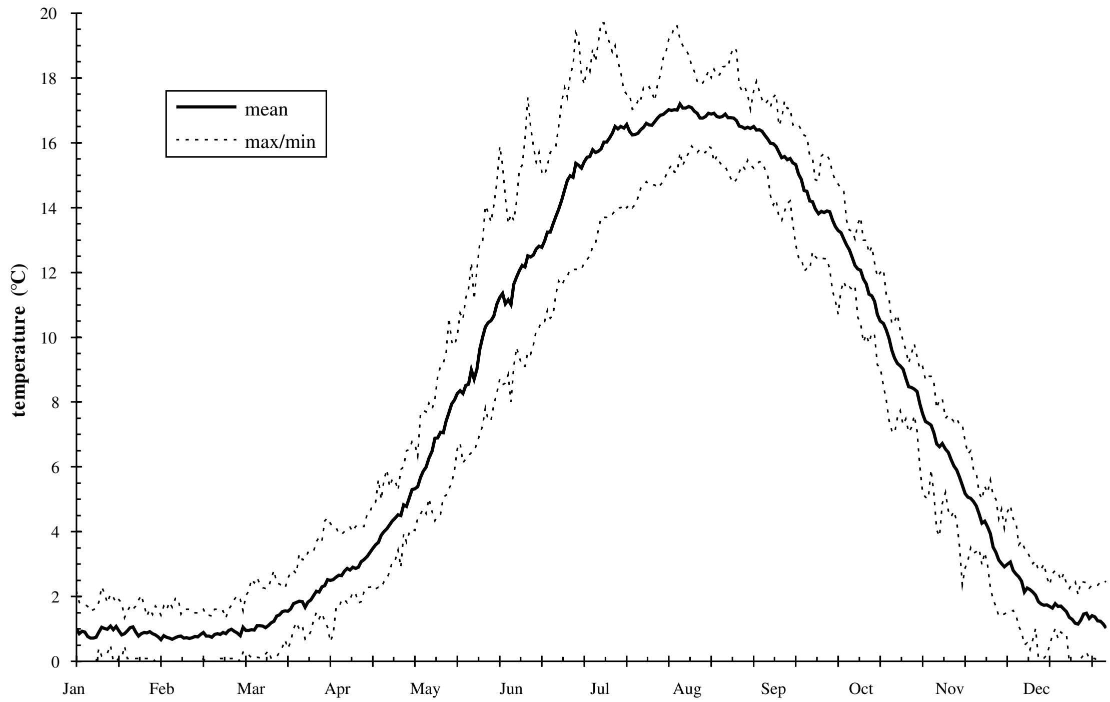
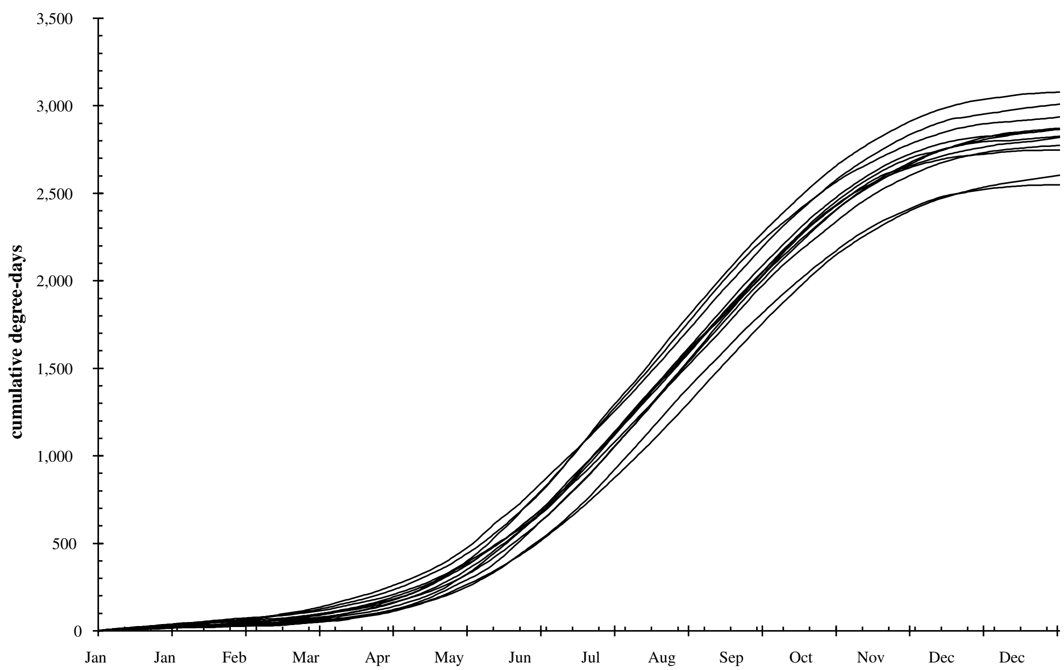


Figure 6.1-2 **Nechako River: cumulative number of degree-days in the upper river (Bert Irvine's Lodge), 1987 to 1998**



From 1990 to 1998, accumulated thermal units (ATU) were calculated from the peak of chinook spawning in mid-September to the end of the Fry Emergence Project the next May. The ATUs for the median date of emergence (50% of fry emerged) ranged from 840 to 1,004 ATUs (**Table 6.1-2**). These were close to the range of ATUs at which chinook fry have been reported to emerge (Shepherd 1984). 1994 and 1998 had the greatest ATUs at the median date of emergence.

Table 6.1-2 **Nechako River: ATUs* from peak of spawning recorded at Bert Irvine's Lodge at the time of 50% of emergence of juvenile chinook (captured in inclined plane traps) 1990 to 1998**

year	date of 50% of emergence	ATUs
1990	13-Apr	935
1991	25-Apr	840
1992	19-Apr	903
1993	22-Apr	938
1994	15-Apr	962
1995	29-Apr	856
1996	06-May	887
1997	30-Apr	862
1998	01-May	1,004

* ATU = accumulated thermal units

6.1.2.2 Nechako River Flows

Since 1987, releases of water into the upper Nechako typically have been maintained at 31 m^3/s from September through to March with increases to approximately 50 m^3/s from April to August. Cooling flows up to a maximum of 283 m3/s are released from mid-July to mid-August as part of the Summer Temperature Management Program. [See *ss.3.1 Summer Temperature Management Program*] After cooling flows cease in mid-August, average flows fall by September 19 to a seasonal low of 29.5 m^3/s to 32.5 m^3/s, then remained stable until the end of the year.

This means that average flows are declining rapidly as the first chinook spawners enter the river in late August and are relatively low and stable during the peak of the spawning period in mid-September. Average flows remained low and stable throughout the egg incubation period, and begin to increase in late April when the fry are emerging.

Figure 6.1-3 shows the variation among years in free spill flow patterns. A plot of "cumulative daily flow on date" shows that flows in the years 1990, 1996 and 1997 followed different schedules than flows in the other nine years (**Figure 6.1-4**). Flows in 1990 spiked in April due to a large forced spill, while the cumulative flow in 1996 was greater than all years except 1997 due to a forced spill from the Nechako Reservoir from late September to early November. The 1997 cumulative flow was more than twice as great as the flow in all other years, except 1996, when forced spills of water from the Nechako Reservoir in late April, May and June combined with larger than usual summer cooling releases.

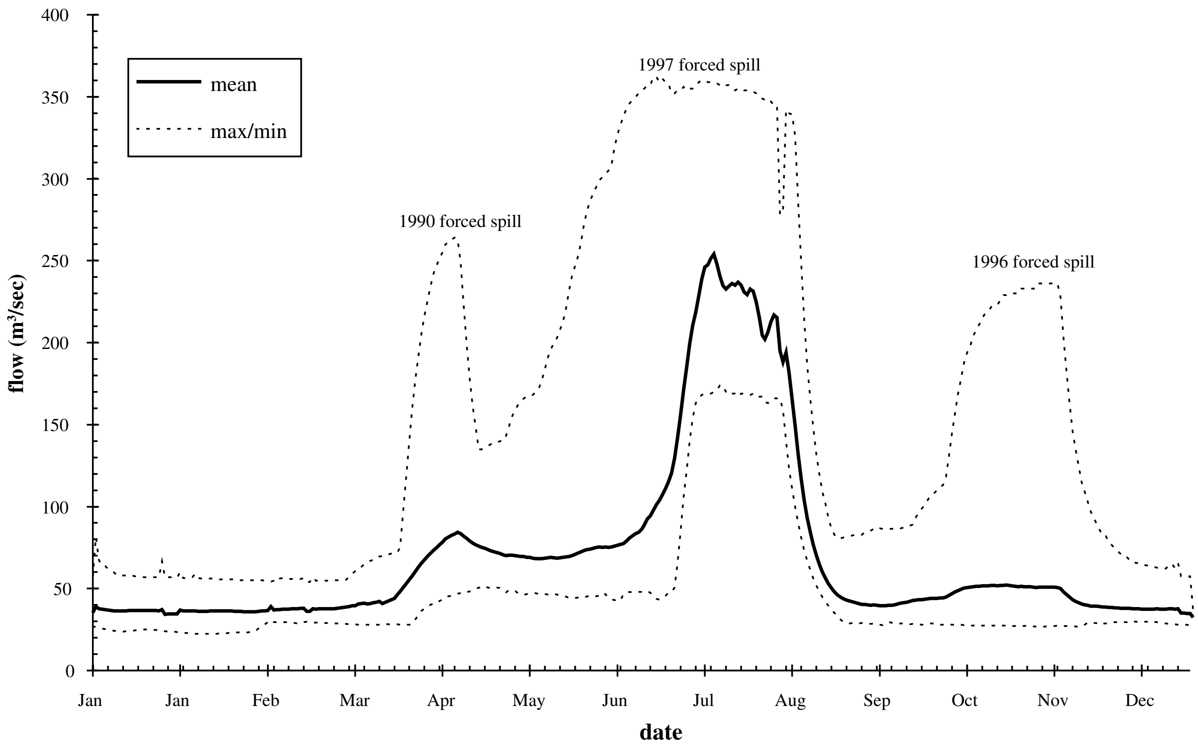
6.1.2.3 Size and Condition of Emergent Chinook Fry

Fry emerge over a period of weeks. The daily mean sizes of these fry are relatively constant until the middle of May when their weight variability increases.

There was little variability from year to year in the mean length, weight or condition of fry in the upper Nechako River. Between 1990 and 1998:

- annual mean fry length ranged from 36.2 to 39.1 mm;
- mean wet weight ranged from 0.36 to 0.45 g; and
- mean condition ranged from 1.90 to 1.95 (**Table 6.1-3**).

Figure 6.1-3 **Nechako River: mean, maximum and minimum daily flow* at Cheslatta Falls, 1987 to 1998**



* peaks in flows due to forced spills

Figure 6.1-4 **Nechako River: cumulative daily flows at Cheslatta Falls, 1987 to 1998**

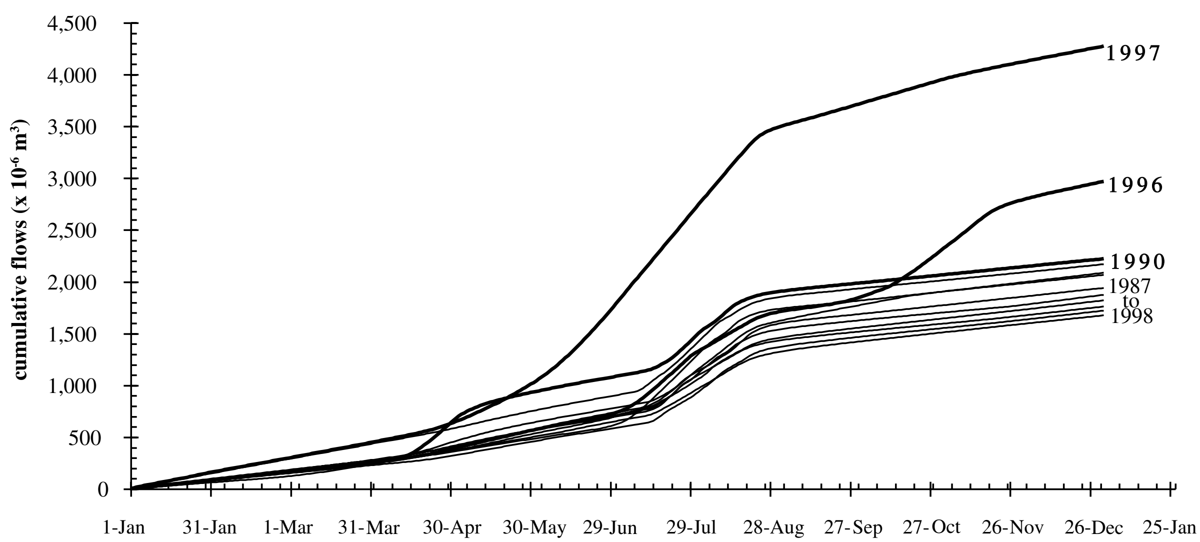


Table 6.1-3 **Nechako River: average fork length, wet weight and development index* of chinook fry captured in inclined plane traps in the upper river (Bert Irvine's Lodge), 1990 to 1998**

year	fork length (mm)	wet weight (g)	KD	N
1990	37.6 (1.8)	0.38 (0.06)	1.93 (0.07)	1,564
1991	38.2 (2.2)	0.40 (0.10)	1.92 (0.08)	4,525
1992	39.2 (2.5)	0.46 (0.12)	1.95 (0.07)	4,895
1993	38.4 (2.7)	0.43 (0.14)	1.95 (0.07)	3,288
1994	38.5 (2.5)	0.41 (0.10)	1.92 (0.07)	2,318
1995	38.4 (2.4)	0.43 (0.14)	1.95 (0.08)	3,119
1996	37.6 (1.8)	0.38 (0.07)	1.92 (0.07)	3,357
1997	36.2 (2.0)	0.36 (0.07)	1.95 (0.06)	3,605
1998	37.5 (2.4)	0.41 (0.13)	1.97 (0.07)	3,637

* SD is in parentheses

The daily mean lengths, weights and development indices varied within a relatively small range from year to year (**Figures 6.1-5** to **6.1-7**). The largest differences in length, weight, and development index were 9.3 mm, 0.54 g and 0.26 (respectively) and the average differences between years at date were 3.7 mm, 0.14 g and 0.10. The largest differences in all variables occurred in the last weeks of the sampling program.

Figure 6.1-5 **Nechako River: mean length of chinook fry sampled by inclined plane traps in the upper river (Bert Irvine's Lodge), 1990 to 1998**

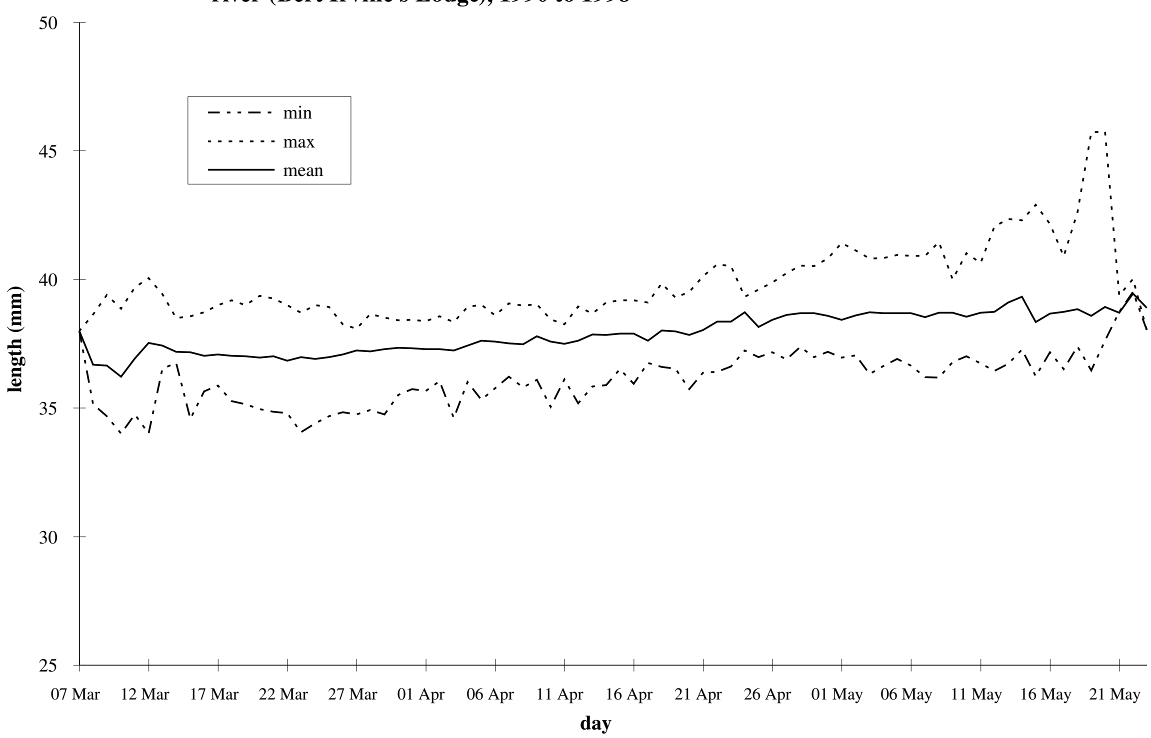


Figure 6.1-6 **Nechako River: mean daily weight of chinook fry sampled by inclined plane traps in the upper river (Bert Irvine's Lodge), 1990 to 1998**

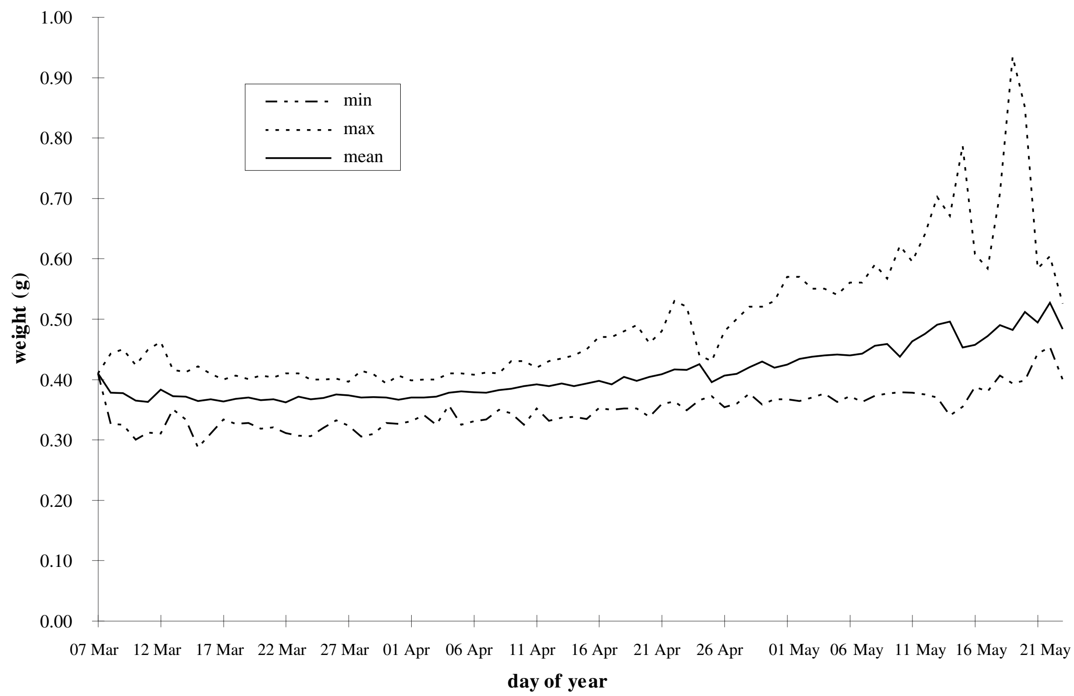
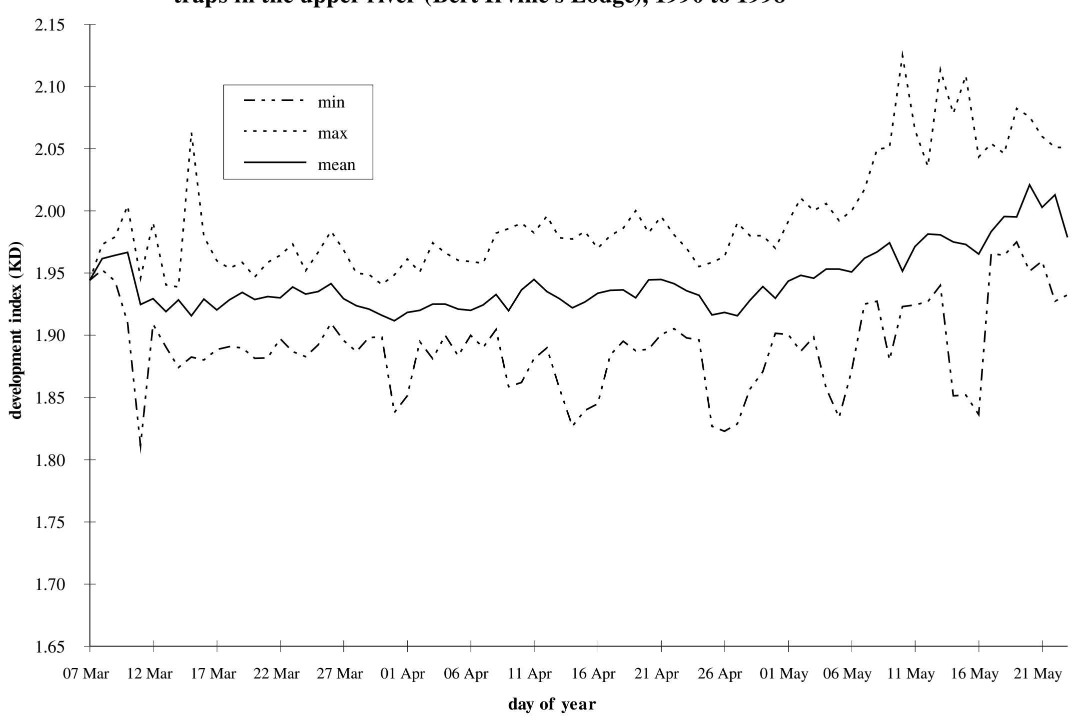


Figure 6.1-7 **Nechako River: mean daily development index of chinook fry sampled by inclined plane traps in the upper river (Bert Irvine's Lodge), 1990 to 1998**



The tendency for fry weight to show more variability towards the end of the study period was used to determine the contribution of growing fry to the population. The date at which growing fry significantly affected the variability in fry weights ranged from May 1 to May 18. The percent of fry that were determined to be newly emerged ranged from to 50.5 % in 1995 to 68.0 % in 1997 (**Table 6.1-4**).

Table 6.1-4 **Nechako River: dates at which growing fry contributed significantly to the variance in fry wet weight and the percent of emergent fry in the catches of inclined plane traps (Bert Irvine's Lodge)**

	cutoff date	percent of emergent fry	mean (SD) wet weight (g)
1991	10 May	58.4	0.38 (0.06)
1992	9 May	59.2	0.45 (0.11)
1993	10 May	54.5	0.41 (0.08)
1994	4 May	61.5	0.40 (0.06)
1995	10 May	50.5	0.40 (0.05)
1996	no difference detected		0.38 (0.07)
1997	18 May	68	0.36 (0.07)
1998	1 May	58.5	0.39 (0.08)

The influence of trap location (*i.e.,* mid-channel or margin) and the time of sampling (*i.e.,* day or night) on fry size varied among years. In general, fry from the margin traps showed a tendency to be slightly longer and heavier than those from the midstream traps, and those fish sampled during the day tended to be longer and heavier than those sampled at night. Interactions between these factors were frequently significant but not consistent, making interpretations difficult.

As the condition of chinook fry varied only slightly from year to year throughout the fry emergence program, no early warnings were triggered for instream gravel conditions. In addition, observed values for ATUs at median date of emergence remained within the range observed in other studies, indicating that development rates of fry in gravel have not been unusual.

6.1.2.4 Index of Fry Emergence

Fry begin to emerge in mid-March. The median date of emergence in the upper Nechako River is likely three to four weeks earlier than in the Stuart River, which usually peaks in late May, the difference probably relating to higher fall temperatures in the Nechako River (Taylor and Bradford 1993). Emergence in the Nechako River generally peaks in late April or early May then tapers off gradually to the end of May. There is variation, however, in the onset and peak timing of emergence (**Figure 6.1-8**).

Total catches at the IPTs ranged from 5,725 in 1994 to 45,189 in 1992. The expanded indices ranged from 127,947 in 1994 to 1,211,894 in 1997 (**Table 6.1-5**). A large part of this variability is accounted for by a strong correlation between the emergent fry index and the number of spawners above the trap site (km 19) the previous fall (**Figure 6.1-9**; Spearman's rho + 0.90, $P< 0.05$). This pattern was also reflected in the emergence success index. Before 1997, the observed emergence success ranged from 42% to 60%. This range is similar to those reported elsewhere for the Nechako River (Neilson and Banford 1983; Envirocon Ltd. 1984a; Russell *et al.* 1983). However, the 1997 and 1998 indices of emergence success were near to, or greater than 100% (**Table 6.1-5**).

Examining the factors which contribute to the emergence index (*i.e.,* the number and distribution of spawning chinook to the placement of IPTs) showed that while all factors have some error or bias associated with them, only river flows and chinook catches were significantly different in 1997 and 1998.

Figure 6.1-8 Nechako River: daily index of fry emergence at Bert Irvine's Lodge, 1991 to 1998

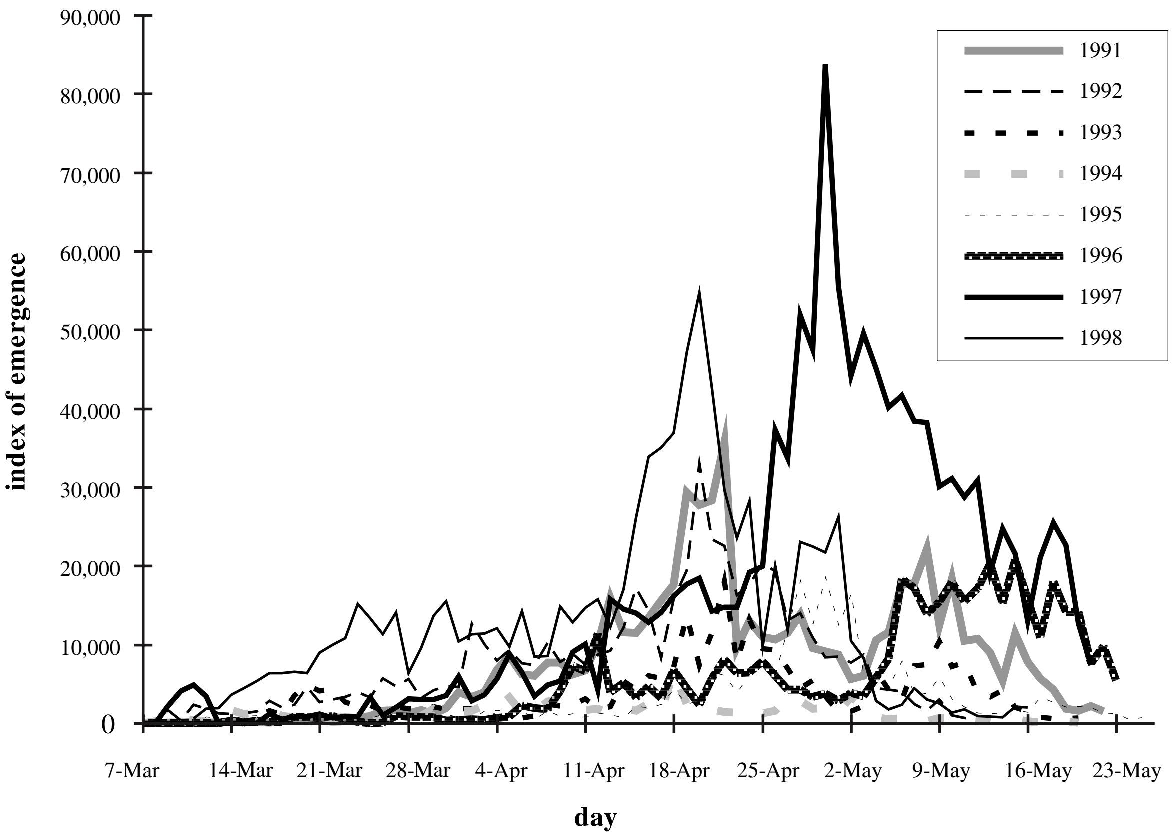
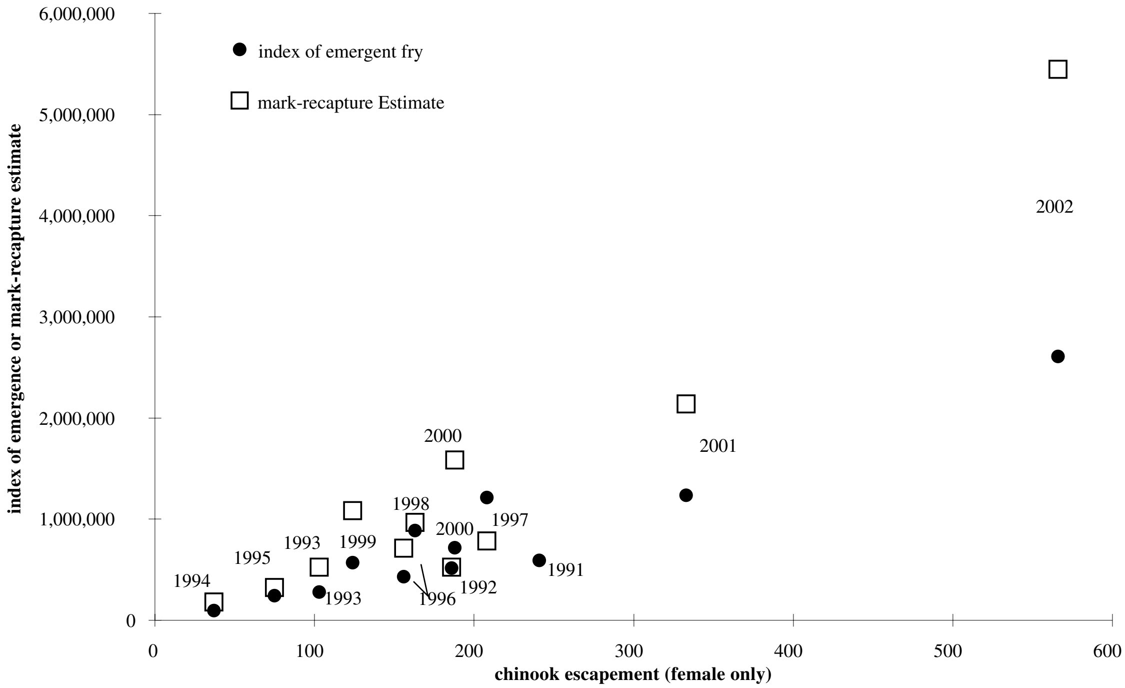


Table 6.1-5 Nechako River: index of fry emergence and estimated emergence success above Bert Irvine's Lodge, 1991 to 1999.

year	escapement the previous fall	number of spawners (females) above km 19	index of fry emergence	mark recapture estimate	emergence success (%)*
1991	2642	241	589,456		42.4
1992	2360	187	512,247	522,844	47.5
1993	2498	112	276,613	522,418	42.8
1994	664	38	127,947	176,638	58.4
1995	1144	74	242,058	320,427	56.7
1996	1689	152	428,663	709,039	48.9
1997	2040	208	1,211,894	783,126	100.1 **
1998	1954	163	884,467	966,746	94.1
1999	1868	129	569,703	1,080,949	76.6

* Fecundity = 5,769 eggs/female (Jaremovic and Rowland 1988)
** due to overestimation of the index because of higher than usual flows

Figure 6.1-9 **Nechako River: index of emergent chinook and mark-recapture estimates vs. spawner escapement above Bert Irvine's Lodge during the previous year, 1991 to 2002***



* Mark-recapture estimates unavailable for 1991

The greatest source of error in the index of emergence is in estimating the number of fry migrating past the trap site[41]. The main assumptions in calculating the index are that the traps sample the same proportion of the river flows regardless of the total discharge, and that the fry are randomly distributed within the water column. These assumptions may not be valid at higher flows.

For example, in 1996 (a typical year in terms of flows during the period of fry emergence) the percentage of the river flow sampled by the traps decreased as the flow increased (**Figure 6.1-10a**). The same holds for other years, such as 1997 (**Figure 6.1-10b**). The index is weighted by the proportion of the discharge sampled, and the decreasing proportion sampled by each trap may result in an inflated index as flows increase. The accuracy of the index is therefore affected by river discharge.

In addition, while fry distribution across the channel is not significantly different from year to year (ANOVA, P>0.05), fry are not distributed evenly across the river (**Table 6.1-6**): margin traps generally catch more fry than the mid-stream traps. This means that the index estimate may be biased by assuming that each trap has an equal chance of capturing fry. At higher flows, there may be a change in the ability of emergent fry to control their location in the river. Also, fry that would have dispersed upstream in years with lower flows may be swept downstream into the traps during higher flows. For example, in 1997 and 1998 a large number of fry were captured during a period of higher than normal flows. These factors probably contributed to unusually high indices of emergence and of emergence success.

[41] See *NFCP 1998 (10 Year Review Background Report) Appendix 2*.

Figure 6.1-10a **Nechako River: flows below Cheslatta Falls and percent of total flow sampled by the four inclined plane traps (Bert Irvine's Lodge), in a typical year (1996)**

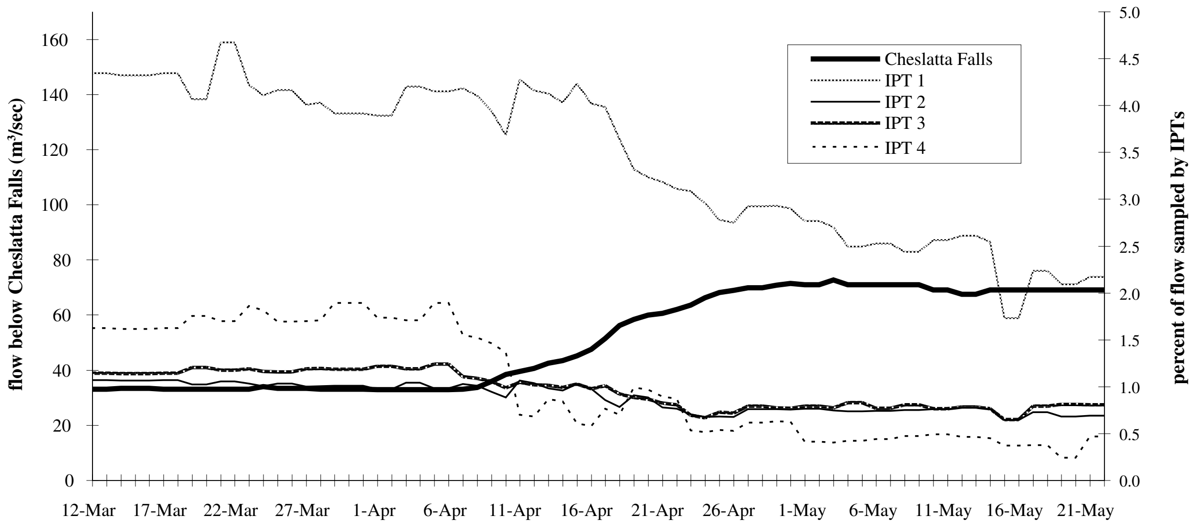


Figure 6.1-10b **Nechako River: flows below Cheslatta Falls and percent of total flow sampled by the four inclined plane traps (Bert Irvine's Lodge), in a forced spill year (1997)**

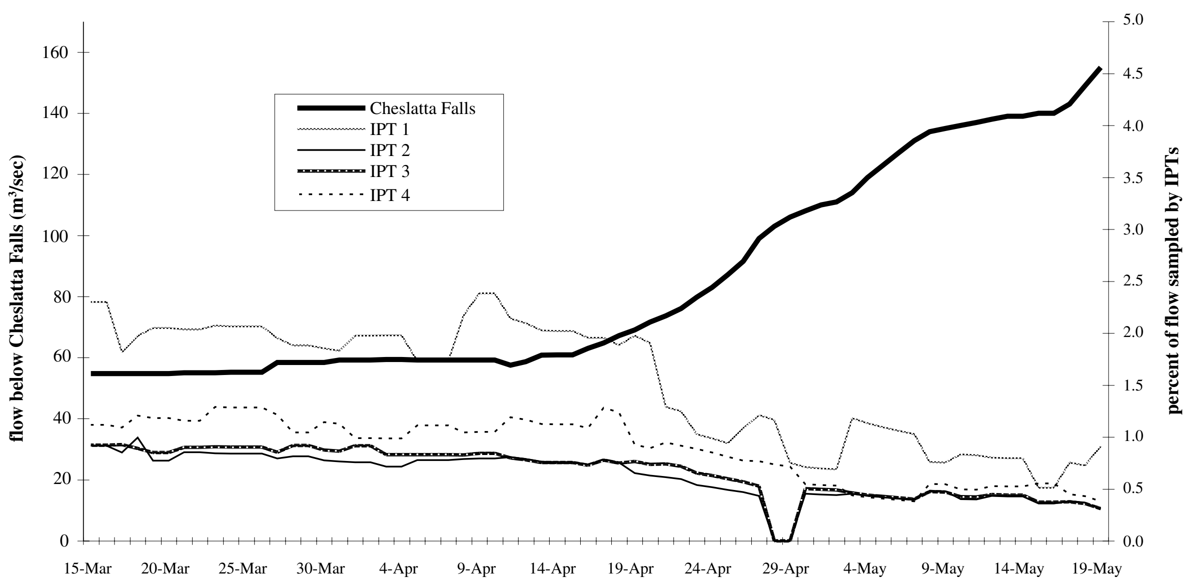


Table 6.1-6 Nechako River: number of chinook fry sampled by inclined plane traps and percent of the total catch by each trap (Bert Irvine's Lodge), 1990 to 1998

	right margin IPT 1		right midstream IPT 2		left midstream IPT 3		left margin IPT 4		
	actual catch	percent of total catch	actual catch	percent of total catch	actual catch	percent of total catch	actual catch	percent of total catch	total catch
1990	3,250	30.5	1,553	14.6	3,710	34.8	2,149	20.2	10,662
1991	9,382	40.9	4,245	18.5	2,816	12.3	6,503	28.3	22,946
1992	21,423	47.4	4,026	8.9	3,606	8.0	16,134	35.7	45,189
1993	3,845	25.5	2,919	19.3	2,643	17.5	5,697	37.7	15,104
1994	2,303	40.2	627	11.0	813	14.2	1,982	34.6	5,725
1995	4,549	35.1	1,167	9.0	1,776	13.7	5,450	42.1	12,942
1996	6,194	29.6	2,247	10.7	3,079	14.7	9,402	44.9	20,922
1997	6,001	18.0	2,988	9.0	3,545	10.7	20,734	62.3	33,268
1998	10,038	30.3	5,273	15.9	4,657	14.0	13,210	39.8	33,178

Mark-recapture experiments have been conducted since 1992 to provide a second index. Average trap efficiency was 3.7%, but the range varied between 1 to 10.8% from 1992 to 1998 (**Table 6.1-7**). There was no significant correlation between the trap efficiency estimates and river flows on the day of the release ($n = 36$, $r = -0.31$, $P>0.05$).

Mark-recapture estimates have been generally higher than the index estimates, but have shown a pattern similar to the index from year to year (**Figure 6.1-9**) with the two estimates significantly correlated (**Figure 6.1-11**; Spearman rho = 0.86, $P< 0.01$). Annual average (weighted) mark recapture estimates ranged from 176,638 to 1,080,949 (**Table 6.1-5**), while estimates based on individual trials ranged from 98,597 to 6,794,989 (**Table 6.1-7**). Higher river flows in 1997 and 1998 which increased emergence index values did not have a similar effect on mark recapture estimates. As discussed in *ss 6.1.1.2 Index of Fry Emergence*, this suggests that mark-recapture indices may be more robust than the flow expansion indices when flows are more variable.

As with the emergent fry index, the mark-recapture estimate was significantly correlated with the number of spawners above Bert Irvine's Lodge (km 19) the previous fall (**Figure 6.1-9**; Spearman rho = 0.90 and 0.83 respectively, $p<0.05$). The correlation between the index of fry emergence and the number of spawners the previous year confirms that it reflects real biological processes and is a reliable measure of fry abundance. The linear nature of this relationship indicates that spawning habitat (area and quality) is not limiting over the range of spawners seen during the program period. However, the 1997 and 1998 indices were approximately twice as high as would be expected from this relationship, based on previous results.

6.1.2.5 Incidental Catch

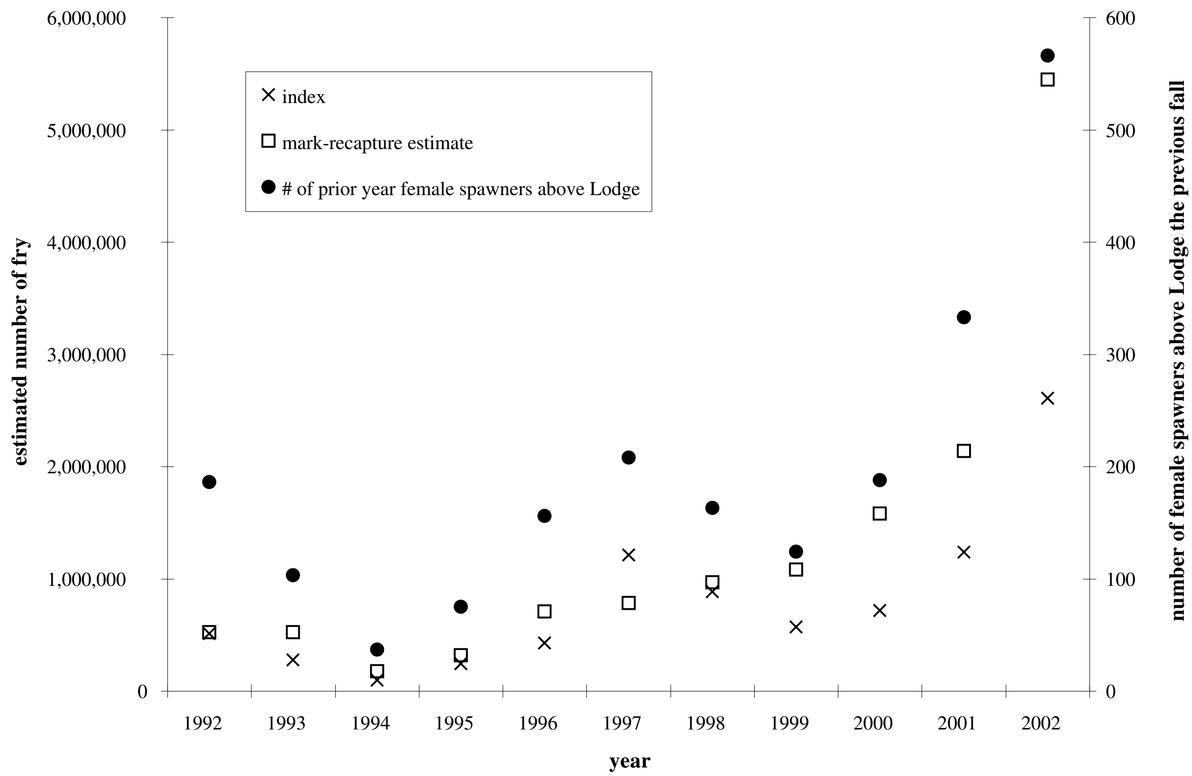
The IPTs captured a range of fish species over the years. The most common incidental species are longnose dace (*Rhinichthys cataractae*), leopard dace (*Rhinichthys falcatus*), redside shiner (*Richardsonius balteatus*), largescale sucker (*Catostomus macrocheilus*), northern pikeminnow (*Ptychocheilus oregonensis*), and mountain whitefish (*Prosopium williamsoni*).

Table 6.1-7 Nechako River: mark-recapture trials at Bert Irvine's Lodge, 1992 to 1998

	date of release	number released	number recaptured	trap efficiency no. recap/ no. released	total catch (entire season)	estimated pop'n total catch/ trap efficiency
1992	8 Apr	2,508	228	9.1%	45,189	496,582
	18 Apr	2,195	146	6.6%		684,682
	26 Apr	1,771	302	10.8%		418,417
1993	1 Apr	700	18	2.6%	15,104	587,378
	15 Apr	990	23	2.3%		650,129
	23 Apr	2,500	98	3.9%		385,306
	3 May	1,431	36	2.5%		600,384
	12 May	1,628	44	2.7%		558,848
1994	23 Mar	155	9	5.8%	5,725	98,597
	31 Mar	185	10	5.4%		105,913
	4 Apr	369	15	4.1%		140,835
	9 Apr	490	22	4.5%		127,511
	16 Apr	797	34	4.3%		134,201
	20 Apr	790	15	1.9%		301,517
	2 May	390	16	4.1%		139,547
	11 May	109	1	0.9%		624,025
	20 May	97	2	2.1%		277,663
1995	15 Apr	304	3	1.0%	12,942	1,311,456
	21 Apr	770	4	0.5%		2,491,335
	25 Apr	850	35	4.1%		314,306
	29 Apr	1,200	50	4.2%		310,608
	1 May	1,260	115	9.1%		141,799
	5 May	1,600	18	1.1%		1,150,400
	9 May	880	4	0.5%		2,847,240
	13 May	1,097	26	2.4%		546,053
	20 May	651	27	4.1%		312,046
1996	16 Apr	1,524	40	2.6%	20,922	797,128
	24 Apr	798	41	5.1%		407,214
	4 May	928	19	2.1%		1,021,875
	13 May	2,007	68	3.4%		617,507
1997	8 Apr	997	45	4.5%	33,268	737,071
	3 May	3,000	125	4.2%		798,432
	12 May	3,268	16	0.5%		6,794,989
1998	25 Mar	1,745	59	3.4%	33,178	981,282
	6 Apr	1,500	45	3.0%		1,105,933
	20 Apr	3,000	112	3.7%		888,696
1999	31 Mar	247	7	2.8%	31,821	1,124,417
	11 Apr	1,783	33	2.0%		1,623,520
	21 Apr	4,000	183	4.7%		672,748
	03 May	1,669	33	2.2%		1,473,194

mean trap efficiency	3.6%
standard deviation	2.3%
minimum	0.5%
maximum	10.8%

Figure 6.1-11 **Nechako River: index of chinook fry emergence, mark-recapture estimate and number of female chinook spawners upstream of Bert Irvine's Lodge in prior year, 1992 to 1998**



The numbers of incidental fish captured in the IPTs varied significantly from year to year (**Figure 6.1-12**). These differences may reflect changes in recruitment of these species, or changes in river flows; however, the variation patterns of individual species between years were dissimilar, which precludes them from any general conclusion.

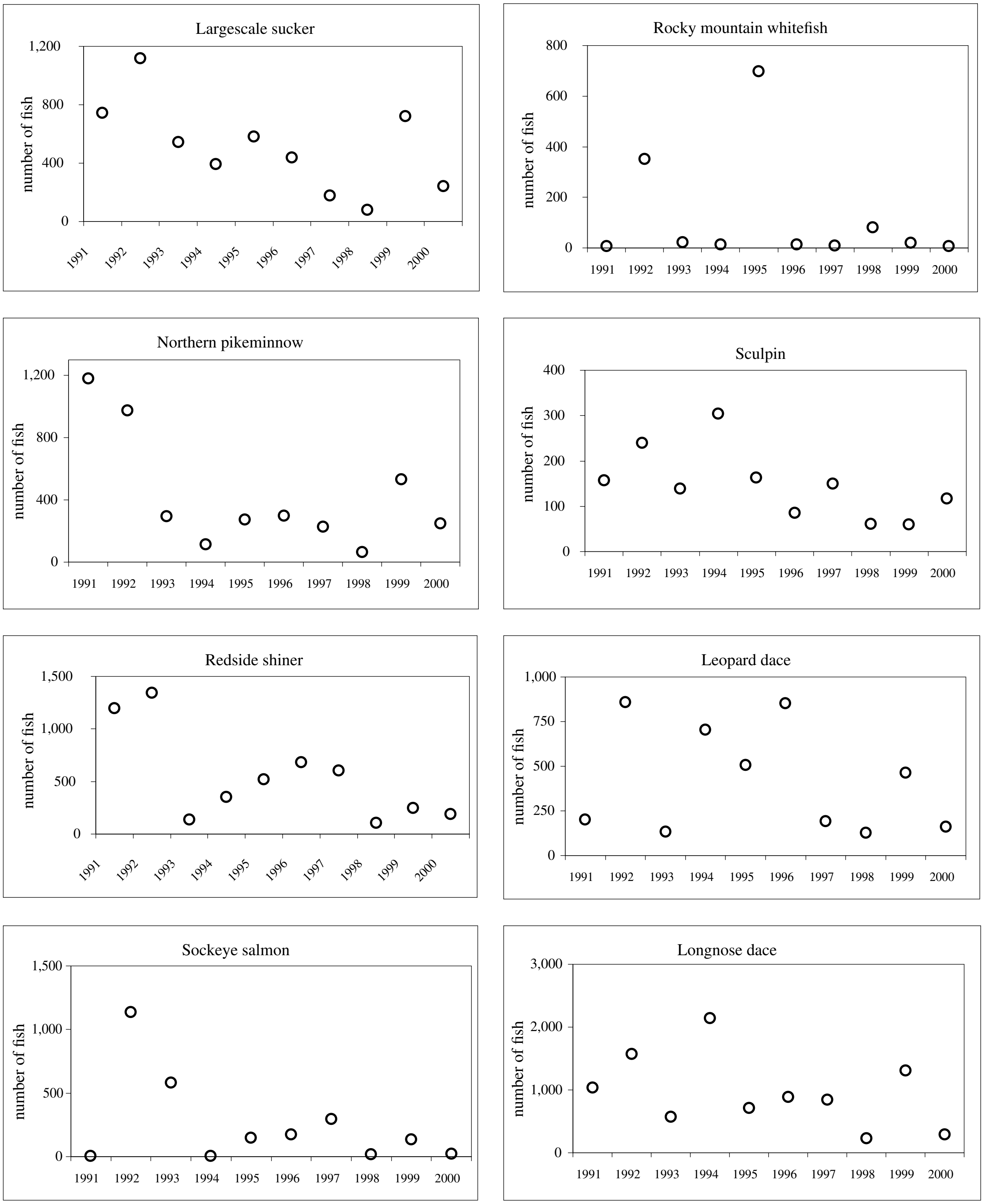
6.1.3 Summary: Fry Emergence Project

Daily water temperatures in the upper Nechako River from 1990 to 1998 varied only slightly during the study period. This suggested that the development and growth rates of chinook eggs and fry would be similar among years, and the data have shown this to be true: there has been little variation in the mean length, weight or condition of fry.

From 1991 to 1996, there was a strong correlation between the index of fry emergence and the number of spawners above km 19. In 1997 and 1998 the index was much higher than expected, based on the number of spawners, while other variables (*i.e.,* the index of out-migration, trap efficiency, fry distribution among traps) remained within the expected range. The only exception was increased river flow.

Under the current flow regime, the index of fry emergence would likely permit deleterious changes in the incubation environment to be detected, as fry emergence would decline. However, if harmful changes are accompanied by higher flows, the chances of detection may decrease.

Figure 6.1-12 **Nechako River: composition of the incidental catch made up of the eight most common fish species sampled by inclined plane traps (Bert Irvine's Lodge), 1991 to 2000**



Overall, the results from the Fry Emergence Project indicate that the quality of the incubation environment in the upper Nechako River appears to be stable and has not shown any degradation over the study years. In addition, no reduction in egg-to-emergent survival has been observed, indicating that spawning habitat (area and quality) is not limiting over the range of spawners that have returned to the Nechako River during the program period.

6.2 JUVENILE CHINOOK OUT-MIGRATION PROJECT

Like the Fry Emergence Project, the Juvenile Chinook Out-migration Project is part of the Early Warning Monitoring Program intended to monitor measures of the key components of chinook salmon early life-history. In this case, the project was designed to monitor key components of juvenile chinook population biology including relative abundance, average size and spatial distribution. The project was not designed to answer specific hypotheses about the relationships between physical features of the upper Nechako River and juvenile chinook population biology but was intended to act as an indicator of the condition of juvenile rearing habitat.

Juvenile chinook out-migration monitoring was conducted only in the upper river, because it is the part of the river most subject to changes in flow due to fluctuations in discharge from the Nechako Reservoir via the Skins Lake Spillway (**Figure 6.2-1**). The lower river is buffered by flows from the Nautley and Stuart Rivers and other large tributaries. In addition, the upper river is a rearing area for a single population of chinook while several populations rear in the lower Nechako River, including those that spawn in the lower river and its tributaries, the Chilako, Endako, Stellako and Stuart Rivers and Ormond Creek.

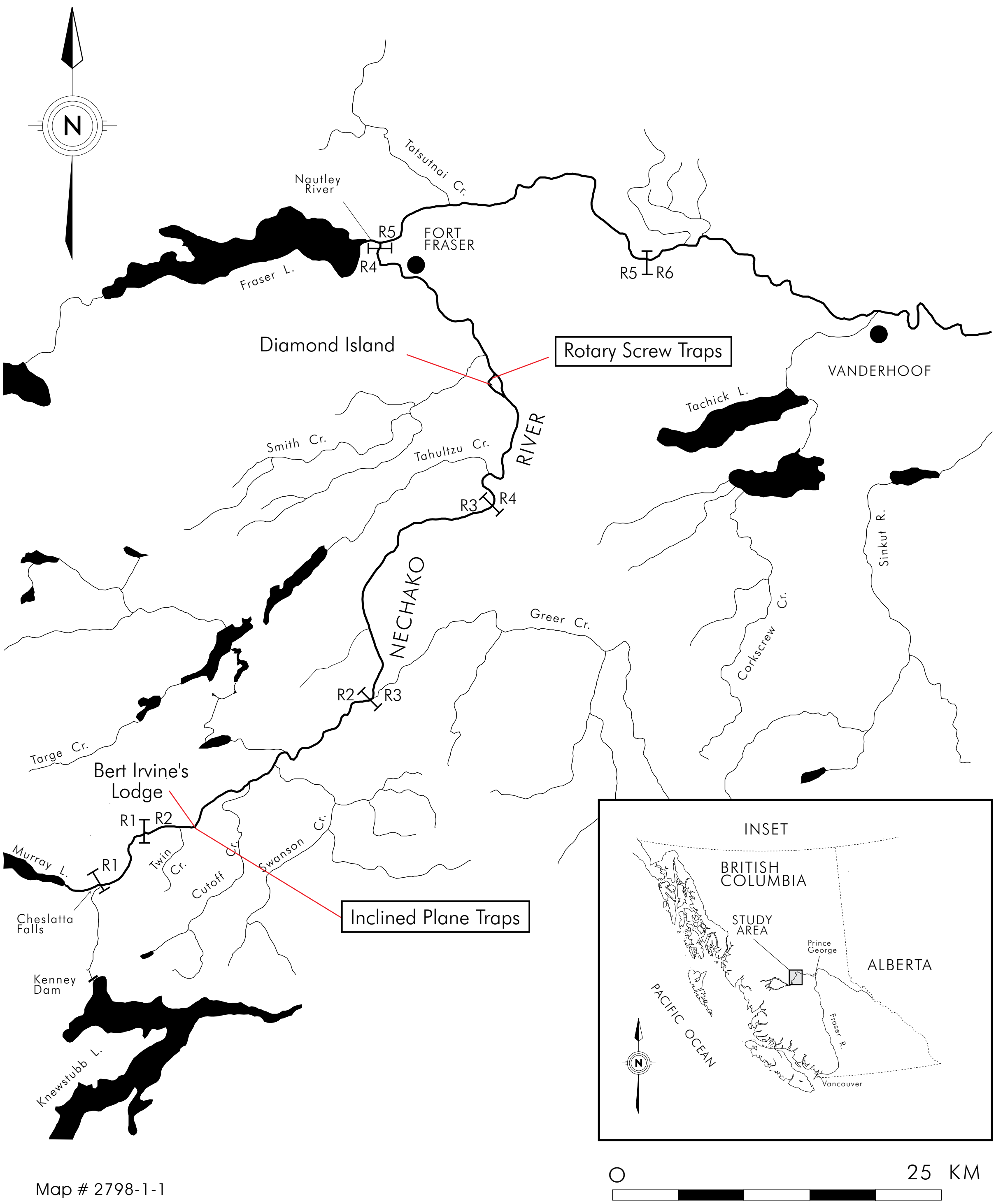
The specific objectives of the project were to:

- monitor temporal and spatial changes in juvenile chinook abundance from spring to autumn within the upper 90 km of the Nechako River;
- monitor juvenile chinook body size, growth and condition;
- develop a standardized index of the number of juvenile chinook salmon leaving the upper Nechako River;
- measure the timing of juvenile chinook out-migration; and
- assess a variety of indicators as an early warning of habitat changes in the upper Nechako River that may be related to changes in the flow regime. These indicators included:
  - out-migrant number and timing;
  - spatial distribution within the upper river;
  - body size; and
  - growth and condition.

The project focussed only on 0+ chinook[42]; 1+ chinook usually leave the upper river before the end of May, whereas 0+ chinook are found in the river from April to December. Although 1+ chinook were captured as part of the project, from 1989 to 1998, they made up less than 1.5% of the number of juvenile chinook captured by electrofishing, and less than 3% of the juvenile chinook captured by rotary screw traps.

[42] Preliminary estimates of the age of juvenile chinook are recorded as 0+ or 1+, based on fork length and season of capture. From April to July, all juveniles less than 90 mm long are classified as 0+, and all juveniles longer than 90 mm are classified as 1+. Juveniles over 90 mm long in late summer are classified as 0+ because by that time all 1+ chinook have migrated out of the upper Nechako River. The 90 mm cutoff length was based on the observation of two distinct modes in the length frequencies of juvenile chinook that are assumed to correspond to 0+ and 1+ fish (**Figure 6.2-9**). That bimodality has been observed each year that the river has been sampled for juvenile chinook from 1989 to 1998 in both the catches of the electrofishing surveys and the rotary screw traps.

Figure 6.2-1 **Nechako River: study area and trap locations**



6.2.1 Index and Out-migrant Sampling: Methodologies

Fish sampling methods used in the Juvenile Chinook Out-migration Project are divided into two groups: those used to sample index sites along the upper river and those used to estimate the number of juvenile chinook migrating out of the upper river.

The two methods require different types of sampling gear. Index sampling requires gear that can be moved quickly from site to site (*e.g.,* electrofishing equipment), while out-migrant sampling gear does not need to be mobile, but must be able to sample the entire width of the river over a wide range of flows (*e.g.,* rotary screw traps).

Mean daily water temperatures were measured by the Water Survey of Canada's (WSC) Data Collection Platform Station 08JA017 near Bert Irvine's Lodge (km 19). Spot temperatures were recorded to the nearest 0.1°C with handheld thermometers during electrofishing surveys and at the Diamond Island (km 84) rotary screw traps each time an electrofishing site or a rotary screw trap was visited. Daily water flows were measured at Station 08JA017.

6.2.1.1 Index Sampling: Electrofishing Surveys

A variety of gear was tested at index sites in the upper Nechako River during the Technical Committee's first four sampling years (1988 to 1991). This included pole seines, beach seines, electrofishing and dipnets.

Pole seines were used at Smith, Swanson and Greer Creeks during the daylight hours of May and July 1989. They were abandoned in 1990 because electrofishing was found to be an easier, more consistently applicable method. Beach seines were used at seinable sites (*e.g.,* gravel bars in the upper river during day and night) from 1989 to 1992, but were also abandoned after 1992 in favor of electrofishing. Dipnets were used at some sites in 1991 when electrofishing gear was out of commission.

Electrofishing[43] has been used in every year since 1990 to measure the relative abundance, spatial distribution and "size-at-date" of juvenile chinook and now serves as the method used for index site sampling. Begun as a temporary replacement for W-traps rendered inoperable in 1990 due to forced spills, electrofishing's ability to show spatial variation in juvenile density during spring and summer—something fixed gear cannot do—has made it one of the most important components of the chinook monitoring program.

An index of juvenile chinook abundance was obtained from single-pass electrofishing surveys of each of the four reaches[44] of the upper river[45]. In 1990 and 1991, monthly surveys to monitor abundance, distribution and size in early-winter began in April and continued through to November after water temperature dropped below 5°C. From 1992 to 1998, the number of surveys was reduced from eight to five, because there was little additional benefit gained from sampling in late summer and early fall. Ongoing sampling now begins in April

[43] Electrofishing is a well-researched survey tool. An insulated researcher uses a backpack generator and electrodes to send a controlled charge through a study area. This charge temporarily stuns the fry and juvenile chinook, allowing them to be counted, etc. The fish are then released live back into the river.

[44] There are six reaches between Cheslatta Falls and Vanderhoof and these have been divided into 16 sections (or sub-reaches) for the purpose of enumerating chinook spawners.

[45] The study area was divided into four reaches, originally defined by Envirocon Ltd. (1984a).

and continues through the critical months of May, June and early July with a final survey in early November. Surveys of reaches 1 through 4 are completed in each of the months sampled.

Electrofishing surveys are carried out during the day and at night — the period between sunset and sunrise. Surveys are conducted on prime habitat for juvenile chinook, defined as:

- water depth >0.5 m;
- velocity >0.3 m/s; and
- a substrate of gravel and cobble (Envirocon Ltd. 1984a).

This habitat is found mainly along the margins of the river, so electrofishing surveys do not sample that portion of the juvenile chinook population that may reside mid-channel[46].

In this study, fish were captured with a single pass of a Smith Root model 15A backpack electrofisher, identified to species, counted, and released live back into the river. The number of fish caught at a site was divided by the area electrofished to generate catch-per-unit-effort (CPUE) of juvenile chinook. The area electrofished is expressed in units of 100 m^2 to avoid a fractional CPUE.

Before release, 10 to 15 chinook were measured for body size. Fork length was measured to the nearest millimeter with a measuring board, and wet weight measured to the nearest 0.01 g with an electronic balance. Fulton's condition factor (Ricker 1975), that is weight (g) x 10^5/[fork length (mm)]^3, was used as an index of physical condition.

6.2.1.2 Out-migrant Sampling: Rotary Screw Traps

Juvenile chinook out-migration was estimated using at least three types of fixed gear: inclined plane traps (IPTs), W-traps, and rotary screw traps (RSTs). IPTs (122 x 122 cm) were installed at the railway bridge at Fort Fraser (km 95) from April to October in 1989; IPTs (61 x 91 cm) were installed at Diamond Island (km 84) in 1989. A 61 x 91 cm IPT was also fished at Larson's Canyon (km 56) once every week from July 21 to August 20, 1989. A W-trap was installed at Diamond Island from May 21 to July 13, 1990; it was removed due to high summer cooling flows then re-installed from August 30 to September 24.

Neither IPTs nor W-traps proved to be satisfactory for estimating out-migration. IPTs were easily damaged or rendered inoperable by high flows, while W-traps were difficult to install and remove. RSTs proved much easier to move and more resistant to damage in high flows and have been the principal means of estimating juvenile chinook out-migration every year since 1990. Fyke nets and IPTs were used for several years to check the movement of fish around RSTs, but they were removed in 1994.

An RST consists of a floating platform topped by a rotating cone. In front of the cone is an A-frame with a winch used to set the vertical position of the mouth of the cone. At the back of the cone is a live box where captured fish are kept until the trap is emptied. The cone is 1.43 m long and made of 3 mm thick aluminum perforated to allow water to drain. The diameter of the cone tapers from 1.55 m at the mouth to 0.3 m at the downstream end.

Inside the cone is an auger or screw, the blades painted black to reduce avoidance by fish. The cone rotates as the current strikes the blades of the screw. A fish entering the rotating cone is trapped in a temporary chamber formed by the screw blades. As the cone rotates, the fish moves down the cone until it is deposited in the live box.

[46] Electrofishing surveys by the Department of Fisheries and Oceans showed that mid-channel densities of chinook were 70 times lower than densities along river margins (Nechako River Project 1987). The department's snorkeling surveys showed that 97% of observed juvenile chinook were found along river margins.

Three RSTs were installed off Diamond Island: RST 1 near the left bank, RST 2 in mid-river, and RST 3 near the right bank. The traps were suspended from a cable strung across the river channel. The 1.5 m space between the right bank of the river and RST 3 was blocked with a wing made of wood beams and wire mesh; the 15 m long space between the left bank of the river and RST 1 was not blocked.

Each trap was emptied twice a day at about 07:00 and 20:00 hours. All of the fish collected were counted and their species identified. A sub-sample of 10 to 15 chinook was kept for length and weight measurement using the methods described in *ss. 6.2.1.3 Index sampling: Electrofishing Surveys*, after which all of the fish, including the sub-sample, were released live back into the river.

The number of juvenile chinook passing Diamond Island in a day was estimated by multiplying the total number of fish caught in an RST in a given time period (day or night) by the ratio of the total flow of the river to the flow that passed through the RST,

$$N_{ij} = n_{ij}(V_j/v_{ij})$$

where:

- N_{ij} = number of juvenile salmon passing Diamond Island on the j^{th} date as estimated by the catches of the i^{th} trap;
- n_{ij} = number of chinook salmon caught in the i^{th} trap on the j^{th} date;
- v_{ij} = water flow (m^3/s) through the i^{th} trap on the j^{th} date; and
- V_j = total water flow (m^3/s) of the Nechako River past Diamond Island on the j^{th} date.

All analyses of RST data were based on expanded numbers rather than on catches.

V_j was estimated from the height of the river surface at Diamond Island measured with a staff gauge, using a linear regression between flow and staff gauge height ($n = 137$, $R^2 = 0.99$, $P<0.001$).

$$\ln(\text{flow, m}^3/\text{s}) = -3.386 + 1.670 \ln(\text{staff height, cm})$$

That regression was calculated for steady flow conditions during April and May from the combined years of 1992 to 1998. Flows and staff gauge height were ln-transformed to make the exponential relationship between the two variables linear.

Water flow though a trap (v_{ij}) was the product of one half the cross-sectional area (1.61 m^2) of the mouth of the trap (the trap mouth was always half-submerged) and average water velocity in front of the trap. Average water velocity (m/s) was measured with a Swoffler (model 2100) flow meter at three different places in the front of the mouth of the RST. The one exception to this rule was RST 3, where v_{ij} was increased to include the water that flowed between it and the right bank of the river because fish that would ordinarily have passed through this gap were diverted into RST 3 by the right wing.

Since there were three RSTs, there were three estimates of the total number of downstream migrants each day. The best estimate of the total index number of chinook out-migrants was the mean of the three estimates weighted by the flow passing through each trap.

RSTs were not re-installed after the end of the summer cooling flow period from 1993 on because catches in the late summer and early autumn of 1991 and 1992 were too low to justify the additional cost. Consequently, in order to provide an index of total out-migrants comparable between years, the sampling period for all seven years was April to mid-July (**Table 6.2-1**).

Table 6.2-1 **Nechako River: comparison of the index numbers of juvenile chinook migrating out of the upper river with numbers of the parent generation**

year	sampling period	total number of spawners the previous year	number of spawners upstream of Diamond Island	index number of outmigrating 0+ chinook the following year
1991*	Apr. 5 - Nov. 15	2,642	1,686	116,538
1992	Mar. 14 - Nov. 17	2,360	1,306	143,000
1993	Apr. 2 - Nov. 16	2,498	1,074	47,589
1994	Apr. 2 - July 17	664	347	45,025
1995	Apr. 13 - July 11	1,144	659	105,576
1996	Apr 11 - July 13	1,689	1,098	133,812
1997	Apr 5 - July 13	2,040	1,455	133,709
1998	Apr 3 - July 18	1,954	1,547	133,709
1999	Apr 2 - July 19	1,868	1,212	102,644
2000	April 2 - July 17	1,917	1,427	83,937

* The number of outmigrants estimated in 1991 (brood year 1990) is not comparable to the numbers of outmigrants estimated in subsequent years because one of the RSTs in 1991 had a wooden wing attached to one side that funneled additional fry into the RST, and therefore required the assumption of greater flow into the trap.

6.2.2 Results and Discussion

6.2.2.1 Trends in Electrofishing CPUE of Juvenile Chinook

Trends in electrofishing CPUE of 0+ chinook have shown similar features over the study period (**Figure 6.2-2**):

- night CPUE has usually been greater than day CPUE, the difference being such that day and night electrofishing catches have to be treated separately; and
- both day and night CPUE reach their maximum in April, May or June, depending on the timing of emergence, then decline rapidly. The loss of CPUE with time is due to a combination of out-migration, natural mortality and size-dependent avoidance of electrofishing gear.

At present, there is no practical method for calculating the contribution of each factor to the summer/autumn decline in CPUE.

Part of the among-year differences in electrofishing CPUE were due to differences in the total number of 0+ chinook that emerged into the upper Nechako River. However, in the absence of independent estimates of the total number of emergent chinook fry, the number of adult chinook estimated to have spawned in Reaches 1 to 4 of the upper Nechako River in the previous year was used to standardize the CPUE (**Figure 6.2-3**). Standardization reduced the among-year variation in the CPUE, but did not eliminate it. The remaining variation was assumed to be due to a combination of differences in out-migration, natural mortality and gear avoidance.

Based on relationships of total numbers of fry electrofished each year compared to the number of spawners that produced the fry, habitat use by rearing juveniles shows an increased number of fry (**Figure 6.2-4**); Spearman rho = 0.91; $p<0.05$). In other words, fry seem to select rearing habitat in proportion to their abundance. This appears

Figure 6.2-2 **Nechako River: mean monthly electrofishing CPUE (number/100 m²) of chinook 0+, 1989 to 1998**

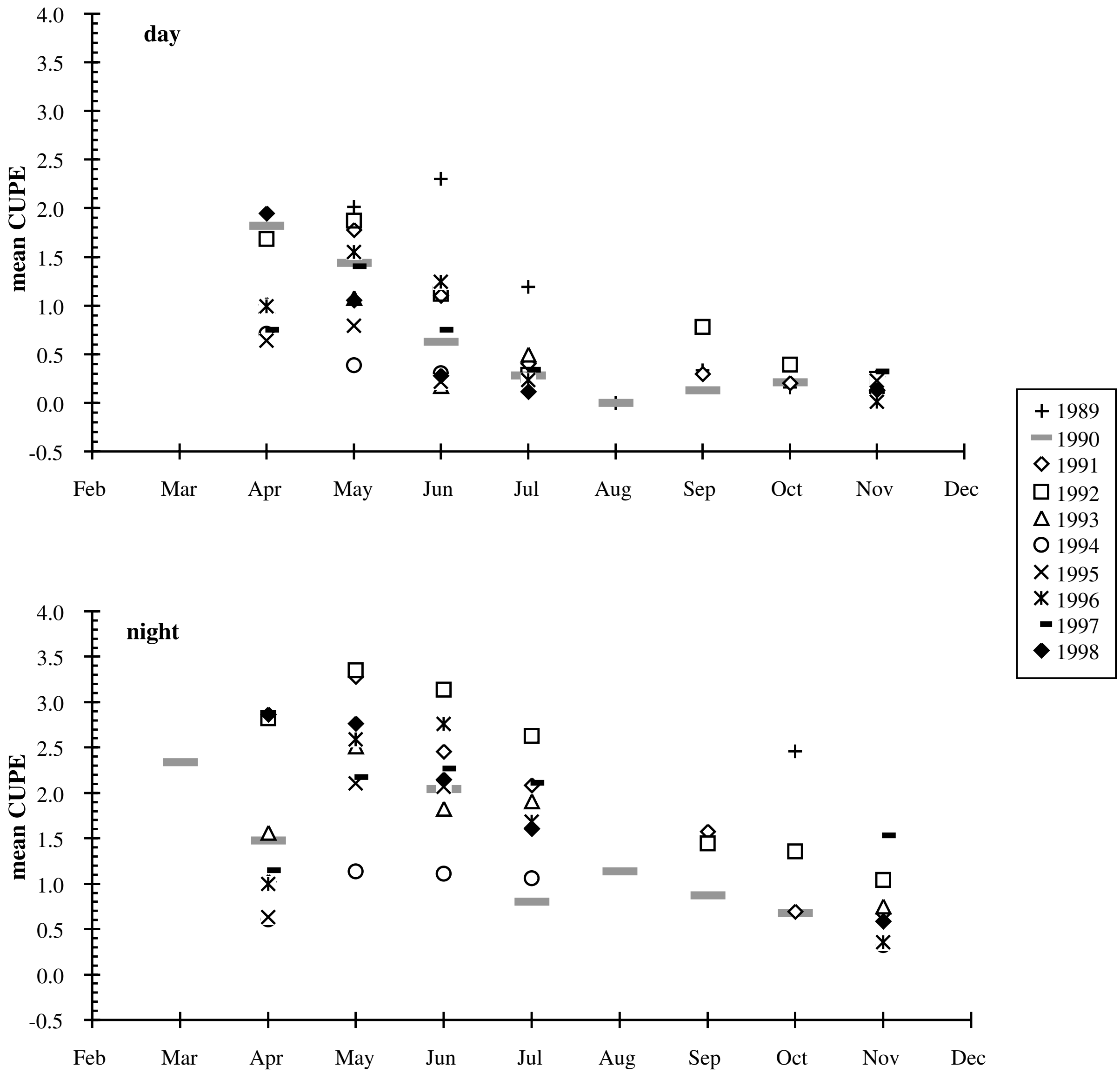


Figure 6.2-3 Nechako River: mean monthly electrofishing CPUE (number/100 m²) of chinook 0+, standardized for the number of spawners in the previous autumn, 1989 to 1998

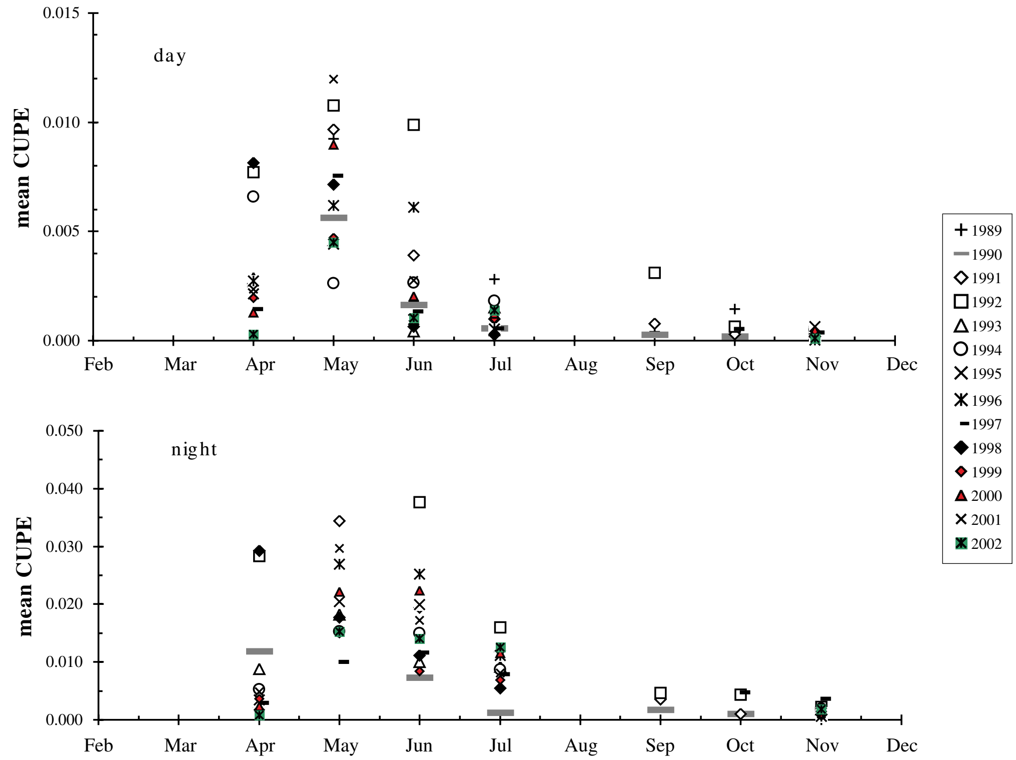


Figure 6.2-4 Nechako River: total number of juvenille chinook 0+ electrofished vs. number of recorded chinook spawners the previous year, 1991 to 2002

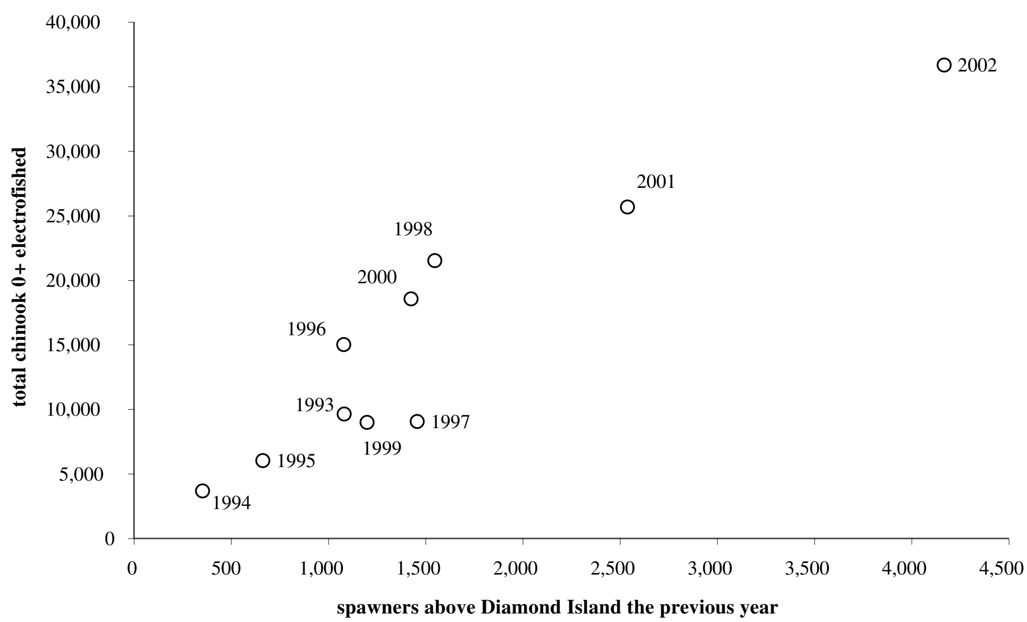
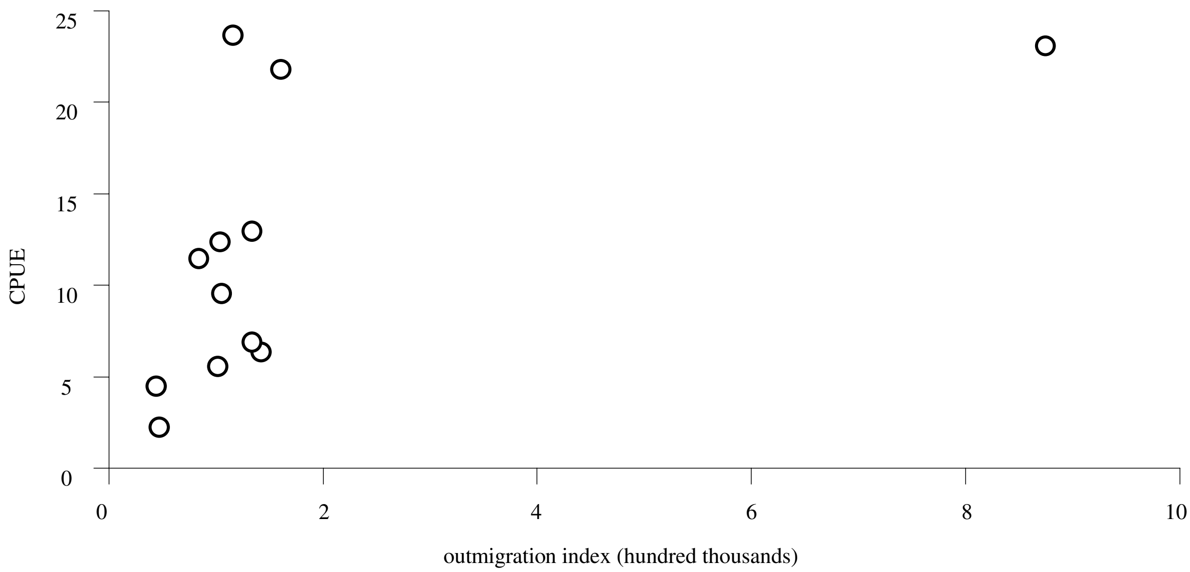


Figure 6.2-5 **Nechako River: catch per unit effort (chinook/m²) vs. outmigration index, 1991 to 2002**



to change in 2002 with the large numbers of fry recruited to the Nechako River as a result of the large return of adults in 2001. Based on this one data point, habitat saturation may be starting to take place. The relationship between CPUE and out-migration demonstrated a similar linear pattern (**Figure 6.2-5**) over the first 11 years and possible density dependency in 2002 due to the large numbers of spawners.

Although the objective of this report was primarily to present data collected to 1998, the Technical Committee felt that it was important to present the 2002 data that indicate possible density dependence, since this is a departure from the results observed to that time. It is important to note that this apparent habitat saturation effect results from a single data point. It is also important to note that the apparent saturation is for spawner returns that exceed the upper range of the Conservation Goal identified in the *1987 Settlement Agreement.*

6.2.2.1.1 Spatial Distribution of Juvenile Chinook

Electrofishing survey data provided the basis for describing the spatial distribution of 0+ chinook in the upper Nechako River by sampling all four reaches each month. For each month, the monthly x-centroid, xm (km)—the weighted center of distribution of 0+ chinook along the longitudinal of the river—was calculated as,

$$x_m = \Sigma\,(CPUE_i.x_{Ii})/\ \Sigma\,CPUE_i$$

where:

- $CPUE_i$ = CPUE at site i; and
- x_{Ii} = longitudinal distance (km) from Kenney Dam to site i.

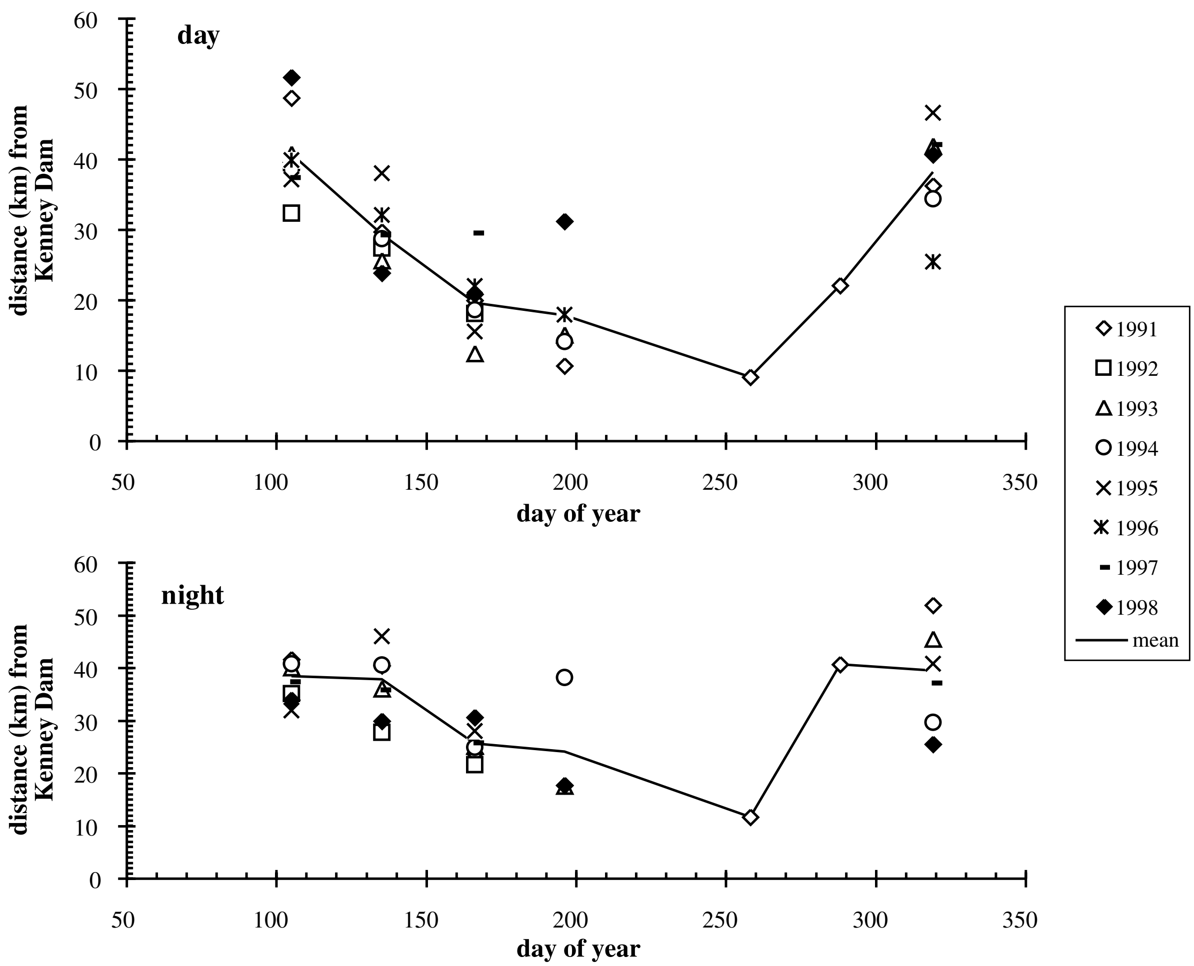
Day and night centroids were calculated separately because of significant diurnal variation in juvenile chinook abundance.

The seasonal trend of both day and night centroids showed that a portion of the juvenile chinook population remained in the river, migrating upstream towards Kenney Dam, presumably in search of rearing habitat (**Figure 6.2-6**). By April 15 (day-of-year 105), the centroid was located an average of 41.6 to 48.8 km from Kenney Dam, and by July 15 (day-of-year 196) it was 17.8 to 24.2 km from the dam. Sometime between mid-July and mid-November, the trend reversed and the centroid moved downstream as the fish prepared for over-wintering.

There were no obvious differences in juvenile chinook spatial distribution between years.

The variation of the centroids about the monthly mean was undoubtedly due in part to annual changes in the distribution of spawners in the upper river, but there is no practical way of adjusting for those changes. In general, although juvenile chinook numbers declined over time through the majority of the study area, CPUE values in Reach 1 tended to increase in June and July, confirming that fish were in fact redistributing throughout the river rather than displaying differential rates of downstream dispersal or survival.

Figure 6.2-6 **Nechako River: monthly centroids of 0+ chinook, upper river, 1991 to 1998**



6.2.2.2 Out-migrant Index

The daily index of 0+ chinook out-migration from the upper Nechako River varied from 45,025 in 1995 to 146,170 in 1993 (143,000 for the May-July period). The index showed a roughly unimodal distribution centered in mid-May, with a possible second peak in late June due mainly to high values in 1993 and 1996 (**Figure 6.2-7**).

Within-year variations were probably due to variations in the cross-sectional distribution of chinook fry in the upper river—the fish in mid-stream presumably being more prone to migrate earlier than the fish near the banks—and to variations in the timing of emergence. As with variations in fry emergence, part of the between-years variations for out-migrants was related to:

- the total abundance of emergent fry; and
- the number of spawners in the previous year as indicated by the positive and significant correlation between the index and the number of adult chinook estimated to have spawned above Diamond Island (km 84) in the previous year (**Figure 6.2-8**; Spearman rho = 0.68, P,0.05).

6.2.2.3 Size, Growth and Condition of Juvenile Chinook

Length frequency distributions of juvenile chinook captured by electrofishing and RSTs showed the same bi-modal pattern (**Figure 6.2-9**):

- a large mode of 0+ fry at an average length of 35 to 45 mm; and
- a much smaller mode of 1+ juveniles at an average length of 95 to 105 mm.

These distributions confirmed that a cutoff length of 90 mm was appropriate for assigning ages (0+ or 1+) from length.

Plots of the mean length-at-date and weight-at-date of 0+ chinook electrofished since 1989 (**Figure 6.2-10**) and captured by RSTs at Diamond Island (km 84) since 1990 (**Figure 6.2-11**), showed the same three-stage growth pattern. Continuous emergence of fry over a period of several weeks during April and May resulted in an apparent low rate of growth of the juveniles in that period. The actual growth rate began after emergence ended (*i.e.,* before mid-May) for the period from May to September. A relatively low growth rate and a flattening of the size/date curves over late summer and early autumn (September to November) due to decreasing water temperature and size-selective out-migration[47], characterized the third stage.

Mean size-at-date did not vary substantially among years (**Figure 6.2-10**), reflecting the similarity in seasonal temperature patterns among years. The variation that occurred was due mainly to small variations in river temperature among years. For example, the mean lengths and weights of 0+ chinook in May, June and July, 1998, were the highest sizes-at-date, reflecting the unusually high water temperatures of those months.

The lower sizes-at-date for November 1998 may also be explained by temperature, albeit indirectly, if unusually fast growth in the spring and summer of 1998 led to size-selective out-migration. If that is the case, a large proportion of 0+ chinook would have left the upper Nechako River before November and only smaller fish would have over-wintered.

[47] Large chinook may have left the upper river earlier than smaller chinook, either to smolt or to search for rearing habitat, leaving an over-wintering population in November that was composed of smaller fish.

Figure 6.2-7 Nechako River: daily indices of 0+ chinook out-migration, Diamond Island, 1991 to 1998

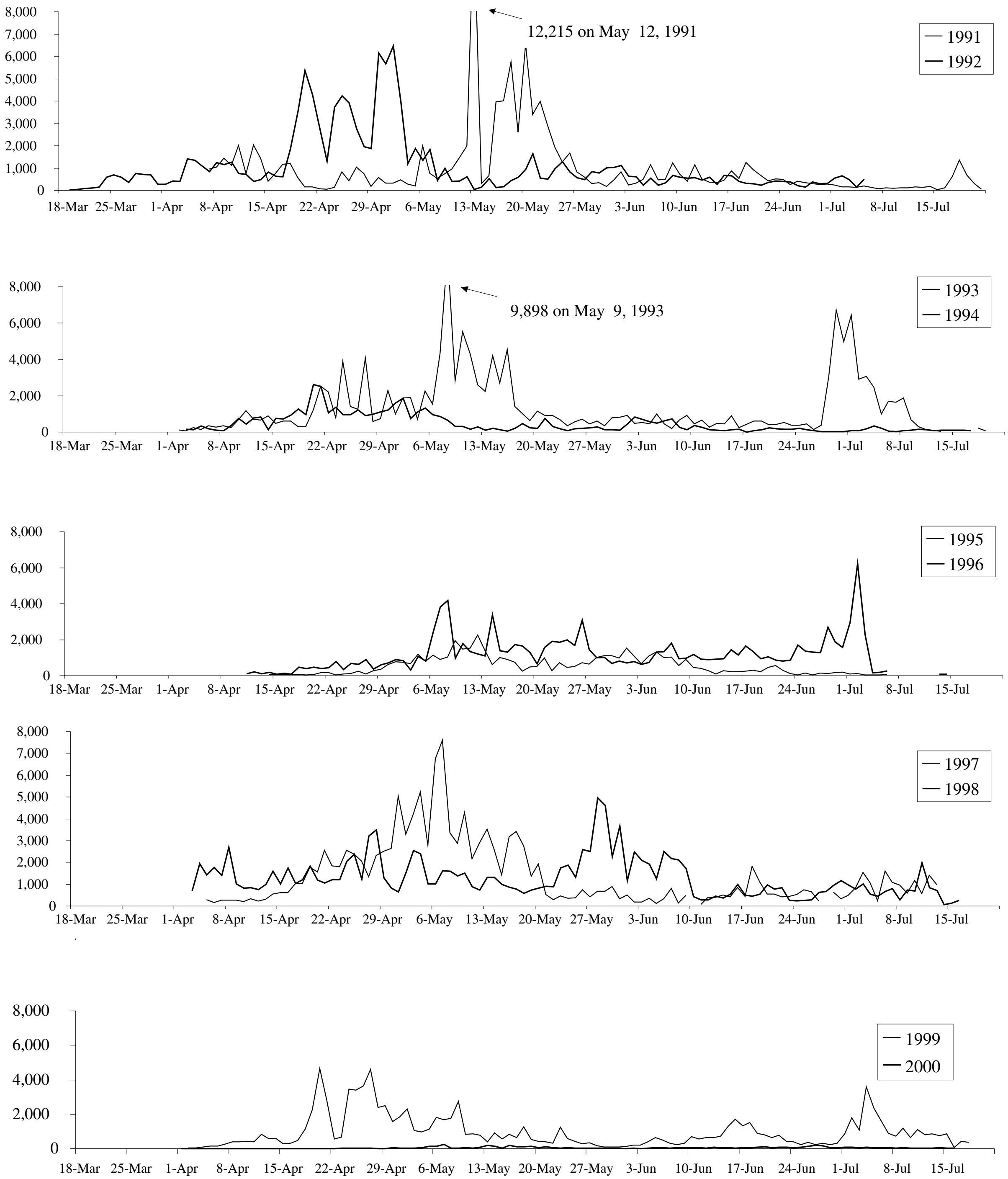


Figure 6.2-8 **Nechako River: index of 0+ out-migrants calculated from rotary screw traps vs. the number of spawners above Diamond Island the previous year, 1991 to 1999**

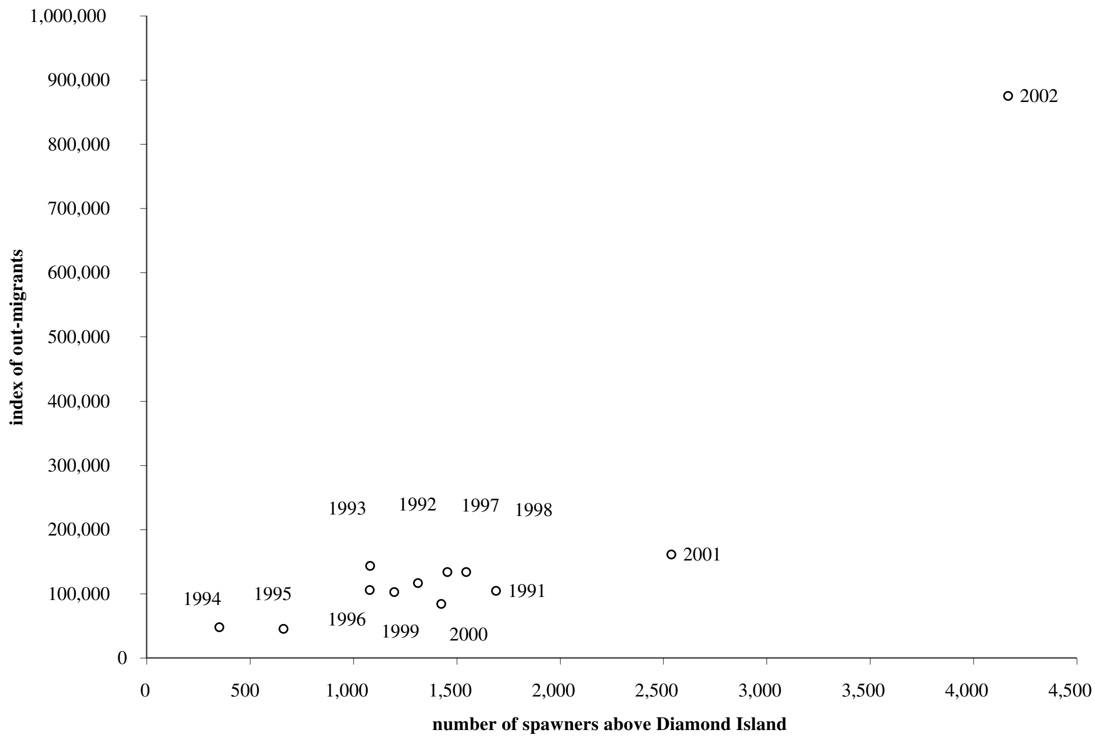


Figure 6.2-9 **Nechako River: length frequency distributions of juvenile chinook captured by electrofishing and rotary screw trap, upper river, 1989 to 1998**

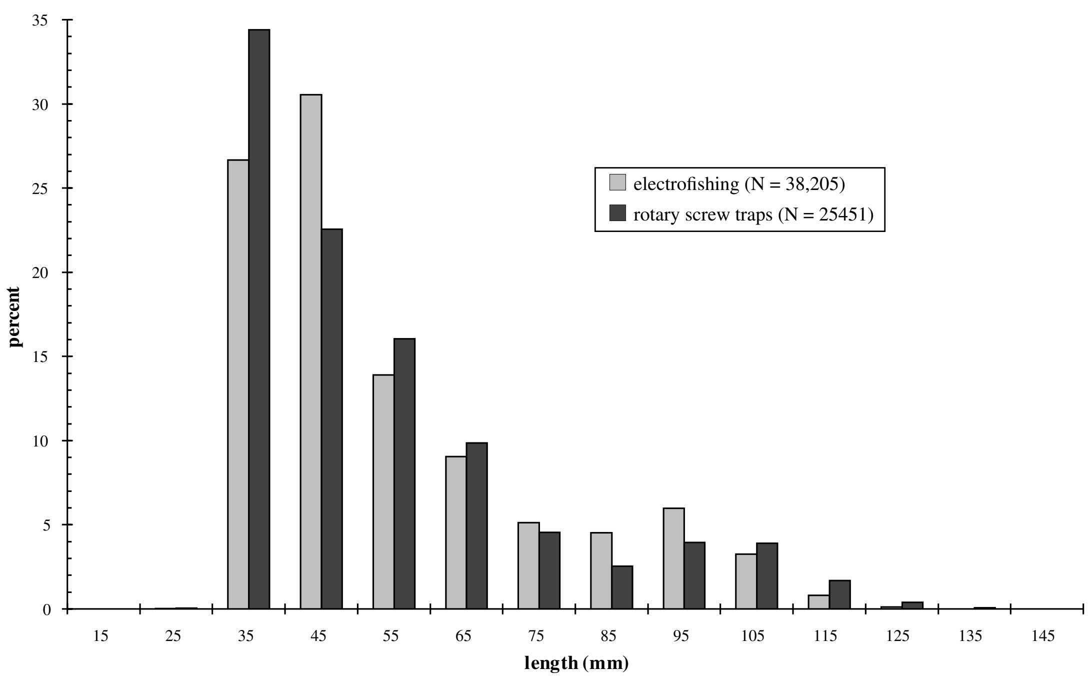


Figure 6.2-10 **Nechako River: mean size-at-date of 0+ chinook captured by electrofishing, upper river, 1989 to 1998**

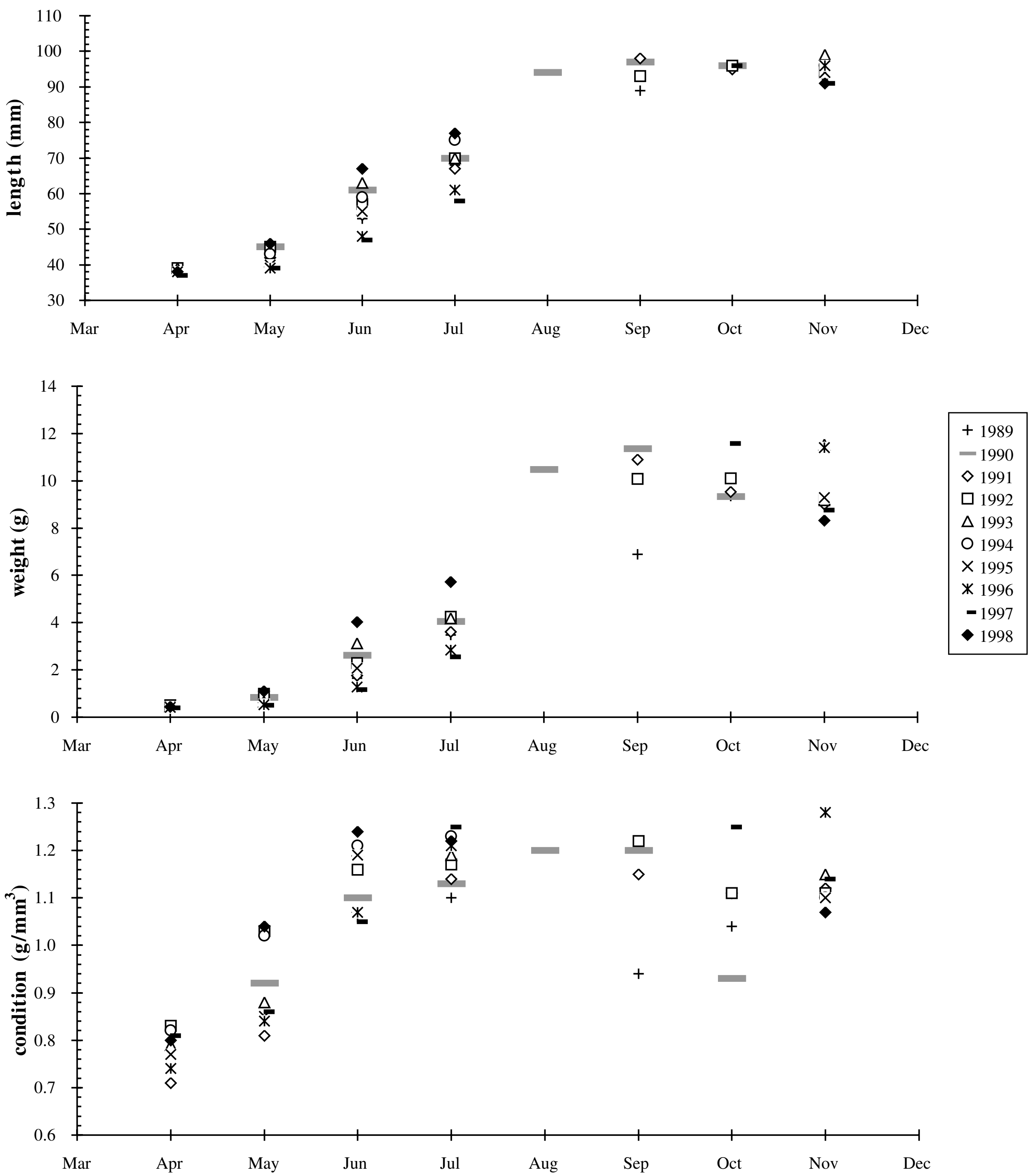
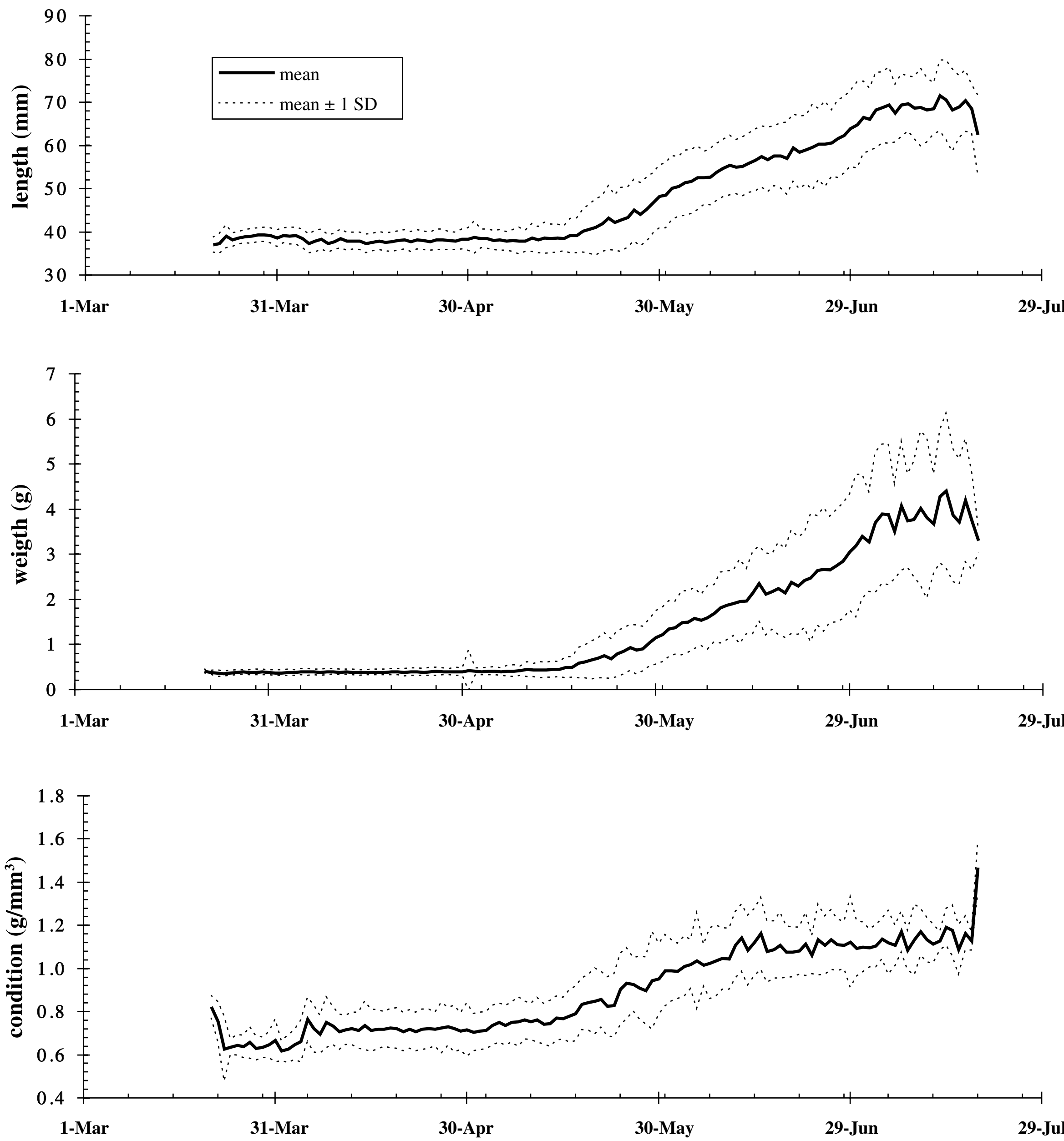


Figure 6.2-11 **Nechako River: mean size-at-date of 0+ chinook captured by rotary screw trap, Diamond Island, 1990 to 1998**



Not shown in **Figures 6.2-10** and **6.2-11** were day/night differences in mean lengths and weights. In most years, and for both electrofishing and RSTs, the average size of 0+ chinook captured was significantly greater at night than during the day. This may be because fish are more vulnerable to capture at night than during the day leading to less size-selection at night.

The weight to length relationship (condition) of 0+ chinook increased rapidly through May and into June, reaching maximum values in June or July, and then remained constant over the remainder of the year (**Figures 6.2-10** and **6.2-11**). The greatest variation in condition among years occurred in September/October, but this was likely due to mainly small sample sizes taken during 1989 and 1990. Otherwise the range of condition-at-date among years was similar to size-at-date. Condition factors during the rearing period were >1, which generally indicates fish in good health.

6.2.2.4 Fish Community

911,146 fish belonging to 15 species were captured and identified in the upper Nechako River from 1989 to 1998 (**Tables 6.2-2** and **6.2-3**). Over 76% were captured by electrofishing while the rest were taken in downstream traps at Diamond Island (km 84) and near Fort Fraser (km 95).

Over 95% of the catch was made up of seven species or families. For electrofishing, the ranking in descending order of abundance is redside shiner, chinook salmon, largescale sucker, northern pikeminnow, leopard dace, longnose dace, and sculpins (**Table 6.2-2**). For RSTs, the ranking is chinook salmon, redside shiner, largescale sucker, northern pikeminnow, leopard dace, sockeye salmon and mountain whitefish (**Table 6.2-3**).

In general, species ranking was similar between electrofishing and RST sampling (**Figure 6.2-12).** The differences were due to migratory behaviour: migrants such as juvenile chinook tended to be caught in greater numbers by RSTs, while resident fish, such as sculpins, were taken by electrofishing sampling.

A plot of the percent of total fish sampled that were juvenile chinook confirmed that RST samples were more dominated by juvenile chinook salmon than were electrofishing catches (**Figure 6.2-13**). However, the plot also shows that the difference between gear types varied substantially among years. The annual difference in percents between RSTs and electrofishing ranged from 1.4 to 47.1% with an average of 27.7% (n = 10, SD = 13.7). The lowest difference occurred in 1990—the year of a large forced spill in the spring—and the highest occurred in 1993—a year with an average flow regime. The years of high forced spills in summer and autumn—1996 and 1997—had percent differences of 30.5% and 33.3%, respectively. Those were slightly higher than average, but still less than the percent differences of 1994 and 1995, two years with average flow regimes.

It appears from this limited comparison that flow affects the relative catch of juvenile chinook by the two gear types only if high flows occur during the spring when juvenile chinook are most vulnerable to downstream displacement. Forced spills at other times of the year do not appear to affect the relative catches of the two gears.

Table 6.2-2 Nechako River: catches of fish by electrofishing and ancillary methods, upper river, 1989 to 1998

common name	scientific name	life stage	percent of annual totals 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	total
Redside shiner	*Richardsonius balteatus*	juv	22.1	31.8	17.4	17.2	19.4	26.6	31.6	24.7	21.6	16.9	22.5
		adult	2.5	5.9	5.9	3.3	8.3	7.0	4.7	3.9	4.0	5.1	5.1
		pooled	24.6	37.7	23.3	20.5	27.7	33.6	36.3	28.6	25.7	22.0	27.6
Chinook salmon	*Oncorhynchus tshawytscha*	0+	19.6	6.8	23.7	29.0	17.1	6.7	8.2	26.1	29.6	27.2	19.6
		1+	0.0	0.1	0.1	0.2	0.6	0.5	0.1	0.5	1.3	0.4	0.3
		pooled	19.6	6.9	23.8	29.2	17.7	7.2	8.3	26.6	30.8	27.6	19.9
Largescale sucker	*Catostomus macrocheilus*	juv	31.0	20.5	11.0	10.5	13.7	13.5	15.5	10.1	7.4	15.7	14.5
		adult	0.3	0.4	0.3	0.3	0.1	0.1	0.5	0.1	0.1	0.1	0.2
		pooled	31.3	20.8	11.3	10.8	13.9	13.6	16.0	10.1	7.5	15.8	14.7
Northern pikeminnow*	*Ptychocheilus oregonensis*	juv	10.8	16.7	16.8	15.0	15.9	11.7	11.7	13.5	12.6	10.3	13.9
		adult	0.1	0.1	0.3	0.0	0.1	0.2	0.3	0.2	0.1	0.4	0.2
		pooled	10.9	16.9	17.1	15.1	16.0	11.9	12.0	13.7	12.7	10.7	14.1
Leopard dace	*Rhinichthys falcatus*	juv	0.1	1.9	2.3	4.8	3.9	6.7	8.7	6.5	5.2	5.5	4.5
		adult	0.8	0.6	3.2	1.5	2.2	2.2	1.7	1.2	2.8	2.8	1.9
		pooled	0.9	2.5	5.4	6.3	6.1	8.9	10.5	7.6	8.0	8.3	6.4
Longnose dace	*Rhinichthys cataractae*	juv	0.2	0.5	6.2	5.4	6.7	10.5	9.9	6.8	3.6	4.6	5.5
		adult	0.2	0.6	0.7	0.7	0.9	1.1	0.7	0.4	0.6	1.6	0.8
		pooled	0.4	1.1	6.9	6.1	7.6	11.5	10.5	7.2	4.2	6.2	6.3
Sculpins (general)	*Cottidae*	juv	1.8	5.3	7.2	5.1	5.2	8.3	3.2	2.2	3.0	3.9	4.8
		adult	0.0	1.0	0.0	0.9	1.9	1.9	1.4	1.5	1.3	2.3	1.2
		pooled	1.8	6.3	7.2	5.9	7.1	10.2	4.6	3.8	4.2	6.1	6.0
Mountain whitefish	*Prosopium williamsoni*	juv	8.3	5.4	3.9	3.2	2.9	2.3	1.3	1.4	5.6	2.3	3.5
		adult	1.5	1.2	0.5	0.4	0.2	0.1	0.1	0.2	0.3	0.2	0.5
		pooled	9.8	6.6	4.4	3.6	3.1	2.3	1.4	1.6	5.9	2.5	3.9
Rainbow trout	*Oncorhynchus mykiss*	juv	0.3	0.6	0.3	0.2	0.4	0.4	0.3	0.4	0.4	0.2	0.3
		adult	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.3	0.1	0.1
		pooled	0.3	0.6	0.3	0.4	0.5	0.5	0.3	0.5	0.6	0.3	0.4
Sockeye salmon	*Oncorhynchus nerka*	0+	0.4	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
		1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.4	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Peamouth chub	*Mylocheilus caurinus*	juv	0.1	0.5	0.0	0.0	0.2	0.1	0.1	0.1	0.3	0.3	0.2
		adult	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.1	0.5	0.1	0.0	0.2	0.1	0.1	0.1	0.3	0.3	0.2
Burbot	*Lota lota*	juv	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0
		adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0
Bull trout	*Salvelinus confluentes*	juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Coho salmon	*Oncorhynchus kisutch*	0+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
		1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Lake trout	*Salvelinus namaycush*	0+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
all fish		**total**	**43,576**	**81,553**	**112,975**	**106,350**	**56,178**	**54,952**	**73,101**	**57,610**	**30,617**	**79,144**	**696,056**

* previously known as "northern squawfish" (Nelson *et al.* 1998).

Table 6.2-3 **Nechako River: catches of fish by rotary screw trap and ancillary methods, Diamond Island, 1989 to 1998**

common name	scientific name	life stage	percent of annual total										
			1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	total
Chinook salmon	*Oncorhynchus tshawytscha*	0+	29.4	8.2	54.4	50.2	64.4	43.0	45.0	55.4	59.8	46.6	42.7
		1+	0.0	0.0	0.2	0.8	0.5	2.8	0.7	1.6	4.3	7.7	1.2
		pooled	29.4	8.3	54.6	51.0	64.8	45.8	45.7	57.1	64.1	54.3	43.9
Redside shiner	*Richardsonius balteatus*	juv	26.9	42.6	12.0	7.4	7.5	8.8	5.8	5.7	4.5	6.7	16.3
		adult	0.0	5.1	5.5	1.9	3.5	3.5	7.6	2.1	1.6	4.6	4.0
		pooled	26.9	47.7	17.4	9.2	11.0	12.3	13.4	7.7	6.1	11.4	20.3
Largescale sucker	*Catostomus macrocheilus*	juv	33.9	17.4	8.9	10.1	10.6	11.8	17.3	14.5	8.3	7.8	13.3
		adult	0.0	0.0	0.7	0.2	0.3	0.3	1.2	0.2	0.1	0.7	0.4
		pooled	33.9	17.4	9.6	10.3	10.9	12.2	18.5	14.6	8.4	8.5	13.7
Northern pikeminnow*	*Ptychocheilus oregonensis*	juv	5.2	18.7	9.4	7.0	5.5	8.5	8.1	11.8	10.6	6.1	10.2
		adult	0.0	0.0	1.2	0.2	0.4	0.4	0.4	0.1	0.4	0.0	0.4
		pooled	5.2	18.8	10.6	7.2	5.9	9.0	8.5	11.9	10.9	6.1	10.6
Leopard dace	*Rhinichthys falcatus*	juv	0.6	3.8	0.1	2.1	1.4	5.2	2.1	2.5	2.2	1.8	2.1
		adult	0.0	0.0	1.5	0.3	1.5	5.3	3.0	1.2	1.0	7.4	1.6
		pooled	0.6	3.8	1.6	2.4	2.9	10.5	5.1	3.8	3.1	9.2	3.7
Sockeye salmon	*Oncorhynchus nerka*	0+	0.7	0.5	0.6	14.3	2.2	1.8	1.7	1.7	0.3	4.2	3.1
		1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
		pooled	0.7	0.5	0.6	14.3	2.2	1.8	1.7	1.7	0.3	4.2	3.1
Mountain whitefish	*Prosopium williamsoni*	juv	0.1	0.2	2.0	3.8	0.7	4.8	5.2	0.4	0.2	3.1	1.9
		adult	0.0	0.0	0.6	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.1
		pooled	0.1	0.3	2.6	3.8	0.7	4.9	5.2	0.4	0.4	3.1	2.0
Longnose dace	*Rhinichthys cataractae*	juv	1.9	1.6	2.0	1.0	0.8	1.8	0.7	1.5	0.5	0.3	1.3
		adult	0.0	0.0	0.5	0.1	0.1	0.6	0.5	0.2	0.2	0.8	0.3
		pooled	1.9	1.6	2.5	1.0	1.0	2.4	1.2	1.7	0.7	1.1	1.6
Peamouth chub	*Mylocheilus caurinus*	juv	0.3	1.3	0.0	0.0	0.0	0.2	0.1	0.5	4.9	1.1	0.5
		adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.3	1.3	0.0	0.0	0.0	0.2	0.1	0.5	4.9	1.1	0.5
Sculpins (general)	*Cottidae*	juv	0.9	0.3	0.2	0.4	0.1	0.5	0.3	0.1	0.4	0.2	0.3
		adult	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.2	0.1
		pooled	0.9	0.3	0.2	0.4	0.2	0.7	0.3	0.2	0.4	0.4	0.4
Rainbow trout	*Oncorhynchus mykiss*	juv	0.0	0.0	0.1	0.1	0.3	0.2	0.1	0.4	0.7	0.5	0.2
		adult	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.2	0.1	0.3	0.2	0.1	0.4	0.7	0.5	0.2
Burbot	*Lota lota*	juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coho salmon	*Oncorhynchus kisutch*	0+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake trout	*Salvelinus namaycush*	0+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bull trout	*Salvelinus confluentes*	juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		pooled	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
all fish		**total**	**10,592**	**45,208**	**39,397**	**29,604**	**27,852**	**11,496**	**12,610**	**17,680**	**5,021**	**15,630**	**215,090**

* previously known as "northern squawfish" (Nelson *et al.* 1998).

Figure 6.2-12 **Nechako River: percent of total number of fish caught each year, upper river, 1989 to 1998**

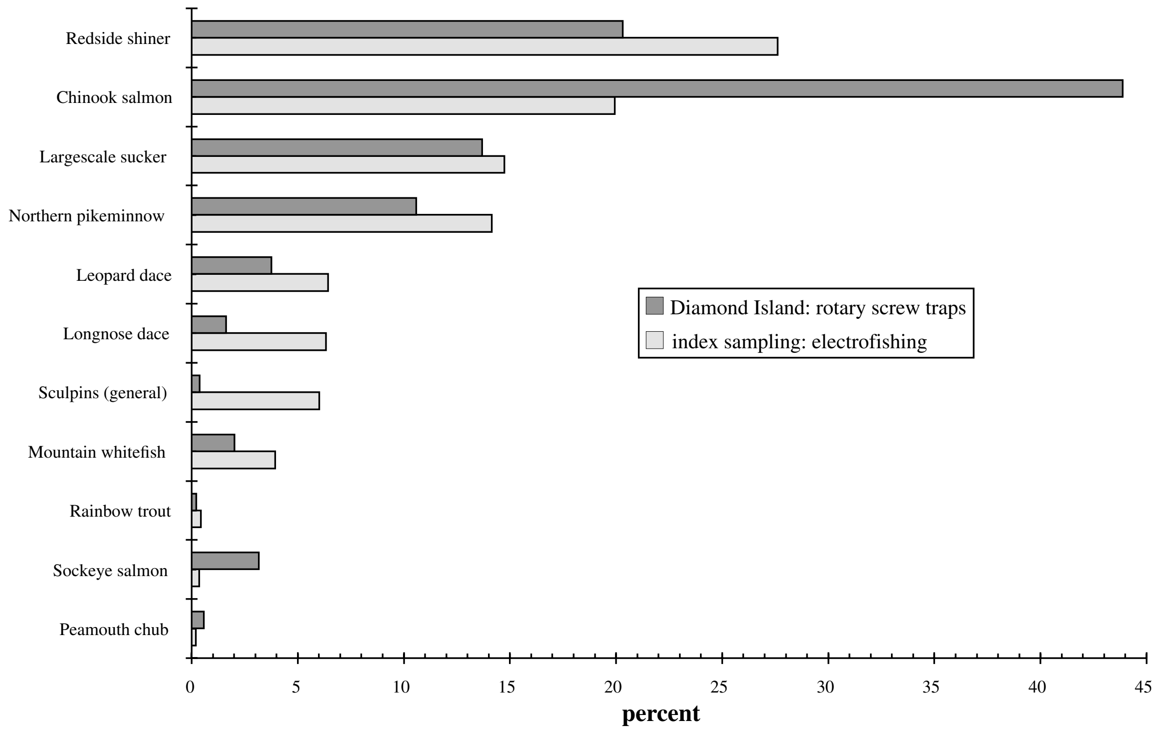
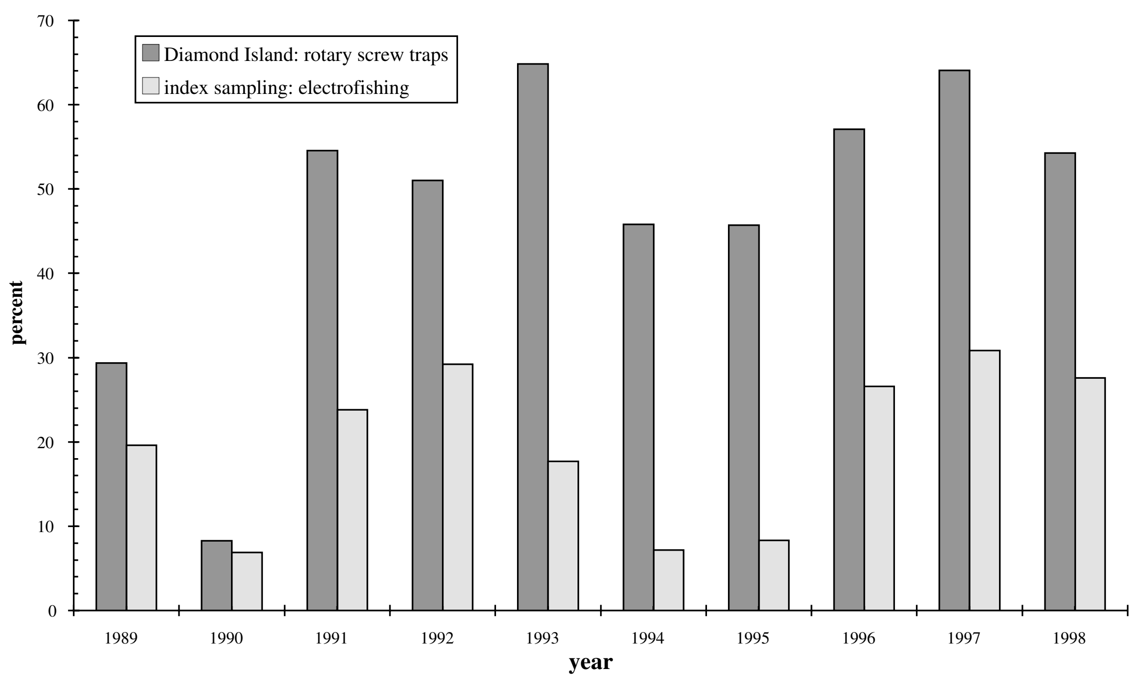


Figure 6.2-13 **Nechako River: percent of total number of fish sampled by rotary screw trap and by index sampling (electrofishing) that are chinook, 1989 to 1998**



6.2.2.4.1 Discovery of Coho in the Upper Nechako River

Between 1990 and 1998, 94 juvenile coho salmon were caught by electrofishing and 15 in RSTs. Until recently, there has been controversy about the presence of coho in the upper Nechako River, mainly because few voucher specimens had been kept for expert examination. However, in 1999 Professor J.D. McPhail of UBC used genetic analysis to definitively identify some specimens as coho.

Based on the location of the electrofishing catches, these coho are assumed to be the product of tributary spawning in the headwaters of the Nechako River near to Cheslatta Falls.

6.2.2.5 Effects of Flows and Temperatures on the Population Biology of Juvenile Chinook

An important conclusion of the effort to monitor juvenile chinook population biology in the upper Nechako River is that biological variables (size, growth, condition factors) have shown relatively little variation among years because of a generally stable flow and temperature regime. There has been relatively little among-year variation in juvenile chinook size-at-age and that variation is probably related to inter-annual variations in temperature. Variations in flows undoubtedly contribute to variations in temperature, but meteorological variables are equally important.

That said, this report does not discuss flow-related variations in size-at-date because it is not possible to reliably separate the influence of flow from the influence of temperature.

6.2.3 Summary: Juvenile Chinook Out-migration Project

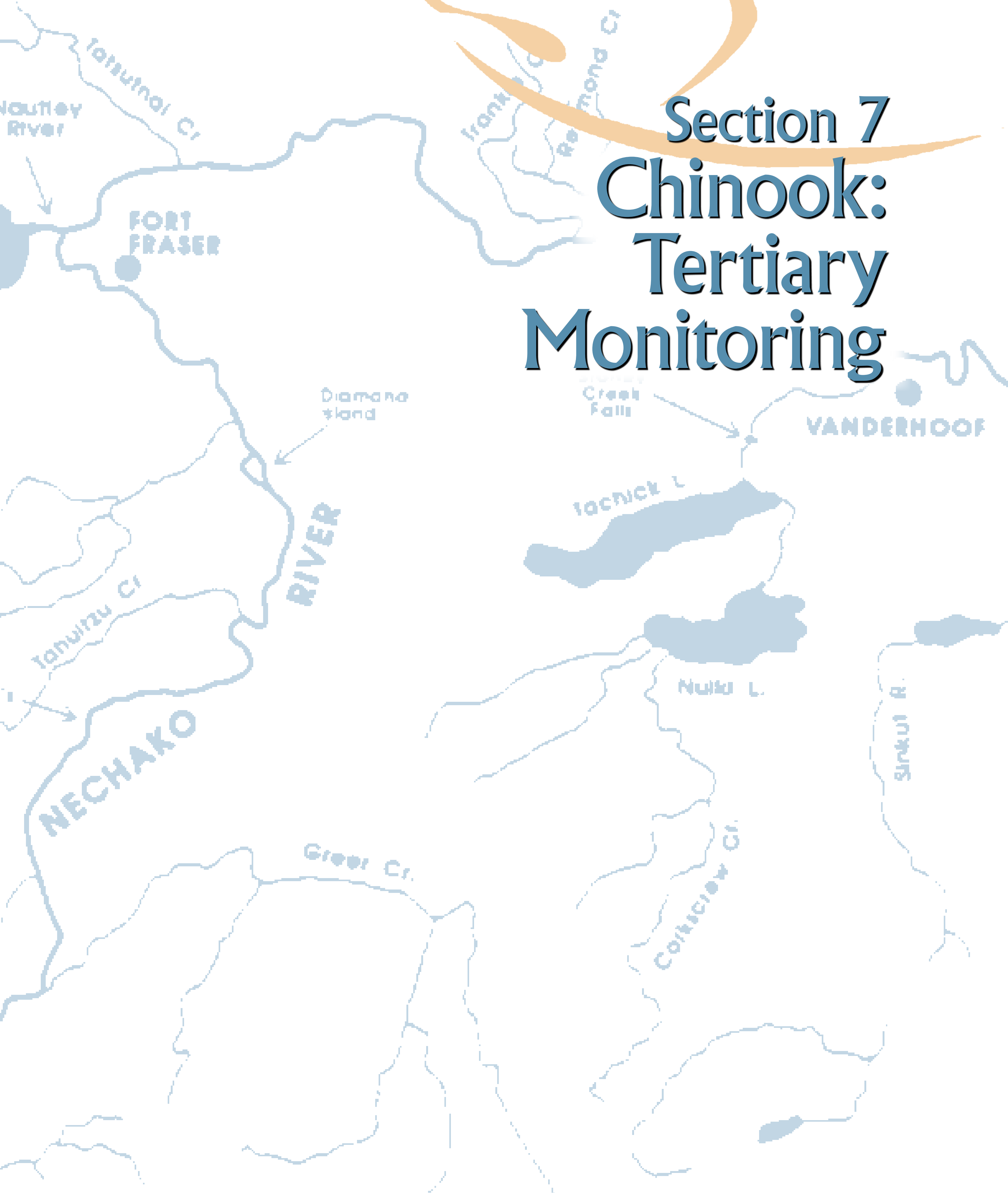
Biological variables for the juvenile chinook population have shown relatively little variation among years over the study period. The index of out-migrants was significantly and positively correlated with the number of adult chinook estimated to have spawned above Diamond Island (km 84) the previous year, indicating a stable rearing environment capable of supporting populations observed in the river over the range of spawners seen during the data collection period. Juvenile chinook have been the dominant or second ranking species in terms of number and density.

The present sampling program is satisfactory for monitoring changes in chinook body size, their relative abundance and spatial distribution in the river, and the number of out-migrants under the current flow and temperature regime. The studies have established a good baseline against which any future measurements of abundance can be compared.

Under the conditions seen during the project period, numbers of fry rearing along margin habitats in the upper Nechako River and emigrating from the upper river were in proportion to the number of adults that spawned in the previous fall. Adult returns of four and five years old, associated with these measured fry (0+) have generally fallen within the range stipulated in the *1987 Settlement Agreement*, indicating that, under current conditions, habitat capacity in the upper Nechako River is sufficient to ensure that the Conservation Goal is met.

The exception is the apparent habitat saturation effect created by the large spawner return in 2001, which exceeded the upper range of the Conservation Goal identified in the *1987 Settlement Agreement*.

Section 7
Chinook: Tertiary Monitoring



A NUMBER OF PARAMETERS SERVE AS IMPORTANT INDICATORS OF SUCCESSFUL CHINOOK SALMON PRODUCTION DURING THE FISH'S VARIOUS freshwater life-history stages. These include:

- physical data (*e.g.,* air and water temperatures; discharge);
- winter physical conditions;
- dissolved O_2; and
- substrate quality and composition.

Changes in these parameters can provide possible explanations for observed changes or trends in primary or secondary monitoring parameters, such as egg-to-fry survival, fry condition and the out-migration index. If a change in secondary monitoring indices is detected, then results from tertiary monitoring can be examined to help isolate the cause for the trend and, if needed, help identify the most appropriate remedial activity.

Recognizing that reliable physical data are required for biological and physical monitoring programs and related fisheries research projects, the Nechako Fisheries Conservation Program (NFCP) Technical Committee instituted the following tertiary monitoring projects[48]:

- Physical Data Collection Project;
- Winter Physical Conditions Project;
- Dissolved Oxygen Monitoring Project; and
- Substrate Quality and Composition Project.

7.1 PHYSICAL DATA COLLECTION PROJECT

The objective of the Physical Data Collection Project was to document air and water temperatures and water flows at several locations on the Nechako River in support of other Technical Committee physical and biological studies. Data from the project were used for Nechako River chinook spawning, incubation and rearing, summer temperature control and winter ice monitoring studies. Where possible, all physical data were compared to long-term data to place the results of each study year into a broader context.

Hydrological data for the upper Nechako River basin were obtained from various agencies, including the Water Survey of Canada (WSC)—specifically from Data Collection Platform Station 08JA017 at Bert Irvine's Lodge (km 19)—and the Atmospheric Environment Service (AES)—specifically from the Vanderhoof Climate Station 1098D90[49]. The committee also maintained up to six water-temperature datalogger sites—Cheslatta Falls (km 9), Greer Creek (km 44), Fort Fraser (km 95), Vanderhoof (km 154), Nautley River, and Prince George above the confluence with the Fraser River. A thermograph was located at km 19 to serve as a backup data source for the WSC station (**Table 7.1-1**). Submersible dataloggers were used beginning in 1996 as general backup data sources and, in particular, whenever technical problems put an installed water-temperature datalogger temporarily out of service.

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[48] Some tertiary projects—*e.g.*, observing ice movements and jam characteristics on the Nechako River—were suspended or cancelled due to lack of relevance subsequent to the province rejected the Kemano Completion Project.

[49] Much of the same temperature and discharge data were used for both the Physical Data Collection Project (providing year round data), and the Winter Physical Conditions Project (providing winter data).

Table 7.1-1 **Nechako River: mean monthly water temperatures (°C) at Bert Irvine's Lodge, 1980 to 2000***

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1980	-	-	-	-	10.6	15.8	16.6	16.0	13.5	10.0	5.7	1.7
1981	1.5	1.8	2.6	4.0	8.3	12.6	16.3	17.4	14.8	9.2	6.6	0.0
1982	0.3	0.7	1.1	1.7	5.4	14.0	17.9	15.5	14.5	10.3	4.2	1.5
1983	1.0	0.8	1.6	-	9.0	12.7	14.9	16.3	13.5	8.9	5.1	1.8
1984	0.6	0.9	2.0	3.8	7.1	10.0	14.0	15.1	12.2	9.0	3.0	1.5
1985	0.9	0.9	1.9	4.0	8.6	13.2	16.2	15.9	13.1	8.8	3.0	1.3
1986	1.1	0.0	1.3	3.9	6.8	13.1	15.7	16.8	14.0	10.2	4.0	1.4
1987	1.3	1.3	1.7	3.9	7.8	13.0	16.8	15.8	14.3	10.2	5.9	1.9
1988	0.7	0.8	2.2	4.1	8.4	12.0	15.3	16.0	14.3	10.3	5.1	1.5
1989	0.8	0.2	1.1	3.1	7.6	14.1	16.5	17.2	15.1	10.7	5.2	2.2
1990	0.9	0.4	1.6	3.6	7.5	12.8	16.9	17.7	15.6	8.8	3.2	0.9
1991	0.6	1.2	1.1	3.7	8.7	13.3	16.7	17.0	14.5	9.4	4.0	2.0
1992	1.2	1.1	2.4	4.7	9.0	15.2	17.0	17.7	13.1	8.6	4.6	1.4
1993	0.9	1.5	2.9	4.9	10.1	14.4	15.7	17.0	14.9	10.2	4.8	2.0
1994	1.3	0.4	1.7	3.8	8.7	13.6	16.5	17.2	15.0	9.9	4.1	1.4
1995	0.8	0.7	1.1	3.2	9.0	14.4	17.0	15.8	15.5	10.0	3.9	1.1
1996	0.3	0.3	0.9	2.4	7.0	11.6	14.2	15.5	13.5	9.5	4.4	1.0
1997	0.6	0.4	0.9	2.7	6.5	10.7	14.2	16.0	14.9	10.0	5.3	2.4
1998	1.0	1.1	1.6	3.7	10.4	15.8	18.2	17.7	14.8	10.0	5.1	1.5
1999	1.1	0.7	1.3	2.9	6.6	11.6	15.1	16.6	14.0	9.1	4.6	1.8
2000	0.4	0.5	1.4	3.4	7.6	13.5	15.4	14.9	12.6	9.2	5.2	2.2
mean	**0.9**	**0.8**	**1.6**	**3.5**	**8.1**	**13.2**	**16.1**	**16.4**	**14.2**	**9.6**	**4.6**	**1.5**

* DFO data

7.1.1 WSC and AES Data Collection

The WSC has maintained a data collection station on behalf of the Department of Fisheries and Oceans at km 19 since 1980. Station 08JA017, which began collecting hydrometric data at the site in 1986, provided the only discharge data compiled in this project. A mechanical thermograph for water temperature and a maximum/minimum air thermometer were also used as backup to the Data Collection Platform data.

Data were regularly retrieved for processing, inclusion in the database and for analysis from km 19 and the AES's air temperature site at the Vanderhoof station. The Department of Fisheries and Oceans also collected water temperature data from kms 9, 44, 95, and 154, and in the Nautley River. The data were made available to other projects on an ongoing basis.

7.1.2 Results and Discussion

The data collected in this project were incorporated into Technical Committee's analyses and reports and were not reported separately. A database was assembled containing air and water temperatures and discharge information for the Nechako River.

7.2 WINTER PHYSICAL CONDITIONS PROJECT

The objective of the Winter Physical Conditions Project was to document the range of variability of water temperature, air temperature and ice conditions on the Nechako River in winter. The data collected by the project from 1988 to 1996 was necessary to help explain some of the changes observed in the secondary monitoring project. It also contributed to better understanding the upper Nechako River system in winter and the affects that could potentially occur as a result of originally proposed alterations to the flow regime. The data was also useful in other projects for such things as calculating accumulated thermal units for fry emergence indexing. [See *ss. 6.1.1.1 Sampling the IPTs*]

Ice formation on the upper Nechako River begins in response to sub-zero air temperatures in the fall. Shore ice develops along the river margins and still water in back channels and interstitial spaces, freezing *in situ*. At about the same time, super-cooling due to water-to-air energy loss results in frazil ice[50]. Mixing the water results in the agglomeration of frazil ice into pans; where there is a more complete mixing to depth, frazil ice sometimes adheres to the gravel and accumulates to form patches of anchor ice.

Floating ice pans grow in size as the current moves them downstream. These combine with shore ice until the river's full width is bridged. This process results in more rapid development of full-width ice cover as pan ice is added to the upstream edge of the bridged section.

Open water leads often persist in similar locations from year to year due to localized up-welling currents or as a result of warmer inflow from tributaries or groundwater. Changes in water level during the winter can result in flooding over the ice surface via open leads or cracks, melting any snow accumulated on the surface, or freezing over the existing ice cover.

Ice cover break-up due to the spring freshet is generally dampened in the Nechako River as a result of flow regulation. While a general and sudden break-up does sometimes occur in response to changes in discharge, most often the ice gradually "rots" in place as air and water temperatures rise in the spring. This results in slower, patchy disintegration of ice cover along the river's length. Shore ice is the last ice to disappear.

7.2.1 Over-flights and Local Observations

Data collection included regularly monitoring hydrological and meteorological data [see *ss. 7.1 Physical Data Collection Project*] including:

- water temperature;
- Nechako River discharge;
- air temperature in the upper Nechako River basin; and
- descriptions of the winter ice regime.

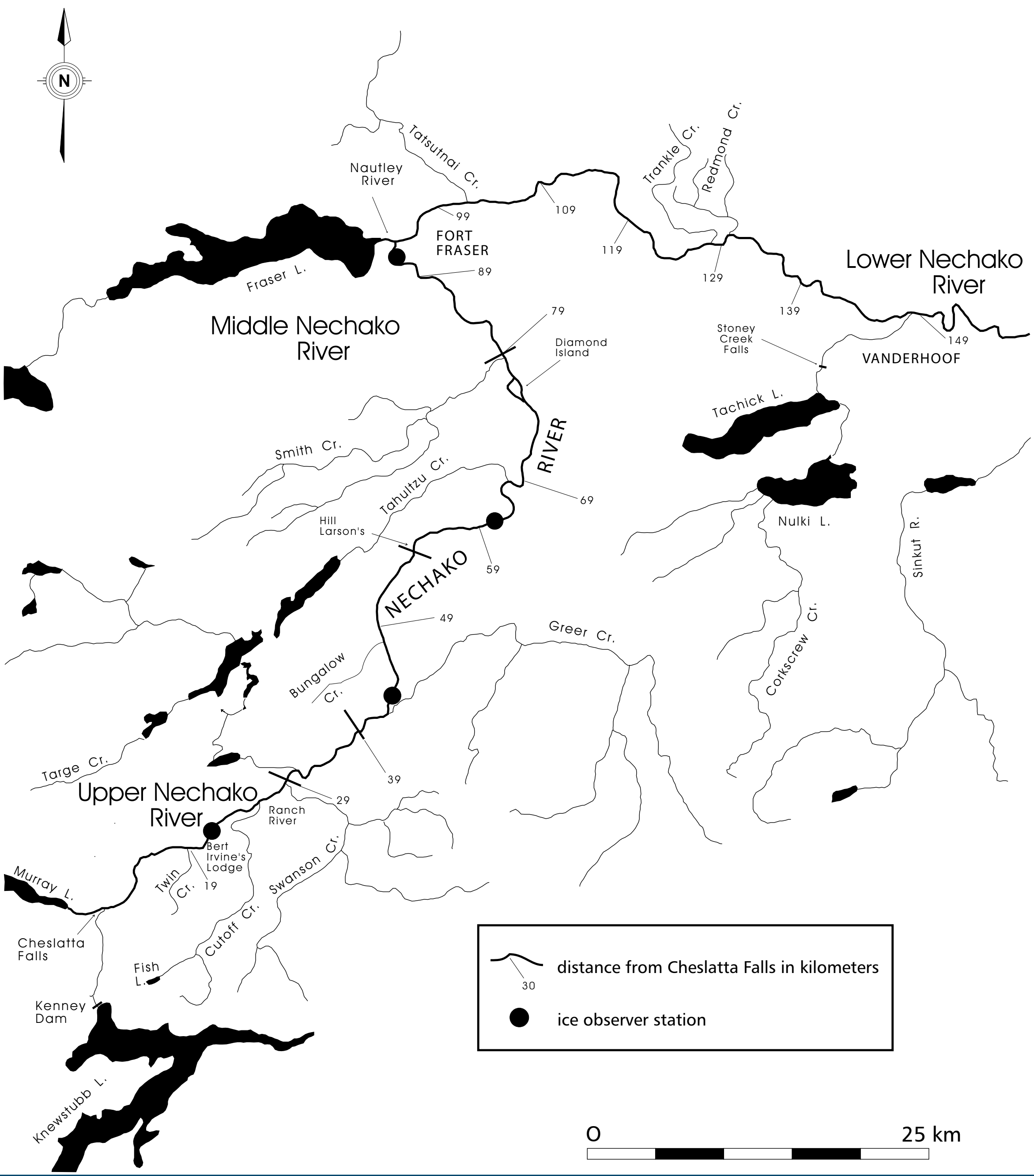
Helicopter over-flights were conducted upstream from the Nechako River's confluence with the Stuart River to Cheslatta Falls two to three time per winter from 1987-88 to 1995–96. Observers on these flights mapped ice conditions, noting the upstream position of the ice's leading edge, the extent and type of ice cover, and the location of open-water leads in ice-covered areas. The presence of anchor ice in open reaches was also noted.

Ice conditions were also recorded almost daily at four sites on the river from November to April each year. These observations were taken near kms 19, 44, 54, and 89. Local observers were trained to identify and record on a standard form

[50] The surface of the water freezes into small, independent ice crystals.

the type and extent of ice occurring at the site and to photograph the ice conditions at a specified location on the river to document changes. Observers also occasionally collected data on ice thickness to aid in understanding the effects of ice on the incubation and over-wintering environment. Ice thickness was measured at kms 54 and 89 and, when sufficient ice had formed, at km 19. The locations of the various data collection sites are shown in **Figure 7.2-1**.

Figure 7.2-1 **Nechako River: location of ice conditions data collection sites in the upper river**



The ice observer data were compiled and analyzed by Department of Fisheries and Oceans staff.

7.2.2 Results and Discussion

The results of the Winter Physical Conditions Project have been described in NFCP annual reports. The data are on file at the Department of Fisheries and Oceans, Vancouver[51].

The recording instruments generally functioned as planned. There were occasional battery and sensor problems common to most datalogger installations in difficult environments, and there were instances of vandalism and tampering that resulted in lost equipment and data. Equipment was repaired and replaced as required, and relocated for logistic reasons and to cope with changes in bank stability.

Winter atmospheric conditions on the Nechako River were typically evaluated relative to the climate record at Vanderhoof where the AES station had kept records since 1916 (**Table 7.2-1**) ranks winter temperature severity, represented by freezing degree-days, 1916 to 1997). The years covered by this project include some of the ten mildest winters on record, the coldest year (1992/93) ranking only 29th out of 81 years. Unfortunately the Vanderhoof station was decommissioned in 1997, making a more recent comparison to the long-term record difficult.

That said, evidence that the climate in British Columbia has been generally warmer during the last 10 to 15 years (Whitfield and Cannon, 2000) supports the fact that the data collected in this project is representative of a period significantly warmer than the earlier portion of the climate record. This should be born in mind when using the data set in the future, particularly if there is a climatic shift back towards the middle or cooler climate range for the area.

[51] The compiled hydrological data are generally in MS-Excel spreadsheets while reports, including ice observer notes, are in MS-Word documents. Ice over-flight maps are on paper, while those from the winter of 1990-91 onwards are also in CorelDraw files.

Table 7.2-1 Nechako River: accumulated degree days below 0°C at Vanderhoof and ranking*, 1916-1997

Rank	Year	Starting date	Ending date	Degree days to Dec. 31	Degree days after Jan. 1	Total degree days below 0 °C
1	1921-22	Nov-07	Apr-16	712.6	1172.5	1885.1
2	1978-79	Oct-26	Apr-13	682.9	1166	1848.9
3	1971-72	Oct-15	Apr-17	728	1117.5	1845.5
4	1919-20	Oct-13	Apr-14	792.9	1041.1	1834
5	1968-69	Oct-10	Apr-02	573.8	1195.2	1769
6	1916-17	Oct-01	May-02	598.1	1075.7	1673.8
7	1935-36	Oct-08	Apr-04	396.2	1262.6	1658.8
8	1956-57	Oct-18	Apr-12	467.1	1129.5	1596.6
9	1970-71	Oct-05	Apr-16	691.5	842.8	1534.3
10	1917-18	Oct-14	Apr-16	609.2	924.1	1533.3
11	1924-25	Oct-17	Apr-15	732.6	798.4	1531
12	1973-74	Oct-19	Apr-26	618.6	893.8	1512.4
13	1964-65	Oct-25	Apr-20	716.9	740.4	1457.3
14	1961-62	Oct-09	Mar-28	611.8	827.6	1439.4
15	1936-37	Oct-30	Mar-28	392.5	1039.4	1431.9
16	1955-56	Oct-18	Apr-06	937.7	488.8	1426.5
17	1979-80	Oct-17	Apr-08	474.7	914.2	1388.9
18	1977-78	Oct-19	Apr-14	711.3	671.1	1382.4
19	1981-82	Oct-21	Apr-15	325.7	1044.5	1370.2
20	1974-75	Oct-28	Apr-08	366.6	994.1	1360.7
21	1929-30	Oct-27	Apr-23	384.4	958.2	1342.6
22	1922-23	Oct-26	Apr-29	411	920.5	1331.5
23	1975-76	Oct-25	Apr-03	506.2	749.9	1256.1
24	1918-19	Nov-05	Apr-13	334.5	918.1	1252.6
25	1972-73	Sep-22	Mar-28	500.1	748.5	1248.6
26	1966-67	Oct-10	Apr-19	506.1	733.6	1239.7
27	1938-39	Nov-05	Apr-05	443.5	791.1	1234.6
28	1937-38	Oct-28	Apr-01	491.2	715.7	1206.9
29	1992-93	Oct-13	Mar-18	426.4	780.1	1206.5
30	1984-85	Oct-17	Mar-29	738.8	463	1201.8
31	1985-86	Oct-07	Apr-12	738.5	460.9	1199.4
32	1958-59	Oct-08	May-01	411	776.6	1187.6
33	1988-89	Oct-28	Mar-22	313.4	867.5	1180.9
34	1990-91	Oct-11	Mar-26	541.5	631.6	1173.1
35	1928-29	Oct-10	Apr-11	331.7	815.1	1146.8
36	1967-68	Oct-28	Apr-12	396.1	685.6	1081.7
37	1959-60	Oct-07	Mar-29	386.9	643.6	1030.5
38	1954-55	Nov-06	Apr-25	228.7	776.4	1005.1
39	1923-24	Nov-04	Apr-27	234.5	763.6	998.1
40	1920-21	Nov-08	May-06	303.9	678.1	982
41	1953-54	Oct-23	Apr-30	173.7	789.6	963.3
42	1940-41	Oct-26	Mar-25	447.5	468.5	916
43	1960-61	Oct-17	Apr-14	417.7	495.8	913.5
44	1952-53	Oct-25	Apr-14	258.9	630.1	889
45	1963-64	Oct-26	Mar-26	452.8	426	878.8
46	1983-84	Nov-05	Mar-20	621.5	237.1	858.6
47	1993-94	Nov-04	Mar-19	229	613	842
48	1982-83	Oct-19	Mar-25	468.9	355.2	824.1
49	1987-88	Nov-02	Apr-02	203.6	443.2	746.8
50	1989-90	Oct-28	Apr-09	186.7	547	733.7
51	1957-58	Oct-02	Mar-25	282.5	448.7	731.2
52	1986-87	Oct-30	Mar-28	404.7	306.8	711.5
53	1939-40	Oct-05	Mar-23	140.1	560.6	700.7
54	1976-77	Oct-14	Mar-30	246.7	424	670.7
55	1980-81	Oct-26	Apr-12	340.5	282.3	622.8
56	1991-92	Oct-17	Apr-10	203.8	228	431.8
57	1993-94					
58	1994-95				Data to be added when available	
59	1995-96					
60	1996-97					
Earliest		**Sep-22**	**Mar-18**			
Mean		**Oct-20**	**Apr-08**			**1203.9**
Latest		**Nov-08**	**May-06**			

* AES data

Table 7.2-2 documents the position of the leading edge of Nechako River ice cover observed during helicopter over-flights. The January locations ranged from km 24.5 to km 45, the February location from km 18.5 to km 34.5, and the March location from km 21.5 to km 75.5. These observations represent a snapshot of the river from a limited number of specific dates and do not encompass the full range of variability of ice cover dynamics.

Table 7.2-2 **Nechako River: helicopter overflight observations of the location of the leading edge of ice cover**

helicopter overflight date	leading edge of ice (river km)
Jan. 13, 1988	28
Mar. 24, 1988	128
Dec. 20, 1988	not defined
Jan. 30, 1989	45
Apr. 14, 1989	170
Feb. 1, 1990	18.5
Mar. 2, 1990	39.5
Dec. 18, 1990	41.5
Jan. 31, 1991	24.5
Mar. 4, 1991	21.5
Feb. 16, 1993	34.5
Mar. 23, 1993	75.5
Jan. 28, 1995	25.5
Mar. 8, 1995	not well defined
Jan. 18, 1996	22.5

Frazil and pan ice generally occurred in open reaches during sub-zero periods, as did shore ice when complete ice cover was not present. Anchor ice was visible from the air and sometimes from the shore in open water areas in the upper river.

Ice at kms 54 and 89—which typically formed full coverage in late November or early December and lasted until mid- to late-March—attained thickness of up to 51 cm. The ice at km 19 occurred only every second or third winter and lasted only 12 to 34 days, usually during and briefly following periods of severe cold[52]. The thickness and persistence of the full-width ice at km 19 was always less than that at kms 54 and 89.

Helicopter over-flights were suspended in 1996 following the provincial government's cancellation of the Kemano Completion Project and having ice observers recording daily ice condition was discontinued in the winter of 1997/98. Monitoring winter river water temperatures and area air temperatures continued as part of the year-round activities of the Physical Data Collection Project.

Since the reduced flow regime was never implemented, the original objective of the Winter Physical Conditions Project—comparing conditions under the interim flow regime with reduced flow conditions—could not be met. Regardless, the database provides a reference that may be useful for data analysis in companion projects under the NFCP, or to future studies of aquatic resources on the upper Nechako River.

[52] The data backing these observations are on file at the Department of Fisheries and Oceans, Vancouver.

7.3 DISSOLVED OXYGEN MONITORING PROJECT

The objective of the Dissolved Oxygen Monitoring Project was to develop and test a system to remotely measure dissolved oxygen in inter-gravel water in order to detect changes in chinook incubation habitat with potential changes in river flow. To reach this objective, links between inter-gravel dissolved oxygen concentrations and biological measures of emergence success or survival needed to be part of the study design to ensure a workable habitat performance criterion. The first step toward making these connections was to develop a technology to continuously monitor inter-gravel dissolved oxygen (DO) in chinook redds.

Various DO probes were reviewed in 1989 and 1990. Suppliers and experts in the field were consulted to determine what type of equipment could measure inter-gravel DO in harsh winter conditions. The recommended equipment was:

- lab-tested under known water temperatures and DO levels;
- placed in a simulated redd and introduced to a range of water velocities to determine if they accurately recorded DO at these velocities;
- installed in the Little Qualicum River (Vancouver Island) spawning channel and the readings compared to readings generated by probes already installed in the channel;
- tested with computer-controlled valves and flow meters to determine the ideal type of DO monitoring system for a natural spawning redd; and
- evaluated for calibration frequency requirements.

In 1992/93, a probe assembly and datalogger system was installed in the Nechako River at a known redd site to test the equipment. The probes were serviced and re-calibrated and the data retrieved on a regular basis. Extreme conditions during the winter of 1992/93 resulted in some changes to the equipment, including the installation of solar panels to continuously charge equipment batteries.

In March 1994, a memory failure occurred in the datalogger unit, possibly due to a voltage spike during a thunderstorm. The equipment was thoroughly serviced and voltage regulators, surge and static suppressers added, and all internal backup batteries replaced. The equipment was reinstalled in July 1994. During the 1995/96 winter season the probe assemblies were forced out of their standpipes on several occasions, probably because of frazil ice accumulations. A new set of standpipes with locking caps to keep the probe assembly in place was manufactured and installed.

The system was eventually to be applied to active chinook salmon redds to monitor changes in the dissolved oxygen content under the reduced flow regime described in the *1987 Settlement Agreement.* However, following the cancellation of the Kemano Completion Project there was no longer a need to continue developing this technology and the project was discontinued. Although there may be scientific merit in continuing this type of work, it does not fall within the mandate of the Technical Committee.

7.4 SUBSTRATE QUALITY AND COMPOSITION PROJECT

The overall objective of substrate monitoring is to detect any long-term changes in chinook spawning and rearing habitat. The short-term objective is to design and test a sampling program which will allow the detection of changes that could affect chinook, and to establish a baseline for comparison with future samples. Substrate quality is important in the egg incubation/fry emergence life stages of chinook, for rearing habitat quality and for benthic[53] invertebrate prey production. Developing a substrate index is especially important in view of the commonly held assumption that substrate quality deteriorates following flow regulation (Reiser *et al.* 1985).

Substrate quality is usually measured as the proportion of fine sediments (<2mm) in stream gravels. In fact, many studies have described inverse relationships between the proportion of "fines" and the percentage of egg survival and fry emergence (BCUC 1994). This is because increased levels of fines cause lower intra-gravel water velocities, which in turn lowers oxygen supply to eggs and alevins[54]. Lower water velocities also decrease the rate at which metabolic wastes are removed from the intragravel environment, while a large proportion of fines has the potential to entomb alevins and fry.

The Technical Committee recognized the potential for siltation following the completion of the Kemano Completion Project, and in August 1989 a substrate quality and composition workshop was held to discuss the technical requirements of a gravel-sampling project. The participants concluded that a slow accumulation of fines was to be anticipated and recommended that:

- intra-gravel DO be measured to monitor the Nechako River's incubation environment;
- sand accumulation be monitored; and
- the project objectives be well defined before collecting baseline data on gravel quality.

The committee addressed these recommendations by:

- developing oxygen measuring techniques;
- developing a baseline gravel quality monitoring project; and through
- HEC-2 modelling. [See *ss. 8.7.1.1 HEC-2 Model Description and Input Data*]

A pilot study on Nechako River substrate[55] quality and composition was conducted in March of 1990 and 1991 to determine the variability of the substrate, and to develop baseline quality data at one chinook spawning site near km 19 (NFCP 1998d). Thirty-seven samples of substrate were collected in the spawning area with a modified freeze-core sampler. The percent of fines averaged 9.4%.

A large number of samples from km 19 had very low percentages of fines in their upper layer. This was postulated to be from the cleansing action of redd building by chinook (NFCP 1998d) and the study recommended that other spawning areas be sampled, as km 19 was upstream of the main sources of sediments (*i.e.,* various tributaries and sand banks). Subsequent studies, reported here, involved collecting samples over a larger area of the upper Nechako River in 1992 and 2000.

7.4.1 Freeze-coring

In March 1992 and 2000 the bed of the Nechako River was sampled in Reaches 2 (km 15 to km 40) and 4 (km 72 to km 89) in areas representative of chinook spawning redds. There were two transects, 10 m apart, per reach. Half or more of the channel width was typically sampled in each transect, depending on the water depth; 1.2 m was

[53] The collection of organisms living on or in sea or lake bottoms.

[54] A life stage between egg and fry.

[55] 'Substrate' was restricted to the proportion of sediment finer than 9.5 mm and to the proportion of sediment finer than 0.84 mm. These sizes were chosen because they are used in fisheries diagnostic work.

the maximum depth at which samples could be taken. The samples were taken with a freeze-coring device, 1 m to 5 m apart along each transect.

The coring device consisted of a core-barrel and a freeze-core probe attached to a 1 m steel pipe. The barrel was inserted approximately 40 cm into the substrate and the substrate sample was extracted after it had been frozen within the freeze-core with liquid nitrogen (NFCP 1998d; NFCP 2002). Most samples were divided into two equal parts, a lower and upper section. In all, approximately 200 samples were taken and analyzed in each year.

Riverbed reaches are generally not uniform within a given cross-section because channel depth and current velocity may vary from one bank to the other. This aspect was taken into account in the analyses by dividing each transect into Right, Center and Left.

Statistical analyses were done only on sediment finer than 9.5 mm and sediment finer than 0.84 mm. The calculation of those proportions depended on the size distribution of the entire sample and assumed that all material was representatively sampled. This was not possible, as material greater than 128 mm could not be reliably sampled. Therefore, samples were standardized: the size distribution of all samples' material was truncated to an upper limit of 64 mm. That is, samples which contained larger material were analyzed on the basis that 100% of their material was smaller than 64 mm.

All analyses consisted of either nested analysis of variance tests (ANOVA) — to test substrate variation among and within transects — or t-tests — to test substrate variability within the cores.

7.4.2 Results and Discussion

The studies found that the river's substrate provided an excellent spawning and egg incubation environment for chinook. The gravel was well graded and clean with a fairly uniform gradation from cobbles to pebbles to granules (BCUC 1994).

Generally, the mean proportion of fines (<2mm) in the surface layers sampled at the three sites in 1992 and 2000 ranged from 8% to 11%. In the sub-surface layer, the range was 16% to 18%. Silt and clay (<0.063 mm) was generally very low with site means of about 0.1% in the surface layers and 0.2% in the sub-surface layers. Generally, fine to medium sands were more abundant and coarse sands most abundant in the samples from both years.

Fine sediments increased at two of the sites between the years. The increases were less than 10% and were not statistically significant; the changes are small relative to the variability within a site in a sample year. The third site showed a net decrease in fine sediments, likely due to deposits of eroded bank materials in the vicinity of the site.

Section 8
Remedial Measures

CLAUSE 3.4 OF THE *1987 SETTLEMENT AGREEMENT* REQUIRES THAT, IN ANTICIPATION OF LOWER FLOWS ASSOCIATED WITH THE Kemano Completion Project, the Nechako Fisheries Conservation Program (NFCP) Technical Committee "establish a comprehensive body of decision making criteria" for designing and implementing remedial measures, including judging the extent of implementation. The Agreement further stipulates that remedial measures must be:

- biologically sound with demonstrated use;
- reasonable, based on practical and proven techniques, and consistent with good science, engineering and fiscal responsibility;
- cost effective compared to alternative means of achieving the same biological objective within the same stage (as defined by the *1987 Settlement Agreement*), taking into consideration initial capital and maintenance costs relative to other measures of equal benefit; and,
- implemented according to the hierarchy of preferences for successive remedial alternatives contained in the Department of Fisheries and Oceans' *Policy for the Management of Fish Habitat.*

Remedial measures set out in the *1987 Settlement Agreement* included flow control, instream fertilization, instream manipulation and off-channel improvements.

A strategy was developed to protect fish and fish habitat—the basis of the Conservation Goal—in the event that lower flows associated with the Kemano Completion Project resulted in a significant loss of habitat. The strategy, which followed the Department of Fisheries and Oceans' *Policy for the Management of Fish Habitat*, was to implement a program of remedial measures to coincide with the change to the Long-Term Water Allocation. Initial measures were to be put in place to offset loss of habitat due to flow change; additional measures were to be implemented if a negative trend was detected in the Nechako River chinook salmon life-history phases.

The order for implementing the different remedial measures is shown in **Figure 1.3-1** however, the committee had the mandate to alter the order to ensure conservation of chinook stocks. That said, no proposed measure was to be rejected unless the feasibility, design and pilot testing results showed that it would be ineffective in the Nechako River, or not cost effective compared to alternative means. This resulted in a commitment from the committee to address all measures.

8.1 INSTREAM HABITAT MODIFICATIONS PROJECT

The objectives of the Instream Habitat Modification Project were generally set out in the Nechako River Working Group's *Summary Report* (1987). The basic goal was to design and test instream habitat modifications such that the NFCP would have the ability to implement proven techniques to replace the function of natural habitat features that would likely be alienated if flows were reduced as a result of the Kemano Completion Project.

The objectives focussed on increasing rearing habitat structural complexity by:

- constructing a limited number of rearing habitat complexes that had been demonstrated to work on other river systems for other species of salmon at sites downstream of known spawning grounds;
- constructing a limited number of rearing habitat complexes that could duplicate habitat that naturally occurs on the Nechako River at sites downstream of known spawning grounds; and,
- assessing the performance of the rearing habitat complexes through a series of small scale pilot tests under a variety of flow and meteorological conditions to determine their hydraulic performance, durability and cost effectiveness[56].

Previous studies in rivers similar to the Nechako River (Murphy *et al.* 1984; Shirvell 1990) had shown that salmonids were often associated with debris such as log and tree windfalls, and that artificial habitat complexes could be as effective as natural habitat in terms of salmonid use (White 1975; Gilbert 1978; House and Boehne 1985, 1986). However, the committee did not know which types of habitat complexes would best meet the requirements of juvenile chinook.

A preliminary assessment of the types of habitat used by Nechako River chinook was conducted in early 1988 via snorkeling surveys. Observations from the surveys were used in conjunction with previous studies on the river habitat (Envirocon Ltd. 1984b) and professional judgment to identify suitable habitat complex designs for pilot testing.

This information was supplemented by a literature review of instream habitat complexing projects (NFCP 1998a). The review indicated that, although habitat complexes had been widely used to create fish habitat, most techniques had only been applied to small streams supporting fish species other than chinook. In addition, quantitative assessment of the effectiveness of these techniques was limited.

A menu of potential remedial measures was prepared following the literature review. Techniques thought to be appropriate to the Nechako River were pilot tested between 1989 and 1997. During this period, several structures were modified—modifications included improving the aesthetics of habitat complexes—or removed.

8.1.1 Previous Research on Habitat Complexes

While manipulating small streams to create in-stream salmonid rearing habitat has a long history of success in North America—particularly in the east and midwest (Shetter *et al.* 1946; Saunders and Smith 1962; White 1975; Gilbert 1978)—early attempts on the West Coast were less successful because

[56] Some aspects of the structural design of habitat complexes used in the Nechako River were in an early stage of development when the project ended.

of the low durability of the habitat structures (Ehlers 1956; Calhoun 1966). Later attempts developed structures that could survive freshet flows within streams with stable channels and streambeds (DFO 1980; Ward and Slaney 1981; Hall and Baker 1982; Anderson 1984; House and Boehne 1985; Heede and Rinne 1990; R.L.& L. Environmental Services Ltd. 1991). However, while the abundance of Pacific juvenile salmonids is positively associated with natural debris structures in small streams (Murphy *et al.* 1984; Shirvell 1990), and debris cover is clearly preferred by young salmon in laboratory streams (Steward and Bjornn 1988), there were no published accounts of larger-scale evaluations of in-stream debris structures in large streams such as the Nechako River.

8.1.1.1 Abundance and Distribution of Natural Rearing Habitat: Nechako River

At least three studies have inventoried the abundance and distribution of natural rearing habitat for juvenile chinook in the upper Nechako River.

1) Envirocon Ltd. (1984b) used Instream Flow Incremental Method techniques to calculate the amount of rearing habitat in relation to river flow. The analysis used hydrological modelling of the river and incorporated habitat preference criteria developed from observing juvenile chinook habitat use in the river.
2) The Nechako River Project (DFO 1987) conducted detailed assessments of rearing habitat in the river to determine:
   - where the fish were distributed within the river;
   - how and on what basis they selected locations within the river;
   - how permanent those locations were; and
   - how the locations where fish held changed as the fish grew larger.

   The study showed that most juvenile chinook salmon reside along river margins. Newly-emerged chinook fry formed schools close to shore in shallow, sheltered areas with little or no current. The fry were highly substrate-oriented and dispersed into the gravel when disturbed.

   Older juveniles used deeper water and higher velocity areas. Day/night sampling showed that these older juveniles moved along the shallow stream margins at night and aggregated in loose schools next to large woody debris during the day. The frequent, close association of juvenile chinook with logjams, beaver lodges and areas with submerged vegetation during the day suggested that any fixed accumulation of this type of debris would serve as preferred daytime habitat.
3) D.B. Lister and Associates Ltd. conducted a detailed inventory of cover sites in the upper and lower river between Cheslatta Falls and the confluence of the Stuart River (NFCP 1998c). The inventory identified 3,884 cover features including 975 major sites (> 2 m^2 in area) and 2,909 minor sites (< 2 m^2 in area). The four most common features—beaver lodges, debris accumulations, tree windfalls and overhanging vegetation—made up 64% of cover sites. Densities of juvenile chinook were significantly correlated with the velocity of the approach water and with the surface area of a cover site, but not with water depth or type of substrate. The number of juvenile chinook did not increase after the cover area exceeded 15 m^2.

   The distribution of juvenile chinook within cover features was highly clumped. Fish selected low velocity areas just inshore from the main downstream flow, often within the shear zone created by the cover feature. Tree windfalls supported higher chinook densities than any other type of cover.

The last two studies showed that:

- most juvenile chinook in the Nechako River reside along stream banks and aggregate in or near woody cover features during daytime; and
- the velocity of approach water is the single most important variable influencing density at cover sites.

The studies suggested that artificial habitat complexes would be at least as well used by juvenile chinook as natural woody complexes, if they produced the same water velocity conditions.

8.1.2 Types of Habitat Complexes

Habitat complexes types were selected for pilot testing in the Nechako River based on:

- a review of similar work on other river systems;
- Nechako River conditions;
- the local availability of materials; and
- cost effectiveness.

Two types of instream cover structures were chosen for testing: debris bundles and debris catchers. The debris bundles were trees or root masses cabled to anchors on the riverbank; the debris catchers were rail structures placed at various locations along the stream margin to intercept and hold the river's natural supply of debris.

Instream modifications associated with installing the woody debris involved excavating or placing riverbed materials to replicate the natural morphological features found in the river. Pocket pools were developed to increase habitat diversity for the rearing period and to provide over-wintering habitat.

8.1.3 Site Selection and Design Criteria

Since 1988, the general criteria for site selection and the design of all habitat complexes were based on:

- a literature review (Lister and Genoe 1970; Everest and Chapman 1972);
- an assessment of chinook life-history data collected during field studies on the Nechako River (Russell *et al.* 1983; Envirocon Ltd. 1984a); and
- the river's physical characteristics and natural habitats.

Selecting specific sites in the Nechako River's mainstem was based on criteria developed by the Department of Fisheries and Oceans (Nechako River Project 1987) and Envirocon Ltd. (1984b). It was expected that installing a given habitat complex would modify velocities at the site, but that the velocities throughout the complex would remain within the specified range. Therefore, the criteria ranges apply to both the site selection and the design of the habitat complexes.

The criteria included:

parameter	criteria range	preferred
velocity (m/s)	0.15 to 0.4	0.3
depth (m)	not less than 0.4	0.75 to 1.0
substrate	gravel to cobble	gravel to cobble
extension[57] (m)	site specific	5.0

The criteria for side channel site selection were developed so that depth and velocity at each complex in the channel would be similar to the preferred depth and velocity criteria of complexes in the mainstem of the river, those being associated with high and low flows of 56.6 m^3/s (2,000 cfs) and 31.1 m^3/s (1,100 cfs), respectively.

parameter	criteria range
maximum depth (m)	0.6
average cross-sectional velocity (m/s)	approximately 0.5
side channel flow range (m^3/s)	1 to 2
Nechako River flow range (m^3/s)	31.1 to 56.6

Side channel bank slopes were graded such that the right bank approximated the existing stable slope

[57] The distance from the river's margin.

of 1.5H:1V and the left bank provided shallow habitat for newly emergent fry through a lower slope of 3.5H:1V. The side channel was assessed for the above parameters in 1997 to determine if the criteria were being achieved. Cover area was also measured during the physical assessments.

Habitat complexes were placed in sites that lacked natural cover in a 25 km section of Reach 2 (km 15 to km 40), and in a 17 km section of Reach 4 (km 72 to km 89) (**Figures 8.1-1** and **8.1-2**) (NFCP 1998i; 1998k; 1998m). Complexes installed in the mainstem of the river from 1988 through 1990 were designed to operate at the Short-Term Flow regime spring and summer rearing flows of 56.6 m^3/s (2,000 cfs), and fall and winter flows of 31.1 m^3/s (1,100 cfs). By comparison, complexes installed in the mainstem of the Nechako River in 1991 were designed to operate at expected long-term rearing flows of 31.1 m^3/s (1,100 cfs), and were located so that they could also operate during lower water levels and river widths associated with future long-term winter flows of 14.2 m^3/s (500 cfs). All complexes were evaluated for approximate high- and low-flows of 56.6 m^3/s (2,000 cfs) and 31.1 m^3/s (1,100 cfs), respectively.

The criteria used for site selection and design of emergent fry structures were slightly modified in 1997, based on observations by the field crew and a review of other general literature. The structures were placed in areas of reduced velocity and shallow depth to be effective for the earliest phase of juvenile chinook fry development. Observations by the field crew and information from the literature indicated that newly emergent fry occupy areas with depths less than 0.2 m and velocities of 0.0 to 0.15 m/s. As the fry develop, they move to areas of greater depth and velocity. The emergent fry structures were designed and located to be wetted during the spring rearing period, and de-water after the summer cooling flows to avoid colonization by non-target species.

Pilot testing in 1996 indicated a good use of the emergent fry structures near known spawning grounds.

8.1.4 Construction and Modifications

The major type of equipment used throughout construction operations from 1988 to 1991 was an excavator. This machine was used for excavating, installing rail debris catcher pilings, placing and removing habitat complexes and/or materials, and securing cables[58].

Rail debris catcher piles were driven into the riverbed using the excavator and a vibrator attachment. Rails were driven to depths ranging from 3.0 to 5.0 m into the substrate with less than 3.0 m remaining above the riverbed. All 1991 complexes used steel rails for anchoring, except in the upper area of Reach 4 (upstream of km 80) where sweepers were placed by hand because the excavator could not access the area due to higher than expected flows.

Fabricating or modifying habitat complexes was completed manually with chain saws, power drills and oxyacetylene cutting torches. A workboat with a jet-converted outboard motor was used to transport personnel and miscellaneous materials. Locally available materials, such as riverbed cobble, large woody debris and timber such as pine and spruce, were used where possible. Materials transported to the sites included used rails, chain and cabling.

Where recommended, rails were removed with the use of a large tracked excavator with a hydraulic thumb. Rails were moved from side to side then lifted with the hydraulic thumb or by a chain attached to a lifting hole at the top of

[58] Photos of selected construction operations were presented in a 1991 construction completion report (NFCP 1991b).

Figure 8.1-1 Nechako River: Reaches 1 (km 0 to km 15) and 2 (km 15 to km 40)

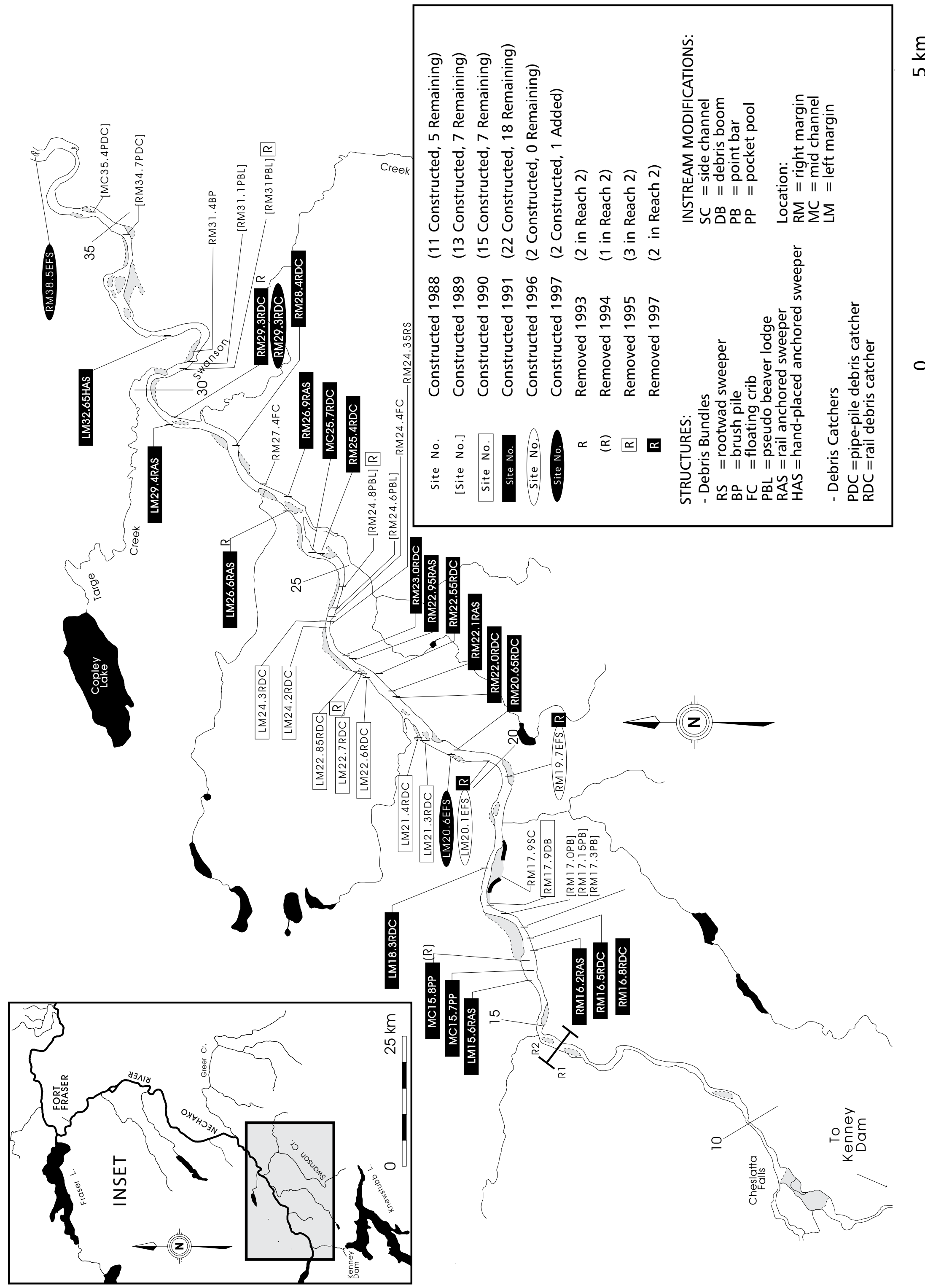
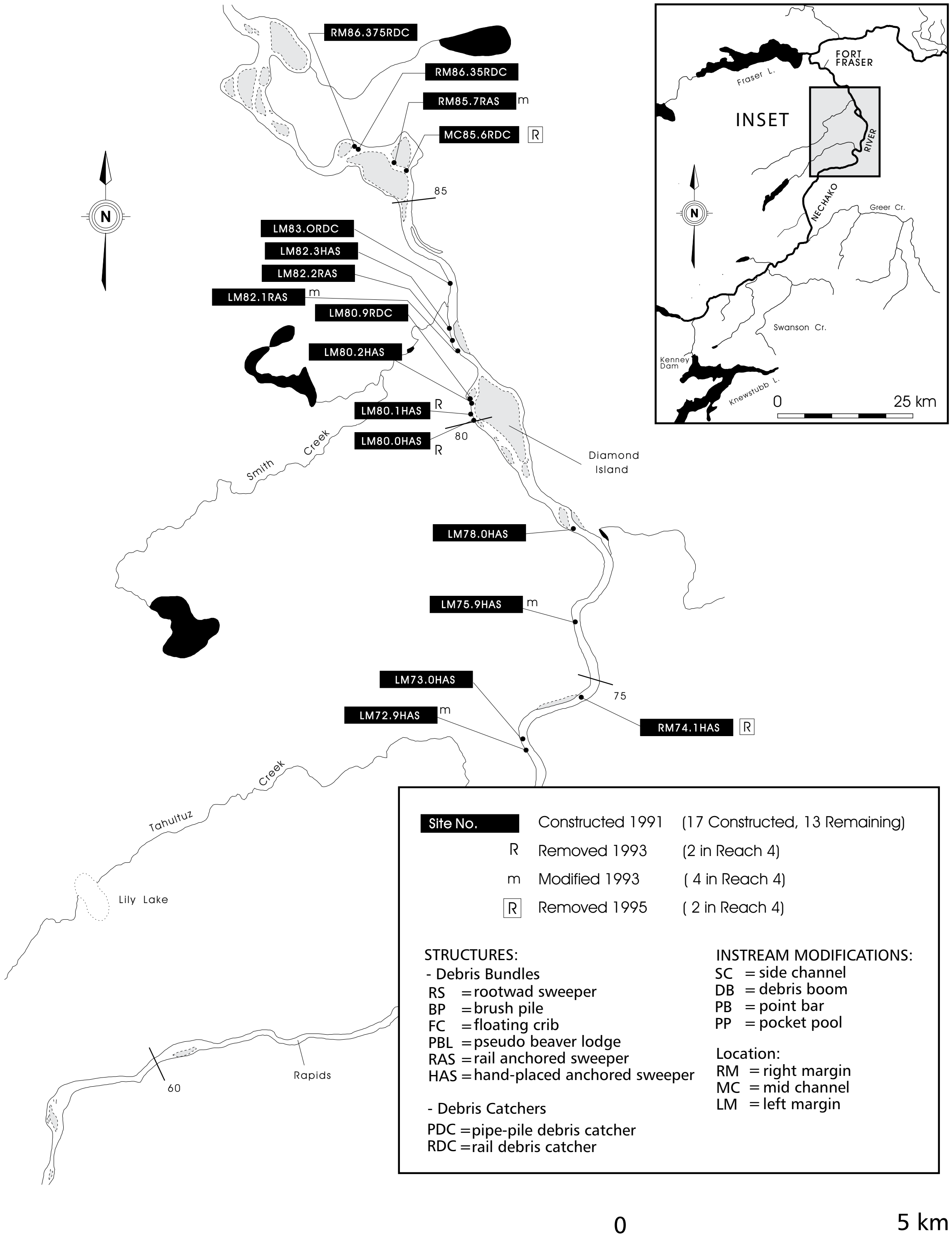


Figure 8.1-2 **Nechako River: Reach 4 (km 72 to km 89)**



Map # 2798-2-2

the rail. Access areas were chosen to minimize disturbance to banks and riparian zones during instream work and the majority of rail removals were completed with minimal instream activity.

Although the majority of rails were completely removed in this manner, some rails broke during removal. Based on an examination of substrate and rust conditions on the rails, all of these rails broke at least 30 cm below the substrate in water depths of 0.5 to 1 m. Rail pieces were completely removed from the area with the excavator and given to a local rancher.

8.1.4.1 Aesthetic Modifications

The British Columbia Utilities Commission (BCUC) hearings into the Kemano Completion Project identified aesthetics as one area of the project that had not been sufficiently addressed in artificial habitat complexes (BCUC 1994). As a result, the 1997 Instream Habitat Modification Project included testing methods for improving the aesthetics of habitat complexes.

Rail covers: These were used to give rail debris catchers the appearance of natural logs standing upright in the river. There were two types:

1) **Log**: The rails were covered with whole logs. Each log was cut in half lengthwise and a V-groove was removed from each half. The logs were then reassembled around the rails and secured in place. A piece of redi rod was inserted through the log and through the lifting hole in the top of the rail to stop the log from lifting off the rail in high water.
2) **Slab**: The rails were covered with several sawmill slabs. As with the logs, these slabs were V-grooved then affixed to the rails and a piece of redi rod was placed through the top to prevent the slabs floating off the rail.

Nesting Boxes: Nesting boxes, constructed and installed according to plans from Ducks Unlimited Canada, were placed on some complexes to improve the aesthetics of the structures and to provide habitat for cavity nesting waterfowl. Entrances were sized to minimize use by mergansers, a species which may prey on juvenile chinook. [See *ss. 9.1.2 Predator/Competitor/Prey Interactions: Field Surveys*]

8.1.5 The Physical/Biological Assessment of Instream Habitat Modifications

The main objective of the Instream Habitat Modification Project was to develop artificial habitat complexes that would be used at similar chinook densities and species composition as natural complexes in the upper Nechako River. Other objectives were to compare the relative abundance and size of juvenile chinook in:

- artificial habitat complexes and nearby control sites with no vegetation cover;
- artificial habitat complexes and nearby sites with natural cover; and
- different types of artificial habitat complexes.

This was to determine which physical characteristics of the artificial complexes were responsible for differences in abundance and size.

Both the physical and biological aspects of habitat complexes were monitored annually to assess how well these objectives were met. Minor modifications have been continuously made to the design and location of complexes, based on the results of monitoring. With the exception of emergent fry structures added in 1996 and 1997, no new habitat complexes were installed after 1991.

8.1.5.1 Physical Assessment

The annual physical assessment entailed a general inspection of all remaining artificial instream habitat complexes that were placed in the Nechako River since the beginning of the Instream Habitat Modification Project in 1988.

The objective was to identify any structural damage or instability that occurred over the winter period and to evaluate the achievement of the design criteria.

No physical assessments occurred in the first year; the structures were installed in the fall. Physical assessments were done in the spring in following years and new complexes were constructed and existing ones modified during the spring or summer. The annual program typically finished with a fall physical assessment to inspect all the habitat complexes[59].

Physical assessments of habitat were conducted from shore, by boat and by snorkeling. Investigations consisted of an inspection and photographic and video documentation of each complex. The following features were noted (where applicable) during the assessments:

- water depths and velocities upstream and downstream (at 1/3 and 2/3 of the extension), at the inside and outside shear zones, and at a flow-through point within the complex;
- cover area;
- extension from margin;
- depth of cover;
- erosion/sedimentation;
- local substrate;
- damage;
- displacement; and
- debris accumulation or loss.

Durability and the structure's position in the river were also noted.

A Swoffer (model 2100) flow meter was used to measure velocity. However, due to equipment problems, the flow meter was not available for all the habitat complex sites and velocities at some locations were estimated by the floating chip method[60]. Water depths were determined using the flow meter rod and extension and principal cover area dimensions were measured with a survey tape. Cover areas were then calculated for each complex.

Hydraulic characteristics of complexes under observed flows were documented to find out if they fulfilled design criteria. The amount of debris accumulation or loss was also recorded to document the function of the habitat complex under prevailing Nechako River conditions. Substrate composition was documented as a relative ranking of the material present.

8.1.5.1.1 Numbers and Types of Habitat Complexes

From 1988 to 1997, 82 structures covering 14 different designs were constructed in Reaches 2 and 4 on the Nechako River[61] (NFCP 1991b) (**Figures 8.1-1** and **8.1-2**). Descriptions of the different types of complexes are provided in **Table 8.1-1**.

The majority of the structures were constructed between 1988 and 1991. Half of the complexes underwent some type of modification, typically to improve stability or debris capture[62]. At the end of 2000, 37 complexes—some of which were modified—remained. Aesthetic modifications (**Table 8.1-2**) were installed in 1997.

[59] Only spring assessments took place from 1993 to 1996.

[60] Timing the movement of a floating woodchip over a measured distance.

[61] Debris bundles installed in the side channel were not included in the total number of complexes installed in the Nechako River. Unlike mainstem complexes, which were installed on the river margins, the side channel complexes were constructed to be full-spanning structures because of lower flows. Therefore, the side channel was assessed as a separate complex.

[62] Summaries of the physical assessments for each program year can be found in NFCP 1991b, 1996a, 1996d, 1996h, 1998i, and 1998k.

Table 8.1-1 Nechako River: types of habitat complexes installed in river, 1989 to 1993

type of structure	complex name	abbreviation	description	extent/size
debris bundles	rootwad sweepers	RS	cabled bundles of trees, with branches and tree root masses	10 m into the water, at water depths from 0.4 m to 1.0 m
	brush pile	BP	bundles of tree tops and tree root masses cabled to a buried stiff-leg	10 m into the water
	floating cribs	FC	timber cribs seeded with large woody debris. Secured to shore with two stiff-legs cabled to anchors on the bank.	5 m by 12 m
	pseudo beaver lodge	PBL	scaled-down versions of floating cribs, made of two logs 10 m long, separated by 25 m logs, chained together to form a crib. Secured to the bank by cabling the 10 m logs and an upstream stiff-leg angled at 45° to buried deadmen on shore.	6 to 8 m from shore
	deep water sweepers	DWS	single tree extending into the river flow. Oriented 45° downstream and secured with cable to a stump or rock on shore.	7 -10 m
	rail anchored sweepers	RAS	trees extending into the current at 45° angle downstream and anchored with steel cable or chain. Butt and tip anchored to 6 m steel rails driven into the substrate. Rail is left 0.5 to 1.5 m above the substrate. Tree butts may be anchored to buried deadmen onto the shore, to stumps or to wood posts, depending on the shore substrate.	10-17 m
	hand-placed anchored sweepers	HAS	used as substitution where rails could not be installed. Trees were felled to leave the majority of the tree on the shore. Tree tips may be attached to short sections of buried steel rail, or attached to a fluke anchor.	
	emergent fry structures	EFS	conifers placed at a 45° angle in a downstream direction. Held in place with one piece of rebar through the base of the trunk and another on the downstream side of the trunk half way along the length.	2-3 m
debris catchers	channel jacks	CJ	cabled tripod made of used steel I-beams. Cabled together in groups to enhance debris entrapment, and secured to the bank for increased stability under high flow or ice conditions.	
	pipe-pile debris catchers	PDC	two floating logs chained between three heavy gauge steel pipes 6 m long driven approximately 3.5 m into the river bed. Arranged in a V configuration with the open end facing upstream to trap floating debris. Logs rose and fell with changes in the water level.	10 m
	rail debris catchers	RDC	similar to the pipe-pile debris catchers, but with a steel rail driven into the river bed instead of a pipe. Positioned 3 m from the offshore anchor and 7 m from the onshore anchor.	3 m
instream modifications	side channel	SC	complex with debris bundles and a Debris Boom. Excavated along the right bank during the spring of 1988 between km 17.9 and 18.6. One debris boom placed at the downstream portion of the side channel to trap floating debris within the channel and to prevent the loss of seeded material.	735 m long; depth 0.5 and 1.0 m, width from 14 m at the upstream end to 6 m at the downstream end.
	point bars with back eddy pools	PB	berm extending approximately 10 m out from the river bank at an angle of approximately 45° downstream, to duplicate shear zones (area where water must flow around the edge of a structure and therefore water velocity increases). Constructed with native river bed materials excavated downstream of the berm. Thought to be potential rearing areas for juvenile chinook.	
	pocket pools	PP	excavations into the river bed to provide deeper water cover for rearing chinook juveniles. Lined with river cobbles and boulders by backfilling.	depths up to 1.5 m.

Table 8.1-2 **Nechako River: summary of habitat complexing construction and modification activities, 1988 to 1997**

type of habitat complex	abbrev.	quantity constructed	year constructed (quantity)	quantity modified	year modified (quantity)	quantity removed	year removed (quantity)	quantity remaining in 1997
STRUCTURES								
debris bundles								
rootwad sweepers	RS	5	1988 (4), 1989 (1)	3	1989 (2), 1990 (1)	4	1990	1
brush pile	BP	1	1988	-	N/A	-	N/A	1
floating cribs	FC	2	1988	2	1989, 1991	-	N/A	2
pseudo beaver lodges	PBL	7	1989	7	1989 (7), 1990 (3), 1992 (1)	5	1990 (3), 1995 (2)	2
rail anchored sweepers	RAS	10	1991	5	1992 (3), 1993 (2)	1	1993	9
hand-placed anchored sweepers	HAS	11	1991	3	1992 (1), 1993 (2)	4	1991 (1), 1993 (2), 1995 (1)	7
deep water sweepers	DWS	7	1990	4	1990	7	1990 (1), 1992 (6)	-
emergent fry structures	EFS	4	1996 (2), 1997 (2)	-	N/A	2	1997	2
debris catchers								
channel jacks	CJ	3	1988	3	1989	3	1990 (2), 1992 (1)	-
pipe-pile debris catchers	PDC	2	1989	-	N/A	-	N/A	2
rail debris catchers	RDC	23	1990 (7), 1991 (16)	9	1990 (2), 1992 (7)	3	1993 (1), 1995 (2)	20 + 1 (see notes below)
IN-STREAM MODIFICATIONS								
side channel*	SC	1	1988	1	1989	-	N/A	1
side channel debris boom**	DB	1	1990	-	N/A	-	N/A	1
point bars	PB	3	1989	3	1991	-	N/A	3
pocket pools	PP	2	1991	-	N/A	1	1994	1
totals		**82**		**41**		**31**		**53**

Sources: Triton Environmental Inc. (1996a, 1996c, 1996g, 1998h, 1998j, 1998l).

* 8 brush piles, 12 rootwad sweepers and a debris boom were installed in the side channel. These complexes are not included in the total number of debris bundles or debris catchers installed in the Nechako River as the side channel was assessed as a unique complex.

** The debris boom was relocated upstream of side channel in 1990 to prevent excess debris from entering side channel. Therefore, the debris boom was assessed as a separate structure, resulting in an additional structure at the end of 1990, for a total of 29 complexes.

Notes:

Rail Covers Installed: A total of 21 rail covers (14 V-groove and 7 slab) were installed on 9 active complexes (LM18.3RDC, RM20.65RDC, LM21.3RDC, LM21.4RDC, RM22.55RDC, LM22.6RDC, LM80.9RDC, RM86.35RDC, RM86.375RDC), and on a remaining rail from removed complex LM22.7RDC.

Nest Boxes Installed: A total of 7 nest boxes were installed on 5 active complexes (RM18.3RDC, LM21.3RDC, LM21.4RDC, RM22.55RDC, LM24.2RDC), on a remaining rail from removed complex LM22.7RDC, and on a rail supporting a dock at Irvine's Lodge.

Added: 1 Rail Debris Catcher (RM29.3RDC) was added to the 1997 assessment. It had been removed in 1993 due to complete loss of logs and debris but was found to have accumulated new debris in 1997.

Initially, 11 habitat complexes were installed in 1988 in Reach 2—one brush pile, four rootwad sweepers, two floating cribs, three channel jacks and one complexed side channel. Thirteen complexes were added in 1989—one rootwad sweeper, seven pseudo beaver lodges, two pipe debris catchers, and three point bars—for a total of 24 complexes.

Seven rail debris catchers were added in Reach 2 in 1990, and nine complexes—four rootwad sweepers, three pseudo beaver lodges, and two channel jacks—were removed. The decision to make these changes was based on the stability and durability of the complexes and on the approach velocities measured at each complex.

It became clear that the size of some of the debris bundles installed in 1988 was excessive. Although the structures were colonized by chinook in early 1989, assessments in 1990 indicated that chinook were associated mainly with the upstream 20% of the structures and the lower 80% were colonized by non-salmonid species. In fact, only the upper 20% of these structures provided suitable velocities for rearing chinook, so the complexes were thinned so only bundles with appropriate flow-through velocities were left in place.

In 1991 a further 22 complexes were added to Reach 2—eight sweepers, 11 rail debris catchers, two pocket pools, and one side channel debris boom. Seventeen complexes were also installed in Reach 4—12 sweepers and five rail debris catchers. These 39 complexes were added to increase sample size (to a total of 61) and to establish pairs of complex and control areas. By the end of 1991, there were 15 pairs: 11 in Reach 2 and four in Reach 4.

From 1992 to 2000, the total number of complexes in the upper river decreased from 61 to 37 as complexes were intentionally removed or suffered natural demolition. The proportion of complexes of each type remained relatively constant.

8.1.5.1.2 Structural Assessment

Rootwad Sweepers: The last remaining of the four rootwad sweeper complexes constructed in 1988 was modified in 1990 to reduce seeded material. Since then, the complex has remained stable; no damage or displacement has been noted.

Brush Pile: The cover area brush pile complex installed in 1988 decreased from a high of 37 m^2 in the spring of 1991 to 1 m^2 in the fall of 1997. The structure was removed from further assessment due to its lack of cover area and continued degradation.

Floating Cribs: The two floating cribs installed in 1988 have provided significant amounts of cover. In 1991, the smaller complex was moved further into the current to increase velocities around it: anchoring was improved by securing the complex to two steel rails driven into the riverbed. However, the failure of a rail in 1992 caused some displacement onto the shore and as a result, the crib's downstream stiff-leg was damaged. The failure of the downstream stiff leg and the upstream shore anchor in 1997 caused significant displacement of the structure (downstream approximately 5 to 10 m). Despite displacement, the structure generally provides adequate depth, cover area and velocity.

The upstream crib was colonized by beavers in the fall of 1989 and has been untouched since. In recent years, the cover areas of these complexes have varied but have always been acceptable.

Pseudo-Beaver Lodges: The design of the pseudo-beaver lodges was modified in the fall of 1989 to enhance stability. Three modified units continued to lose debris in 1991 and an extra boom was added to one complex prior to reseeding in the spring of 1992 to provide additional floatation and assist in retaining debris. This modification appeared to help retain debris over the summer cooling flows, but the complex and two others were again damaged or displaced at higher flows.

Two lodges were removed from assessment in 1995 due to the continued loss of debris; in 1996, one of the last two structures failed and in 1997 it completely collapsed and lost all its cover area and has been removed from further assessment. Consequently, only one lodge structure offering cover area within the design criteria range remains. Due to debris retention problems, it was not recommended that further units be constructed.

Deep Water Sweepers: The deep-water sweepers installed in 1990 were adequate in size, but anchoring them only at the butt end made them unstable. As flows receded, the sweepers were left dewatered. Velocity distributions assessed prior to structure displacement were generally within the lower portion or below the design criteria range.

These complexes were relocated in the fall of 1990. During the winter of 1990/1991 they were again displaced and left isolated from the current. They were subsequently omitted from any further physical assessments.

Rail Anchored Sweepers: In general, rail anchored sweepers required significant repairs during their rather short duration in the Nechako River (NFCP 1996g). The shorter rails used in these complexes allowed less vertical movement as water levels rose, which may have accounted for a lack of collected debris. In 1997, six structures were damaged or displaced and recommendations were made to repair or remove all nine complexes. Since 1997, two rail anchored sweepers have been removed and the remaining sweepers are only providing small amounts of cover.

Hand-Placed Anchored Sweepers: As with rail anchored sweepers, these complexes were not successful at capturing additional debris, provided minimal cover areas and tended to be stripped, damaged or displaced during winter ice movement and high summer flows. Six of the structures have been removed from assessment since they were installed in 1991. Two hand-placed anchored sweepers are still being assessed.

Emergent Fry Structures: The NFCP undertook an experiment in 1996 to pilot test emergent fry structures along the margins of the Nechako River. These structures were designed to mimic transient low velocity cover along river margins in proximity to spawning areas. Small coniferous trees were fixed along a gravel bar downstream of a major spawning area at km 19. The structures were assessed for use and physical attributes over the period of design use (mid-April to mid-May).

Channel Jacks: The original channel jack design did not adequately trap debris and the individual tripods proved unstable during winter conditions. The modified design, which included weighting the bases and booming channel jack groups, improved the ability of the structures to trap debris; however, the tripods were still unstable and toppled over, allowing debris to escape. The last channel jack was removed in 1992.

Pipe-Pile Debris Catchers: The pipe-pile debris catchers were generally stable under variable flow conditions, despite pilings being bent or pulled from the riverbed. Sedimentation, due to the large size of the complexes and low velocities, was observed at both sites from 1993 to 1995. The smaller complex lost a significant amount of debris in 1995, including its downstream piling, and again in 1996. In 1997, it was recommended that pipe-piles from one structure be removed because they posed a potential navigational hazard.

Rail Debris Catchers: In general, large-size rail debris catchers have been quite durable. However, the smaller structures have required repairs and reseeding after higher summer cooling flows. In addition, the catchers' ability to trap and hold large woody debris appeared to be site-specific. Some structures lost and trapped new debris on a regular basis during fluctuating flows, while others continuously failed to trap any significant new debris despite being undamaged.

Other potential site-specific problems included excessive velocities at high flows. This may have caused material to be broken into smaller pieces, thereby preventing debris retention. The structures may also have failed to trap large woody debris due to the position of the thalweg[63] at high flows, which may have caused material to drift by the structure. Only two rail debris catchers have had to be removed.

Side Channel and Debris Boom: The side channel built in 1988 just upstream of km 19 had problems with excessive debris accumulation, and the debris boom was moved upstream of the channel entrance in 1990 to prevent excessive loading within the channel. The full-spanning habitat complexes in the side channel were also removed and replaced with smaller single logs buried at intervals along the margins (NFCP 1996a). Despite these modifications, low flows and subsequent dam construction within the side channel by beavers resulted in velocities well below criteria limits. No recommendations for improvements were made as inadequate flow and continued blockage by beavers made the complex unfit for long-term use.

The debris boom installed upstream of the side channel in 1990 was designed to prevent excessive debris accumulation in the side channel. The shore deadman anchor was unearthed in 1992, and the offshore anchor cable snapped in 1997. Despite this damage, the complex has remained stable and is successful at retaining debris. No further displacement has occurred.

Point Bars: The point bars were modified in 1991 to reduce their extension and to increase their elevation. This was done to encourage formation of a back eddy and to reduce surface erosion during overtopping of the complexes in high summer flows. Some erosion of a point bar at the shoreline was noted in 1997. The erosion may have been due to the unusually high flow releases during 1997. Fines had been deposited in the back eddy pools of these complexes indicating that downstream velocities were low.

Pocket Pools: One of the two pocket pools constructed during the summer of 1991 had low velocities and sedimentation, while the other had high velocities and channel scouring. In 1994, the high velocity pocket pool was removed from further assessment due to significant erosion. The other pool continues to provide adequate cover area, although erosion has caused cobbles and boulders to be deposited within the pool.

Summaries of construction activities per year and per habitat complex type are shown in **Tables 8.1-3** and **8.1-4**.

8.1.5.1.3 Flows and velocities

Flows in the Nechako River during the spring physical assessments ranged from 56.6 m^3/s (2,000 cfs) to 72.5 m^3/s (2,560 cfs) (**Table 8.1-5**). The highest flow occurred following a forced spill at the Skins Lake Spillway during the spring of 1990 and was not considered representative of spring flows. [See *ss. 5.1.2.4 Escapement Estimates: Nechako River*]

[63] The line defining the deepest points along the length of a riverbed or valley.

Table 8.1-3 Nechako River: summary of habitat complexing construction by year, 1988 to 1997

year	number of complexes*	comments
1988	12	Construction of channel jacks, brush pile, rootwad sweeper, side channel and debris broom.
1989	15	Modification of channel jacks. Construction of pipe-pile debris catchers, point bars, and pseudo beaver lodges.
1990	15	Modified side channel, rail debris catchers, deep water sweepers.
1991	43	Modification of floating crib and point bars, rail anchored sweepers, hand-placed anchored sweepers, rail debris catchers and pocket pools.
1992	13	Modification of rail anchored sweeper, hand-placed anchored sweeper, rail debris catcher and pseudo beaver lodge. Removal of channel jack.
1993	4	Modification of rail anchored sweepers and hand-placed anchored sweepers.
1994	0	
1995	0	
1996	2	Construction of emergent fry structures.
1997	30**	Construction of emergent fry structures. Removal of previous emergent fry structures. Installation of rail covers and nesting boxes.

Sources: NFCP 1996a, 1996c, 1996g, 1998h, 1998j, 1998l.
* refers to the number of complexes on which work was done.
** number includes rail covers and nesting boxes.

Table 8.1-4 Nechako River: summary of habitat complexing construction by complex type

type of habitat complex	quantity constructed (units)
rootwad sweeper	4
brush pile	1
floating crib	2
pseudo beaver lodge	7
deep water sweeper	7
rail anchored sweeper	10
hand-placed anchored sweeper	10
channel jacks	3
pipe-pile debris catcher	2
rail debris catcher	22
side channel construction	735 m
side channel complexing	200 m
side channel debris boom	1
point bar	3
pocket pool	2
emergent fry structures	2
v-groove rail covers	14
slab rail covers	7
nest boxes	7

Sources: NFCP 1996a, 1996c, 1996g, 1998h, 1998j, 1998l.

Table 8.1-5 Nechako River: flows in spring, summer and fall seasons, 1989 to 1997

	flows m3/s (cfs)		
year	spring	summer	fall
1989	56.6 (2000)	-	28.3 (1000)
1990	72.5 (2560)*	56.6 (2000)	28.3 (1000)
1991	54.4 (1920)	51.0 (1800)	31.5 (1112)
1992	44.3-46.0 (1565-1625)	-	31.5 (1112)
1993	57.5-59.5 (2031-2101)	-	32.7 (1155)
1994	62.3 (2200)	-	-
1995	62.3 (2200)	-	-
1996	69.1 (2440)	-	-*
1997	-	-	81.8 (2887)

Sources: NFCP (1996a, 1996c, 1996g, 1998h, 1998j, 1998l).
* High water levels due to forced spills at Skins Lake Spillway.

During the summer physical assessments, flows ranged from 51.0 m^3/s (1,800 cfs) to 56.6 m^3/s (2,000 cfs). In the fall, flows ranged from 28.3 m^3/s (1,000 cfs) to 32.7 m^3/s (1,155 cfs). However, the fall of 1997 saw extremely high flows of 81.8 m^3/s (2,887 cfs), well above the high end of the criteria range of 56.6 m^3/s (2,000 cfs).

In general, the majority of the depths at the structures were greater than the minimum criterion of 0.4 m. Velocities at the complexes were evenly distributed below, within, and greater than the criteria range of 0.15 to 0.4 m/s. Outside shear velocities were typically on the high end of the range or above.

The substrate at the complex sites was typically gravel or cobble, satisfying the design criteria. Fine sediment (sand, silt and clay) were deposited at a couple of sites where velocities were very low.

8.1.5.1.3.1 Resistance to Winter Conditions

From 1992 on, complexes in Reach 4 of the Nechako River were assessed for winter resistance. From 1993 to 1995, several rail anchored sweepers and hand-placed anchored sweepers lost branches or were damaged. Two hand-placed anchored sweepers located in high velocity areas were severely damaged by ice in 1993 and were removed from biological and physical assessment. Rail anchored sweepers located in Reach 2 experienced similar damage.

Both pipe-pile debris catchers in Reach 2 had their pilings lifted from the riverbed due to ice conditions[64]. In 1997, at least ten of the rails used to construct rail debris catchers were slightly lifted by ice; when the program ended, more than 50% had been lifted by ice.

As some sites in Reach 4 experience higher velocities and stage changes than in Reach 2, damage to structures in Reach 4 may also occur due to summer cooling flows. It should be noted that in addition to more severe ice and high flow conditions, Reach 4 also experiences lower debris recruitment, which means smaller debris accumulations in the structures compared to those in Reach 2.

8.1.5.1.4 Results and Discussion

The majority of habitat complexes constructed in the early phases of this project have been replaced with much more durable structures. These improvements reflect the effectiveness of physical performance monitoring, which helped the Technical Committee understand some of the factors affecting complex durability and/or performance. Of the 53 structures remaining in 1997, 37 provided effective amounts of juvenile chinook cover in 2000 and continue to be monitored periodically for durability.

8.1.5.1.5 Summary: Physical Assessment

The Technical Committee's Instream Habitat Modification Project identified several physical criteria for successful habitat complexes. These include providing appropriate shear velocity, cover area and substrate. Adequate anchoring was also found to be crucial for maintaining structural integrity during fluctuating flows.

8.1.5.2 Biological Assessment

Slaney *et al.* (1994) described physical and biological assessments of habitat structures for the years 1989 to 1991, and Goldberg *et al.* (1995) described physical and biological assessments of habitat structures for the years 1989 to 1993. However, the 10 annual NFCP technical

[64] In the long-term, these structures may lose most of their debris.

reports on the biological assessments of habitat complexes that were written for the years 1988 to 1997 (NFCP 1996c, 1996f, 1996i, 1996j, 1996k, 1998a, 1998b, 1998j, 1998l, 1998n) dealt only with each year's data and did not compare results among years.

As it was felt that there were no significant changes in the results of the biological assessments after 1993, this section of the report is based largely on the two review papers published in the primary literature covering the years 1989 to 1993.

8.1.5.2.1 Surveys

Snorkel and electrofishing surveys were conducted on instream cover structures (debris bundles and debris catchers), instream channel modifications and side channel modifications from 1989 to 1999 (**Table 8.1-6**). Unlike snorkel surveys, which were used only for habitat assessment, electrofishing was a component of both habitat assessment and the Juvenile Out-migration Project. Consequently, electrofishing surveys, which continue to this day, covered more months per year than snorkeling surveys.

Juvenile chinook use of both artificial and natural habitat structures was assessed through snorkel surveys. Careful and experienced snorkel divers could count most fish; however, snorkel surveys could not be done at night and did not allow for the capture and measurements of fish. This meant that all night surveys were conducted by electrofishing, and all size measurements were taken from electrofished specimens.

8.1.5.2.1.1 Snorkel Surveys

Snorkel surveying the upper Nechako River took three days: two days for Reach 2 and one day for Reach 4. A team of three divers equipped with dry suits and snorkel gear conducted each survey. Two divers were in the water and one diver drove a support boat. Team members traded places every kilometer.

Each of the active divers was responsible for counting fish on one bank of the river. The maximum range of visibility was three meters, so the divers stayed within that distance of the riverbank, periodically rotating from one bank to the other so that every person spent an equal amount of time on each bank.

Table 8.1-6 Nechako River: schedule of snorkel (S) and electrofishing (E) surveys in Reach 2, 1989 to 1999

year	April	May	June	July	August	September	October	November
1989		S	S	S		S	S	–
1990	E	S/E	S/E	S/E	E	S/E	S/E	E
1991	S/E	S/E	S/E	S/E	E	S/E	S/E	S/E
1992	S/E	S/E	S/E	S/E	–	–	–	S/E
1993	E	S/E	S/E	S/E	–	–	–	E
1994	E	S/E	S/E	S/E	–	–	–	E
1995	E	S/E	S/E	S/E	–	–	–	E
1996	E	S/E	S/E	S/E	–	–	–	E
1997	E	E	S/E	S/E	–	–	–	E
1998	E	E	E	E	–	–	–	E
1999	E	E	E	E	–	–	–	E

Each diver carried a set of waterproof maps of Reaches 2 and 4. Each map covered one kilometer of the river. As the divers drifted down the riverbanks, they counted all fish species and marked the counts and the locations of counts on the appropriate maps with a pencil. Divers were able to assign counts to specific sites by noting the boundary flags of each site as they passed them[65].

To survey artificial habitat structures, a diver would hold a part of the structure for anchorage, push his/her head into the structure, wait for fish to adjust to the intrusion and then count the fish. During daylight hours, fish within the structures tended to concentrate in schools that scattered at first, but quickly reformed on realizing that the diver was not a predator.

With few exceptions, divers did not double-check each other's counts. This introduces some diver-specific bias into the counts. That bias was minimized by rotating divers from one riverbank to the other, and by using the same snorkel team during most of the project.

8.1.5.2.1.2 Electrofishing Surveys

Electrofishing surveys were conducted monthly at specific sites in Reaches 2 and 4 using a single pass of a backpack-mounted Smith-Root Model 15-A electrofisher. Each site was sampled once during the day and once at night with the density of fish expressed as the number per 100 m^2 of surface area to avoid fractional densities.

No blocking nets were used due to the high flows and wide widths of the Nechako River and, unlike the snorkel surveys, areas between sites were not electrofished. This means that electrofishing counts underestimate the total count in a site.

All captured fish were identified to species, counted, and released live back into the river. Before release, a sub-sample of 10 to 15 juvenile chinook was measured to the nearest 1 mm for fork length with a measuring board and to the nearest 0.01 g for wet body weight with an electronic balance. The age of juvenile chinook was recorded as 0+ or 1+, based on fork length with chinook:

- less than 90 mm long and those over 90 mm long in late summer and autumn, classified as 0+; and
- over 90 mm in the spring and early summer classified as 1+. [See *ss. 6.2 Juvenile Chinook Out-migration Project*]

8.1.5.2.2 Results and Discussion

The number of chinook surveyed by snorkeling in Reach 2 from 1989 to 1993, and the percentage found in the artificial habitat complexes, are shown in **Table 8.1-7**. The general pattern was one of increasing use of the structures from May to June/July. Excluding the 1990 season when there was a forced spill, this percent ranged from 40% to 88% of all chinook seen in the survey.

Table 8.1-7 **Nechako River: chinook fry enumerated by snorkeling in Reach 2, 1989 to 1996**

	1989			1990			1991			1992		1993		1994		1995		1996		
Month	May	June	July	May	June	July	May	June	July	May	June	May	June	May	June	May	June	May	June	July
Total number of fry	8,588	42,044	2,495	1,582	2,517	318	2,004	9,621	2,552	11,950	7,770	4,214	11,655	258	3,133	8,179	5,891	6,494	11,990	13,09
(*)	14	68	79	7	47	3	24	70	65	73	60	52	73	22	74	26	67	15	46	95

(*) percent in artificial habitats on south (= right) margin

[65] Counts of fish observed along the riverbanks outside the boundaries of sites were expressed as "numbers per reach" and are not used in the analyses described in this section.

In total, the habitat complexes averaged from 1.3 to 5 % of the surveyed area. However, this is slightly misleading as the total margin area could not be colonized because velocities and depths were frequently outside the range of preferred use. Based on divers' estimates of the proportion of useable velocities and depths, 20 to 25% of the margin area was suitable as rearing habitat for 1 to 2 g chinook fry, which puts the area covered by the structures at 2.6 to 12.5% of the useable area. Considering the percent of chinook found in the artificial habitat complexes, this still reflects a distinct preference of juvenile chinook for these structures.

Overall, there were two to three times more fry counted on the south margin than on the north margin of the river, where the artificial structures were installed, although south margin chinook were seen more in the open sites than in the structures. Within the structures, there were no significant differences in mean densities of chinook between catchers and bundles, except in June, when the former tended to harbour more fish than the latter. The composition of the fish community (by percent) within the artificial habitat complexes did not differ from that found in natural sites (**Table 8.1-8**).

Chinook may have increased in size from association with the structures. Possible reasons for an increase in weight include:

- reduced energy expenses and increased food availability; and/or
- preferred habitat selection by fitter individuals.

Overall, the percent of all Reach 2 structures occupied by chinook from May to July varied from 74% (1993) to 100% (1991).

With the possible exception of the month of May (due to variable recruitment), snorkel surveys probably accurately measured juvenile chinook abundance in the upper Nechako River.

Underwater counts have been reported to be an accurate index of abundance of small salmonids (Gardiner 1984), and were highly correlated with catch-per-unit-effort (CPUE) from seine hauls in the river (r = 0.90, May to October; NFCP 1998b). Snorkeling also permits enumerating fish in sites unavailable to other techniques. Hankin and Reeves (1988) emphasized that the much greater sampling fraction achievable by snorkelers will usually more than compensate for errors in estimation. However, underwater counts of Atlantic salmon fry have been reported to be less reliable when temperatures are below 10°C (Gardiner 1984; Cunjak *et al.* 1988), which suggests that counts during May could be less accurate than those taken in June and July.

The biological assessment from 1989 to 1993 of the artificial debris structures clearly showed high levels of colonization by juvenile chinook. That conclusion was supported by biological assessments carried out from 1994 to 1997 (P. Frederiksen, Triton, pers. comm.). Debris structures attracted a high proportion of the fry counted on each margin of the river in 1989 and 1991, years of high fry abundance.

The colonizing of artificial structures observed in this study was similar to that observed in natural debris cover (NFCP 1998c). The exception was in 1990 when the numbers of fry in the upper river were very low—only 6% to 19% of the total monthly counts of 1989, and their percentage in the structures was lower than in any other year (**Table 8.1-7**)—and natural cover generally held greater percentages of young chinook than artificial cover. This low abundance may have been partly influenced by a high flow release that peaked at 258 m^3/s in late April and declined to 51 m^3/s by late May; this may have displaced many fish further downstream.

Table 8.1-8 Nechako River: percentages of dominant fish enumerated in instream debris structures and natural sites, 1991 to 1993

			1991								1992								1993							
			complex				natural				complex				natural				complex				natural			
			May		June		May		June		May		June		May		June		May		June		May		June	
reach	method		day	night	day	night	day	night	day	night	day	night	day	night	day	night	day	night	day	night	day	night	day	night	day	night
2	snorkel	CH0+	82	-	79	-	94	-	78	-	78	-	79	-	24	-	81	-	90	-	72	-	89	-	42	-
		CH1+	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
		Salmonidae*	1	-	1	-	1	-	1	-	1	-	1	-	0	-	11	-	1	-	0	-	7	-	3	-
		Cyprinidae	16	-	19	-	4	-	16	-	18	-	19	-	54	-	0	-	9	-	27	-	1	-	53	-
		C. macrocheilus	1	-	1	-	1	-	5	-	2	-	1	-	22	-	7	-	1	-	1	-	4	-	2	-
		Total number	5,945		8,583		2,850		364		11,155		5,915		247		256		2,403		11,572		139		607	
2	electro-fishing	CH0+	22	51	17	31	17	43	11	42	40	63	10	49	29	44	21	40	12	36	1	23	15	25	1	21
		CH1+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Salmonidae*	0	1	0	1	0	2	0	2	2	1	0	0	2	3	0	1	0	1	0	3	0	6	0	21
		Cyprinidae	68	42	70	63	72	47	83	51	53	32	80	44	58	44	71	51	78	54	97	63	72	60	99	48
		C. macrocheilus	10	6	13	5	11	8	6	5	5	4	9	7	10	9	8	9	10	8	2	12	13	10	1	11
		Total number	4,539	7,963	2,463	2,928	4,561	7,238	3,144	4,444	2,389	10,665	4,390	3,712	810	3,111	1,056	1,814	3,310	3,859	713	2,336	1,831	1,762	425	1,613
4	snorkel	CH0+	-	-	-	-	-	-	14	-	65	-	51	-	9	-	6	-	68	-	35	-	54	-	10	-
		CH1+	-	-	-	-	-	-	0	-	3	-	2	-	0	-	0	-	0	-	0	-	0	-	0	-
		Salmonidae*	-	-	-	-	-	-	1	-	3	-	1	-	1	-	0	-	3	-	3	-	1	-	1	-
		Cyprinidae	-	-	-	-	-	-	81	-	27	-	46	-	89	-	80	-	28	-	58	-	45	-	82	-
		C. macrocheilus	-	-	-	-	-	-	5	-	2	-	1	-	1	-	13	-	1	-	5	-	0	-	7	-
		Total number							883		1662		505		2328		374		818		1546		243		585	
4	electro-fishing	CH0+	-	-	-	-	10	44	1	32	26	53	3	33	5	37	1	19	2	43	0	15	8	28	0	7
		CH1+	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Salmonidae*	-	-	-	-	0	9	0	12	9	10	0	20	0	7	0	1	0	5	0	11	0	5	0	6
		Cyprinidae	-	-	-	-	82	37	87	49	52	31	82	37	87	45	91	66	95	42	81	53	89	44	40	62
		C. macrocheilus	-	-	-	-	8	10	12	7	14	7	15	11	8	11	9	14	3	8	19	22	3	23	60	24
		Total number					1,116	3,221	1,233	900	392	976	198	545	1,304	1,039	873	1,062	193	617	357	505	238	1,460	710	595

* Salmonidae do not include chinook

The low percent of occupancy of the structures in May could also relate to higher flows, which made the structures less optimal, and to higher water levels, which made other riparian habitats available for use by juvenile chinook. However, the flows in July 1990 were similar to those of other years and cannot explain the low percentage of chinook in the structures in that month.

Debris catchers tended to have higher chinook densities than debris bundles during the peak migration of fry in June. There were no differences in other months. The catchers resemble natural logjams with a mixed matrix of fine and coarse debris, and probably provide suitable foraging space and shelter from predators. In laboratory flumes, chinook fry and fingerlings moved deep into a matrix of debris structures, which out-performed other treatments such as rock layers, rock piles and undercut banks by two- to three-fold (Steward and Bjornn 1988).

Debris structures may also attract predators and "coarse fish" or competitors, but counts of potential predators, such as large northern pikeminnow and bull trout, did not support this hypothesis (NFCP, unpublished data). The larger structures were well used by potential competitors such as shiners, juvenile peamouth chub and young northern pikeminnow; however, smaller structures (< 15 m^2) with higher water velocities were much less colonized by potential competitors (NFCP 1998b). In addition, chinook migrants move downstream mainly at night, and the structures were used as refuges during daylight, which may improve survival.

Further examination of colonization by various fish species in relation to physical variables—including velocity, depth, debris size, structure size, and hydraulic location—is needed to optimize structure design and location criteria. In general, habitat improvement projects specifically designed to increase rearing habitats for sport fish do benefit salmonids at the expense of non-salmonids (Elser 1968; Hale 1969), so the potential negative effects of the structures appear to be outweighed by their benefits to salmonids.

A historical criticism of habitat improvement is that there is little net increase in production: fish just move to the artificial habitats from less preferred habitats. However, in areas with limited natural rearing cover (Lowery 1971; Latta 1972), habitat improvement resulted in large net increases in abundance of many salmonids (Shetter *et al.* 1946; Boussu 1954; Saunders and Smith 1962; Hunt 1969, 1976; Boreman 1974). Natural cover was sparsely distributed in the upper Nechako River, and about 75% of pre-smolt captured in April inhabited debris structures.

The sheer magnitude of the level of colonization of artificial structures by chinook fry during the period 1989 to 1993 leaves little doubt about the effectiveness of adding debris cover to provide shelter for chinook, especially debris catchers.

8.1.5.2.3 Summary: Biological Assessment

Juvenile chinook colonized a very high percentage of artificial habitat complexes. Fry density was similar to that in natural woody debris cover and fish groupings within artificial habitat features were similar to those of natural habitat cover once the artificial complexes had been appropriately sized.

Debris catchers were more extensively used than debris bundles during the rearing and migratory period in June. During June and July, most chinook fry counted along the margins of the study reaches inhabited the debris structures. Our assessment has concluded that man-made structures can be placed in the Nechako River to provide rearing habitat equivalent to natural structures.

8.2 RIPARIAN BANK STABILIZATION PROJECT

The Technical Committee recognized that, once operational, the lower flows generated by the Kemano Completion Project might reduce the capacity of the Nechako River to transport sediments out of the system. An increase in sediments entering and being stored in the channel might degrade spawning and rearing habitat for chinook.

One of the remedial measures proposed by the committee in the event of an increase in sediments was to promote vegetation along the banks of the river (riparian zones) to stabilize the banks and prevent sediments eroding into the river. Vegetation also provides cover for fish along the river margins and habitat for insects that are the primary prey of juvenile salmonids.

8.2.1 Study Plan

Rehabilitating slopes and riverbanks through revegetation techniques has been successfully used in Europe for many years. However, it is relatively new in North America and there is little documented information on rehabilitating riverbanks in British Columbia, or the rest of Canada. Consequently, the Technical Committee initiated a four-year pilot study (1990 to 1993) of riparian revegetation techniques in the upper Nechako River. The three-stage study plan included:

- **Year one (1990)**: a literature review of riparian revegetation techniques to identify techniques appropriate for the upper Nechako River. Members of the committee also visited the Deadman Creek watershed near Kamloops to observe riverbank revegetation activities conducted by the Shuswap Nation Tribal Council;
- **Year two (1991)**: experimental use of selected riparian revegetation techniques at a site on the mainstem of the upper Nechako River and at a site on Greer Creek, a tributary of the Nechako River; and
- **Years three and four (1992 and 1993)**: monitoring the survival and growth of the new riparian vegetation, and the structural integrity of stabilization measures[66].

8.2.1.1 Literature Review

A search of three computerized databases produced 192 articles on riverbank revegetation techniques. Thirty-nine of these were reviewed, 13 being used as primary references in the review.

According to the general findings of the review:

- each site targeted for revegetation should first be assessed to determine if a bioengineering approach could effectively be applied to reduce erosion, or if a hard engineering approach — *i.e.,* installing rip rap or concrete deflectors, or using earth moving machines to reduce the slope of a bank — might be more effective;
- various bioengineering techniques are often required to reduce erosion — stream banks have three components, a toe, face and top, each of which may require a different technique;
- factors to consider when selecting techniques include:
  - simplicity of design and implementation;
  - cost relative to other options;
  - availability of plant materials;
  - ease of access to the site;
  - stream hydrology at the site; and
  - biophysical aspects of the site;
- whenever possible, indigenous plant species should be selected over introduced species. Indigenous species are adapted to local

[66] The results of those investigations were published in four technical reports: NFCP 1993g; NFCP 1996f; NFCP 1998f; NFCP 1998g; NFCP 1998h.

conditions, are less expensive than introduced species, and are aesthetically compatible with existing riparian communities; and
- regular monitoring and maintenance of revegetated areas is necessary.

8.2.1.2 Site Selection

A pilot Riparian Bank Stabilization Project was initiated at two sites in the upper Nechako River basin in 1991. Site selection was based on six criteria:

1. The erosion at the site is representative of erosion at other locations in the Nechako River system.
2. The site is not exposed to high water velocity or excessive water depth.
3. Bank material at the site is composed mainly of sand, silt or clays, the materials with the most potential to degrade spawning habitat.
4. Desirable plant material—mainly members of the willow (*Salix* spp.) family—is available close to the site.
5. The site has a southern exposure to optimize growing conditions.
6. The site is readily accessible by truck or boat.

The first site chosen was an undercut bank made of silt/clay on the left bank of Greer Creek (km 44), 100 m south of the Greer Creek bridge and within easy walking distance of Kenney Dam Road (**Figure 8.2-1**).

Greer Creek is one of the major tributaries to the upper Nechako River, and a major source of sediment (NFCP 1999a). The bank was sloughing due to undercutting at the toe of the bank by freshet flows. Thinleaf alder (*Alnus tenuifolia*), Pacific willow (*Salix lucidia lasiandra*) and Bebbs willow (*Salix bebbiana*) were readily available at the site.

The second site was a silt/clay bank on the left bank of the mainstem Nechako River, 30 km downstream of Kenney Dam and just upstream of the confluence of the Nechako River with Targe Creek. Relatively easy to reach by boat, the site was close to suitable plant material on Copley Flats at the mouth of Targe Creek. A shelf at the foot of the bank during low winter flows was suitable for planting shrubs and/or reeds.

8.2.1.3 Revegetation Techniques

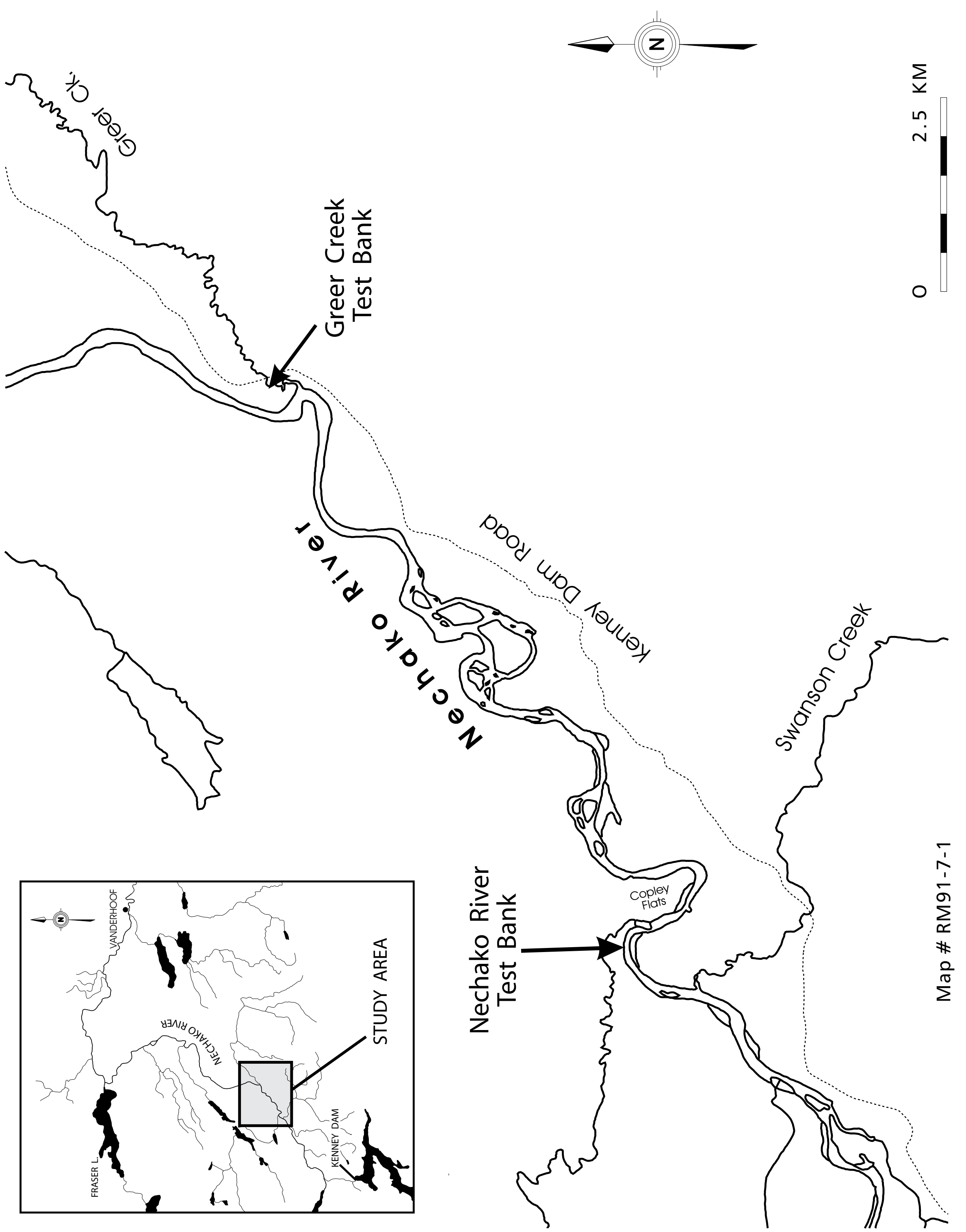
A technique known as "spiling" was chosen for the Greer Creek site. Spiling involves driving a series of stout, live wooden posts into the ground at the base of an eroding bank to a depth of about half their length. Slender live branches called "weathies" are interwoven between the posts to create a fence between the stream and the bank. The area between the fence and the bank is then backfilled with soil collapsed from the bank.

Between April 9 and 11, 1991, a four-person crew built 45 m of spiling fence along the toe of the Greer Creek bank using alder and willow cut from the surrounding area. Posts (mostly alder) with an average length of 2 m and ranging in diameter from 8 to 15 cm were pounded into place 0.7 to 1.1 m from each other to armour the bank. Weathies were made mostly of alder and Bebbs willow. A shorter spiling fence 5 m in length was constructed at the upstream end of the main fence and riveted with two small coniferous trees to provide extra protection from high freshet flows.

After freshet subsided in June, the backfilled area behind the spiling fence was seeded with a mix of Creeping Red Fescue (*Festuca rubra*), Alsike clover (*Trifolium hybridium*) and Rye grass (*Lolium multiflorum*). A starter fertilizer (34-0-0 nitrogen:phosphorus:potassium) was added to help establish growth.

There was very little vegetation growing on the surface of the bank at the second site (km 30) and sand and clay slumped continuously into the river.

Figure 8.2-1 **Nechako River: locations of test banks for the revegetation pilot project**



This meant that initiating plant growth to stabilize the surface of the bank was more important than armoring the toe of the bank—as was done at Greer Creek—to prevent erosion. Several methods of reducing wave erosion at the toe of the bank were tested.

Revegetation at km 30 was done by a three-person crew between April 12 and 15 and on May 30. In April, 405 unrooted alder and willow cuttings, each 20 cm long and 2 cm in diameter, were dipped in rooting hormone and buried in the bank leaving approximately 2 cm of each cutting exposed. The cuttings were buried in two separate areas about 30 m apart. One area of 30 m^2 was planted at a density of about four cuttings per m^2, and a second area of 200 m^2 was planted at a density of about one cutting per m^2.

A brush mattress 10 m wide and extending 6 m up the bank was also installed between the rooted and unrooted cuttings in April. The mattress was comprised mainly of young alders and Bebbs willow branches pressed against the bank with trembling aspen (*Populus tremuloides*) poles anchored with stakes and baling wire. The toe of the mattress was protected against water current with two layers of wattles made of slender alder and willow branches 2 to 3 m long and 20 to 40 cm thick. The mattress was partially covered with soil.

A small section of contour wattles with an area of about 15 m^2 was constructed adjacent to the brush mattress. Four wattles were placed in four separate trenches. Each wattle was secured with 1 m long stakes driven into the bank. Several rows of wattles were dug into the toe of the bank to protect it from wave erosion.

An approximately equal number of rooted cuttings were planted on the bank on May 30. These cuttings had originally been taken in two batches, one in mid-March and the other in mid-April, and shipped live in coolers, to the coldframe greenhouses at Deadman Creek operated by the Shuswap Nation Tribal Council. There the cuttings developed roots before being transferred to small peat pots and burlap bags and transported back to the Nechako River where they were buried in the same way as the unrooted cuttings.

Finally, 10 lengths of rebar were pounded into the bank at six locations along the length of the test area to act as erosion index stations. The distance between the toe and each rebar stake was recorded.

8.2.2 Results and Discussion

The two test sites were monitored in late May and late August 1991. High spring flows at the Greer Creek site had flattened 5 m of the spiling fence, but no other significant erosion was observed. Both the live posts and the weathies showed signs of growth on May 31; however, by the end of August, leaf growth was reduced, most likely due to an absence of root growth.

Rooted cuttings at km 30 showed some growth on May 30, but unrooted cuttings showed very little growth. By the end of August, the growth of most cuttings had slowed, and there was extensive mortality (up to 75%) among rooted cuttings. The brush mattress and wattles showed good growth over 1991.

The two test sites were re-visited on May 20/21 and August 12/13, 1992. The spiling fence at Greer Creek continued to grow well, providing lush foliage and extensive roots. In contrast, only grasses continued to grow well at km 30. The growth of woody structures was greatest for the brush mattress, followed by the wattles then the rooted and unrooted cuttings. Cuttings survival was lower in 1992 than in 1991 with only 9% of unrooted cuttings and 5% of rooted cuttings still alive by May 1992.

The test sites were visited again when field crews had the opportunity, then in November 1993. In June, high flows had shifted Greer Creek away from its old channel, isolating the test site. Vegetation showed good growth and survival, although the spiling had begun to unravel at its downstream end and was partly buried by sediment from a flood event.

None of the vegetation planted at km 30 showed good growth or survival rates over 1993. Dry conditions and slope instability limited establishing both planted and natural vegetation. The brush mattress and the wattles installed at the shoreline remained intact, but the contour wattling became exposed and was less effective at holding soil. Both erosion and deposition of material occurred at the site.

The study was terminated at the end of 1993.

8.2.3 Summary: Riparian Bank Stabilization Project

This study showed that riparian revegetation could potentially be used to stabilize the banks of the Nechako River and tributaries, thereby reducing sediment input to the river. However the study also showed that some of the river's steep, sandy slopes (*e.g.,* those found at km 30), could not be stabilized with the bioengineering techniques tried in the study. The dry, steep, sandy banks of the km 30 site did not offer a hospitable environment for vegetation, whether planted or natural.

The major findings of this study were that:

- structural techniques such as spiling, brush mattresses, and wattling would be most effective in tributary systems, but probably not effective for mainstem banks;
- willow (common in the study area) propagated well from cuttings, but thinleaf alder did not;
- rooted or unrooted cuttings may require irrigation during the first year of growth to establish themselves on dry sites (*e.g.,* km 30), or dry-tolerant species, such as wild rose, could be tested in future revegetation projects; and
- in the absence of irrigation, bioengineering techniques were not appropriate for dry, steep slopes, such as those found at the km 30 site, unless they are used in combination with hard engineering approaches.

8.3 CHESLATTA AND MURRAY LAKES INFLOW INVESTIGATIONS

The objective of the Cheslatta and Murray Lakes Inflow Investigations was to develop a method of forecasting both the timing and volume of the spring freshet into the upper Nechako River from the Cheslatta Lake and Murray Lake watersheds. The average annual contribution from the Cheslatta-Murray system was estimated to be 4.9 m^3/s at the time of the signing of the *1987 Settlement Agreement* (Schedule "C"). This value was used to calculate the difference between mean annual reservoir releases and the mean annual flow expected at the Water Survey of Canada's Data Collection Platform Station 08JA017 near Bert Irvine's Lodge (km 19).

In 1988, the Technical Committee concluded that a detailed knowledge of the magnitude and timing of local inflows to the Cheslatta and Murray Lakes' watershed was not critical for managing the Short-Term Flow regime. However, as inflows would account for approximately 20% of the flow in the Nechako River below Cheslatta Falls under the Long-Term Flow regime, information on inflows was necessary for making management decisions under that regime about allocating water for the benefit of chinook (the Conservation Goal).

8.3.1 Estimating Inflows

Developing the methods to forecast inflows was based on data collected from December 1989 to June 1993 as part of the Cheslatta and Murray Lakes System Hydrological Data Collection Project (NFCP 2000). This project (1989/1990) collected data from a climate station and a water level recorder installed in a temporary station on Bird Creek (**Figure 8.3-1**) near the outlet of Bird Lake, and four snow course stations within the Cheslatta and Murray Lakes watershed (one within the Bird Creek sub-basin). The database developed from the information consisted of:

- mean daily air temperatures;
- mean daily relative humidity;
- accumulated total precipitation;
- streamflow of the Bird Creek sub-basin; and
- snow pack measurements from the snow course station located within the Bird Creek sub-basin.

The Bird Creek watershed was selected for this study after considerable discussion with the provincial Water Management Branch and after manually recording snowpack in several sub-basins of the Cheslatta-Murray watershed. The Bird Creek drainage area includes 10% of the entire Murray-Cheslatta watershed which is, hydrologically, a significant proportion. This allowed the flows for the entire watershed for the years 1989 to 1993 (years in which the temporary Bird Creek station operated) to be extrapolated from the measured or estimated flow from the Bird Creek drainage. To predict flows for periods before and after that time, it was necessary to identify a long-term WSC hydrological station and a WSC snowpack station from outside the area that:

- had data for the same period as the temporary station on Bird Creek (1989 to 1993);
- exhibited similar hydrological characteristics as Bird Creek (*e.g.,* timing and relative magnitudes of flow events); and
- was active and could be expected to continue in service for at least the next decade.

Information from stations that met these criteria could be used as surrogates for information from Bird Creek and extrapolated to estimate flows for the entire Murray-Cheslatta watershed.

Five hydrological stations met the criteria. The Van Tine Creek (**Figure 8.3-1**) database was selected as the most appropriate for analysis.

Several snowpack stations in the Nechako River basin were considered as surrogates. The provincial Ministry of the Environment, Lands and Parks collected snowpack data from the Bird Creek basin, but other stations were required to support the data and indicate when, if ever, conditions in Bird Creek varied from the average for conditions outside the Nechako River basin. Bird Creek and Mount Swannell shared similar timing of snow depths, although Bird Creek's snow depths peaked slightly earlier than Mount Swannell and tended to melt earlier (**Figure 8.3-2**). Therefore, it was assumed that snow pack data measured from Mount Swannell could be used to determine if snowpack data measured in the Bird Creek drainage differed from conditions outside the Nechako River basin[67].

Two types of analysis were performed with data from the surrogate stations and the Bird Creek temporary station. These were:

- comparisons of trends in flows between the Bird Creek watershed and WSC stations to identify potential surrogates; and
- linear regression analyses to quantitatively support the qualitative results of the trend analyses.

[67] **Figure 8.3-2** provides data beyond 1993 as this station is currently active and maintained by the province.

Figure 8.3-1 **Cheslatta and Murray Lakes: watershed study area**

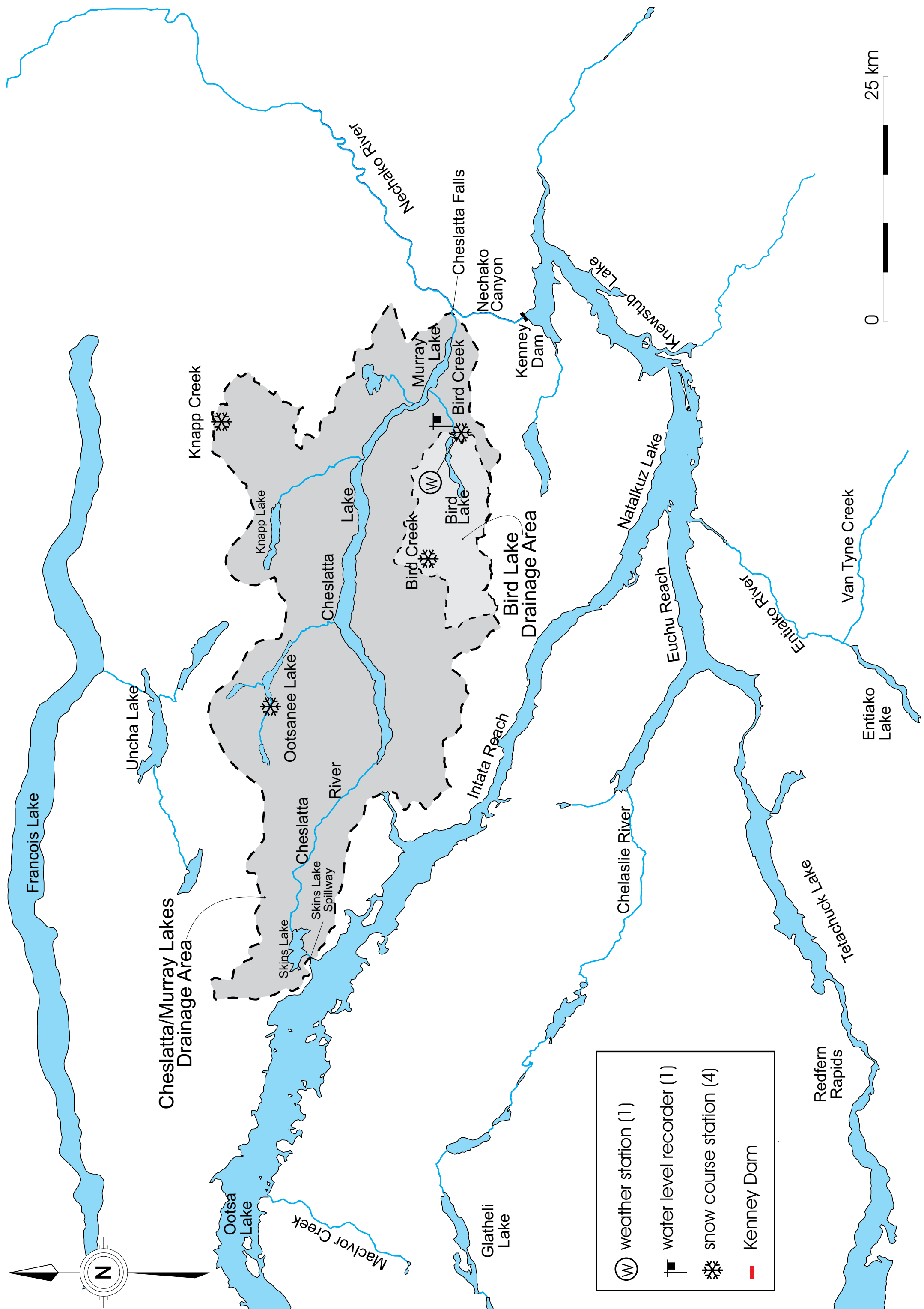
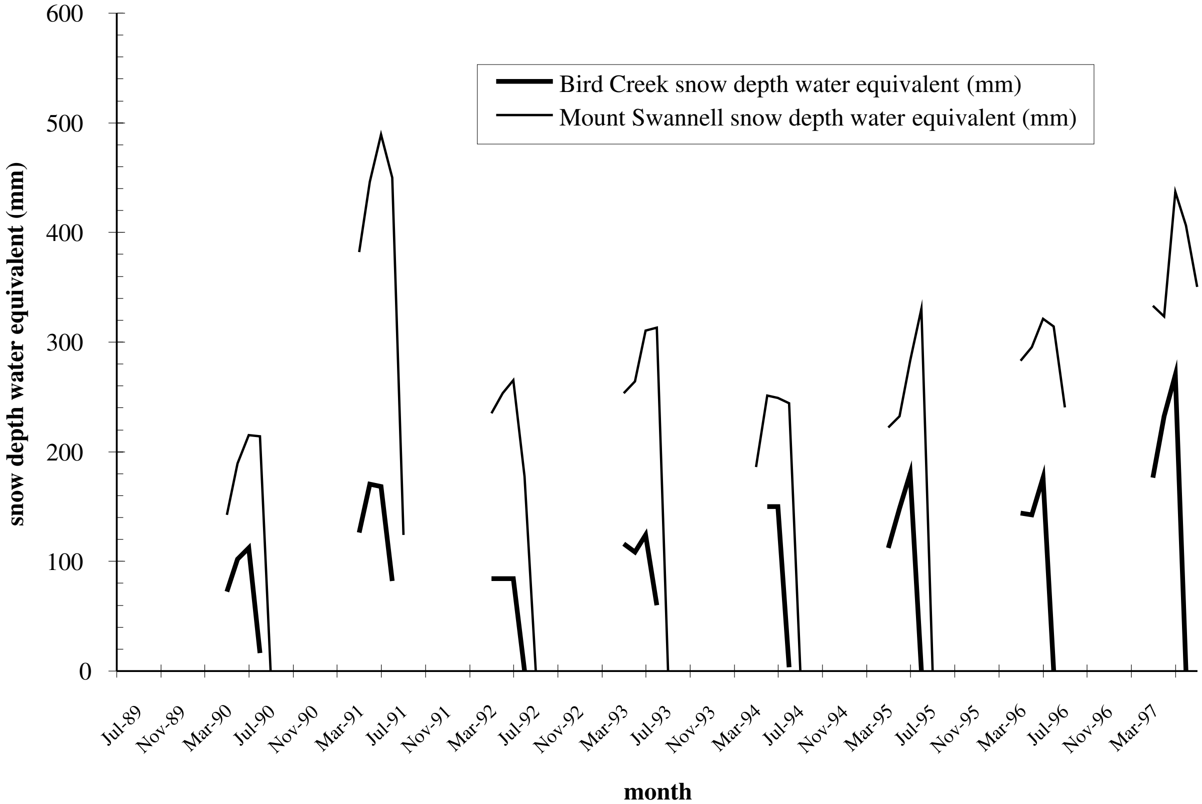


Figure 8.3-2 **Nechako River Basin: comparison of Bird Creek and Mount Swannell snow depth water equivalent, 1989 to 1997**



8.3.2 Results

8.3.2.1 Recorded Data

The mean monthly air temperatures ranged from -18.3°C (January 1993) to 14.6°C (July 1992), and averaged 1.9 °C for the entire period of recorded data. Mean annual air temperatures for April to March—the NFCP water year—for 1990/91, 1991/92 and 1992/93 were 1.9°C, 3.6°C and 1.4°C, respectively. Mean annual relative humidity was in the low- to mid-70% level for the three years.

Total annual precipitation recorded at Bird Creek ranged from approximately 343.6 mm (1991/92) to 610.1 mm (1990/91). Average annual snow depth (water equivalent) ranged between 76 mm (1989/90) and 137 mm (1990/91). Bird Creek's mean annual discharge ranged from approximately 0.5 m^3/s (1990/91) to 0.7 m^3/s (1991/92); its peak flow tended to occur slightly in advance of the peak flow from the Van Tine Creek drainage.

Air temperature, relative humidity, total precipitation, discharge and snow depth (water equivalent) data recorded during the Cheslatta and Murray Lakes Inflows Investigation are presented as mean monthly values in **Figures 8.3-3** through **8.3-7**.

Figure 8.3-3 **Bird Creek: summary of recorded mean monthly air temperature November, 1989 to June, 1993**

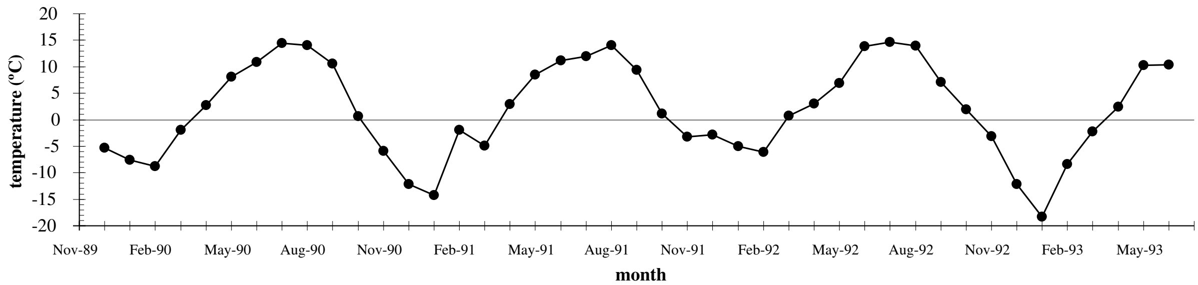


Figure 8.3-4 **Bird Creek: summary of recorded mean monthly relative humidity November, 1989 to June, 1993**

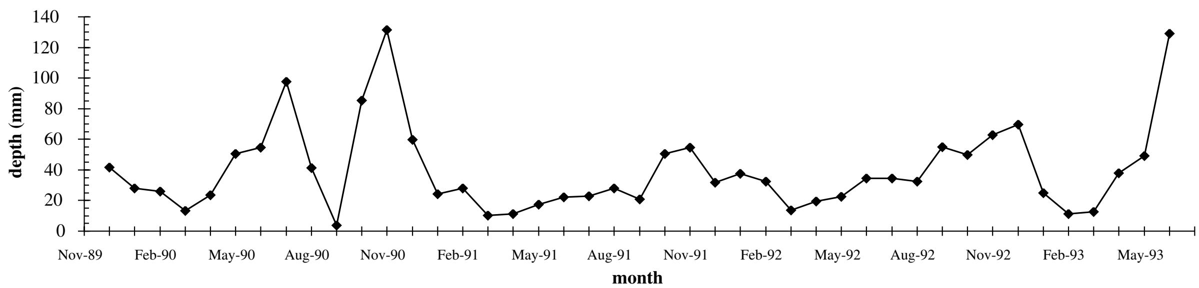


Figure 8.3-5 **Bird Creek: summary of recorded total monthly precipitation November, 1989 to June, 1993**

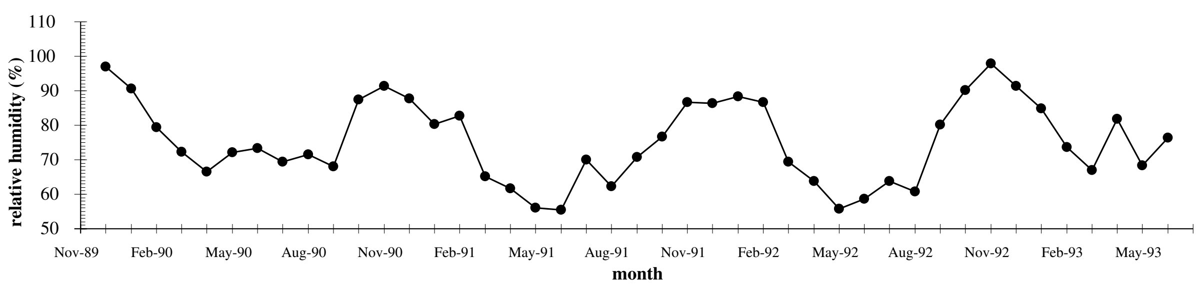


Figure 8.3-6 **Bird Creek: summary of recorded mean monthly discharge November, 1989 to June, 1993**

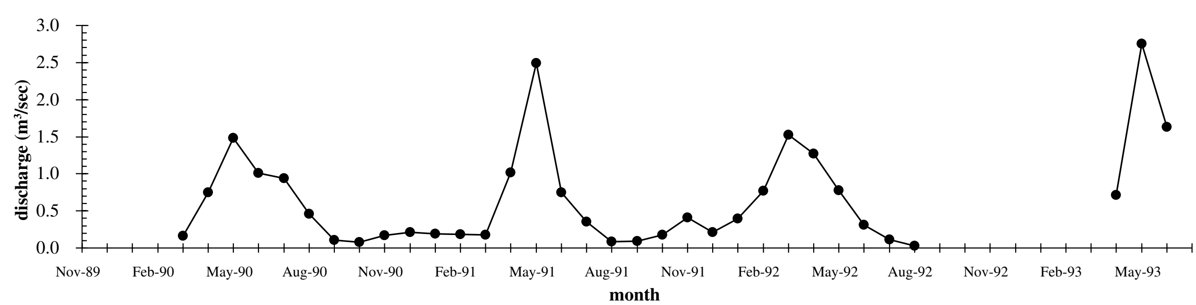
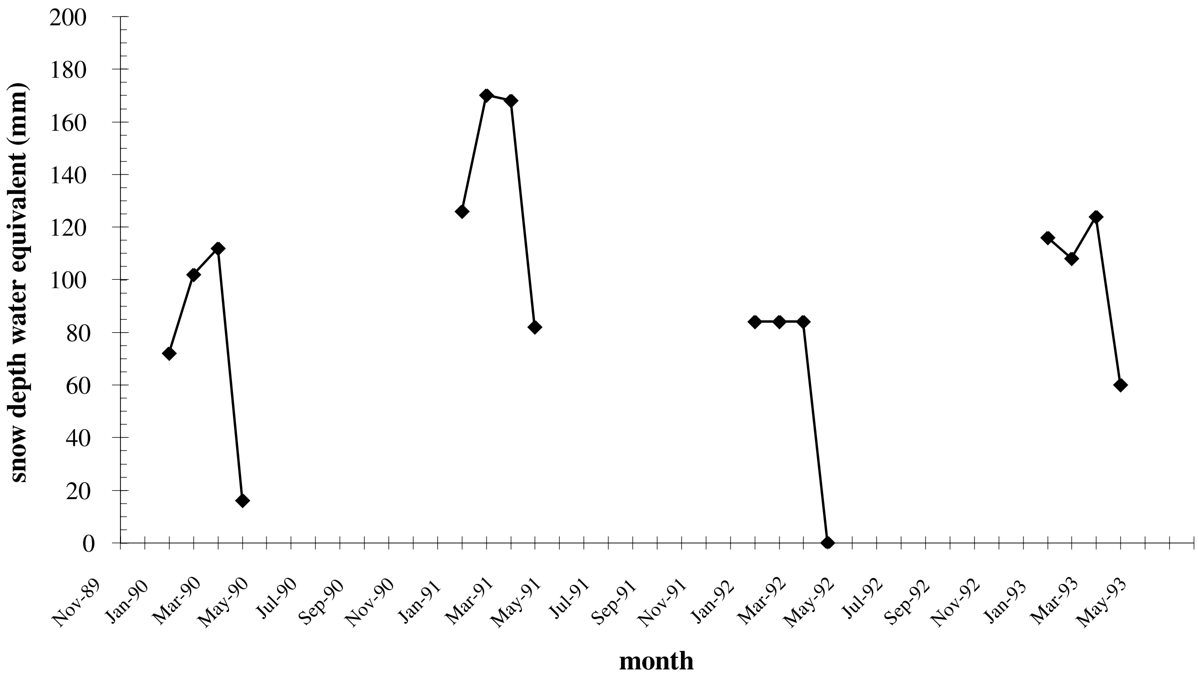


Figure 8.3-7 **Bird Creek: summary of recorded mean monthly snow depth water equivalent November, 1989 to June, 1993**



8.3.2.2 Data Analyses

Comparing mean monthly flows recorded in Van Tine Creek and Bird Creek from October 1989 to September 1993 showed that their annual hydrographs shared similar timing, although the peak flow from the Bird Creek drainage tends to occur slightly in advance of the peak flow from Van Tine Creek. Maximum mean monthly flows occurred between May and June, with low flow periods from August to March (**Figure 8.3-8**). Comparisons of these flows are represented as mean monthly hydrographs in **Figure 8.3-9**.

On average, from 1989 to 1993, Van Tine Creek's annual flow (0.903 m^3/s) was 1.75 times greater than Bird Creek's annual flow (0.515 m^3/s). Therefore, it was assumed that Bird Creek flows could be estimated by dividing Van Tine Creek flows by an average factor of 1.75.

8.3.2.3 Proposed Forecast Procedure

An eight step forecasting procedure was developed for Bird Creek and Cheslatta and Murray Lakes.

1. Obtain the latest WSC monthly flow values for the year from Van Tine Creek.
2. Obtain snow depth (water equivalent) values (mm) from the Bird Creek and Mount Swannell stations for the corresponding periods (if available).
3. Plot and compare the latest recorded Van Tine Creek flows to the long-term hydrograph.
4. Plot and compare the latest recorded Bird Creek and Mount Swannell snow depth (water equivalent) values (mm) to the long-term average.
5. Assume average rainfall for the year.
6. Predict the Bird Creek flow regime for the remainder of the year based on average flows and snow depth (water equivalents). For

Figure 8.3-8 **Bird and Van Time Creeks: comparison of mean monthly flows, 1989 to 1993**

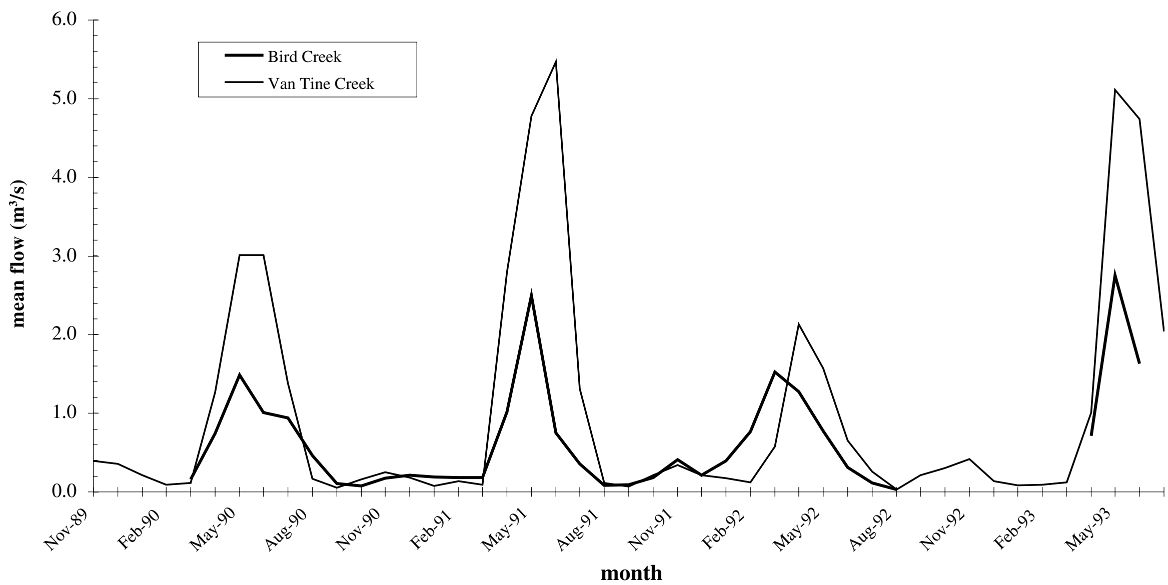
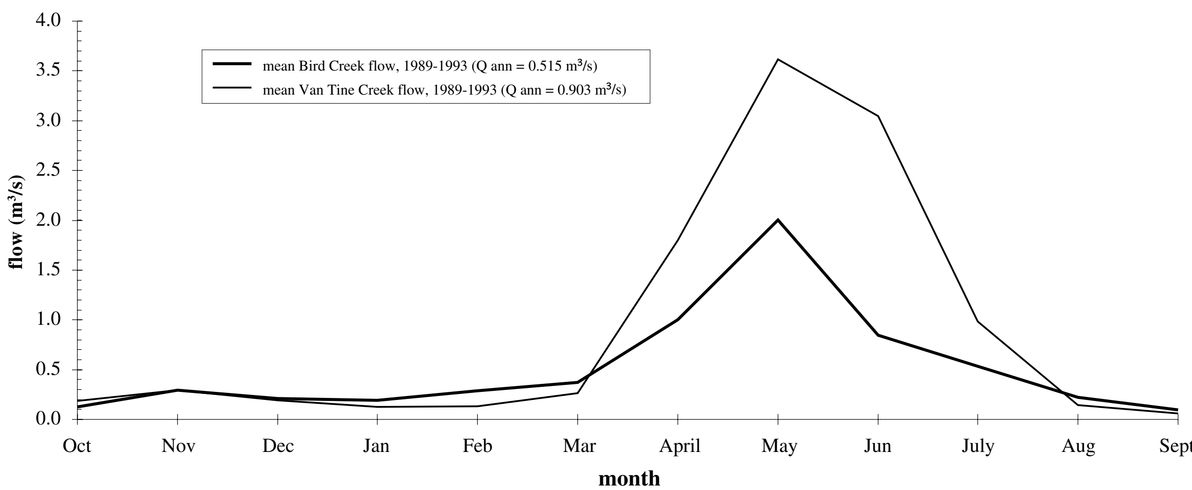


Figure 8.3-9 **Bird and Van Time Creeks: comparison of recorded mean monthly flows, averaged by month, 1989 to 1993**



example, if the flows recorded at Van Tine Creek for a specific year were below average by a given percentage and the snow depth recorded was also below average by a certain percentage, it is reasonable to predict that flows at Bird Creek would be below average by a similar average percentage for that year.

7. Extend the results of the Bird Creek flow prediction (step 6) to the Cheslatta and Murray Lakes watershed based on a factor related to the drainage area ratio.
8. Revise and update the Bird Creek and Cheslatta and Murray Lakes watershed inflow predictions in the same manner, as more current flow data and snow course data becomes available.

8.3.3 Discussion

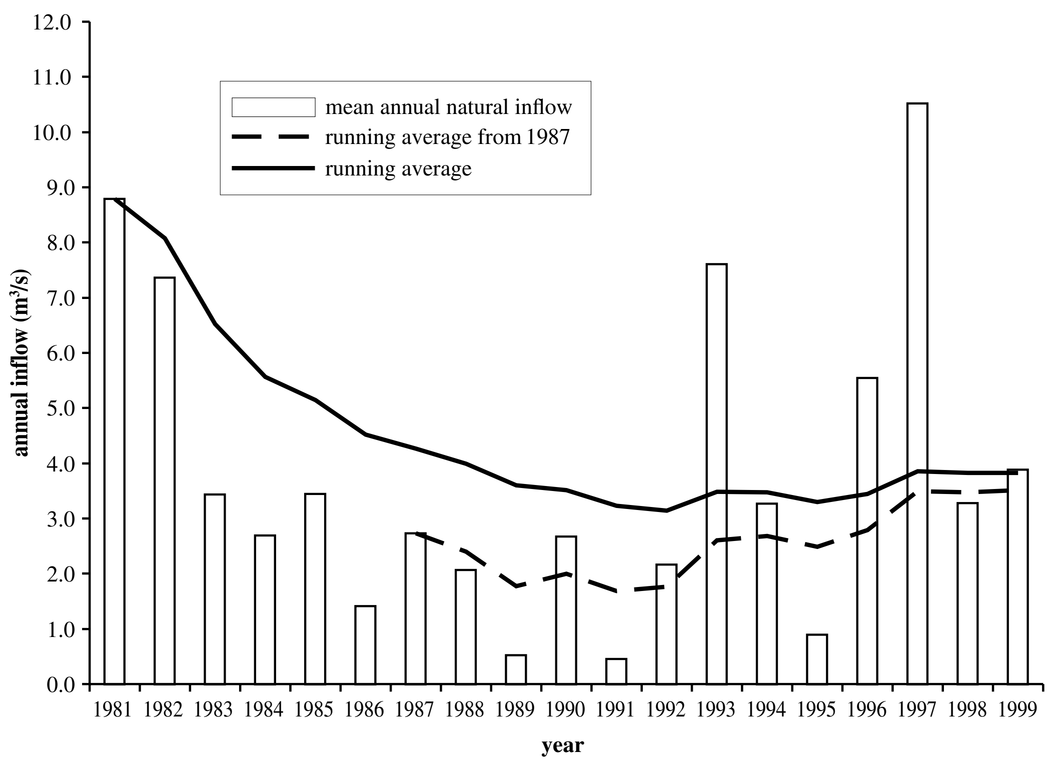
The data collected from the Bird Creek sub-basin indicated that the time of peak flow contributions from the Murray-Cheslatta watershed was in early May.

Extrapolating the average annual inflow recorded in Bird Creek—approximately 0.5 m^3/s—to an average annual inflow from the Murray-Cheslatta watershed using a drainage area ratio of 1:10 suggested a value of about 5 m^3/s, which is close to the value of 4.9 m^3/s used in the *1987 Settlement Agreement.* However these values did not agree with an average annual inflow estimate derived from subtracting the average annual flow released from the Skins Lake Spillway from the average annual flow measured at WSC Station 08JA017 (km 19) (**Table 8.3-1** and **Figure 8.3-10**). In this case, the average over a period of 19 years was 3.8 m^3/s.

Table 8.3-1 **Nechako River Basin: natural flow contribution to the Cheslatta River and Chelsatta and Murray lakes drainage, downstream of Skins Lake**

year	mean annual natural inflow, m^3/s	running average from 1981, m^3/s	running average from 1987, m^3/s
1981	8.8	8.8	
1982	7.4	8.1	
1983	3.4	6.5	
1984	2.7	5.6	
1985	3.4	5.1	
1986	1.4	4.5	
1987	2.7	4.3	2.7
1988	2.1	4.0	2.4
1989	0.5	3.6	1.8
1990	2.7	3.5	2.0
1991	0.4	3.2	1.7
1992	2.2	3.1	1.8
1993	7.6	3.5	2.6
1994	3.3	3.5	2.7
1995	0.9	3.3	2.5
1996	5.5	3.4	2.8
1997	10.5	3.9	3.5
1998	3.3	3.8	3.5
1999	3.9	3.8	3.5

Figure 8.3-10 **Nechako River Basin: natural flow contribution between Skins Lake and Bert Irvine's Lodge (Water Surveys of Canada Station 08JA017)**



The difference between the extrapolated values based on the Bird Creek drainage measurements and those derived from flow records could be due to one, or a combination of several factors, including, but not necessarily limited to:

- the accuracy of measuring flows at the Skins Lake Spillway and Station 08JA017;
- loss of flow between the Skins Lake Spillway and Station 08JA017; or
- the average annual flow estimate for Bird Creek and the extrapolation factor applied to estimate flow contributions from the entire Murray-Cheslatta watershed.

The accuracy of flow measurements at Skins Lake Spillway and Station 08JA017 was assessed by a field program undertaken in 1999 in conjunction with Environment Canada at a time when the flows in the river were about 30 m^3/s (Hay & Company 1999). The assessment concluded that flow measurements at both locations were accurate to within +/- 3% at a 95 % confidence level, suggesting that the estimate of inflow realized at the station, based on the subtraction of the Skins Lake flows, was accurate.

There have been times, particularly in the fall, when the flows recorded at km 19 were less than flows released from the spillway. This has occurred when flow releases have been steady, removing the possibility that the difference in daily readings was a result of the time interval between the release of water at Skins Lake and that increase being recorded at km 19. This suggests that the discrepancy might have been more likely due to losses to groundwater[68] or problems estimating Skins Lake Spillway gate releases.

The third possible factor is the extrapolation on an area ratio of 1:10 based on the annual average flow of the Bird Creek drainage. Applying an area ratio without adjusting for geology, ground cover, or other factors that affect runoff may introduce an error. However, without data that can be used to calibrate the extrapolation factor, using the raw area ratio is a good "first estimate."

8.3.4 Summary: Cheslatta and Murray Lakes Inflow Investigations

The Technical Committee set out to gather data on inflow volumes and timing into the Cheslatta-Murray Lakes to assist in flow management decisions following the implementation of the Kemano Completion Project. Given that the project was cancelled, further data collection to help refine the estimates of timing and volume of the inflows has not been carried out. That said, the forecast procedure developed for the Murray-Cheslatta flow is a useful tool should forecasting these inflows be required for water management on the Nechako River.

Four years is a short period of time in which to derive a representative average; a comparison could be made with a longer flow record from a comparable watershed to determine whether the period of 1989 to 1993 was representative of average conditions elsewhere. Caution should be used in extrapolating the results of this study to other nearby watersheds.

[68] The Technical Committee continues to study the reasons for the discrepancy in flows between the Skins Lake Spillway and Station 08JA017.

8.4 INORGANIC FERTILIZATION PROJECT

The objectives of the Inorganic Fertilization Project were to:

- determine optimum nutrient enrichment ratios and loading rates;
- assess the effect of fertilization on the benthic community; and
- collect periphyton baseline data on the Nechako River.

Studies on various river systems have shown that adding inorganic nutrients to nutrient-deficient streams increases periphyton production (Stockner and Shortreed 1976; Peterson *et al.* 1985, 1993; Perrin *et al.* 1987), insect growth and abundance (Milbrink and Holmgren 1981; Mundie *et al.* 1983, 1991; Peterson *et al.* 1985; Johnston *et al.* 1990; Deegan and Peterson 1992), and the growth of steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) (Slaney *et al.* 1986; Johnston *et al.* 1990).

Fertilization was first proposed by the Nechako River Working Group in preparation for the *1987 Settlement Agreement.* The Working Group recognized that introducing cool water from the proposed Kenney Dam Release Facility might reduce the growth of both juvenile chinook and their prey and that stream fertilization was one method of possibly counteracting some of the negative ecological effects of the releases.

Although fertilization had been shown to increase the growth of some species of salmonids, its effect on chinook had not been demonstrated. Consequently, a series of experiments were conducted in the upper Nechako River between 1988 and 1991 to test the effect of fertilization on periphyton and benthic invertebrate production and on juvenile chinook abundance and growth.

A full river fertilization trial was not conducted due to the province cancelling the Kemano Completion Project.

8.4.1 Study Plan

From May through July of 1988, two experiments were conducted to measure the relationship between periphyton biomass and nutrient concentration in the upper Nechako River. The first experiment was the *in situ* fertilization of a side channel opposite Bert Irvine's Lodge (km 19), accompanied by the measurement of periphyton biomass and species composition. The second experiment was a bioassay designed to identify the response of periphyton to a wide range of nitrogen (N) and phosphorus (P) concentrations. The bioassay was conducted on a floating platform at km 19.

From May to July 1989 another two experiments measured the relationship between periphyton biomass and nutrient concentration in the upper Nechako River. The first experiment was a scaled-up version of the *in situ* experiment conducted in 1988. Inorganic fertilizer was released into the river at its confluence with Swanson Creek (km 29) and then nutrient concentrations and periphyton biomass were measured at sites up to 50 km downstream. The body size and relative abundance of juvenile chinook were sampled concurrently at sites up and downstream of the fertilizer release site to measure growth response.

The second experiment was a repeat of the bioassay experiment conducted in 1988 using a combination of N and P concentrations designed to measure the response of periphyton to seven levels of N at surplus P levels.

From May to July 1990, another two experiments were conducted, and the upper river was surveyed for nutrient concentrations, periphyton biomass and juvenile chinook abundance and body size. The first experiment was a mesocosm study designed to quantify relationships between nutrient concentrations, periphyton biomass and the abundance of aquatic insects. The second experiment was a repeat of the bioassays conducted in 1988 and 1989, but with lower concentrations of nutrients[69] (**Table 8.4-1**).

Table 8.4-1 **Nechako River: inorganic fertilization study plan, 1988 to 1990**

year	location/ assessment technique	experimental design
May-July 1988	side channel	*In situ* side channel fertilization
May-July 1988	bioassay	Nechako km 19; N+P loadings
May-July 1989	Nechako River	*In situ* fertilization at confluence of Swanson Ck.
May-July 1989	bioassay	Nechako km 19, 7 conc. of N at surplus P
May-July 1990	mesocosm	nutrient, periphyton, insect correlation
May-July 1990	bioassay	repeat of 1988/89 with no nutrient additions

The survey of nutrients and periphyton biomass in the upper river was designed to determine whether the increase in periphyton biomass seen in 1989 at a site 50 km downstream of the fertilizer release site was due to fertilizer or to natural sources of nutrients. The survey of juvenile chinook abundance and size was done as part of the Technical Committee's annual out-migrant survey, but also included snorkel surveys designed to assess the baseline status of juvenile chinook in the upper river during a non-fertilization year.

The results of the investigations described above were published in nine NFCP technical reports (NFCP 1993a, 1993d, 1993h, 1993i, 1996b, 1996c, 1996d, 1998b, 1996e). Parts of those investigations were also published in two papers in the primary scientific literature (Slaney *et al.* 1994; Perrin and Richardson 1997). This report presents only the major results of the fertilization project.

8.4.2 Experiments

Experiments to monitor increases in periphyton biomass usually have three phases and rarely run longer than three weeks:

- **Phase one (three to five days)**: the substrate is colonized and settlement is the main process instead of growth;
- **Phase two (usually lasting 10 to 17 days)**: there is exponential growth in the plant community; and
- **Phase three (after the 17th day)**: biomass declines, or becomes highly variable, due to sloughing of the plants from their substrate.

8.4.2.1 *In situ* Fertilization, 1988

The 1988 *in situ* fertilization experiment ran from May 6 to July 10, 1988, and covered two separate cycles of periphyton biomass increase. The fertilization experiment took place in the side channel near km 19. The channel was 300 m long with an average wetted width of 31.5 m and an average depth of 0.37 m. Flows averaged 6.1 m^3/s, or about 10% of the mainstem flow.

A fertilizer blend of 70% 34-0-0 (N:P:K) and 30% 12-51-0 was released at the upstream end of the side channel from two high-capacity feeders suspended from aluminum A-frame supports and equipped with spreaders to distribute the fertilizer over a 20 m width of channel. Electronic controls released the fertilizer for several seconds each 3 minutes, 24 hours a day. The system was powered by a battery continuously charged by solar panels.

[69] The 1990 survey produced equivocal results; a forced spill from the Nechako Reservoir during that year may have scoured the river bottom and reduced periphyton biomass.

Approximately 60 kg/day of fertilizer were released into the side channel during the first two weeks. That rate was increased to between 80 and 90 kg/day for the remainder of the study in order to increase dissolved nutrient levels in the side channel to attain target levels of 40 μg/L of dissolved inorganic N and 10 μg/L of P.

The effects of adding fertilizer to the side channel were measured as changes in:

- dissolved nutrient concentrations;
- taxonomic composition of the periphyton;
- increase in periphyton biomass; and
- dissolved oxygen concentrations in spawning gravel.

Measurements of nutrients and periphyton biomass were taken at a control site 50 m upstream of the fertilizer dispensers, and at a treatment site at the downstream end of the side channel, 300 m from the dispensers. Nutrient samples were also taken at sites 1.5 and 3.4 km downstream of the dispensers. Water samples for measuring nutrient concentration were taken weekly from the control site and biweekly from the three treatment sites.

Triplicate samples of periphyton biomass were taken from the control and treatment site in the side channel every three days over the duration of the experiment by cutting plugs from three Styrofoam sheets anchored at each of the two sites. Biomass was expressed as the number of milligrams of chlorophyll a per surface area of the plug (mg/m^2). At the end of the study, two periphyton samples were taken and preserved in Lugol's solution for a description of species composition.

The dissolved oxygen concentration was measured at the end of the fertilizer release period (July 10) at five randomly-chosen sites in the side channel and the mainstem. Dissolved oxygen was measured with a YSI meter at the surface and at a depth of 15 cm.

8.4.2.1.1 Results

Flows in the side channel ranged from 4.8 to 6.7 m^3/s between May 6 and June 7, then fell abruptly to 2.8 m^3/s on June 8 as a result of the temporary closure of the Skins Lake Spillway due to a drowning accident. When flows resumed, the stored water caused higher than normal flows from June 10 through June 25. Since changes in flows cause changes in nutrient concentration in the side channel, the experiment was divided into two periods: May 13 to June 10 and June 17 to July 8. Fortunately, the timing of these periods corresponded to the timing of the two cycles of biomass accrual.

Before fertilization began, nutrient concentrations in the side channel were not significantly different between the control and treatment sites: N and P concentrations were below detection limits. After fertilization began, nutrient concentrations at the treatment site in the side channel were extremely variable and did not match the target concentrations of 40 μg/L N and 10 μg/L P. For example, concentrations of NH_3 ranged from less than 5 μg/L to more than 700 μg/L. The variability was due to:

- the release of fertilizer in pulses every 3 minutes;
- the absence of effective longitudinal dispersion within the side channel; and
- nutrients assimilated by plants within the side channel.

Average nutrient concentrations at the two sites further downstream were only slightly greater than those measured at the control site (*e.g.,* total dissolved P ranged between 2 and 15 μg/L). The presence of several samples with nutrient concentrations substantially greater than those at the control site suggested that nutrient mixing was still not complete even at a distance of 3.4 km from the release site.

Taxonomic composition of the periphyton community was similar in both natural and artificial substrates, but different between artificial substrates at control and treatment sites. Adding fertilizer caused a shift from a diatom-dominated community to one having equal proportions of diatoms and chlorophytes.

Chlorophyll *a* concentrations at the treatment site in the side channel reached levels more than one order of magnitude greater than control levels in both of the two sampling series (*i.e.,* May 13 to June 10 and June 17 to July 8) (**Table 8.4-2**). The periphyton growth rate at the side channel treatment site was five to seven times greater than at the control site.

Table 8.4-2 **Nechako River: indices of growth and biomass of periphyton measured on artificial substrates at control and treatment (fertilized) sites on a side channel of the upper river, 1988**

index	control	treatment	treatment/ control ratio
Series 1 (May 13 to June 10)			
peak biomass* (mg/m^2)	5.53	149.0	26.9
sustainable biomass** (mg/m^2)	3.92	111.0	28.3
k*** (cell divisions/day)	0.063	0.439	6.97
Series 2 (June 17 to July 8)			
peak biomass (mg/m^2)	14.90	218.0	14.6
sustainable biomass (mg/m^2)	8.12	121.0	14.9
k (cell divisions/day)	0.088	0.416	4.73

* Peak biomass is the highest average concentration of chlorophyll a that was measured on any day within a series;
** Sustainable biomass is the average concentration measured on the last two days of a series
*** k is the rate of growth of chlorophyll a during the period of exponential growth between the 10th and 17th day of a series, expressed as the number of cell divisions/day.

Dissolved oxygen concentrations did not change after the fertilizer was added. Average surface concentrations were 8.7 mg/L at both the control site and the side channel treatment site, and average concentration at 15 cm depth was greater at the treatment site (8.3 mg/L) than at the control site (6.8 mg/L).

8.4.2.2 *In situ* Fertilization, 1989

The 1989 fertilization experiment took place from May 4 to July 10. In this experiment, 29.36 tonnes[70] of fertilizer (70% 34-0-0 and 30% 12-51-0) were added to the mainstem of the Nechako River immediately downstream of its confluence with Swanson Creek. The target concentrations were half those used in 1988 as the 1988 bioassay indicated that periphyton growth was saturated at nutrient concentrations of not more than 20 μg/L of N and 5 μg/L of P. [See *ss. 8.4.2.4 Bioassay, 1988*]

The fertilizer was dispensed from six automatic feeders placed across the wetted width of the river and equipped with spreaders that sprayed fertilizer over a 5 m diameter area. The dispensers were programmed to release fertilizer every five minutes, 24 hours a day. Each dispenser was activated independently allowing the feeders to operate in offset intervals, thereby avoiding the pulsed release of fertilizer that occurred in 1988.

Dissolved nutrient concentrations, periphyton biomass and the taxonomic composition of periphyton were measured at a control site upstream of the fertilizer dispensers and at treatment sites 1, 5, 10, 20 and 50 km downstream of the dispensers. Dissolved oxygen concentrations were measured at the control site and at the 1 km treatment site.

Sampling techniques were the same as those used in 1988. In addition, trihalomethane production[71] was measured at the control site and at the 50 km treatment site. Periphyton samples were also tested for concentrations of metals found in trace quantities in the fertilizer.

[70] 1,000 kilograms.

[71] Trihalomethanes are produced by chlorination of water containing nitrogen compounds.

8.4.2.2.1 Results

Nutrient concentrations in the upper Nechako River were consistently less than the predicted target concentrations due to nutrient uptake by aquatic organisms. Many samples had concentrations below detection limits.

Peak chlorophyll *a* concentrations at the treatment sites were between 4.5 and 8.5 times greater than at the control site (**Table 8.4-3**). Chlorophyll *a* concentrations at the control site increased slowly over the study period and peaked six days before the end of the experiment.

Table 8.4-3 **Nechako River: peak biomass of periphyton measured on artificial substrates in the upper river at six sites during *in situ* fertilization, 1989**

location*	peak biomass** (mg/m^2)	date of peak biomass	treatment/ control ratio
control	15.6	July 4	1.00
T1	133.2	June 1	8.54
T5	84.2	May 26	5.40
T10	70.9	July 4	4.54
T20	104.1	July 4	6.67
T50	122.4	July 4	7.85

* "T" refers to treatment site.
** peak biomass is the highest average concentration of chlorophyll a that was measured on any day within the study period; and

Biomass at the 1 km treatment site peaked in early June, fell in mid-June, and peaked again in early July. Similar results were reported in the 1988 *in situ* experiment. Biomass at the 5 km treatment site followed the two-cycle pattern seen at the 1 km site, but the peak biomass of the first cycle was lower than at that site. Biomasses at the 10, 20 and 50 km treatment sites were low and constant until June 21 then increased rapidly to peak on July 4.

The initial low biomass at the three most distant treatment sites indicated that most nutrients released by the dispensers were assimilated within 5 km and did not persist in a dissolved state over the rest of the upper Nechako River. The rapid rise of periphyton biomass at these sites in late June and early July indicated that either the sites were colonized by algae sloughed from upstream locations close to the nutrient dispensers, or that substantial concentrations of nutrients were reaching those sites after a delay in transit.

The first possibility is unlikely: most drifting organic matter in the river was of detrital origin and contained little live algal biomass. In the case of the second possibility, nutrients could have been transported downstream in a form other than dissolved nutrients. A process called "spiraling" in which nutrients are taken up by algae, then released as organic matter which is oxidized into nutrient form and taken up again in a continuous process[72] may have been involved.

Dissolved oxygen concentrations at the 1 km treatment site were not significantly different from those measured at the control site. Trihalomethane concentrations at the 50 km treatment site were 29 times lower than the critical levels for drinking water established by the Canadian Council of Resource and Environment Ministers (1987).

There was no significant increase in metals concentrations at the treatment sites compared to the control sites.

8.4.2.3 Summary: *in situ* Fertilization, 1988 and 1989

The two 1988 fertilization experiments showed that adding fertilizer to the upper Nechako River increases periphyton biomass. It also confirmed

[72] There may have been natural sources of N and P in the upper Nechako River, but no data on those putative sources were available.

the findings of the bioassay that the principal limiting element was N, and that P was co-limiting. [See *ss.8.4.2.4 Bioassay, 1988*]

The experiments also showed that:

- nutrient dispersal in the upper Nechako River was not complete within three km from the release site; and
- fertilization had no effect on dissolved oxygen concentrations in surface and subsurface water.

The 1988 findings were used to design the larger 1989 *in situ* fertilization experiment. This experiment confirmed that adding N and P to the Nechako River increased periphyton biomass without degrading water quality. It also successfully tested a method for fertilizing the whole river.

8.4.2.4 Bioassay, 1988

The first bioassay was conducted from June 3 to June 20, 1988. Ten flow-through chambers were constructed of Plexiglas, each with a Styrofoam substrate on which periphyton was allowed to grow. Nutrients were dripped into the upstream end of each chamber from plastic bottles suspended over the platform and mixed with river water flowing through each chamber. Three levels of N (0, 20 and 50 μg/L) and three levels of phosphorus P (0, 5 and 10 μg/L), plus their interactions, resulted in nine treatments. The tenth chamber was a control: no nutrients were added.

Sampling followed the same protocol as the *in situ* experiment. Water samples were taken from each chamber once a week, triplicate periphyton cores were taken every three days, and a final core was taken at the end of the experiment for taxonomic analysis.

8.4.2.4.1 Results

Water samples taken from the bioassay chambers had nutrient concentrations close to the target concentrations. The chlorophyll *a* concentrations increased in all chambers due to colonization and algal growth. Chambers in which only P was added showed the same peak biomass as the control chamber, but chambers in which N was added showed a five-fold increase in peak biomass, and chambers in which both N and P were added showed almost a 13-fold increase (**Table 8.4-4**).

Table 8.4-4 **Nechako River: peak biomass of periphyton measured on artificial substrates in bioassay chambers, upper river, 1988**

treatment	peak biomass* (mg/m^2)	treatment/ control ratio
control	6.0	1.0
P alone	6.8	1.1
N alone	29.1	4.9
N + P	76.7	12.8

* peak biomasses are for the highest nutrient levels tested in the bioassay: N = 50 ug/L and P = 10 ug/L.

This suggests that periphyton growth was primarily limited by N and secondarily by P. Once N was added, growth increased and in turn drove the community into P-deficiency that could only be removed by adding P. The data suggested that growth was saturated at nutrient concentrations of not more than 20 μg/L N and 5 μg/L of P.

8.4.2.5 Bioassay, 1989

The primary objective of the 1989 bioassay was to determine the response of periphyton to a range of N concentrations when P was at surplus concentration, estimated from the 1988 bioassay to be 5 μg/L.

The bioassay apparatus was anchored upstream of the fertilizer dispensers and ran from June 10 to July 8, 1989. It was identical to the apparatus used in 1988, except that the flow-through chambers were slightly wider. The 1989 bioassay also operated in a manner identical to the 1988 bioassay, with the exception of the relative concentrations of nutrients. Seven concentrations of N (0, 5, 10, 20, 35, 50 and 100 μg/L) were combined with a P concentration of 5 μg/L. The bioassay also measured periphyton response to surplus N alone—assumed to be 50 μg/L—and a control in which no nutrients were added.

8.4.2.5.1 Results

Biomass of periphyton in the control chamber increased slowly over time. Adding only N or P produced no significant difference in periphyton biomass compared to the control chamber, but the combination of N and P increased biomass seven-fold. This indicated a co-limitation by N and P.

In those chambers in which P was added at a surplus concentration of 5 μg/L and where a range of N was added, periphyton biomass increased with increasing N concentration (**Table 8.4-5**). Over 60% of the maximum biomass was reached at an N concentration of only 10 μg/L, indicating that substantial increases in periphyton biomass could be stimulated with adding relatively low concentrations of nutrients: 10 μg/L of N and 5 μg/L of P.

Table 8.4-5 **Nechako River: peak biomasses of periphyton measured on artificial substrates in bioassay chambers, upper river, 1989**

phosphorus concentration (ug/L)	nitrogen concentration (ug/L)	peak biomass* (mg/m^2)	percent maximum biomass
5	0	5.0	26.3
5	5	4.5	23.7
5	10	12.0	63.2
5	20	12.5	65.8
5	35	15.0	78.9
5	50	14.5	76.3
5	100	19.0	100.0

* peak biomass is the highest average concentration of chlorophyll *a* that was measured on any day within the study period.

8.4.2.6 Bioassay, 1990

The primary objective of the 1990 bioassay was to measure the response of periphyton to low levels of co-limiting nutrients when one nutrient was at surplus concentration.

A bioassay apparatus installed 300 m upstream of km 19 between May 24 and June 26, was similar in design and operation to the bioassay apparatuses installed in 1988 and 1989. The difference was in the relative concentrations of N and P used in the treatments:

- six levels of N (0, 3, 5, 8, 10 and 20 μg/L) were used at surplus P (defined as 5 μg/L from the 1989 bioassay); and
- four levels of P (0, 1, 3 and 5 μg/L) were used at surplus N (defined as 10 μg/L).

8.4.2.6.1 Results

The 1990 bioassay showed responses similar to those observed in 1988 and 1989: N and P co-limited the growth of periphyton.

8.4.2.7 Summary: Bioassay, 1988, 1989 and 1990

The 1989 bioassay confirmed the 1988 finding that periphyton growth was co-limited by N and P, and identified the minimum critical concentrations required to stimulate growth as N = 10 μg/L and P = 5 μg/L. The 1990 bioassay tested the response of periphyton to low levels of a co-limiting nutrient in the presence of a surplus nutrient. That information in combination with the results of the 1988 and 1989 bioassays allowed the construction of a relationship between the ratio of peak biomass and maximum peak biomass and nutrient concentration which predicted that 80% of the maximum possible biomass could be produced by nutrient concentrations of 40 μg/L N and 5 μg/L P. These concentrations were the recommended target concentrations to be used in any further *in situ* fertilization of the Nechako River.

8.4.3 Mainstem Surveys

8.4.3.1 Growth and Abundance of Juvenile Chinook Survey, 1989

The objective of this survey was to estimate the average size and abundance of upper Nechako River juvenile chinook. The size and abundance were measured each month from May to October 1989, over a period of one to two weeks in the middle of each month.

Four methods were used:

- **beach seines and electrofishing -** Seining and electrofishing provided estimates of catch-per-unit-effort (CPUE), defined as the number of juvenile chinook captured per seine set, or the number caught per 100 m^2 of area electrofished. Seines were used along flat, debris-free areas of the shoreline, and electrofishing gear was used for habitat complexes and other areas where seines could not be used. Stop nets were not used to close off an area before electrofishing, and only one pass was made. Therefore, the electrofishing CPUE was only an index of absolute abundance. All captured fish were counted, identified to species and released live back to the river. Sub-samples of juvenile chinook were measured for fork length and wet weight, allowing average length and weight to be estimated.
- **snorkel surveys -** Divers floating down both margins of the Nechako River from km 20 to km 40 counted all fish (by species) that they observed.
- **mark-recapture –** 5,664 juvenile chinook captured during June and July by seines or electrofishing were fin-clipped and released live back into the river. The mark-recapture study then estimated the relative numbers of juveniles above and below the fertilizer dispensers.

8.4.3.1.1 Results

The relative abundance of juvenile chinook in the upper river did not support or confirm a fertilizer effect. Both the seine CPUE and snorkel counts of juvenile chinook were greater upstream of the fertilized section of the river than downstream for the months of May and June. However, the relative abundance was identical for both sections from July to October. That pattern was as likely to reflect the spatial and temporal patterns of fry emergence and fry movement within the river as a fertilizer effect.

Similarly ambiguous results were found from comparing average lengths and weights of juvenile chinook captured above and below the fertilizer dispensers:

- average lengths were significantly greater downstream than upstream for the months of May, June and August, but not for the months of July, September or October; and
- average weights were significantly greater downstream than upstream for the months of June and August, but not for May, July, September or October.

These results may reflect enhanced food supply in the fertilized section of the river or they may reflect differences in fry age or density between the two sections (*i.e.,* fry captured downstream of the fertilizer dispensers may have been slightly larger than fry captured upstream of the dispensers because they emerged earlier in the season and had more time to move farther downstream and to grow larger). Alternatively, juvenile density may have influenced growth (*i.e.,* higher fish densities may have reduced upstream growth rates).

Only one marked fish was recovered, making it impossible to estimate relative abundance from the mark-recapture study. The disappearance of the marked fish from the study area could indicate a very rapid downstream migration.

8.4.3.2 Periphyton Assessment and Chinook Survey, 1990

The objective of the Periphyton Assessment and Chinook Survey was to compare nutrient concentrations, periphyton biomass, and abundance and growth of upper Nechako juvenile chinook for a fertilized year (1989) and a non-fertilized year (1990).

Dissolved nutrient concentrations, periphyton biomass and taxonomic composition were measured in 1990 at seven sites in the upper river:

1) just downstream of Cheslatta Falls;
2) near the mesocosm apparatus [see *ss.8.4.2.3 Mesocosm Experiment*];
3) upstream of the Swanson Creek confluence;
4) & 5) between the confluence of Swanson Creek and Greer Creek (km 44);
6) upstream of Hill Larson's Lodge (km 54); and
7) Diamond Island (km 84) near Fort Fraser.

Water samples were collected from each site on May 31, June 14 and July 14. Triplicate samples of periphyton biomass were collected from each site on a weekly basis from May 26 to July 10, using Styrofoam substrates anchored in the river.

From early April to late October, juvenile chinook were sampled from 29 sites within Reach 1, nine to 15 km downstream of Kenney Dam. Five snorkel surveys were conducted, one each month from May to October with the exception of August. Electrofishing surveys were also conducted each month with the exception of August and September. The same techniques were used as in previous years.

In addition, 23 juvenile salmon were captured in June and July and the contents of their stomachs sampled.

8.4.3.2.1 Results

Only small changes in dissolved N concentrations were found between sampling dates and locations; however, substantial changes in dissolved P were found. On both May 31 and June 14, total dissolved P levels were close to undetectable in the uppermost three sites (upstream of Swanson Creek), but increased eight-fold at the fourth site, near Swanson Creek and remained high over the three downstream sites. That increase may have been due to the release of P from fields grazed by cattle and drained by Swanson Creek, or it may have been due to the release of P stored in the hyporheic zone[73] of the Nechako River since the 1989 *in situ* fertilization experiment.

On July 4, the increase in total P concentrations at sites four to six (downstream from Swanson Creek) was no longer present, but an increase was observed at the second site (upstream). That change coincided with Swanson Creek drying up and the period of lowest flows in the upper Nechako River that summer. The increase in P levels at the second site was ascribed to the weathering of exposed phosphorus-rich rock due to low river levels.

Periphyton biomass remained at low levels at the first five sites for the first 20 days of the study, then:

- peaked at the first two sites on days 34 and 42;
- reached maxima at the next three sites that were only one-quarter of those reached at the first two sites; and
- increased steadily at the sixth and seventh sites until day 42.

Peak biomass at the seventh site was comparable to peak biomass at the second site; peak biomass at the fifth site was between that observed at the third and seventh sites.

[73] The low current zone in the gravel bed of the channel.

This pattern was interpreted as a response to site-specific changes in N and P levels over the duration of the survey. The increase in biomass at the first two sites occurred simultaneously with the increase in P concentrations due to weathering of P-rich rock in the upper river. The relatively low peak biomasses at sites three to five despite relatively high P concentrations were interpreted as due to N-limitation.

Comparison of peak periphyton biomass at sites in the upper river between 1989 (a fertilization year) and 1990 (a no-fertilization year) showed that peak biomass was substantially greater at all sites in 1989. The ratio of peak biomass in 1989 compared to 1990 rose from 2.4 at the control site just upstream of Swanson Creek to 3.9 at Diamond Island (km 84). The accrual biomass rates were similar at the control site between years, but between three and 47 times greater in 1989 than in 1990 at the other sites. These comparisons confirmed that the fertilization experiment of 1989 had indeed been responsible for the increases in peak biomasses observed at km 84 in 1989.

The spatial distribution, relative abundance and average size-at-date of juvenile chinook in Reach 1 in 1990 appeared similar to those observed in 1989. However, comparisons were confounded by a forced spill from the Nechako Reservoir between April 6 and 30. On May 1, peak flows of 250 m^3/s were recorded, which was similar in magnitude to the summer cooling flows. The forced spill was suspected of altering the movement and growth of juvenile chinook in Reach 1.

8.4.3.3 Periphyton Assessment and Chinook Survey, 1991

The 1991 surveys of nutrient concentrations, periphyton biomass and the relative abundance and size-at-date of juvenile chinook were conducted in the upper Nechako River at the same sites and with the same objectives and sampling protocol as the 1990 survey. Flows in 1991 were more similar to the average pattern than in 1990; a small spill in April raised flows to a peak of 95 m^3/s, just one-third the size of the 1990 spill.

8.4.3.3.1 Results

Except for measurements taken on the first sampling date (May 21), concentrations in 1991 of all forms of N and P were lower than those observed in 1990 at all seven sites in the upper Nechako River. Since cattle grazing on the land drained by Swanson Creek occurred in both years, this introduced uncertainty about the significance of runoff from grazing areas as a source of nutrients. Instead, the higher concentrations observed in 1990 may have been due to leaching from a hyporheic region that had been charged in 1989 by the *in situ* fertilization experiment and depleted within one year.

Periphyton biomass increased with time at all sites. The highest peak biomass occurred at km 84, followed by the next site upstream, km 54, and the first and second most upstream sites. The 1991 peak and rate of increase in biomass were similar to 1990, and both were several times lower than the 1989 peak biomasses, the year of *in situ* fertilization. The rate of accrual of biomass showed a similar trend.

This confirmed that the *in situ* fertilization experiment had substantially enhanced periphyton at all sites in 1989, including at km 84, 50 km downstream of the fertilizer release site. The similar peak biomass and accrual rates observed in 1990 and 1991 were due to N limiting growth in both years (*i.e.,* although P concentrations were much higher in 1990 than in 1991, N was at very low levels in both years).

The relative abundance of juvenile chinook was greater in 1991 than in 1990, but size-at-date was similar. The difference in abundance may have been due to lower flows in April 1991 than in 1990, or they may have been due to other factors such as a difference in the spatial distribution of fry emergence.

8.4.3.4 Summary: Periphyton Assessment and Chinook Surveys - 1990 and 1991

Surveys of nutrient concentrations and periphyton biomass in the upper Nechako showed that the peak biomass and the rate of accrual of biomass was several-fold higher in 1989, the year of *in situ* fertilization, than in 1990 and 1991. That observation confirmed that fertilization and not nutrient addition from Swanson Creek had been responsible for the increase in periphyton biomass observed at km 84 in 1989.

The 1989 surveys of relative abundance and average size-at-date of juvenile chinook did not find any convincing evidence of a fertilizer effect because of the difficulty in separating such an effect from the effects of downstream dispersal of juvenile chinook. Surveys of juvenile chinook abundance in Reach 1 were confounded by a forced spill from the reservoir between April 6 and 30. Therefore, comparisons of juvenile chinook population biology between 1989 and 1990 were also confounded. Relative abundance was higher in 1991; the size-at-date was similar in all years.

8.4.3.5 Mesocosm Experiment

A mesocosm apparatus was installed in Reach 1, 4.5 km downstream of Cheslatta Falls in late May 1990 to determine the abundance and species of insects generated by nutrient enrichment. Water and biota from the Nechako River were gravity fed through the apparatus, which consisted of 16 flow-through Plexiglas troughs. Downstream of a mixing chamber in each trough was a 1.2 m section containing a 5 cm deep layer of drain gravel that was used for rearing benthic invertebrates. Above the gravel was an insect emergence trap. Downstream of the gravel was a 0.32 m section fitted with a Styrofoam surface for sampling periphyton biomass. Each trough emptied into a bucket that served as an insect drift collector. Each bucket had openings covered in 253 μm Nitex mesh.

Nutrients were introduced to the upstream ends of the Plexiglas troughs by drip feed. Four of the troughs had 10 μg/L of N added, four had 5 μg/L of P added, four had both 10 μg/L of N and 5 μg/L of P added, and four control troughs had no nutrients added.

The experiment lasted from May 24 to June 26, 1990. Periphyton and water samples were collected from each trough weekly. A final periphyton sample was taken at the end of the experiment for taxonomic purposes.

Insect drift from the troughs was collected over 24-hour periods on three dates: June 11, 18 and 25. Insect emergence traps were emptied weekly. At the end of the experiment (June 26), the contents of the trough were emptied by agitating the gravel and washing zoobenthos through a 253 μm mesh screen. All insects were preserved in 5% formalin.

8.4.3.5.1 Results

Nutrient additions produced a periphyton response similar to that observed in the bioassay. The greatest response was obtained from troughs in which both N and P were added. A massive decline in periphyton biomass occurred soon after peak biomass was reached due to sloughing of periphyton. Diatoms were the dominant taxon.

Drift of insects out of the troughs was analyzed by calculating the number of drifters of a taxon as a fraction of the density of that taxon in the troughs. Per capita drift did not vary significantly among nutrient treatments. Insects caught in the emergence traps included mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), caddisflies (*Tricoptera*), and true flies (*Diptera*). Some terrestrial and semi-aquatic species were caught incidentally.

The total numbers of insects caught over the study ranged from 593 for control troughs to 951 for the N-enhanced troughs (**Table 8.4-6**). An analysis

Table 8.4-6 **Nechako River: total numbers of insects that emerged from the mesocosms installed in the upper river, May 24 to June 26, 1999**

group	control	N added	P added	N+P added
Ephemeroptera	21 3.5%	21 2.2%	19 3.0%	17 2.0%
Plecoptera	27 4.6%	39 4.1%	46 7.3%	76 8.8%
Tricoptera	155 26.1%	119 12.5%	125 19.9%	138 16.0%
Chironomidae	358 60.4%	722 75.9%	395 63.0%	590 68.4%
other dipterans	32 5.4%	50 5.3%	42 6.7%	42 4.9%
total number	593	951	627	863

of variance showed that adding only N produced more animals than the control, as did adding N plus P. However, adding only P, or N plus P did not produce more animals than adding only N. There was no effect of nutrient treatment on species richness.

8.4.3.5.2 Summary: Mesocosm Experiment

The mesocosm study showed insect production was enhanced by adding N and N plus P, confirming that fertilization increases insects, as well as periphyton biomass. The most common insects captured in the emergence traps were chironomids, which were the most common insect prey of juvenile chinook in the upper river at the time of the experiment. This implied that fertilizing the Nechako River could increase the supply of prey items for juvenile chinook, thereby increasing their growth and survival.

8.4.4 Discussion: Inorganic Fertilization

The fertilization project successfully met all but one of its objectives. While two of the three links in the nutrient-plant-insect-fish system of the upper Nechako River were tested and confirmed, the third link—the response of juvenile chinook to increased insect prey abundance caused by fertilization (*e.g.,* enhanced growth and abundance), the original justification for the experiments—was not measured. The intent was to include a complete river fertilization trial that would have tested the insect/fish link in the fifth and final year of the program. That trial was not conducted after the province cancelled the Kemano Completion Project.

Comparing the relative abundance and size-at-date of juvenile chinook in the upper Nechako River in 1989—the *in situ* fertilization year—with 1990 and 1991—years with no fertilization—did not demonstrate an effect from fertilization on any aspect of juvenile chinook population biology. Either the great majority of juvenile chinook did not stay long enough in the upper river to encounter enhanced feeding conditions mediated by adding fertilizer, or enhanced feeding conditions stimulated growth of juvenile chinook, which in turn stimulated size-dependent downstream dispersal. The end result is the same—most juveniles would leave the upper river whether they were affected by fertilization or not, leaving behind the smallest fry and little evidence of a fertilizer effect.

Whole-river fertilization experiments on steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) in the Keogh River of northern Vancouver Island (Johnston *et al.* 1990), on grayling (*Thymallus arcticus*) in the

Kuparak River of northern Alaska (Deegan and Peterson 1992), and on sockeye salmon-bearing lakes of Alaska (Nelson and Edmonson 1955) and British Columbia (Hyatt and Stockner 1985) all found that adding fertilizer was accompanied by an increase in fish size due to an increase in plant biomass and invertebrate abundance. The fundamental difference between those studies and the Nechako River study was the length of time that the target fish remained within the treatment area. Juvenile steelhead and coho reside in the Keogh River for at least one spring and summer before smolting and migrating to the sea. Grayling reside within the Kuparak River drainage their entire lives. Juvenile sockeye reside in their nursery lakes for at least one year. In contrast, most juvenile chinook appear to leave the upper Nechako River by the end of June after spending less than one month in the upper river.

Some chinook do remain in the upper Nechako River for as long as one year, and other salmonids such as rainbow trout spend their entire adult lives in the upper river. Those fish and other resident species are expected to exhibit a growth response to stream fertilization. However, the juvenile chinook that spend their first year in the upper river make up a very small proportion of the entire juvenile population, so increased growth of those fish would have little effect on brood year survival and escapement.

No comparisons of insect densities were made between 1989 — the *in situ* fertilization year — and 1990 and 1991 — the non-fertilization years. Such comparisons would be technically difficult: emergence and drift of aquatic insects are highly variable with time and space due to the insects' small size, short life spans, rapid rates of growth and mortality, and the ability of adult stages to move long distances by air. Since the mesocosm study showed that insect emergence in experimental troughs was enhanced by fertilization, it is reasonable to assume that a similar response would occur if the experiment was scaled up to the size of the upper Nechako River. This hypothesis still needs to be examined in a natural environment.

8.4.5 Summary: Inorganic Fertilization

Four years of research showed that inorganic fertilization of the upper Nechako River resulted in an increase in nutrients, periphyton and insect abundance. However, research could not demonstrate a direct effect of fertilization on the average size and abundance of juvenile chinook.

8.5 IDENTIFYING AND RANKING SOURCES CONTRIBUTING SEDIMENT TO THE UPPER NECHAKO RIVER

The Technical Committee recognized that, once built, the Kemano Completion Project would generate lower flows that might lead to increased sediment deposition along the bed of the Nechako River. Fine sands, silts and clays can infiltrate the immobile gravel substrate, while coarser sands and gravels may be deposited on the bed surface. Increased proportions of fine sediments are associated with reductions in the spawning success of salmonids while sediment on the riverbed surface can degrade salmonid rearing habitat.

Consequently, the committee developed and ranked an inventory of sediment sources to use in reaching decisions on the necessity and priority of controlling sediment contributions from individual sources. A consultants report listing sources was published as an NFCP technical report (NFCP 1999a).

8.5.1 Methods: Literature Reviews, Over-flights and Ground-truthing

Two literature reviews were conducted. One review determined the surficial and bedrock geology of the upper Nechako River as it affects sediment supply and transport. The second review examined studies and measurements of sediment sources and sediment transport in the upper river.

All tributaries to the upper river and their drainage areas were inventoried with 1:100,000 National Topographic Services maps; 41 streams were included in the inventory. This tributary inventory was ground-truthed with helicopter over-flights on May 10 and 11, 1989 (NFCP 1999a, Appendix A).

Analyses of historical airphotos and 1:7,500 scale airphoto mosaics of the Nechako River were used to prepare an inventory of sediment sources contributing directly to the upper Nechako River (NFCP 1988a). This inventory was ground-truthed by helicopter on August 4, 1989, and by reconnaissance trips by boat from August 30 to September 1, 1989[74].

Suspended sediment loads were measured in selected tributaries. A single discharge-weighted sediment concentration measurement was made on May 10 or 11, 1989, in ten tributary streams. Depth-integrated samples were collected at identified depths of the water column, depending on the width of the stream.

There were several Water Survey of Canada (WSC) stations on the Nechako River and its major tributaries in and near the study area (*e.g.*, the Stuart and Nautley Rivers), but none of the tributaries to the upper river had had stations. A list of streams with gauging stations near the study area was compiled and was used to estimate the mean annual flow, mean annual floods and timing of mean annual floods of tributaries to the upper Nechako River (**Tables 8.5-1** and **8.5-2**).

Table 8.5-1 **Nechako River Basin: Water Survey of Canada gauging stations on the Nechako Plateau (near the study area and on the river)**

stream	gauge	drainage area (km²)	period of record
stations on the Nechako Plateau			
Van Tine Ck near the mouth	08JA014	153	1974-91 RC
MacIvor Ck near the mouth	08JA016	53	1976-80; 83-86 RC 1981-82; 87-91 RS
Murray Ck at Vanderhoof	08JC006	125	1962-67 MS 1968-74 MC
Murray Ck above East Murray Ck	08JC008	20	1967-74 MC
Clear Ck near Vanderhoof	08JC007	52	1967; 70-72 MS
Stony Ck at Stony Ck	08JC013	342	1981 MS 1983-84 RS
Stony Ck below Tachick Lk	08JC010	451	1977-79 RS
Nadina R at outlet of Nadina Lk	08JC008	399	1964-74 MS 1975-89 MC 1990-91 RC
Nautley R near Fort Fraser	08JB003	6,030	1952-73 MC 1976-91 RC
stations on the Nechako River			
Skins Lake Spillway Nechako Reservoir	08JA013	reservoir releases	1952-91 RC
Nechako River below Cheslatta Falls	08JA017	15,600	1980-91 RC
Nechako River at Vanderhoof	08JC001	25,100	1948-55 MS 1956-88 M/RC
Nechako River at Isle Pierre	08JC002	42,500	1950-91 RC

R = recording C = continuous M = manual S = Seasonal

[74] The results of the helicopter and boat reconnaissance trips are summarized in NFCP 1999a *Appendix D.1*.

Table 8.5-2	Nechako River Basin: characteristics of gauging records on small streams on the Nechako Plateau						
			mean annual flood			1989 annual maximum	
stream	gauge	drainage area (km²)	(m³/s)	(L/s/km²)	timing of peak flow	date	discharge (m³/s)
Van Tine Ck near the mouth	08JA014	153	8.89	58	April 16 to May 26	May 1	4.59
MacIvor Ck near the mouth	08JA016	53	7.07	132	May 26 to June 19	June 1	4.82
Murray Ck at Vanderhoof	08JC006	125	5.01	40	April 1 to May 6	**	**
Murray Ck above East Murray Ck	08JC008	20	1.28	63	April 2 to May 2	**	**
Nadina R at outlet of Nadina Lk	08JC008	399	39.7	99	May 10 to June 13	June 2	38.7

** Nadina River is regulated

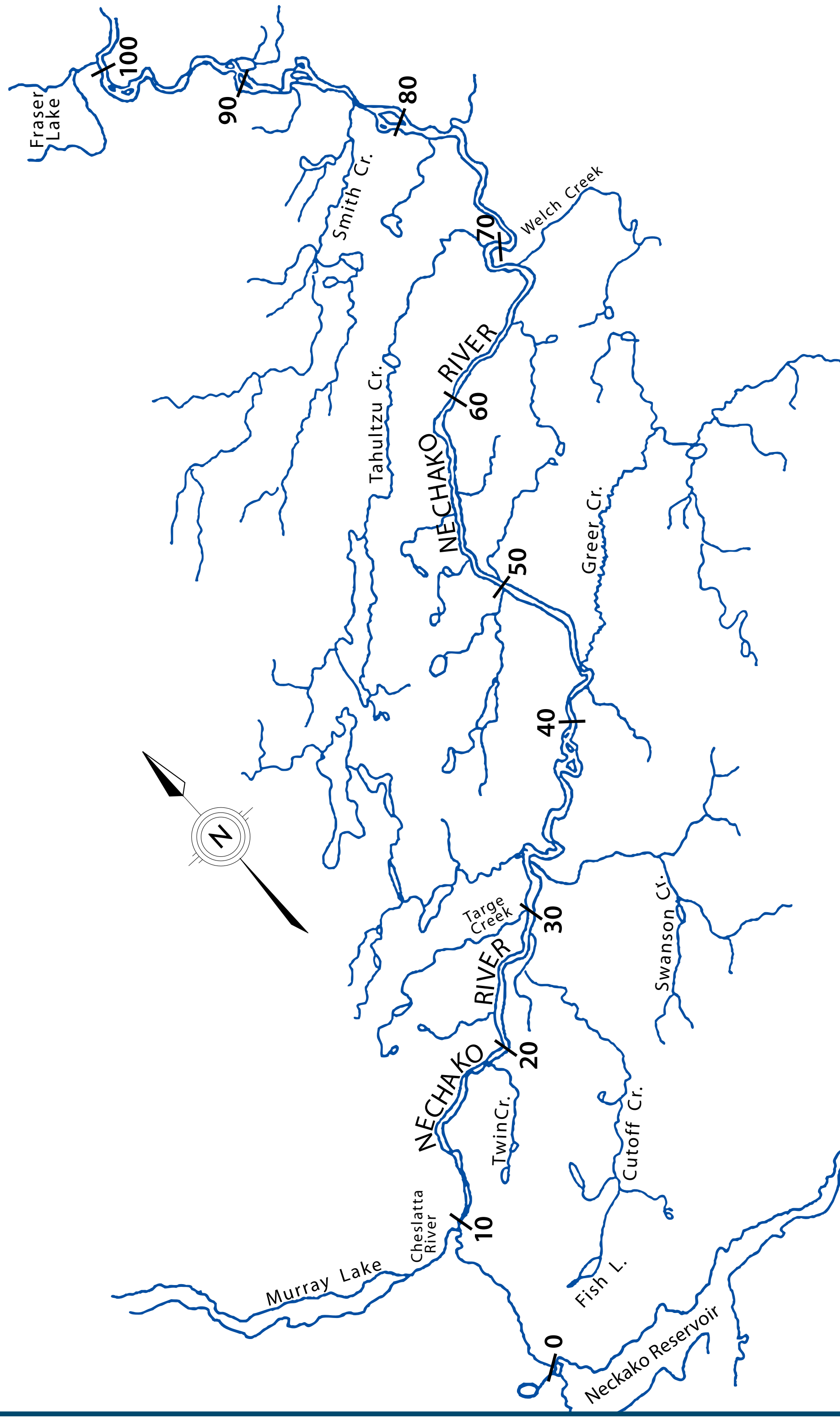
Sediment loads were estimated using two methods. Method 1 calculated the annual load by assuming that the concentration measured on May 10 or 11 was the average annual sediment concentration. Method 2 assumed that the measured suspended load on May 10 or 11 was the average daily load for the year. Several calculations of the daily load over four years are presented in **Table 8.5-3** for the Nechako River at the community of Vanderhoof. Suspended sediment concentrations and calculated loads for May are shown relative to other times of the open water season.

Grain size distributions of sediment sources contributing directly to the Nechako River were measured. The bed material of Twin, Swanson, Targe, Greer and Smith Creeks (**Figure 8.5-1**) were sampled to determine the portion of fine materials (<2 mm) that could contribute to the stream sediment load as the creek beds were mobilized and coarse sediments delivered to the Nechako River. Bed material samples were collected from bars and sieved to 16 mm in the field before being sent to the lab for analysis. Grain size distributions were also measured on eroding banks and valley walls.

Table 8.5-3 Nechako River: suspended sediment measurements at the Vanderhoof gauge

date	daily discharge (m³/s)	sediment concentration (mg/l)	daily load (Mg)
May 10, 1989	143	16.2	200
July 5, 1989	123	1.8	19
July 26, 1989	99	4.0	34
August 09, 1989	282	10.6	258
Sept 25, 1989	52	2.2	10
May 01, 1990	331	18.2	520
May 14, 1990	190	10.4	171
June 22, 1990	162	6.6	92
July 31, 1990	310	6.5	174
August 23, 1990	135	4.0	46
October 11, 1990	45	1.8	7
April 30, 1991	314	18	488
June 19, 1991	414	5.2	186
July 31, 1991	430	6.6	245
August 20, 1991	455	8.2	322
October 10, 1991	118	3.4	35
April 9, 1992	113	12.4	121
May 19, 1992	143	6.8	84
July 8, 1992	231	10.2	204
July 21, 1992	309	6.4	171
August 13, 1992	231	4.6	92
October 9, 1992	45.4	2.2	9

Figure 8.5-1 Nechako River: upper river and selected tributaries



The contribution of sediment to the upper Nechako River from a tributary was assessed from its estimated annual suspended load and the position of the tributary relative to chinook spawning areas. Bank and valley wall erosion sites were classified on the basis of their estimated annual erosion volume, their dominant grain size and their nearness to spawning sites. All sediment sources were ranked and mapped on 1:7,500 scale airphoto mosaics.

8.5.2 Results

8.5.2.1 Physiography, Geology and Sources of Sediment

A deep layer of glacial drift exceeding 150 m thickness in some locations covers the Nechako Plateau (Tipper 1963, 1971); there are few exposures of local bedrock. The Nechako Valley is incised a hundred meters into silt and clay deposits, which are exposed in the channel bed at several locations near Diamond Island (km 81).

There are three sources of sediments in the upper river:

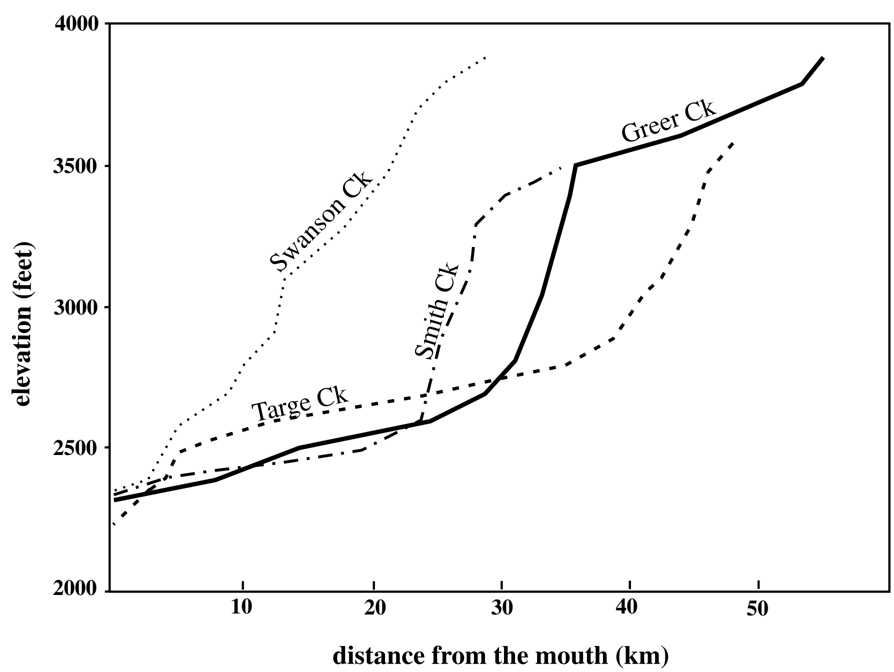
- fine sediment passing through Murray and Cheslatta Lakes;
- banks and valley walls along the Nechako River; and
- sediments transported by tributaries.

The steepest portion of tributaries often lies in the reaches descending into the Nechako River valley. Sediment production in these reaches is from eroding glacio-fluvial or glacio-lacustrine sediments in the steep stream segments. Greer, Targe and Swanson Creeks meander on moderate gradient slopes leading to the Nechako River (**Figure 8.5-2**).

8.5.2.2 Hydrology of the Study Area

The mean annual discharge of the tributaries to the upper Nechako River was calculated as 6.8 m^3/s and the mean annual floods were estimated as 54 $L/s/km^2$. The timing of annual floods—estimated

Figure 8.5-2 Swanson, Targe, Greer and Smith Creeks: longitudinal profiles



from gauging stations on streams near the study area — was between mid-April and mid-May. In 1989, the estimated annual stream flows at each station were one half to three quarters of the mean annual flood.

8.5.2.3 Sediment Measurements on the Nechako River

Based on non-filterable residue measurements, annual suspended load was estimated to be 5,000 metric tonnes in the upper Nechako River and 20,000 metric tonnes near Vanderhoof (Reid Crowther and Partners Ltd. 1987). These loads correspond to average annual sediment concentrations of approximately 3 mg/L in the upper river and 7 mg/L near Vanderhoof. Measured suspended concentrations reached a maximum of approximately 20 mg/L during the spring freshet (**Figure 8.5-3**). Based on suspended sediment measurements by the Water Survey of Canada at Vanderhoof, the annual suspended load was estimated to be 15,000 metric tonnes.

Sutek Services Ltd. (1988) estimated the total sand accumulation on the Nechako River from 1953 to 1986 as 420,000 m^3 (630,000 metric tonnes). A review of the rate of bank erosion and estimates of the total supply from the Cheslatta Falls washout suggested that annual rates of sand supply were about 7,800 tonnes/year from valley wall and bank erosion and about 5,900 tonnes/year from tributaries.

8.5.2.4 Field Estimates: Tributary Sediment Loads

Estimated daily and annual suspended loads typically increased with drainage area and were greatest for the largest tributaries (**Table 8.5-4** and **Figure 8.5-4**). The total daily load from all the tributaries amounted to approximately 10 tonnes. Total estimated annual suspended load for the sampled tributaries amounted to 1,200 tonnes for Method 1 and 3,500 tonnes for Method 2. Grain size distributions in the tributaries were similar in each stream and the fine portion of the bed material consisted mostly of medium and coarse sand (**Table 8.5-5** and **Figure 8.5-5**).

Only four tributaries supplied a substantial load of coarse material: Swanson, Targe, Greer and Smith Creeks. From 1953 to 1986, Swanson Creek added approximately 20,000 m^3 of coarse material to its fan. Targe Creek also added approximately 20,000 m^3 (Reid Crowther and Partners Ltd. 1987) while Smith Creek supplied approximately 3,000 to 4,000 m^3. The load from Greer Creek is assumed to be similar to that of Swanson and Targe Creeks. This means that the total coarse sediment accumulation in the upper river during that time was (approximately) 60,000 m^3, or 2,000 m^3/year.

8.5.2.5 Field Estimates: Contributions from Bank Erosion

Measurements of bank and valley wall erosion were done through a review of a time series of unrectified maps prepared from airphotos (Reid Crowther and Partners Ltd. 1987)[75]. There were three sites where measurable bank retreat was occurring:

- opposite Targe Creek between km 30.5 and km 30.8 on the right bank – approximately 13,000 m^3 over 33 years or 400 m^3/year;
- on the right bank at the downstream end of Diamond Island between km 81.0 and km 81.3 – approximately 11,000 m^3 over 33 years or 300 m^3/year; and

[75] Results of the inventory of bank and valley wall erosion are summarized in NFCP 1999a *Appendix D.2.*

Table 8.5-4 **Nechako River: measured discharges and sediment concentrations and predicted mean annual flows, mean annual floods and annual loads ungauged tributaries to the upper river**

		predicted discharges (m^3/s)		measurements on May 10 & 11			predicted annual load (mg)	
stream	drainage area (km^2)	mean annual flow	mean annual flood	discharge (m^3/s)	sed. conc. (mg/l)	calculated daily load (mg/day)	method 1*	method 2**
Km 48.6 Creek	10.1	0.02	0.6	0.018	379	0.59	239	215
Twin Creek	17	0.03	0.9	0.014	9.5	0.01	9	4
Km 27.5 Creek	21	0.04	1.2	0.09	7.5	0.06	10	21
Bungalow Creek	22.7	0.05	1.2	0.016	51	0.07	80	26
Cutoff Creek	77	0.15	4.1	0.023	12	0.02	57	9
Tahultzu Creek	81.8	0.16	4.4	0.025	7.3	0.02	37	6
Smith Creek	214	0.42	11.6	0.826	13	0.93	172	339
Swanson Creek	223	0.44	12	0.525	6	0.27	83	99
Targe Creek	314	0.62	17	6.04	4.4	2.30	86	838
Greer Creek	389	0.76	21	3.18	19	5.22	455	1,905
TOTALS						9.49	1,228	3,462

* Method 1 calculates annual load by assuming measured concentration is the average annual concentration.
** Method 2 calculates annual load by assuming the computed daily load is the average daily load.

Table 8.5-5 **Twin, Targe, Greer and Smith Creeks: bed sediment characteristics**

creek	sample size (kg)	portion less than 2 mm (%)	dominant size fraction
Twin Creek	18	28.8	coarse sand
Swanson Creek	131.8	9.1	coarse sand
Targe Creek	152.7	24.7	coarse sand
Greer Creek	127.7	25.4	medium sand
Smith Creek	133.4	12.3	very coarse sand

Note: dominant size fraction is the Wentworth size class of the sub-16 mm material with greatest percentage of the total weight.

Figure 8.5-3 **Nechako River: suspended sediment concentration and discharge at Vanderhoof**

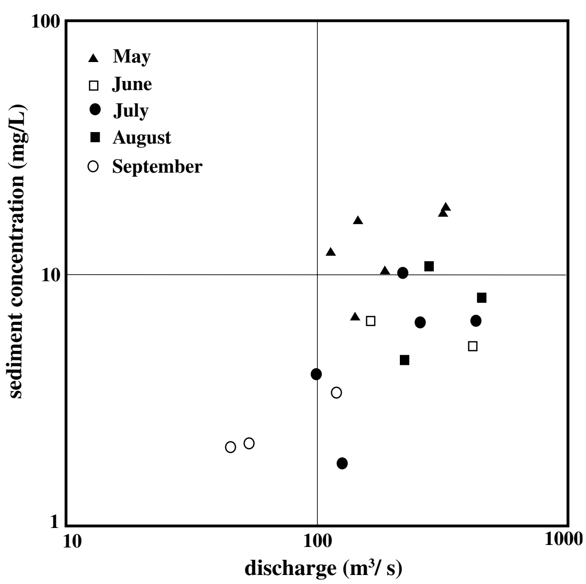


Figure 8.5-4 Nechako River: plot of daily suspended load against drainage area, upper river

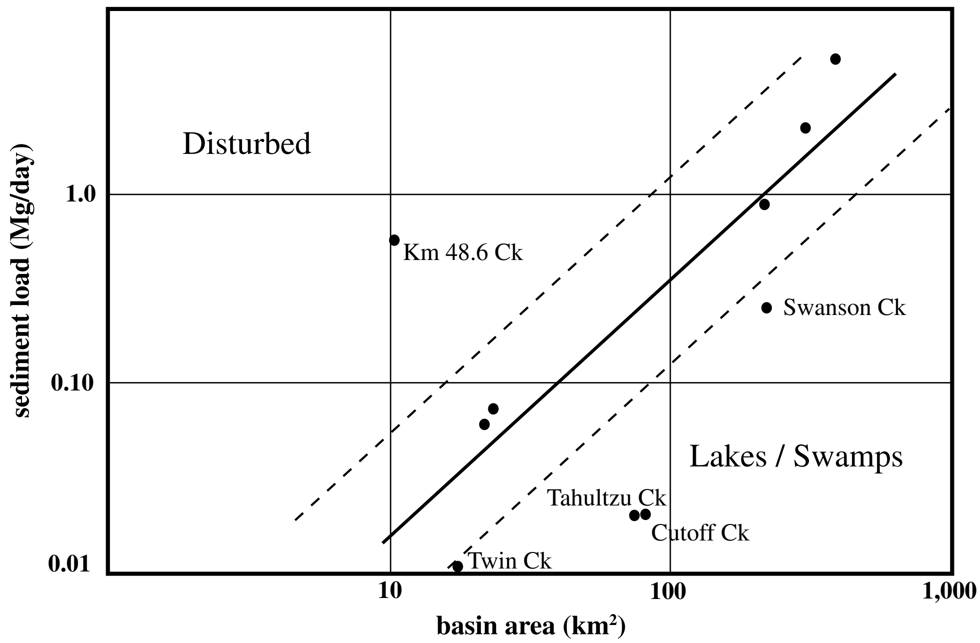
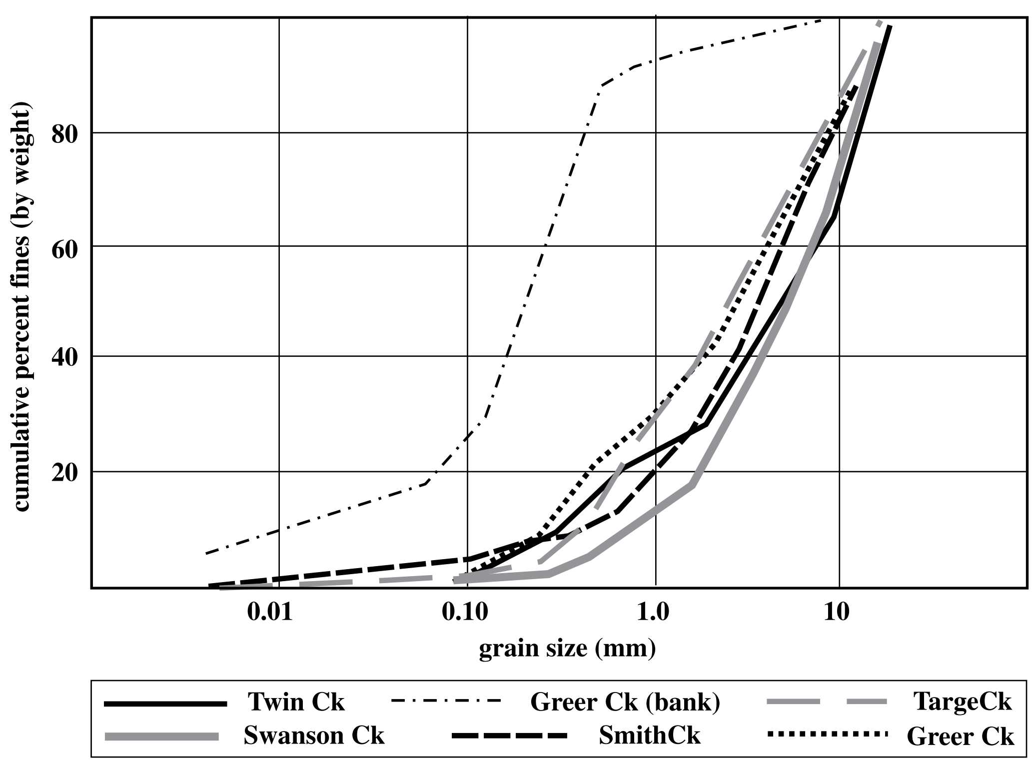


Figure 8.5-5 Nechako River: grain size distributions of sub-16 mm sediments in the bed of tributaries to the upper river



- valley wall erosion along the left bank of the Nechako River at the apices of bends between km 29.8 and km 38.7 – approximately 500,000 m^3 over the 33 years or 8,700 m^3/year (Sutek Services Ltd. 1988).

Grain size distributions on eroding banks and valley walls exhibited a broad range of dominant size classes, with the alluvial banks consisting of mostly fine and medium sand and the valley walls in the upper river consisting of mostly very fine sand and silt (**Table 8.5-6** and **Figure 8.5-6**).

8.5.2.6 Ranking Sediment Sources

The results of ranking sediment sources are presented in **Table 8.5-7**. These rankings were based on:

- the relative contribution of the sediment source;
- the position of the sediment source relative to spawning reaches along the upper Nechako River; and,
- (in the case of bank and valley wall failures) the size of the material contributed by wall failure.

Table 8.5-7 **Nechako River: tributaries and bank and valley wall failures in the reach with the major spawning population and rank as major contributors to reaches with moderate spawning populations**

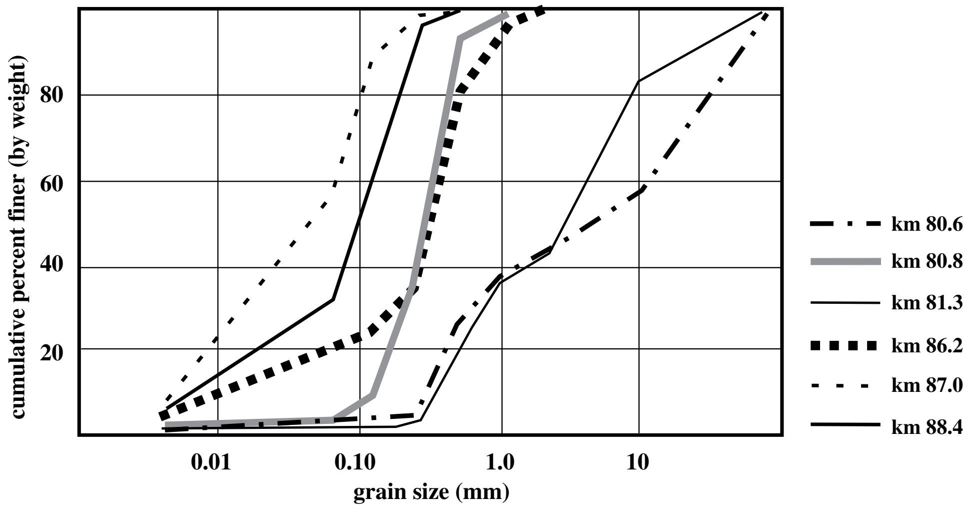
rank of spawning reach	sediment sources	rank of sediment sources	grain size/ comment
tributaries			
1	Twin Creek	4	
1	km 21.2l	5	
1	km 23.6l	5	
2	Swanson Creek	1	
2	Targe Creek	1	bed degradation
2	Welch Creek	3	eroding valley wall
2	Tahultzu Creek	3	
2	Smith Creek	1	
bank and valley wall erosion sites			
1	km 17.5-17.8	3	
2	km 26.6-26.9	2	coarse sand and gravel
2	km 29.8-30.1	1	silt and fine sand
2	km 30.4-30.6	2	coarse sand and gravel
2	km 36.4-37.1	1	silt and fine sand
2	km 37.2-37.5	2	coarse sand and gravel
2	km 38.4-38.6	2	sand
2	km 38.7	2	sand
2	km 78.0-78.3	2	sand
2	km 81.0-81.2	2	sand

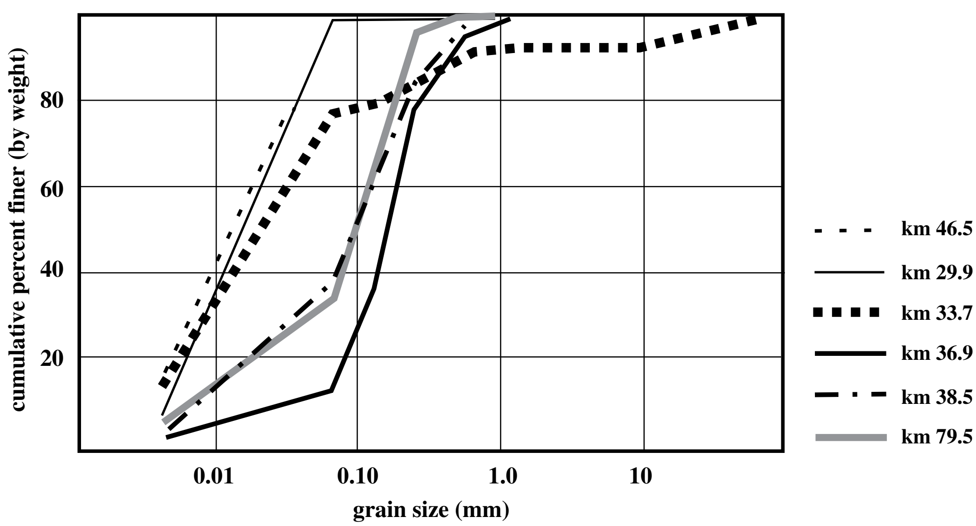
Table 8.5-6 **Nechako River: stratigraphy and grain size of eroding banks and valley walls along the upper river**

site	location (km)	erosion site description	stratigraphy	dominant size fraction*
4A	88.1-88.4	eroding alluvial bank; 2 m high; bend apice	sand above sand and gravel	fine and very fine sand (upper)
7A	86.9-87.1	eroding alluvial bank; 3 m high; bend apice	silty sand & sand above sand and gr.	silt and very fine sand (upper)
8B	86.2	valley wall in s.c.; 15 m high; bend apice	sand, silty sand over silts	medium sand (talus)
11	81.2-81.4	eroding terrace; 5 m high; talus apron	sand and gravel over gravel and sand	granules (upper)
12	80.5-80.7	eroding alluvial bank; 2 m high; very active	sand over sand and gravel	medium sand
15	79.2-79.5	eroding terrace; 8 m high; top 2 m oversteep; talus below	laminated silt and fine sand over silt	fine and very fine sand
28	38.4-38.6	eroding valley wall; 15 m high; steep	sandy silt, medium & coarse sand over silt	silt, very fine and fine sand
30	36.4-37.1	left valley wall; 30 m high; cliff at top; talus	coarse sands over strata of sandy silt	fine and very fine sand (lower unit)
33	33.6-33.8	left valley wall; 30 m high; silts exposed at base	coarse sands over strata of sandy silt over silt	silt (middle unit)
37	29.8-30.1	left valley wall; 25 m high; silts exposed at base	sands and gravels over silty sand over silt	silt (lower unit)

* Dominant size fraction is Wentworth size class with the greatest percentage of the total weight.

Figure 8.5-6 Nechako River: grain size distribution of selected bank and valley wall erosion sites, upper river





8.5.3 Discussion: Identifying and Ranking Sources Contributing Sediment to the Upper Nechako River

The main sediment sources for the upper Nechako River are from bank and valley wall erosion along the river and from its tributaries. The largest tributaries (*i.e.,* Greer, Swanson, Smith and Targe Creeks) typically have sediment loads ranging from 100 to 1,000 times as much as small, undisturbed watersheds. Swamps and lakes that make up the tributaries often intercept sediment loads, and it is erosion along the lower reaches of the tributaries that is most likely to affect the Nechako River. Overall, sediment loads measured on the Nechako River are similar to those of other regulated or lake-controlled systems.

Some small watersheds with large, discrete sediment sources may have annual loads comparable to the larger basins. Erosion often occurs along the steep reaches where tributaries flow from the Nechako Plateau into the incised Nechako Valley. Failures and erosion of glacio-lacustrine or glacio-fluvial sediments elevates sediment loads in these reaches. However, as most sediment results from individual failures, there may be an opportunity to control sediment supply in these small watersheds.

Active erosion occurs at approximately 38 sites along the upper Nechako River; however, the majority of the annual supply is contributed by only a few sites. Erosion rates vary but the failures from km 29.8 to km 38.7 are the most important sources of fine sand and silt in the upper river while tributaries and bank and valley wall erosion sites that contribute sediments directly to reaches hosting major and moderate spawning populations have potentially the greatest effect on fish habitat in the river.

8.5.4 Summary: Identifying and Ranking Sources Contributing Sediment to the Upper Nechako River

Bank and valley wall erosion along the mainstem of the river and the river's tributaries were the main contributors of sediments to the Nechako River: tributaries contributed roughly the same annual volume of sediment as bank and valley wall erosion over the last 30 years. The largest tributaries, such as Greer, Swanson, Smith and Targe Creeks, typically had sediment loads ranging from 100 to 1,000 times as much as small, undisturbed watersheds.

Active erosion occurred at approximately 38 sites along the upper river, but only a few sites contributed most of the annual supply. Erosion rates varied but the failures from km 29.8 to km 38.7 were the most important sources of fine sand and silt.

The measured Nechako River sediment loads were similar to those of other regulated or lake-controlled systems.

8.6 FLOW MANAGEMENT PROJECT

The *1987 Settlement Agreement* established the NFCP Technical Committee's responsibility in reaching decisions on the release of the Annual Water Allocation (AWA) from the Nechako Reservoir. The AWA is a mean annual release of 36.8 m^3/s at Skins Lake Spillway.

> *2.1A (c) i – The Technical Committee will manage the Short Term Annual Water Allocation with the object of achieving the flows set out in Column II of Schedule "C" to this Agreement or as the Technical Committee may otherwise determine in accordance with this Agreement, and shall direct Alcan accordingly…*

and again at 3.3(e) i of the *Agreement*:

> *…The Technical Committee, among other things, will:*
> i - *determine any matter specified in this Agreement to be for decision or determination by the Technical Committee including, without limitation, managing releases of the Annual Water Allocation in the applicable Annual Water Year.*

The committee has given Alcan directions concerning the release of the AWA each year. To date, the default clause (2.1A(c) ii) included in the *1987 Settlement Agreement* has not been used. According to that clause:

> *Alcan will release the Short-Term Annual Water Allocation in accordance with such directions, or failing such directions, in accordance with Column I of Schedule "C" to this Agreement.*

The objective of the AWA is to allocate water flows to provide the greatest benefit for Nechako River chinook. This is defined as a mean annual flow of 41.7 m^3/s in the Nechako River below Cheslatta Falls measured near Bert Irvine's Lodge (km 19) at the Water Survey of Canada's (WSC) Data Collection Platform Station 08JA017.

To achieve its flow objective, the AWA takes into account natural inflows and tries to replicate the natural hydrograph of the river[76]. Any flows in excess of the AWA are used to:

- redistribute water evenly throughout the September to March spawning and overwinter period;
- decrease the temperature of releases during the summer months;
- steadily increase the hydrograph during April to June; and
- smooth the transition from the higher discharge summer cooling flows to spawning flows in September.

8.6.1 Decision Protocol

Early in its deliberations, the Technical Committee established a seven-point procedure for making flow management decisions (NFCP 1988b).

1. Develop a clearly rationalized objective for the shape of the hydrograph below Cheslatta Falls at hydrometric Station 08JA017, consistent with the intent of the *1987 Settlement Agreement.*
2. Estimate the expected Murray/Cheslatta inflow hydrograph each year in January-March and obtain a projection of any potential forced spills from Alcan.
3. Establish a tentative protocol for release of the AWA in late March.
4. Monitor the actual hydrograph at Station 08JA017 and compare it to the objective in (1) above.
5. Revise the Skins Lake release protocol only if, in the opinion of the Technical Committee, the actual flows below Cheslatta Falls would jeopardize the objectives in (1) above.
6. Instruct Alcan at least monthly about the required Skins Lake releases.
7. Prepare yearly summaries of the hydrographs from Skins Lake Spillway, hydrometric Station 08JA017, and the estimated Murray/Cheslatta inflow, along with rationale behind all flow management decisions.

Early in the committee's deliberations, Alcan representatives expressed concern that the timing of the runoff in the Murray/Cheslatta basin could be very different from the assumed timing found in Schedule "C" of the Agreement. If the schedule's timing was adopted in month-to-month decision-making, then the actual flows below Cheslatta Falls could differ substantially from the flows suggested by the schedule.

Consequently, the committee decided to follow the procedure for AWA releases set out in Decision Record (NFCP 1988b) through 1988 while embarking on a study of the run-off timing and volume for the Murray-Cheslatta basin for use in future AWA decisions by the committee. [See *ss.8.3 Cheslatta and Murray Lakes Inflow Investigations*]

By early 1989, the anticipated number of decisions required by the AWA and the limited difference in flows that would be experienced downstream of Cheslatta Falls in spite of the monthly flow changes suggested in Schedule "C" led the committee to decide that a constant release throughout the spring months (April, May and June) would be more practical. The natural variation in flows from the Murray/Cheslatta drainage would provide some variance in flows below Cheslatta Falls, which was seen as being potentially beneficial for juvenile chinook. A similar rationale was used to set the fall/winter release from the Skins Lake Spillway.

[76] The Comptroller of Water Rights for B.C. may limit the rate of flow in the Nechako River during June to minimize downstream flooding in the Fraser River.

The one additional amendment to the AWA decision-making procedure was the decision to wait until a significant open lead developed in the ice adjacent to the shores on Murray and Cheslatta Lakes before initiating the spring increase in releases. This amendment was adopted to allow fur-bearing mammals that den in winter just above lake level to escape to higher ground when the releases were increased. This policy has been followed since the spring of 1989.

Mean annual Skins Lake Spillway releases and mean annual flows in the Nechako River below Cheslatta Falls are calculated from mean daily flows recorded by the WSC. A comparison of the annual reservoir release specified in the *1987 Settlement Agreement*, and the annual reservoir release recorded by the WSC for the period April 1 to March 31 at the Skins Lake Spillway is used to determine if the AWA has been achieved for each year. The Skins Lake Spillway release is based on Alcan's operational release which is defined as the WSC-recorded spillway release less forced spills (releases in excess of normal releases) and additional cooling water releases as required for the Summer Temperature Management Program. [See *ss.3.1 Summer Temperature Management Program*]

In addition, the Technical Committee interacted with Alcan and the Comptroller of Water Rights in regard to forced spills from the Nechako Reservoir. The Technical Committee provided recommendations for timing and magnitude of forced spills to best manage risk to Nechako River chinook.

8.6.2 Results and Discussion: Flow Management Project

The mean Skins Lake Spillway discharges are shown in **Figure 8.6-1**. The annual water allocation released from Skins Lake Spillway every year was calculated by adjusting the recorded release on the following basis (**Table 8.6-1**):

Figure 8.6-1 **Skins Lake Spillway: mean daily discharges, 1988 to 1998**

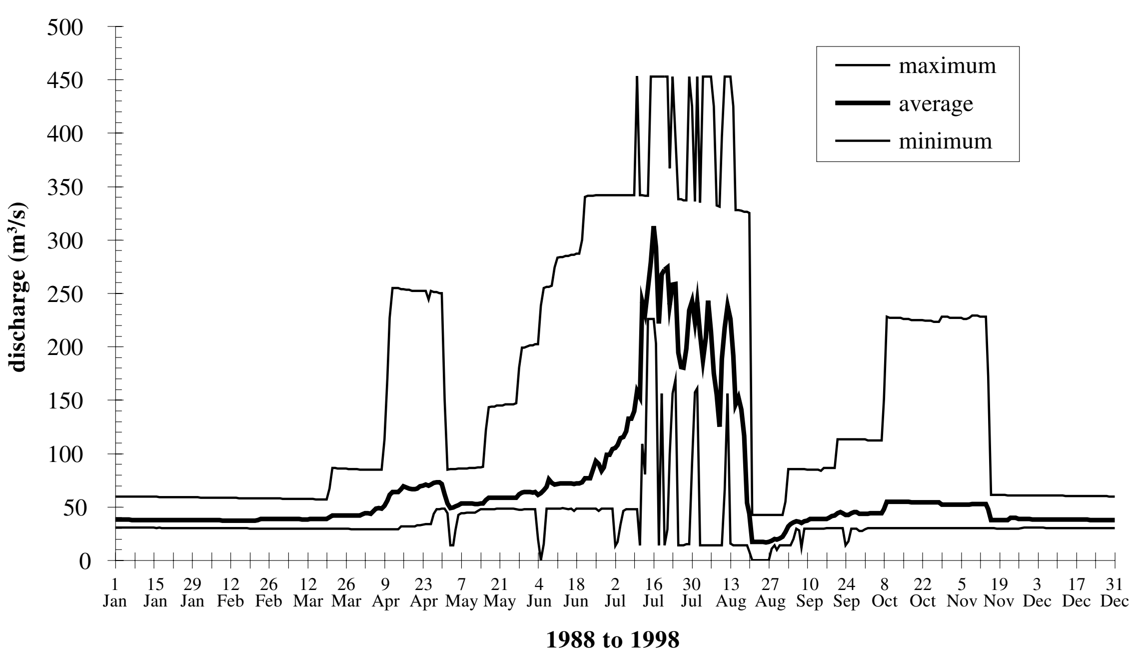


Table 8.6-1

Skins Lake Spillway: summary of recorded Water Surveys of Canada and adjusted mean annual releases and Nechako River flows below Cheslatta Falls

NFCP water year (April to March)	recorded SLS release (wsc) (m^3/s)	difference between recorded SLS release and 36.8 m_/s (m^3/s)	adjusted* SLS release (m^3/s)	difference between adjusted* sls release and recorded (m^3/s)	difference between adjusted* SLS release and 36.8 m_/s (m^3/s)	SLS short term annual water allocation (m^3/s)	recorded Cheslatta Falls (WSC) (m^3/s)	adjusted** Cheslatta Falls release (m^3/s)	Cheslatta short term annual water allocation (m^3/s)	difference between adjusted** Cheslatta Falls and 41.7 m^3/s (m^3/s)	difference between recorded Cheslatta Falls and 41.7 m^3/s (m^3/s)
1988/89	50.2	13.4	37.4	12.9	0.6	36.8	52.6	39.7	41.7	-2.0	10.9
1989/90	55.3	18.5	38.0	17.3	1.2	36.8	55.8	38.5	41.7	-3.2	14.1
1990/91	70.2	33.4	37.7	32.5	0.9	36.8	69.8	37.3	41.7	-4.4	28.1
1991/92	58.0	21.2	37.6	20.3	0.8	36.8	61.8	41.5	41.7	-0.2	20.1
1992/93	64.3	27.5	37.0	27.3	0.2	36.8	66.5	39.2	41.7	-2.5	24.8
1993/94	50.1	13.3	37.3	12.8	0.5	36.8	58.5	45.7	41.7	4.0	16.8
1994/95	57.2	20.4	39.3	17.9	2.5	36.8	59.6	41.7	41.7	-0.0	17.9
1995/96	54.2	17.4	38.1	16.0	1.3	36.8	55.1	39.1	41.7	-2.6	13.4
1996/97	94.7	57.9	37.6	57.1	0.8	36.8	100.0	42.9	41.7	1.2	58.3
1997/98	123.5	86.7	36.9	86.6	0.1	36.8	134.9	48.3	41.7	6.6	93.2
1998/99	59.5	22.7	37.4	22.1	0.6	36.8	62.6	40.5	41.7	-1.2	20.9
1999/00	51.4					36.8					
average	67.0	30.2	37.7	29.4	0.9	36.8	70.7	41.3	41.7	-0.4	29.0

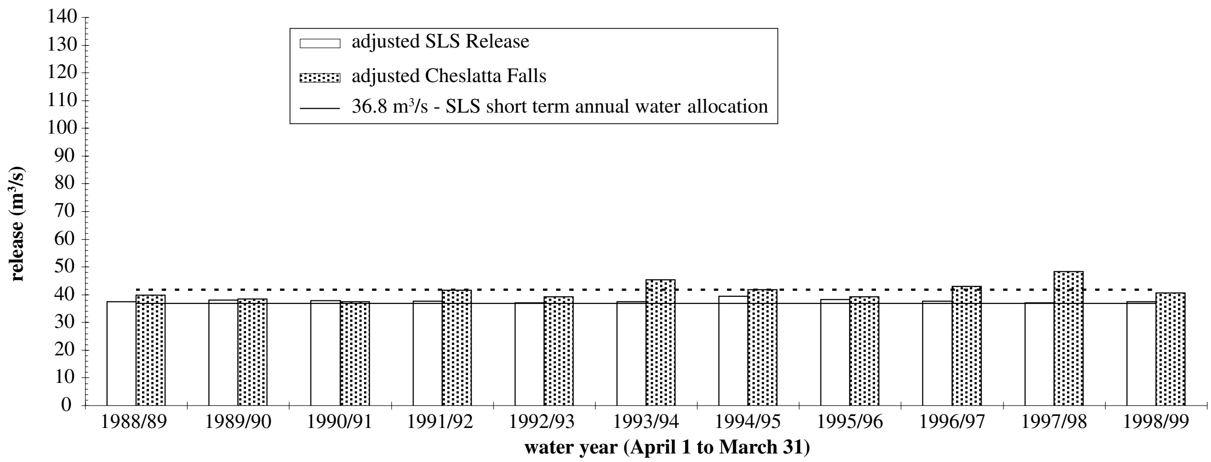
* Adjusted SLS releases are recorded SLS (WSC) releases less summer cooling water releases and forced spills

** Adjusted Cheslatta Falls flows are recorded Cheslatta flows (WSC) less the difference between the adjusted* SLS release and recorded.

- from April 1 to August 17, all flows above 49.0 m^3/s that are associated with forced spills, or cooling water flows were subtracted, and
- from August 18 to early September, all flows above 14.2 m^3/s associated with forced spills were subtracted.

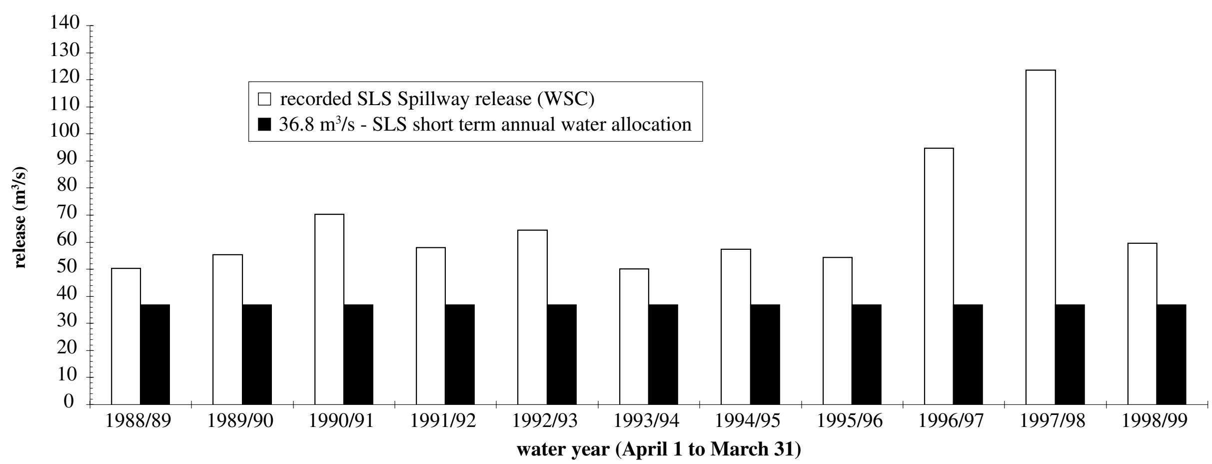
Based on these calculations, the average AWA from the Skins Lake Spillway for the years 1988 to 1999 ranged from 36.9 m^3/s to 38.1 m^3/s with an average of 37.7 m^3/s. In every year the release was above the AWA minimum requirement of 36.8 m^3/s (**Figure 8.6-2**). **Figures 8.6-3** and **8.6-4** describe the Skins Lake Spillway releases vs. the flows recorded in the Nechako River below Cheslatta Falls, and the flows recorded vs. adjusted flows for the Nechako below Cheslatta Falls, respectively.

Figure 8.6-2 **Skins Lake Spillway: adjusted* releases vs. adjusted** mean annual flows below Cheslatta Falls (Water Surveys of Canada) April to March, 1988/89 to 1998/99**



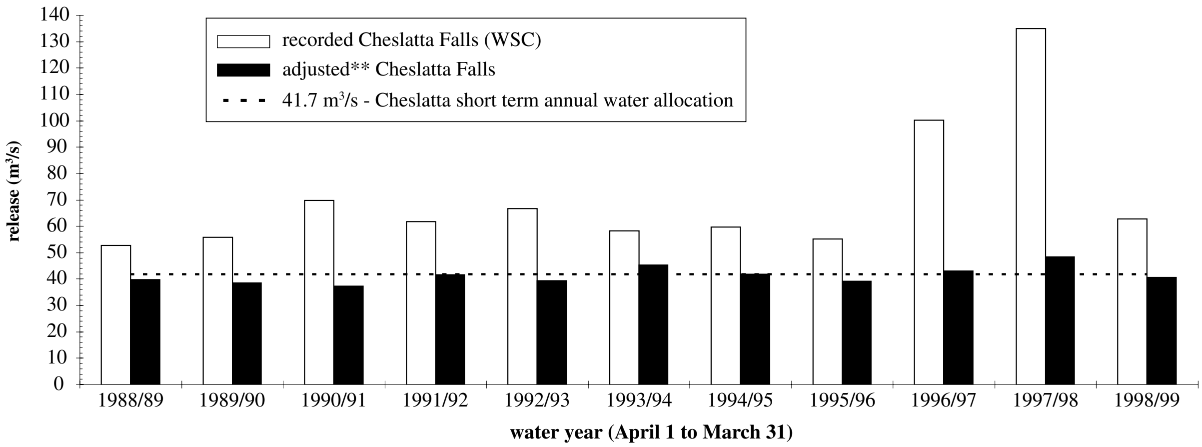
*adjusted SLS releases are recorded SLS releases (WSC) less summer cooling water releases and forced spills.
** adjusted Cheslatta Falls flows are recorded Cheslatta flows (WSC) less the difference between the adjusted* SLS release and recorded.

Figure 8.6-3 **Skins Lake Spillway: release recorded mean annual flows, April to March, 1988/89 to 1998/99**



Source: Water Survey Canada

Figure 8.6-4 **Nechako River: recorded vs. adjusted mean annual flows below Cheslatta Falls, April to March, 1988/89 to 1998/99**



** adjusted Cheslatta Falls flows are recorded Cheslatta Flows (WSC) less the difference between the adjusted SLS Release and recorded. The adjusted SLS releases are recorded SLS releases (WSC) less summer cooling water releases and forced spills.

Source: Water Survey Canada

An operational release in excess of the specified 36.8 m^3/s is due to the nature of the spillway gate-setting schedule in response to changing reservoir elevations, especially during winter months. Spillway gate settings are established by Alcan in response to release recommendations made by Triton Environmental Ltd. under the auspices of the Technical Committee, and are based on the reservoir elevation at the time the gate is set.

During ice-free conditions, spillway settings are periodically reviewed (usually weekly) and adjusted to ensure requested releases are achieved. Until recently, Alcan generally set the gates once in the fall for the entire winter. The winter release was typically set above the requested release in anticipation of a decreasing reservoir elevation due to low winter inflows. This approach usually resulted in differences between the operational releases and the AWA specified in the *1987 Settlement Agreement*.

However, due to below normal reservoir inflows in the winters of 1998 and 1999, Alcan requested and received approval from the committee to manage the winter releases in a manner that would ensure that average winter releases met the specified releases. This procedure has been adopted as a standard and operated well during the winters of 1998/99 and 1999/2000.

The objective of releasing a mean annual flow of 36.8 m^3/s from the Skins Lake Spillway is to achieve a mean annual flow of 41.7 m^3/s at WSC Station 08JA017 (km 19). To assess whether this objective is being met, the flows measured at the station were adjusted with the same subtractions for cooling water flows and forced spills as were applied to the Skins Lake releases. Based on these adjustments, the flow at Station 08JA017 ranged from 37.3 m^3/s (1991) to 48.3 m^3/s and averaged 41.3 m^3/s (**Table 8.6-1**, **Figure 8.6-2**).

The reason the minimum annual average flow of 37.3 m^3/s was below the Skins Lake Spillway release for the same year is because the forced spill that occurred in 1991 bracketed the start of that water year (April). The lag time in flow between Skins Lake and the WSC station resulted in the release just before the beginning of April being counted in the Skins Lake Spillway flow but not the WSC flow. This does not affect the average of the values since the difference is included in the subsequent year.

As noted above, the mean annual adjusted flow in the Nechako River below Cheslatta Falls is 41.3 m^3/s. The reason the objective of achieving 41.7 m^3/s at the WSC station has not been reached on an average basis is likely due to the inflows downstream of Skins Lake Spillway being less than estimated at the time of the Agreement. Based on the Station 08JA017 rating curve, the difference in water depth would be about 4 mm for a change in flow of 0.5 m^3/s when the river flow is in the order of 40 m^3/s.

8.6.3 Summary: Flow Management Project

The protocol for flow releases from the Skins Lake Spillway between the Technical Committee and Alcan has worked well. The AWA released through the spillway has exceeded 36.8 m^3/s every year, and though the average flow of 41.7 m^3/s at Station 08JA017 at km 19 has not been achieved, the consequence for water depth is not significant.

8.7 RIVERBED SURVEY

The Kemano Completion Project would have reduced discharges and associated water levels in the Nechako River. The flow changes would have been greatest in the upper Nechako River between Cheslatta Falls (km 9) and the confluence with the Nautley River at Fort Fraser (km 95).

In order to assess the pre- and post-Kemano Completion Project conditions of the river, the Technical Committee recommended that the water surface profile of the upper river be numerically modeled. The results of the modelling could then be used as a planning tool to formulate appropriate mitigation and/or compensation strategies to protect the fisheries resource.

8.7.1 Method: HEC-2 Modelling

In March 1990, Hay and Company Consultants Inc. (Hayco) planned the survey requirements for water surface profile modelling of the Nechako River between Cheslatta Falls and the Nautley River confluence. W.D. McIntosh, B.C. Land Surveyor, Vanderhoof, initially surveyed the river during the summer of 1990 in association with McElhanney Engineering Services Ltd. of Prince George. Final surveys were completed in March 1991.

Results of the surveys were used by Hayco to set up and calibrate a model of the river. Following calibration, a channel roughness sensitivity test was conducted to assess the sensitivity of the model to variations in roughness. The model results were then forwarded to the Technical Committee for future use.

The model used in this application was HEC-2, a water surface profile prediction model developed by the US Army Corps of Engineers (1990) and released by the Hydrologic Engineering Centre (HEC).

8.7.1.1 HEC-2 Model Description and Input Data

HEC-2 modelling of the Nechako River progressed from downstream to upstream, extending from the Nautley River confluence to Cheslatta Falls, a distance of approximately 91 kms. The modelling study incorporated over 300 cross sections of the river, each selected to depict distinct changes in slope, cross-sectional area and channel roughness. Sections were located upstream and downstream of principal tributaries in accordance with standard practices for HEC-2 modelling (US Army Corps of Engineers 1990). Cross sections were also included at locations with actively eroding banks as identified in an independent report prepared for the Technical Committee (Rood 1998). The average distance between cross sections was approximately 317 m.

Cross sections were located using 1:7,500 scale airphoto mosaics (NFCP 1988a). These mosaics were developed from airphotos taken from May 31 to June 1, 1978, at which time the river flow was approximately 56.6 m^3/s. Personnel from Hayco, Triton, and K. Rood and Associates conducted a reconnaissance survey on June 4/5, 1990, to verify the location of cross sections selected from the airphoto mosaics. A few minor adjustments were made to some of the cross sections and some additional sections were added.

The discharge in the Nechako River recorded at Water Survey of Canada's (WSC) Data Collection Platform Station 08JA017 (km 19) varied from (approximately) 52 to 63 m^3/s during the survey period.

8.7.1.1.1 River Survey: Overview

McIntosh (1991) documented river survey procedures and detailed survey results[77]. Cross sections were generally surveyed to a point on the bank a minimum of 1.2 m above the water level in the river at the time of the survey. At locations with actively eroding banks, cross sections were extended to the tops of the banks.

Documentation at each cross section included:

- the location of the edge of the water;
- the instrument station;
- control points; and
- basic profile data.

In addition, site photos imprinted with section number codes were taken at each section with views looking upstream, downstream and at the left and right banks.

Following the cross section survey, the water surface profile of the river was surveyed on July 9/10, 1990. Temporary staff gauges located near the riverbank on the main channel at each cross section were read from a boat starting at Cheslatta Falls and proceeding downstream. The relatively short period of this survey minimized the potential effects of changing flows during the measurement period. The resulting profile was used to calibrate the model.

8.7.1.1.2 Hydrology

A hydrologic analysis established the flow distribution in the Nechako River study area corresponding to the July 9/10, 1990, water surface profile measurement period. **Table 8.7-1** presents the WSC station locations and data used in the analysis[78].

Table 8.7-1 **Nechako River hydrology: stream guage analysis**

station number	description	discharge (m^3/s) July 9 1990	discharge (m^3/s) July 10 1990
08JA017	Nechako River below Cheslatta Falls	56.7	56.0
08JB003	Nautley River near Fort Fraser	53.8	53.3
08JC001	Nechako River at Vanderhoof	141	141

[77] Cross section locations and survey reference control points are shown on copies of the 1:7,500 scale airphoto mosaics presented in the MacIntosh report.

[78] Due to problems with the Vanderhoof station during the river surveys period, flows at Vanderhoof were estimated and are therefore less reliable than data from both the Nechako River below Cheslatta Falls and the Nautley River stations.

After subtracting the Nautley River inflow and ignoring routing effects, total local inflow between the Nechako River stations below Cheslatta Falls and at Vanderhoof was determined to be 30.5 and 31.7 m^3/s for July 9 and July 10, respectively. Apportioning this inflow according to drainage area suggests local inflows between the Cheslatta and Nautley River gauges of 19.8 m^3/s and 20.6 m^3/s, respectively. This result (*i.e.,* higher flow on July 10) contradicted both the records for these stations and local rainfall data, which indicated that local creeks should be in recession during this period.

An average inflow of 20.2 m^3/s was assumed during the water surface profile measurement (**Table 8.7-2**). This inflow was subsequently apportioned, according to the tributary catchment area, as follows:

Table 8.7-2 **Cutoff, Swanson, Targe, Greer, Tahultzu and Smith Creeks: estimated in-flow**

location	inflow (m^3/s)
Cutoff Creek	1.70
Swanson Creek	3.29
Targe Creek	4.63
Greer Creek	5.74
Tahultzu Creek	1.69
Smith Creek	3.16
Total	20.20

These inflows were added in succession to the average discharge below Cheslatta Falls on July 9/10, 1990 (56.4 m^3/s) to give the cumulative Nechako River discharge downstream of each tributary during the calibration period.

8.7.1.1.3 Input Data

The stations at the channel banks (bank stations) were selected after examining the plotted cross sections, airphoto mosaics and site photos. In general, the stations were selected to match survey points that were just slightly above river-level at the time of the survey. These points usually corresponded to a well-defined demarcation line between the vegetated and non-vegetated portions of the river cross-section.

Strictly regulating the river in recent years has resulted in prolonged periods of stable flows that have encouraged grasses and low shrubs to cover former river bars and banks. Since bank stations are used in the model to differentiate between channel flow and overbank flow with different flow resistance characteristics, the limit of vegetation was a natural choice for this division. Overbank channel resistance was not properly modelled in the subsequent model calibration. [See *ss.8.7.1.3.3 High Flows*]

Several of the model sections were developed from separate cross sections taken on the channels around islands. These separate sections were combined and treated as single cross sections with a common water surface. In these and other cross sections involving islands, the main channel flow was separated from the side channel flow by choosing the bank stations to be on the main channel. In such cases, overbank flow is, in effect, flow in the side channels.

Initially the model was to be used to look at the Kemano Completion Project base flows which would be lower than the calibration flow. Consequently there was no need to differentiate between channel and overbank roughness as overbank flows would not occur. This approach allowed flows in the individual channels to be treated separately, rather than as a single combined flow for the entire cross section.

Procedures are available for correctly modelling the channel roughness variations at the island sections and these can be adopted when modelling flows are higher than the calibration discharge. Except for these multiple channel sections, realistic overbank roughness coefficients for the single channel sections can be easily entered into the model when required. This was not done initially due to both a lack of calibration data at higher discharges, and in order to expedite delivery of the model to the Technical Committee.

The lengths of the channel and overbank reaches used in the model were derived from the 1:7500 airphoto mosaic map (NFCP 1988a). Channel reach lengths correspond approximately with the thalweg marked on the maps obtained from the river survey (McIntosh 1991).

In addition to the basic modelling described above, some cross sections required special modelling techniques. For example, sections through some side channels have wetted flow areas that are not effective at low flows as there is no upstream connection to the main channel. These areas were prevented from being used until water levels exceeded the controlling elevations in the upper reaches of the channels.

8.7.1.2 Model Calibration

The model was calibrated by adjusting coefficients so that predicted water levels from the model matched, as closely as possible, the known water surface measured on July 9/10, 1990.

Several adjustments and refinements were required to achieve a satisfactory calibration. For example, while water level deviations were limited to ±0.05 m from the surveyed profile, further measurements had to be taken to maintain flow continuity around islands.

HEC-2 does not accept divided flow data where two or more sections cross an island: each flow split is treated independently and there is no provision for maintaining a constant flow in each channel between sections. Only an iterative process using separate HEC-2 models for each channel can analyze this situation correctly. Consequently, flow splits were assumed and the backwater analysis repeated until a common water level was achieved at the upstream end[79]. To simplify the analysis, a reasonable estimate was made for the flow split; side channel roughness was artificially varied to maintain a reasonably consistent flow split between sections.

A total of 11 islands involving two or more cross sections were modelled. Not all of the side channels associated with these islands were actively flowing at the calibration discharge.

The adopted flow split at Diamond Island (km 81) and at the large island in the vicinity of cross section 46 was approximately 60:40 (left and right channels). This split gave realistic velocities in the main channel when compared to channel velocities at sections immediately upstream and downstream of the islands.

8.7.1.3 Model Limitations

8.7.1.3.1 Flow Split Approximation at Islands

One of the principal limitations of the model is the need to approximate flow split around islands. Flows around islands should be reasonably correct in the main channel, but flows in side channels with artificially imposed roughness coefficients should be viewed with caution. Additional field data — including water levels and flow metering of individual channels — are required to properly calibrate the model in these areas.

8.7.1.3.2 Low Flows

The present model should adequately represent conditions in the river for flows comparable to the calibration discharge (keeping in mind the caution expressed in the previous section).

[79] This process would have to be repeated for each change in discharge.

However, the model was not tested at lower flows. These flows might indicate the need for further refinements to the model, particularly for conditions at the interpolated sections that were artificially introduced to duplicate the measured water surface elevations at adjacent surveyed cross sections[80]. These sections did not represent true riverbed elevations.

Irrespective of the interpolated sections, the model output will likely exhibit even more warnings at lower flows as more bed controls become effective. The opposite should be true at higher flows. If certain reaches of the river appear particularly important from a fisheries management perspective, then additional cross sections could be added for improved accuracy in these areas.

8.7.1.3.3 High Flows

The model was calibrated only for relatively low flows near the calibration discharge of 56.4 m^3/s, with overbank and channel roughness coefficients that—with the exception of flow split adjustments around islands—were the same at each cross section. To accurately model overbank flow, overbank coefficients should be estimated and entered for the single channel cross sections.

In spite of the fact that the overbank areas were not correctly modeled, the method used should provide reasonable results to perhaps two or three times the calibration flow. This assessment is based on a number of factors.

- The roughness coefficient is not a fixed parameter but varies with river stage (Chow 1959).
- The roughness coefficient for a river channel is usually smallest near the bank-full stage and tends to increase for both higher and lower stages. At higher stages the increased roughness due to vegetation in the overbank areas is offset by decreased roughness in the main channel such that the net effect can range between an increase or decrease in overall roughness for the cross section. Cross sections in well-incised river reaches would not involve significant overbank flow and consequently there should be little change in the overall channel roughness. The model's results in this case should be reasonably accurate for all higher flows.
- The cross sections involving large overbank areas should exhibit a net increase in overall channel roughness at higher stages and predicted water levels should be low.

Overall, the accuracy of the present model at higher flows will depend on the characteristics of the particular river reach.

8.7.2 Results

8.7.2.1 Calibrated Model

The detailed output for each cross section included warning messages and comments with respect to divided flow, conveyance change, critical depth assumptions, and changes to contraction and expansion loss coefficients between sections.

The maximum difference between the computed and known water levels was only 0.05 m as per the adopted calibration tolerance. In practice, it would not be practical to improve on this tolerance as in some cases as many as 10 trial runs were necessary to achieve an acceptable match at a single cross section.

The profile showed the first 10 km of the Nechako River above the Nautley confluence[81] to be

[80] At very low flow, only the thalweg was active and this condition could be duplicated at the interpolated sections without an actual survey.

[81] The channel distance reference for this project is at the Nautley River confluence, not the centerline of Kenney Dam as with other projects.

relatively flat. The slope steepens over the next 29 km above cross section 32 (km 10.4), culminating in a control section formed by the rapids near cross section 126.9 (km 38.9) (**Figure 8.7-1**). The slope again flattens for a few kilometers above the rapids before rising toward a second set of controlling rapids near cross section 149.9 (km 45.4). A flatter slope over the next 5 km is followed by minor rapids near cross section 167.9 (km 50.7).

A second major tranquil reach extends for approximately 12 km above cross section 167.9, ending near cross section 203 (km 62.4). The slope steepens over the next 6 km toward a third control section formed by a riffle near cross section 218.9 (km 68.8). This control is relatively minor and could disappear at higher flows. The 15 km reach above cross section 218.9 has the same overall slope as the 6 km reach below the cross section.

Above cross section 260 (km 84.1) there is a marked increase in the overall slope due to a closely spaced pattern of chutes and pools. A fourth control section was modeled at cross section 281.9 (km 89.1) near the head of a set of rapids.

Although there were other major rapids in the upper reach below Cheslatta Falls, these were effectively modelled by varying the roughness coefficient within a realistic range. By definition, each of these other rapids could also be considered to be a control section.

8.7.2.2 Sensitivity Tests

The calibrated model was tested to see how sensitive the results would be to variations in channel roughness. As a general observation, a 20% change in roughness resulted in stage changes of between 0.1 and 0.2 m throughout most of the model. In most cases the model became less sensitive to further increases to channel roughness. The more tranquil sections with low velocities tended to be less sensitive to variations in channel roughness.

8.7.3 Discussion

The model was not calibrated for flows significantly different than the calibration discharge. The model should fairly represent river conditions for flows less than the calibration discharge, subject to the limitations discussed above. As the overall channel roughness effectively increases at lower river stages, consideration should be given to factoring up the roughness coefficient by perhaps 10% to 50% depending on the magnitude of the discharge reduction from the calibrated flow.

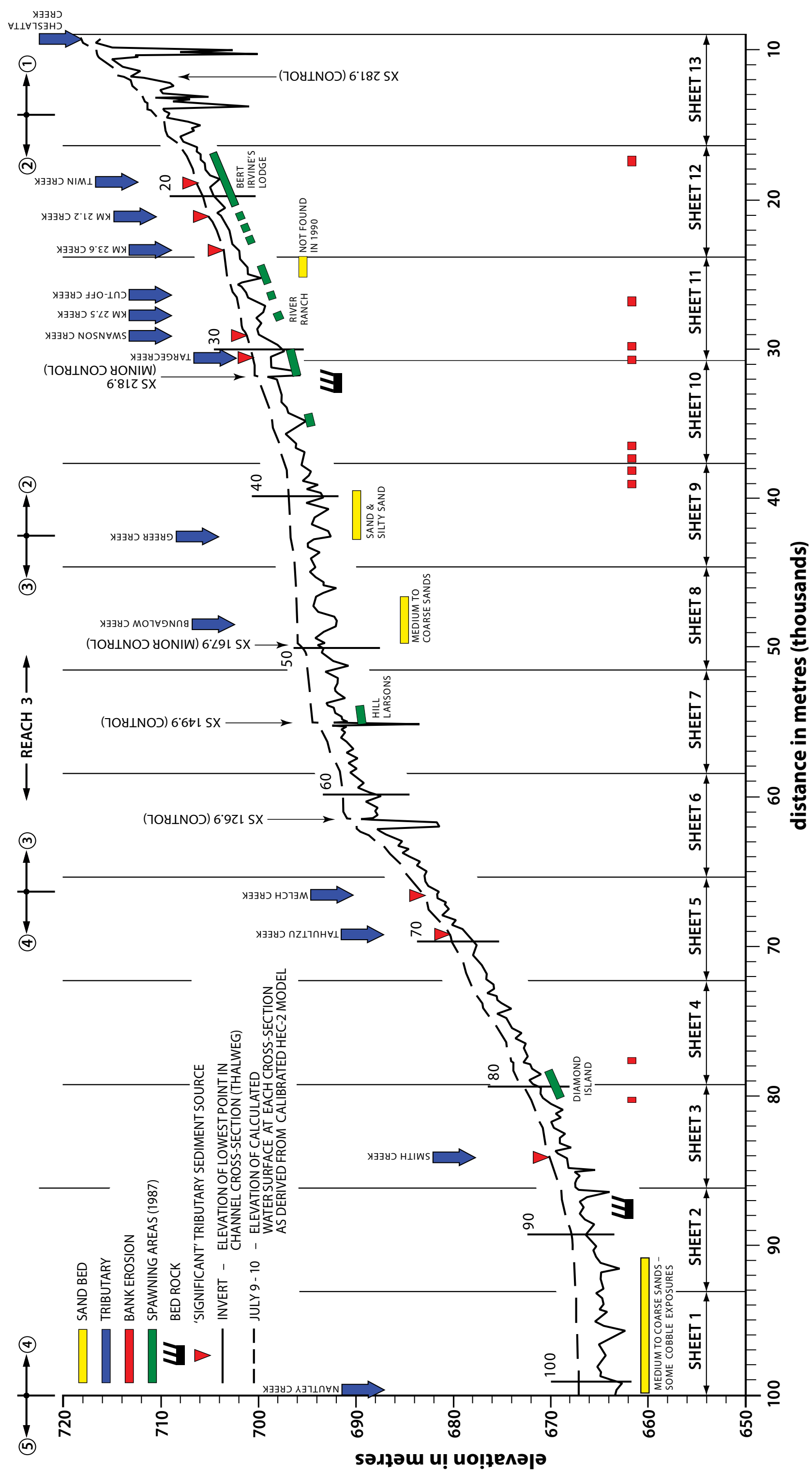
No attempt was made to correctly model overbank flow; the same roughness coefficient value was used across the entire cross section except for flow split adjustments around islands. The existing model will likely provide reasonably accurate results for discharges to perhaps two or three times the calibration discharge. The need for modelling overbank roughness coefficients will depend on the specifics of the particular river reach.

The rating table at WSC Station 08JA017 (km 19) could be used to assess the reliability of the calibrated model at higher and lower flows. Calibration checks against this gauge would also give an indication of the adjustment factors required at lower flows.

8.7.4 Summary: Riverbed Survey

The high incidence of warnings in the model output indicates that, while the model is deemed sufficiently accurate for present purposes, consideration should be given to adding cross sections for improved accuracy in those river reaches which appear particularly important for fisheries management.

Figure 8.7-1 **Nechako River: map of sand beds and major bank erosion areas, 1990**



8.8 NECHAKO RIVER SAND MAPPING PROJECT

The Nechako River Sand Mapping Project involved:

- locating major sand beds upstream of the Nautley River;
- defining the upstream and downstream limits of major sand beds, and marking them on 1:7,500 airphoto mosaic sheets; and
- collecting samples of riverbed material from each major sand bed and characterizing the grain size distribution.

8.8.1 Methods: Literature Review, Ground-truthing and Pipe Dredging

Two reports were used to compile a list of sand beds. In 1987 a geomorphology study of the river using field trips and discussions with local residents (Reid Crowther and Partners Ltd.) found four reaches where sand covered the entire width of the river and extended for more than several hundred meters along the river:

- km 24 to km 25;
- km 40 to km 43 (upstream of Greer Creek);
- km 48 to km 50 (upstream of Roristan Rapids); and
- km 91 to km 101 (upstream of Nautley River).

They also noted and described several other sites where sand did not cover the entire width of the river and did not extend for more than several hundred meters.

In 1989 D.B. Lister and Associates Ltd. measured substrate characteristics along the river as part of a comprehensive habitat inventory (NFCP 1994a). Their sampling sites were typically located along the river margins, in association with cover, because that is where most juvenile chinook rear. Consequently, the measured substrate characteristics may not reflect the materials in the middle of the river channel.

Based on these two reports, sand beds were classified into three groups, major, minor and local.

- **major beds**: thick sand deposits extending across the entire river channel; can be up to several kilometres long; often occur upstream of rapids, large alluvial fans or other features on river gradient.
- **minor beds**: often do not extend across the channel; are usually only several hundred metres long; typically have thin, patchy sand cover organised in dunes, or thin streaks through which the underlying gravel or cobble substrate may be visible.
- **local beds**: occur where sand accumulates in deep pools or the lee of bars and islands; accumulations may be thick, but are usually only a few hundred square meters in area.

These sand beds were marked on 1:7500 scale maps, then visited and verified during two field trips in 1990. Sand beds were only found between Targe Creek and Greer Creek, between Greer Creek and km 57, and from km 86 to the Nautley River[82]. Boundaries of major, minor and local sand beds were transferred from field map sheets to overlays of 1:7500 scale airphoto mosaics.

On June 4/5, 1990 the upper river was surveyed by boat from the Nautley River to Cheslatta Falls. [See *ss. 8.7.1.1 HEC-2 Model Description and Input Data*] The main purpose was to identify locations where additional cross sections were needed to describe sand bed reaches. The trip was also used to verify the location of sand beds originally reported by Reid Crowther and Partners Ltd. (1987) and NFCP (1988a), to identify any other sand beds, and to prepare a preliminary map of the extent of the sand beds.

[82] These reaches are covered by airphoto mosaic sheets 6, 7, 8, 9, 14 and 15, shown in Appendix C of NFCP (1996e).

The channel bed was not all visible from the boat because of cloudy weather and relatively high flows. Consequently, between September 17 and 24 of the same year, all previously identified sand beds were re-visited and any channel reaches not clearly visible in June were re-inspected.

Samples of riverbed material were taken during this second trip. Sand was distinguished from gravel and cobble in three ways. The first and most common method was to examine the riverbed visually. This worked well in shallow water. The second method, probing the substrate, was used mainly in deeper water. However, probing cannot detect thin accumulations of sand that just fill the interstices of cobble substrate.

The third method was to collect samples of the substrate using a pipe dredge, similar to the Canadian Drag Bucket samplers used by the Sediment Survey of Canada[83]. The pipe dredge was 40 cm high and 16 cm in diameter. It had a cutting edge on the front end and screened drainage holes on the rear end. It was lowered to the river bottom and dragged until it was full of sediment. The maximum sample volume was approximately 6 kg, which was in excess of the volume required for accurate analysis (Church *et al.* 1987). The volume was sub-sampled and approximately 1 to 2 kgs were bagged for laboratory analysis. A total of 69 samples were collected.

The Water Survey of Canada (WSC) recommends collecting five replicate samples at each vertical station to overcome among-sample variation and reduce the error in the estimates of average grain size to less than 10% (Ashmore *et al.* 1988). More than five samples may be required in silty areas, but only one sample is required in well-sorted medium and coarse sands. Since the latter type of sands are common on the Nechako River, and the objective of the survey was to describe variation between and among major sand beds rather than precisely define grain size distribution, only one sample was taken at each station.

Bed material samples were analysed by Pacific Soil Analysis Inc. Samples were dried, weighed and then shaken through a stack of eight sieves (75, 9.5, 2.0, 1.0, 0.5, 0.25, 0.125 and 0.063 mm mesh width). The last six sieves correspond to the Wentworth grade scale (Lane 1974). The weight retained on each sieve was measured and expressed as a percent of the total sample weight. No further analysis was carried out on the silt and clay portions of the samples because they formed less than 1% of the total sample weight. Grain size distributions (*i.e.,* plots of the cumulative percent of sample weight on grain size, expressed on a logarithmic scale from 0.01 to 10 mm), were prepared for each sample station (NFCP 1998e).

8.8.2 Results and Discussion

Major sand bed reaches were found to cover a total of 17.1 km (19%) of the upper Nechako River (**Figure 8.7-1**):

- **km 39.5 to km 42.8, upstream of Greer Creek**: mixed sand and silty sand, patchy, with some gravel exposures in the bottom of pools;
- **kms 46.6 to km 50.2, upstream of Roristan Rapids**[84]: medium and coarse sands; and
- **kms 90.8 to km 101, upstream of the Nautley River**: medium and coarse sands, with some gravel exposures.

[83] Ashmore *et al.* (1988) point out that drag bucket-style samplers may not adequately describe the grain size distribution in silty sands because they do not retain the fine portion of the sample.

[84] It was difficult to locate with precision the upstream end of the sand bed as it gradually tapered to a gravel bar over a distance of one kilometre.

The sand bed between km 24 and km 25 reported by Reid Crowther and Partners Ltd. (1987) was not found in 1990, despite searching for it in both June and September. The apparent disappearance of the sand bed suggests that sand is mobile in much of the Nechako River under the present flow regime, and that sand beds may appear or disappear seasonally or from year to year.

Minor sand beds were found mainly near the major sand bed reaches. Some minor beds may be seasonal accumulations downstream of eroding banks, particularly between km 36 and km 40. Sand was visible at those sites during September, but not in June.

Minor accumulations at km 31.8, downstream of Targe Creek, and km 87.3 were found in deep pools at bedrock-controlled bends. The beds are limited to areas of low water velocity and contained small volumes of sand. Those accumulations may be seasonal in nature.

Table 8.8-1 summarises the results of the grain size measurements. The median grain size was similar to the D50 measurement commonly used in sediment studies. The dominant fraction is the Wentworth size class that contained the largest percentage of the total sample weight. The material deposited in the major sand beds consisted mainly of medium and coarse sand, and fine gravels (granules or pebbles).

Within each reach there was a trend of decreasing grain size with distance downstream. Typically, fine gravels were the dominant class near the upstream end, while medium sands were the dominant class near the downstream end. There was also a decrease in the variation of the average grain size with distance downstream: the upstream ends had poorly sorted material whereas the downstream ends had well-sorted material.

Table 8.8-1 **Nechako River: median grain size and dominant size fraction of bed material from the upper river, September 1990**

transect	location (km)	median grain size (mm)	dominant fraction
major sand bed reaches			
7	98.5	0.43	medium sand
13	96.3	0.42	coarse sand
24	93.4	3.60	fine gravel
29	91.7	0.48	coarse sand
168	50.2	0.42	medium sand
171	49.0	0.38	coarse sand
175	48.0	0.81	coarse sand
177	47.0	0.90	fine gravel/medium sand
193	42.1	0.52	coarse sand
194	41.5	0.49	medium sand
196	40.7	0.44	fine gravel
199	39.8	4.60	fine gravel
minor and local accumulations			
41	87.2	1.50	fine gravel/coarse sand
151	55.3	0.36	medium sand
153	54.9	0.37	medium sand
158	53.5	0.11	very fine sand
184	45.0	2.30	fine gravel/coarse sand
220	31.8	0.21	fine sand

The single exception to those trends was the major sand bed upstream of Greer Creek. Bed material in that reach varied greatly across each transect, ranging from fine sands along the left bank to fine gravels in other portions. Gravel and cobbles were exposed in some locations.

A wide variety of bed materials were observed in the minor and local sand accumulation zones. Some of the samples were bi-modal, consisting of fine sand mixed with fine gravel. This may have been due to a mixing of surface sand with underlying gravel.

The boundaries between sand beds and gravel deposits are blurred. A sand bed may change from complete cover to alternating patches of sand and gravel to streaks of sand overlying a gravel substrate. Consequently, the extent of major sand banks could not be defined more accurately than ±10 m. Minor and local accumulations were mapped with less accuracy; however, minor and local sand beds appear to be transitory features whose boundaries change seasonally.

8.8.3 Summary: Nechako River Sand Mapping Project

A review of two reports and two field visits defined three types of sand bed in the upper Nechako River. Major deposits were thick and extended across the channel and for several kilometres along the river. These reaches covered 17.1 km of the river and extended from km 38.5 to km 40.2, from km 44.3 to km 50.2, and from km 90.8 to km 101. The sand beds were mainly medium and coarse sand and fine gravels with a broad "downstream-fining" trend. Fine gravels dominated at the upstream ends; medium sands dominated at the downstream ends.

Minor sand beds occurred near or between major sand beds. They often had thin covers of streaky sand overlying gravels, and were generally only several hundred metres long. There was a broad range of grain sizes, and some of the minor deposits may appear and disappear seasonally. A sand bed mentioned in an earlier report was not found in 1990, suggesting that sand is mobile under the present flow regime and may form and disappear seasonally.

Local sand beds occurred in deep pools or the lee of bars and islands. These beds may be thick, but are usually only a few hundred square meters in area.

8.9 LITERATURE REVIEW: WINTER REMEDIAL MEASURES

A reduction in flow during the winter period following the implementation of the Kemano Completion Project had the potential to affect winter rearing values for Nechako River juvenile chinook salmon. This led to a literature review to document what remedial measures had been implemented in other systems and could possibly be applied to the Nechako River if future needs were identified, and to research to better understand winter habitat use.

8.9.1 Methods

A review of primary and grey literature on winter habitat use by salmonids and on winter remedial measures was completed, while specific habitat information was collected for the Nechako River through a multi-year study of juvenile chinook over-wintering in the river (Archipelago Marine Research Ltd. 1990).

8.9.2 Results

In British Columbia, anadromous fish reside in streams for various amounts of time up to several years before migrating to sea. Much of the time spent in the streams occurs during the winter months when physical conditions are severe, typified by low water temperatures, accompanied by snow and ice cover and severe freshets (Bustard and Narver 1975).

The literature on winter habitat indicated that many stream fishes have (generally) similar winter habitat requirements: low water velocities and abundant cover (Cunjak and Power 1986). Hunt (1969) noted reductions in winter mortality and emigration as physical improvements in protective cover, water depth, and pool areas increased.

According to Archipelago Marine Research Ltd. (1990):

- juvenile chinook were distributed throughout the Nechako River, with an overall density of 1.8 fish per 100 m of shoreline in both November and March. The only significant difference in chinook abundance was in November, when the mean density of chinook per site in the lower river (*i.e.,* downstream of the Nautley River confluence) was less than the upper river;
- the only apparent shift in over-wintering distribution was an increase in density of chinook on the lower river between November and March;
- length/weight data showed little growth over the winter season, but the condition factor of the fish—an indicator of fish health—remained high;
- chinook sampled from Nechako River tributaries in November were significantly smaller than those sampled in the mainstem. Chinook sampled from the lower river in March were significantly smaller than chinook from the upper river;
- at night, juvenile chinook were typically positioned near the shore (<4 m), in water less than 1 m deep, in a slow current (<15 cm/s), and close to the bottom;
- chinook were found most frequently in complex or diverse shoreline habitat containing shear zones, back eddies, scalloped shoreline or near-shore cover; and
- juvenile chinook were found during the day within both shoreline cover and near-shore bottom substrate.

The literature review for winter remedial measures found that limited research has been directed at improving over-wintering habitat or at developing remedial measures for fish during winter months relative to warm water periods. Increasing water depth during winter using weirs built across the stream channel was found to be one way to mitigate for winter effects. However the practicality of placing full span log or rock weirs in the Nechako River is low, due to the width of the river and the potential for creating navigation hazards during non-winter months. In addition, changes in water velocities associated with pooling upstream of weirs placed in the proximity of spawning areas might decrease the quality of the inter-gravel incubation environment.

Based on available literature, the most practical methods for developing remedial measures for winter fish habitat in a system like the Nechako River will be those that:

- **increase the availability of protective cover** - Over-winter research conducted on the Nechako River determined that man-made structures were providing cover habitat used during the winter period. The availability of protective cover for holding over-wintering fish could be increased by adding deadfalls, streamside cover, debris catchers, riparian vegetation and large rocky substrate.
- **increase localized water velocity and depths** - Flow velocities and depths in some river sections could be increased by altering the river channel by constructing structures such as opposing wing deflectors or “V” weirs at strategic points along the river. The structures would have to be constructed and sited in a manner that does not affect sensitive habitats, such as spawning and incubation areas, and does not create undue risks to navigation. Increased flow velocities would enable salmonids to minimize energy expended on swimming, while maximizing energy intake. In addition, increased flows would help

entrain air, thereby increasing concentrations of dissolved oxygen, facilitating waste assimilation, and helping transport away sand and silt.

- **reduce frazil and anchor ice build up** - Ice booms used in conjunction with frazil ice collector lines may help minimize or prevent frazil ice forming in the interstitial spaces between the gravel particles on the riverbed. This could help reduce fish mortality by preventing possible freezing of redds and alevins. In addition, fish would not be forced to migrate in search of ice-free conditions, thereby expending critical energy reserves.

8.9.3 Summary

The literature review providing information on winter habitat used by salmonids was augmented by research conducted in the Nechako River; only limited information was available for winter remedial measures.

Increasing water depth, providing complex cover and reducing the incidence of frazil ice were identified as actions that could mitigate winter effects, as were habitat complexes that could provide over-wintering habitat. These types of remedial measures could be of use if in the future there is a reduction in winter stream flow and a need for remedial activity is identified.

Section 9
Applied Research

The Nechako River Working Group's *Summary Report* (1987) identified important gaps in knowledge in four areas relevant to Nechako River chinook salmon:

1) predator/competitor/prey interactions;
2) juvenile chinook winter habitat use;
3) temperature effects on food and fish growth; and
4) integrating available information to assess factors limiting productivity in chinook on the Nechako River.

The Nechako Fisheries Conservation Program (NFCP) Technical Committee oversaw a series of applied research projects designed to fill these gaps. The projects were undertaken by Department of Fisheries and Oceans Science Branch staff and/or consultants. The objective of the applied research was to incorporate the products of the projects into the design and implementation of the remedial measures.

An initial five-year research plan was outlined in 1987. The timeline was modified in 1990 when it became clear that the Kemano Completion Project would not be ready in 1993.

9.1 PREDATOR/COMPETITOR/PREY INTERACTIONS

The Summary Report raised concerns that changes in river characteristics resulting from the Kemano Completion Project could increase predation of, and competition with Nechako River juvenile chinook. Consequently, research was directed at identifying potential fish and avian predators, and the risk of predation on juvenile chinook. The research identified six of 20 resident fish species as predators and six others as potential predators. Avian predation was dominated by two species.

9.1.1 Predator/Competitor/Prey Interactions: Literature Review

A literature review on competition/predation in streams with reduced flows (Bruce 1991) concluded that reduced flows can affect competition/predation by:

- concentrating species in a smaller area;
- changing the competitive, predatory or predator avoidance abilities of fish through shifts in temperature away from the optimum temperature;
- changing the patterns of spatial and temporal segregation of prey/predator through shifts in

temperature and stream velocity; and

- changing the social behaviour/structure of salmonids through shifts in stream velocity.

It was apparent from Bruce's review (1991) that the effects of reduced stream flow on juvenile chinook intra- and interspecific behavioural interactions were likely varied and complex. Bruce's review also made it clear that attempts to predict the outcome of flow reductions on species interactions within the resident fish community without further research would be highly speculative and have little practical value.

9.1.2 Predator/Competitor/Prey Interactions: Field Surveys

Baseline data were collected in 1990 and 1991 on potential fish and bird predators in the Nechako River. From stomach contents collected in the fall, it appeared that:

- mountain whitefish (*Prosopium williamsoni*) consumed small benthic insects (primarily larval chironomidae);
- northern pikeminnows (*Ptychocheilus oregonensis*) consumed primarily small fishes and some rodents; and
- rainbow trout (*Oncorhynchus mykiss*) consumed the widest range of prey, primarily drift insects (Brown *et al.* 1992).

Brown (1995) concludes that northern pikeminnows, which primarily consumed small fish, were the greatest predatory fish threat to chinook juveniles due to their abundance in the Nechako River[85].

Common mergansers (*Mergus merganser*) and belted kingfishers (*Ceryle alcyon*) accounted for the majority of the piscivorous birds identified on the Nechako River (Brown *et al.* 1995). Mergansers presented the greatest threat in May/June when broods actively feed along the shallow river margins where chinook fry are most abundant. Based on a simplistic model of bird feeding, Brown *et al.* (1995) estimated that these birds had the potential to consume up to 40% of the chinook fry that emerged in the Nechako River in 1991.

The availability of juvenile chinook to predators feeding along the margins of the Nechako and Stuart Rivers varied seasonally, diurnally, and spatially (Brown *et al.* 1994). In the spring, juvenile chinook in the lower river used flooded (vegetated) habitat more than exposed sites, whereas they used exposed sites more than the flooded sites in the upper river. In the fall, they used the exposed sites more in both portions of the river. In addition, juvenile chinook shifted from shallow sites in spring to deeper sites in autumn, appearing to occupy faster water. From this information, it was speculated that recently emerged chinook fry (46 mm or 1.0 g) were available to predators feeding along the river margins only for a short period (30 to 40 days) in the spring, and that chinook fry would not be preferentially selected if predators select their prey on the basis of size (Brown *et al.* 1994).

9.2 JUVENILE CHINOOK WINTER HABITAT USE

Over-wintering studies were carried out from 1988 to 1990. SCUBA diving and electrofishing studies showed that juvenile chinook over-winter throughout the upper Nechako River with over-wintering more common in the uppermost section of the river (km 9 to km 70) than downstream (km 70 to km 100) (Emmett 1989, Emmett *et al.* 1990).

[85] Although bull trout (*Salvelinus confluentes*) are almost exclusively fish eaters, they are rare in the study area. Juvenile chinook were found in only two bull trout stomachs (Brown *et al.* 1992).

Juveniles chinook were more active at night in the winter than during the day when they hid in interstitial space among cobbles, boulders, and large, near-shore organic debris covers, such as beaver lodges (Emmett 1989, Emmett *et al.* 1992). At night, juvenile chinook were typically positioned close to the bottom near the shore (< 4 m), in shallow water (< 1 m deep) with a slow current (< 15 cm/sec.) (Emmett *et al.* 1990).

Although little growth occurred over the winter, the fish were healthy and gained weight (Emmett *et al.* 1990). Stomach content analyses showed that chinook fed predominantly at dawn on aquatic insects, such as nymphs (*Ephemeroptera*), and on adult water boatman (*Hemiptera*) (Emmett *et al.* 1992).

Chinook sampled from the lower Nechako River in March were significantly smaller than fish from the upper river. Chinook sampled from the tributaries in November were significantly smaller than those sampled in the mainstem (Emmett *et al.* 1990)[86].

9.3 TEMPERATURE EFFECTS ON FOOD AND FISH GROWTH

There was an interest in understanding the effects of colder water temperatures on Nechako River juvenile chinook and their invertebrate food supplies given the proposed release of colder water into the Nechako River for the benefit of sockeye. Research conducted by the Department of Fisheries and Oceans and overseen by the Technical Committee attempted to clarify the relationships between temperature changes, invertebrate production and fish survival rates.

Laboratory studies indicated that fish reared at lower summer water temperatures show slower growth in the summer and faster (compensatory) growth in the fall than a control group (Shelbourn *et al.* 1995). As a result, both groups enter the winter period at the same weight.

The effect of cooling flows on the food supply at a level sufficient to allow fish growth could not be verified. Mesocosm experiments showed that benthic productivity was nutrient limited (nitrogen was most limiting) and that algal and benthic invertebrate abundance were closely coupled (Perrin and Richardson 1997). Benthic invertebrates, the predominant prey for chinook salmon fry, showed the most increase in abundance with the addition of nutrients. [See *ss. 8.4.2.3 Mesocosm Experiment*]

9.4 INTEGRATING FACTORS LIMITING THE PRODUCTIVITY OF NECHAKO RIVER CHINOOK

The intent of this project was to develop a model of limiting factors for each stage of a Nechako River chinook salmon's life-history. This model would then be used to assess the effects of management actions (*e.g.*, reductions in flow, habitat enhancement, stream fertilization) (English *et al.* 1989).

A number of factors prevented developing a complete model. These included a lack of information on mortality at different juvenile chinook life-history stages, as well as information on ocean survival and harvesting.

DNA research work undertaken by the Department of Fisheries and Oceans has recently led to identifying individual markers for the Nechako River chinook stock. These markers may be used to define Fraser River migration

[86] Protocols for monitoring winter populations of Nechako River juvenile chinook were developed for future use, if needed.

timing and to clarify the in-river harvest component. Nechako and Stuart River juvenile chinook tend to be larger than other upper Fraser River chinook and appear to be fairly common among the juvenile chinook rearing in the Fraser River mainstem (Bradford in NFCP 1998, Tab 7).

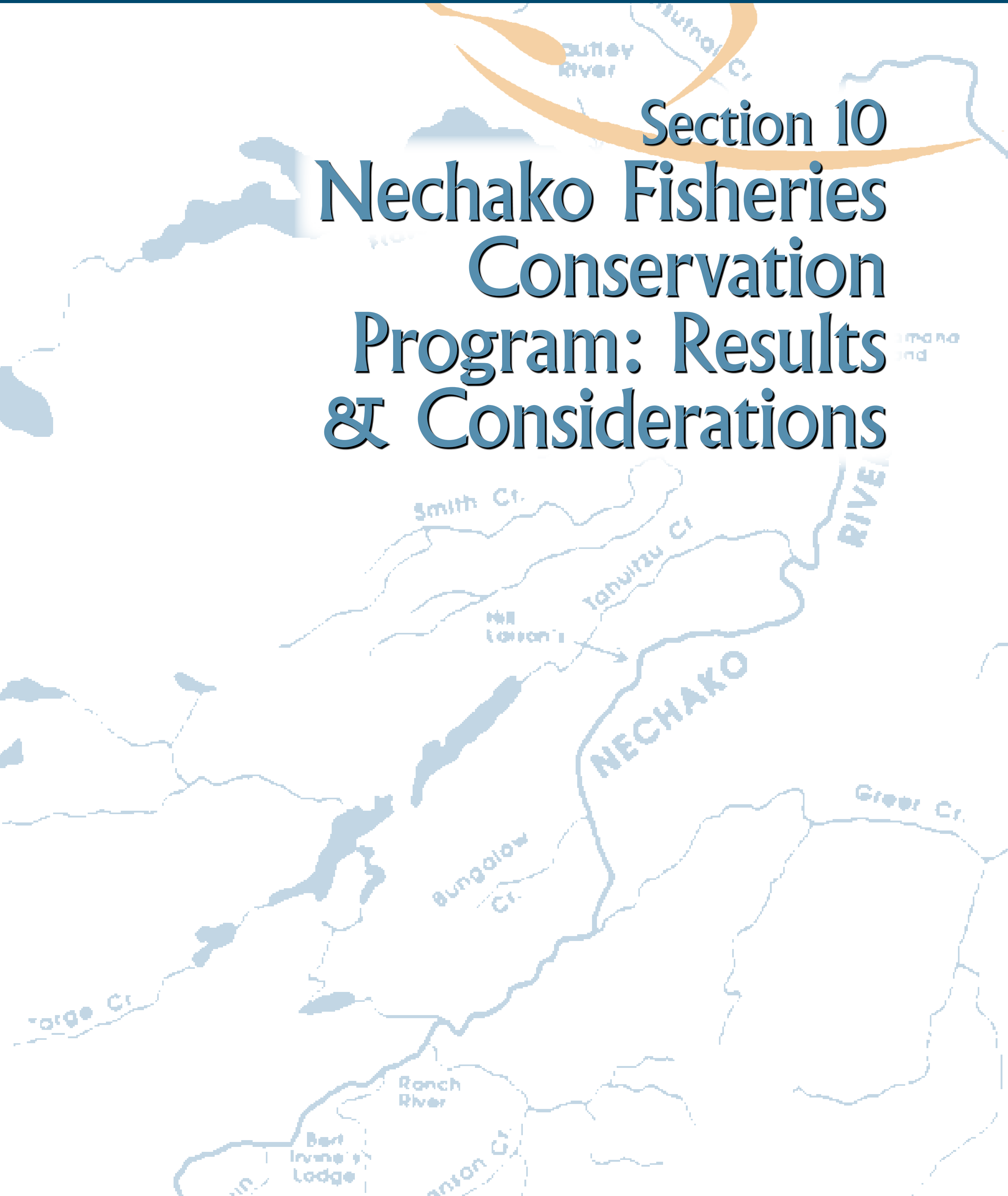
According to information provided by the department on chinook ecology, returns from brood years with a high percentage of spawners distributed in the upper river have shown a decline based on three years (1978, 1979 and 1980) (Bradford 1994). Hypotheses describing these declines include:

- early emergence caused by elevated fall and winter water temperatures;
- a higher rate of predation on juveniles;
- loss of rearing habitat; or
- an inability of the fish to effectively move into available downstream habitats due to elimination of the spring freshet.

9.5 SUMMARY: APPLIED RESEARCH

The results of the applied research projects complemented the Technical Committee's understanding of fish habitat use and species interaction on the Nechako River. There is still important work that can be done to provide more information on Nechako River ecology; however, as no flow reduction is planned, no additional research has been identified.

Section 10
Nechako Fisheries Conservation Program: Results & Considerations



THIS SECTION SUMMARIZES AND EVALUATES THE PROJECTS UNDERTAKEN BY THE NECHAKO FISHERIES CONSERVATION PROGRAM (NFCP) Technical Committee. The projects are described in detail in Sections 3 through 9 of this report.

This section organizes the projects under five general headings:

1) **Summer Temperature Management Program**: the only program directed at protecting migrating sockeye salmon.
2) **Physical Processes**: projects that collected the core physical data required to support biological programs.
3) **Remedial Measures**: projects designed to provide information to ensure conservation of chinook salmon under a reduced flow regime.
4) **Biological Monitoring and Research**: projects responsible for determining the status of the Nechako River chinook salmon stock.
5) **Conservation Goal**: the measure against which the Technical Committee was expected to evaluate the success of the Nechako Fisheries Conservation Program for chinook.

A complete list of these projects can be found in **Table 10-1** grouped under three general categories— remedial measures, monitoring, and applied research.

- **Remedial measures projects**: designed to meet the Nechako River Working Group's requests for:
  - inventories of physical habitat variables in the Nechako River that might change following the introduction of reduced flows; and
  - the development and pilot testing of both in-stream structures, for potentially offsetting habitat loss, and in-stream fertilization techniques, to reduce possible productivity losses due to flow changes.
- **Monitoring projects**: designed to monitor either biological or physical parameters. The

objective of these projects was to provide the data necessary to detect changes in variables before and after the completion of the Kemano Completion Project and the initiation of a lower flow regime. Most of these projects were intended to collect baseline data along a continuous time series[87].

The guiding principle behind these projects was the Department of Fisheries and Oceans' Policy for the Management of Fish Habitat, which is based on "no net loss of productive capacity of fish habitat." Inventories and pilot testing were to provide the data and tools necessary to ensure the objectives of the policy were met.

- Research projects: (originally identified in the Nechako River Working Group's Summary Report) designed to fill gaps in knowledge about Nechako River chinook ecology. These projects also aimed at characterizing the biological effects of a changing Nechako River flow regime.

Table 10-1 includes information on the date and duration of each project, including their various components, the type of data collected, and general results.

10.1 SUMMER TEMPERATURE MANAGEMENT PROGRAM

Objective: Moderate the effect of high water temperatures during sockeye migration by manipulating the timing and volume of water released from the Nechako Reservoir to the Nechako River with the intent of reducing the frequency of water temperatures >20°C in the Nechako River above the Stuart River confluence.

The Summer Temperature Management Program (STMP) is the only annual activity of the NFCP directed at conserving sockeye. The protocols used to regulate summer water flows to control temperatures in the Nechako River, thereby reducing temperature during sockeye migration, are referred to in the *1987 Settlement Agreement*[88].

Methods: Existing protocols and numerical models embedded in the *1987 Settlement Agreement* were implemented and monitored to make decisions to regulate summer water flows.

Results and Conclusions: The protocols and numerical models have been implemented annually since 1987. This has limited the frequency of mean daily temperatures >20°C measured at Finmoore upstream of the confluence of the Nechako and Stuart Rivers. Nechako River temperatures have rarely exceeded 20°C even though meteorological conditions have warmed over the study period. In fact, the frequency of water temperatures in excess of 20°C during this warmer period is similar to that recorded in a cooler period prior to the STMP being implemented.

Future Considerations: The NFCP was not mandated to collect the information necessary to assess the benefits of the STMP in relationship to migrating sockeye. That said, determining the value of the twenty-year old protocols in protecting migrating sockeye would be useful, particularly in light of the number of parties interested in altering the timing of water releases to (among other things) possibly enhance other species (*e.g.*, Nechako River sturgeon[89]).

[87] Since the Kemano Completion Project has been cancelled and flows will not be reduced, the usefulness of these projects is being reassessed.

[88] The protocols were developed and used for most of the decade prior to the signing of the *1987 Settlement Agreement*.

[89] A recent study (Korman and Walters, 2001) concludes that the Nechako River sturgeon is in significant decline.

Table 10.1 NFCP 10-year Review: Project Overview

Project	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	Data Collected
REMEDIAL MEASURES													
Cheslatta Murray Data Collection		✓	✓	✓	✓	✓		✓					Runoff volume and timing; snow course stations; water levels in Bird Creek; climate stations
Summer Temperature Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Water temperature, air temperature, river stage, and meteorological data
Instream Habitat Modification	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			Physical characteristics and durability of structures and safety
Biological Assessment of Habitat Complexing		✓	✓	✓	✓	✓	✓	✓	✓	✓			Fry density in complexes and natural sites; fry length, weight and condition; electrofishing CPUE along margins of river
Fertilization	✓	✓	✓	✓	✓								Periphyton and insect response to nutrient addition
Inventory of Habitat		✓	✓										Characteristics of natural complex habitat
Inventory of Sediment		✓											Sediment sources to Nechako River
Flow Control		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	SLS releases and flows in the Nechako River
Winter Remedial Measures			✓										Literature review on winter remedial measures
River Bed HEC-2 Model				✓									300 River cross sections surveyed
Riparian Bank Stabilization				✓	✓	✓							Literature review; pilot test
MONITORING													
Adult Chinook Spawner Enumeration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Chinook aerial counts; chinook distribution; Stuart River chinook mark-recapture; residence time
Chinook Carcass Recovery	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Age class; egg retention; POH length

Analyses Performed	General Results	Discussed in Sections
Hydrological database used to develop a model to forecast MC Lakes inflows into the Nechako River	Data were consistent with those collected locally by WSC. Results were used to estimate inflow to the Cheslatta and Murray Lakes system.	8.4 10.3.3
Flow and temperature models used on a daily basis to predict water temperatures, and are the basis for flow release decisions	Temperatures in the Nechako River during the summer are maintained below 20°C at a frequency that is less than historical data.	3.0 10.5
Correlation of physical characteristics to fish use; durability of design	Both debris bundles and debris catchers generally meet physical criteria. Catchers are more durable than bundles.	8.1 10.4.2
Fry distribution; chinook fry use of complex and natural sites during the day and night. Community structure within complexes.	Complexes at least as well utilized as natural sites, sometimes better. Structures used as overwintering habitat for juvenile chinook. Community structure within complexes is similar to natural habitat in the Nechako River.	8.2
Periphyton and benthic insect response to different levels of N and P additions. Whole river response to treatment of N and P on periphyton accruals.	Both periphyton and benthic insects showed a positive and significant response to nutrient additions. N and P are co-limitng. Stream fertilization is a viable technique for increasing primary and secondary production.	8.5 10.4.3
	Background document to be used in event remedial measures are required.	10.4.1
Calculation of sediment inputs from various sources including, Nechako tributary systems and eroding banks along the Nechako River.	Sediment contribution split between inputs from tributary systems and from eroding banks of the Nechako River. No critical inputs were identified that put Nechako chinook at risk.	8.6 8.9 10.3.5
Monitoring of flows from Skins Lake Spillway.	SLS releases have met or exceeded SA flows.	8.7 10.3.2
	Not much information on remedial measures for the winter period. Most information focussed on control of physical events such as ice jamming and frazil ice formation. Winter conditions not believed to be limiting, no need for winter measures.	10.4.4
River bed profile constructed.	Can be used, if needed to establish river depths and velocities.	8.8 10.3.1
Monitored results of pilot test on 2 sites one on the mainstem Nechako River and one on a bank of Greer Creek.	Nechako bank showed poor success. The techniques used in Greer Creek demonstrated good results, however the river channel shifted away from the bank which nullified the pilot test.	8.3 10.4.5
AUC; escapement to the Stuart River.	Nechako populations were relatively stable from 1988-1992. From 1993 to 1997 populations were less than the brood followed by increases over brood years to 2002. Reductions in returns caused by factors external to the Nechako River.	5.1 5.3 10.6.4
% contribution by age class (aging by scales and otoliths). Length frequency, sex ratio.	Nechako River chinook are generally 5 year old fish with 1 full year of freshwater residency. Age class is similar to Stuart River chinook.	5.2 10.6.4

Table 10.1 NFCP 10-year Review: Project Overview (continued)

Project	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	Data Collected
Juvenille Outmigration Monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Outmigrants at Diamond Island CPUE (index sampling) chinook fry length, weights and condition index
Winter Physical Conditions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			Ice conditions; winter temperatures; winter stage and flow and meteorological conditions
Physical Data Collection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Air and water temperatures at Bert Irvine's Lodge; discharge and meteorological data
Fry Emergence		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Numbers of fry in traps, day and night; fry length, weights and condition index; mark recapture experiments
Gravel Quality	✓	✓	✓	✓	✓							✓	Gravel sampling workshop, development of techniques, and sampling design. Collection of baseline sample (1991)
Dissolved Oxygen Monitoring				✓	✓	✓	✓	✓	✓	✓			Background research; pilot test
Evaluation Framework and Trend Analysis				✓	✓	✓	✓	✓	✓	✓			
RESEARCH													
Ecology of Juvenile Chinook Salmon									✓	✓			Distribution and abundance of juvenile chinook throughout the Nechako River (including downstream of the Stuart River)
Chinook Life History Model		✓							✓				Looked at requirements for LH model and determined gaps in information for a Nechako specific model.
Predator Prey Studies			✓	✓	✓	✓	✓	✓					Community structure, survey to determine potential predators for Nechako juvenile chinook
Temperature Effects					✓	✓	✓	✓					Through experiments at different temperatures to assess the effect of temperature and ration on juv. chinook growth
Chinook Overwintering	✓	✓	✓		✓	✓		✓					Habitat information and distribution and abundance of juvenile chinook overwintering in the Nechako River

Analyses Performed	General Results	Discussed in Sections
Relationship between index and # spawners; distribution of fry along NR margins; rate of decline of catches; overwintering chinook fry	Positive relationship between number of spawners previous fall and index of outmigrants. Rate of decline shows density dependency. (overwintering population is similar regardless of recruitment).	6.2 10.6.3
Ranking of severity of winters. Progression of ice edge	Ice edge generally between Berts and Greer Creek. Only during coldest weather does ice edge move above Berts.	7.1 10.3.7
Physical data used for other projects	Physical data used for other projects	7.2 10.3.6
Index of emergence (estimated numbers); Index of emergence success. Incidental catch	Strong relationship between index of emergent fry and number of spawners previous year for years with “normal” flows	6.1 10.6.2
Power analysis to determine appropriate no. of samples to detect a 10% change in fines. % composition by size fraction of field samples.	Nechako gravel samples indicated low percentage of fines.	7.4 10.3.4
Testing of various probe configurations	Selection of appropriate technology. Some field testing undertaken.	7.3 10.3.8
Review and evaluate the linkages between biological and physical data collection		10.7.4
DNA analysis of juvenile chinook in the Nechako and Fraser Rivers	Percentage of Nechako and Stuart River chinook in the Nechako downstream of the Stuart confluence, reflects relative contribution from both upstream spawning populations. Nechako and Stuart River chinook are abundant in downstream rearing areas of the Fraser mainstem.	9.4
	At time of development inadequate database to develop model	4.5.4 9.4 9.5.4
Populations of marginal fish communities (species composition). Developed predation model to assess risks to juvenile chinook from predation. Stomach content analysis of fish species to document actual predation of juvenile chinook.		4.5.1 9.1 9.5.1
Effects of temperature changes on food production and fish growth. Appears to be compensatory growth in chinook that are raised at lower temperatureeratures through the summer growth period.	Mergansers are the dominant avian predators, but juvenile chinook do not appear to be the primary prey selected by these birds. The major fish predator appears to be pikeminnow but large-scale predation of chinook not documented through stomach analyses	9.3 9.5.3
Habitat information and distribution and abundance of juvenile chinook overwintering in the Nechako River	Enclosure measurements - estimates of numbers of chinook overwintering in the Nechako River. Power analysis on monitoring sites to assess requirements for monitoring overwintering populations.	9.2 9.5.2

10.2 PHYSICAL PROCESSES

The following projects address issues that required core physical data in order to evaluate possible causes of observed biological changes.

10.2.1 River Bed Survey

Objective: Develop a model for use in locating habitat complexes.

> The data from this survey was used to create a river gradient profile and were used in a hydrologic model.

Methods: A river survey was conducted from Cheslatta Falls to the confluence of the Nechako and Nautley Rivers. In total, 300 cross sections were taken along 91 kms of river.

Results and Conclusions: The data proved useful in placing habitat complexes. The model is currently available as a management tool and can be used to provide information on water depth and wetted perimeter, as well as to estimate changes in water velocity. That said, caution should be exercised in using the tool as changes in the riverbed may occur over time.

10.2.2 Flow Control

Objective: Release the AWA to provide the greatest benefit to chinook salmon.

> The Technical Committee is responsible for the timing and magnitude of the release of the Annual Water Allocation (AWA) from the Nechako Reservoir under provisions of the *1987 Settlement Agreement*. Although there is a default flow release identified in the Agreement, the committee can, and did, develop alternative release strategies.

Methods: The decision making process for determining the release pattern for the AWA includes considering such factors as ice conditions and chinook ecology.

Results and Conclusions: The AWA has been released each year in a pattern that, in the judgment of the Technical Committee, is consistent with the needs of chinook in the Nechako River. Releases from the reservoir to date have met the requirements set forth in the *1987 Settlement Agreement*.

Future Considerations: There is strong interest among some stakeholders to make changes to water flows in the Nechako River watershed. These changes are intended to benefit interests beyond chinook, and as such are beyond the current mandate of the Nechako Fisheries Conservation Program.

10.2.3 Murray/Cheslatta Data Collection

Objective: Develop a model to forecast inflows to the Nechako River from the Murray/Cheslatta drainage system.

> Flows in the upper Nechako River are a combination of Skins Lake Spillway releases and natural inflows from the Murray/Cheslatta drainage system. Current inflows to the system, small relative to the spillway releases, would have represented a larger portion of the releases following the implementation of the Kemano Completion Project.

Methods: The Technical Committee collected snow course and water level data within the Bird Creek sub-basin of the Murray/Cheslatta drainage system to develop a method of predicting inflows.

Results and Conclusions: A method of predicting inflows to the Murray-Cheslatta basin from snow melt—which would have allowed the Technical Committee to take Murray/Cheslatta drainage system inflows into account—was developed but not implemented due to cancellation of the Kemano Completion Project.

10.2.4 Substrate Quality and Composition

Objective: Assess changes in fine sediment storage within spawning gravel.

> A reduction in the Nechako River's ability to transport sediment due to decreased flows stemming from the Kemano Completion Project could have led to the accumulation of fine sediments in the river channel, adversely affecting spawning grounds.

Methods: Pilot studies using freeze core sampling were carried out in 1990 and 1991. Full-scale studies on grain size composition of the gravel beds were undertaken in 1992 and 2000.

Results and Conclusions: The percentage of fine sediments (clays, silts and sands) in the Nechako River spawning gravel in both 1992 and 2000 ranged between 8% and 11% in the surface layers and 16% and 18% in the lower layers. This is typical of good spawning gravels. Most of the fine sediments were fine to coarse sands (>98%). There was a statistically non-significant increase in the fine sediments at two of the sites between the years. The third site showed a net decrease in fine sediments, likely due to erosion and deposition of bank materials in the vicinity of the site.

Future Considerations: Sampling should be considered again in 2011 to determine if the observed trend continues.

10.2.5 Inventory of Sediment Sources

Objective: Do an inventory and rank the relative importance of sediment sources to estimate sediment inputs from tributaries to the Nechako River and from eroding banks on the river.

> It was important both to assess watershed sediment sources and to estimate the changing effect of their contributions once the Kemano Completion Project was implemented, given the possibility of reduced sediment transport capacity and a risk of increased sediment deposition.

Methods: Sediment volumes from both sources were calculated and the sources evaluated for their potential risk to Nechako River chinook. The evaluation included measuring and assessing the magnitude of the sediment sources and their location in relationship to important chinook spawning/incubation habitats.

Results and Conclusions: No sediment sources were identified that put Nechako River chinook at risk. The study determined that while tributary sources could have a greater effect with reduced flows, that effect would be offset by reduced bank erosion along the mainstem of the Nechako River.

10.2.6 Temperature Data Collection

Objective: Collect air and water temperature data to assess the conditions of the physical environment, specifically as it relates to the ecology of the Nechako River system.

> Monitoring air and water temperature is necessary to establish baseline data on long-term changes in environmental conditions and to assess their effect on Nechako River chinook.

Methods: The Technical Committee established data collection stations on the Nechako River in 1988 and has continued to collect water temperature data since that date. This is supplemented by data from the Water Survey of Canada and Atmospheric and Environment Service stations.

Results and Conclusions: Water and air temperature has been collected since 1988 to support all of the Technical Committee's biological projects. For example, air/water data is routinely used to calculate expected-emergence-timing and start-up dates for the Fry Emergence Project [see *ss. 6.1 Fry Emergence Project*], as well as to interpret year-to-year variability in fish size over the rearing period in the Juvenile Chinook Out-migration Project [see *ss. 6.2 Juvenile Chinook Out-migration Project*]. Winter temperature data has enabled winter conditions to be ranked to better understand variability in ice conditions under different temperature regimes.

10.2.7 Winter Physical Conditions

Objective: Define existing (baseline) winter ice conditions on the Nechako River.

> Decreased winter flows resulting from the Kemano Completion Project could have resulted in increased risks to chinook associated with winter icing events (*e.g.*, increases in frazil and anchor ice could pose a threat to incubating eggs, alevins, and over-wintering juveniles), highlighting the need for baseline data on winter water temperatures and ice formation in the river.

Methods: Ice cover was observed and recorded along the Nechako River. These records were interpreted in the context of data regularly collected on the upstream extent of the ice lead/open-water interface, the formation of frazil/anchor ice in upstream open-water sections of the river, and winter temperature data ranking the severity of winters.

Results and Conclusions: There is no indication that current winter conditions affect the incubation success of Nechako River chinook. [See *ss. 6.1 Fry Emergence Project*] The Technical Committee has continued to collect data on water and air temperatures.

Future Considerations: No additional monitoring of winter physical conditions is deemed necessary under the current flow regime.

10.2.8 Dissolved Oxygen Monitoring

Objective: Develop a method of measuring changes in the concentration of dissolved oxygen in the winter within active redds.

> Decreases in winter flows resulting from the Kemano Completion Project could increase the risk to eggs and alevins in the gravel through increases of frazil and anchor ice that would limit inter-gravel oxygen availability.

Methods: A program to test and modify automated dissolved oxygen monitoring techniques for harsh Nechako River winter conditions was developed and implemented.

Results and Conclusions: Preliminary results from testing equipment in the Nechako River indicated that—with some further development—data on the concentration of dissolved oxygen could be collected from automated monitors throughout the winter. The project was discontinued due to cancellation of the Kemano Completion Project.

10.3 REMEDIAL MEASURES

The following projects were designed to provide information important to conserving Nechako River chinook stocks and/or remediate negative changes in biological variables following the implementation of the Kemano Completion Project and the resulting shift from the short-term flow regime to the proposed long-term regime. This shift would have led to changes in wetted river width and in the availability of complex habitat cover (*e.g.*, fallen trees, log jams, beaver lodges) along the river's margins. Habitat would either be left out of the water or might experience water velocities unfavourable to rearing chinook. Although habitat values were expected to increase again over time as the river adapted to the flow regime, the flow change would likely affect Nechako River chinook and, consequently, the Conservation Goal described in the *1987 Settlement Agreement*.

The 1990 Decision Chart (**Figure 1.3-1**) provided the framework for developing these projects, which either compiled inventories (*e.g.*, sediment sources) or designed and pilot tested remediation techniques, including constructing artificial habitat complexes. The complexes were to be in place prior to changes occurring in the flow, thereby compensating for expected losses in habitat.

Pilot testing did occur: many of the pilot structures were functioning at the writing of this report. However, plans for future structures were ended following cancellation of the Kemano Completion Project.

10.3.1 Habitat Complexes

The Technical Committee was mandated to:

- inventory all available cover habitat in the Nechako River mainstem and side channels;
- arrive at an estimate of the possible magnitude of the change of status of instream cover in the Nechako River between short-term and long-term flows; and
- identify potential sites for placing artificial habitat complexes.

10.3.1.1 Inventory of Habitat Cover/Cover Opportunities

Objective: Estimate potential changes to cover habitat and the amount and location of artificial cover required in the Nechako River following implementation of the Kemano Completion Project.

Methods: Existing habitat cover was measured over a two-year period. Changes from current flows to the projected post-Kemano Completion Project flows were estimated by assessing the amount and quality of juvenile chinook habitat at rearing flows in late spring and comparing it to fall flow values that approximate the predicted low-flow spring levels. Changes in the amount of habitat cover and the potential reduction in habitat complex rearing values were estimated, and the depth and velocity associated with the fish bearing structures were measured.

Results and Conclusions: Preliminary estimates of changes in cover habitat values were developed and potential sites for placing man-made habitat structures were identified. In addition, data collected on juvenile chinook habitat preference confirmed the criteria used for siting habitat complexes. An artificial habitat program was not developed due to cancellation of the Kemano Completion Project.

10.3.1.2 Instream Habitat Modifications

Objective: Design and place artificial habitat complexes in the Nechako River in a manner similar to natural in-river habitat complexes, and assess their suitability for rearing chinook.

Methods: From 1988 to 1992, more than 60 habitat complexes were installed on the Nechako River. Fish use was assessed through snorkeling and electrofishing several times throughout the rearing period, and physical measurements and video documentation were taken annually. As of 2000, 37 complexes[90] were providing significant amounts of cover and were still being monitored for structural integrity and biological use.

[90] The remaining 23 complexes were removed.

Results and Conclusions: The project's objective was achieved: while some designs were rejected either due to structural failure or because they produced less than optimal habitat, many complexes continued to function well at the time of writing of this report. Pilot tests indicated that several designs could be placed and maintained in the Nechako River, and snorkeling and electrofishing surveys demonstrated high use of the structures by juvenile chinook. In most cases, usage was comparable to, or better than that found in natural habitat complexes; the fish community structure was similar to that in found high quality natural complexes.

An artificial habitat program was not developed due to cancellation of the Kemano Completion Project.

Future Considerations: Successful designs for several artificial habitat complexes were developed for use on the Nechako River, and could apply to other river systems. With the cancellation of the Kemano Completion Project, further analysis of the information collected during the project was not carried out; however, the data base is a rich source of information that could be used to investigate such things as why the densities and numbers of juvenile chinook per complex varied widely over a range of conditions and structure, or to investigate their effectiveness in increasing survival.

10.3.2 River Fertilization

Objective: Evaluate the effect on food (*i.e.,* algae and invertebrate) production of adding nutrients to the Nechako River.

> A major component of the Kemano Completion Project was the construction of a cold-water release facility at Kenney Dam designed to deliver surface water mixed with cooler, deeper water from the Nechako Reservoir to the lower Nechako River for the benefit of migrating sockeye. However, releasing cold water into the river had the potential to reduce growth rates and/or abundance of resident fish—including chinook—by decreasing food production (*i.e.,* algae and invertebrate populations).

Methods: The Technical Committee conducted a number of river fertilization studies to examine the effects of adding nitrates and phosphates to a side channel and to the Nechako River mainstem. These included measuring algae (periphyton) production and experiments with trough systems designed to measure insect response to nutrient additions. Laboratory experiments were also conducted on Nechako River juvenile chinook to assess their growth rates at different temperatures and nutrient levels.

Results and Conclusions: While in-river experiments showed that adding nutrients increased algal and invertebrate production in the Nechako River, the tests scheduled for the final year—tests which would have compared fish response to fertilization on the river to several years of baseline data—were not carried out due to cancellation of the Kemano Completion Project. That said, work on other rivers has provided solid evidence that adding nutrients benefits fish growth and survival.

Given the results from the Nechako River and other nutrient-poor rivers in British Columbia, stream fertilization was deemed an effective tool to increase primary, secondary and tertiary productivity.

Future Considerations: The Technical Committee does not see the need to conduct further river fertilization studies at this time. However, implementation of a full-stream fertilization program should take into consideration the effects of fertilization on all resident species and river ecology in general. In addition, applied research studies indicated that juvenile chinook reared at lower summer water temperatures show slower growth in the summer and faster (compensatory) growth in the fall than a control group. [See *ss. 9.3 Temperature Effects on Food and Fish Growth*] This should also be considered prior to deciding to implement a full-stream fertilization project.

10.3.3 Winter Remedial Measures

Objective: Collect information on winter remedial measures to assess the effect on over-wintering chinook.

> Reduced winter flows resulting from the Kemano Completion Project could increase risks to over-wintering and rearing Nechako River chinook, incubating eggs and alevins due to flow change and increases in frazil and anchor ice.

Methods: A literature review of potential winter remedial measures was completed.

Results and Conclusions: Although there was little information on winter remedial measures, habitat complexes were identified as important for salmonid winter habitat. This was supported by winter habitat research done on the Nechako River indicating that habitat complexes were used by over-wintering juvenile chinook.

Future Considerations: No future work is anticipated unless a significant change is proposed to winter flows in the river.

10.3.4 Riparian Bank Stabilization

Objective: Explore bioengineering techniques for stabilizing stream banks.

> Reduced flows resulting from the Kemano Completion Project were expected to decrease the Nechako River's capacity to transport sediment, leading to a potential degrading of in-river habitats. Stabilizing mainstem and tributary riverbanks could reduce the input of sediments and offset risks associated with this reduced transport capacity.

Methods: Although a conventional engineering technique to stabilize banks (*i.e.,* rip rap) is well known in North America, this was not the preferred option due to the costs associated with the technique and the desire to use bioengineering for more natural sediment control. A review of bioengineering techniques (*e.g.*, using plant material to strengthen banks) in Europe and in North America—including riverbank revegetation activities conducted by the Shuswap Nation Tribal Council—led to selecting a number of techniques which were pilot tested along a bank of the Nechako River and a tributary stream bank (Greer Creek).

Results and Conclusions: Bioengineering techniques were found unsuitable for the Nechako River's large clay/silt riverbanks unless the toes of these large banks are stabilized through conventional engineering methods. However, results from the Greer Creek study suggested that—given the correct site—bioengineering the stream banks of smaller tributaries can be effective. That said, the Inventory of Sediment Sources provided no evidence that sediment contributions from tributary or mainstem sources negatively affect Nechako River habitat values.

Future Considerations: No additional work is anticipated unless spawning gravel quality monitoring data indicates that remedial work on a specific sediment source is required.

10.4 CHINOOK BIOLOGICAL MONITORING AND RESEARCH

The majority of work undertaken by the Technical Committee has focused on the design and implementation of projects to conserve chinook that spawn and rear in the Nechako River. While much of this work followed directions given in the Nechako Working Group's *Summary Report*, the committee spent considerable time and effort—especially in the early years of the program—researching alternative approaches to data collection in order to choose methods that were both appropriate to the Nechako River and fiscally responsible.

For example, although spawner enumeration was selected as a primary monitoring measure, it was not the only indicator relied on to assess the *1987 Settlement Agreement*'s Conservation Goal. Spawner enumeration reflects the effects of both intrinsic factors (*e.g.*, river velocity, water temperature, sedimentation rates) and extrinsic factors (*e.g.*, Fraser River and ocean food production, water quality, predation, and fish harvesting). This means that the number of returning adult spawners does not solely reflect changes in the Nechako River habitat and, therefore, cannot be used to evaluate the effects of changing river conditions on the Nechako River chinook population.

Consequently, a second level of monitoring was introduced by the committee to detect riverine habitat influences on Nechako River chinook. These secondary projects had two major objectives:

- monitoring fry emergence to assess the quality of the incubation environment; and
- monitoring juvenile chinook rearing in, and migrating out, of the river to assess the quality of the river habitat.

The projects were designed to provide information on:

- habitat conditions prior to the Kemano Completion Project being implemented;
- the effects of changes in river habitat on the numbers of returning chinook spawners; and
- the stage in chinook life-history when changes in habitat affect chinook production.

10.5 FRY EMERGENCE

Objective: Generate a fry emergence index in a river reach with a known spawning population to:

- detect changes in the quality of the incubating (in-gravel) environment: and
- monitor fry size and condition.

  The upper Nechako River was chosen as the site for the fry emergence program because it:
  - exhibited the highest concentration of spawners;
  - was ice-free during the emergence period; and
  - was expected to experience significant flow changes once the Kemano Completion Project was implemented.

Method: Inclined Plane Traps provided two annual indices of fry emergence. One index expanded the actual trap catches as a function of the proportion of discharge sampled. The other index provided a mark/recapture estimate. Data on the length, weight and condition of emergent fry were also collected. The same methodology has been applied consistently since 1990.

Results and Conclusions: It is extremely difficult to directly measure the survival of fry from individual redds: trials to develop redd trapping techniques for Nechako River chinook were unsuccessful. Consequently, the Technical Committee agreed on using (estimated) fry emergence success in an area of the river with a known spawning population as a surrogate measure. As factors such as ice cover made appropriate locations in lower portions of the river unfeasible for sampling, monitoring activities were restricted to the upper river where ice cover generally is not an issue during the emergence period.

The estimates of fry emerging from the gravel and the number of spawners upstream of the trapping site have been strongly correlated and have indicated consistent and high emergence success. Both indices show a strong relationship between the number of spawners and the number of fry migrating past the trap site. Higher flows during 1997 and 1998 affected the flow expansion index to a greater extent than the mark/recapture index, suggesting the latter methodology may be more robust under variable flow regimes.

Analyses of the length, weight and condition data for emergent fry over the period indicate no significant changes over time. Other parameters such as time of emergence, a function of accumulated thermal units, and morphological data also were stable.

Overall, the results of the Fry Emergence Project suggest that in-gravel habitat conditions have not changed throughout the program period and that emergence success is relatively stable. Emergence success has not changed over a range of flows and numbers of spawners (measured from 1988 to 2000) indicating that the capacity of the spawning habitat has not been exceeded.

Future Considerations: If fry emergence is to be monitored in the future, then it is important to use, at a minimum, a mark/recapture methodology, as this methodology does not appear to be biased by high flows.

10.5.1 Juvenile Chinook Out-migration

Objective: Provide a surrogate measure of in-river habitat changes by estimating the numbers and monitoring the quality (*i.e.,* average size and spatial distribution) of juvenile chinook leaving the upper Nechako River.

> As juvenile chinook spend a portion of their first year in the Nechako River before migrating downstream, information on the condition and relative abundance of juveniles over time is presumed to reflect changes in the quantity and/or quality of the rearing habitat.

Methods: Since 1992, downstream migrant surveys have been done by Rotary Screw Traps installed at Diamond Island (km 84) during the main out-migration period (April 1 to July 10). Electrofishing samples have also been taken at numerous sites along the upper Nechako River to provide information on spatial distribution and juvenile condition during the rearing period.

Results and Conclusions: The numbers of fry both rearing along margin habitats in the upper Nechako River and leaving the upper river have done so in proportion to the number of adults that spawned the previous fall. The number of fry per spawner is similar year to year, indicating no limiting effect from the available habitat as spawner numbers increase. The exception is the apparent saturation effect created by the large spawner return in 2001, which exceeded the upper range of the Conservation Goal identified in the *1987 Settlement Agreement*.

Both the number of fry rearing in the upper river, and the number of fry leaving the system, increased linearly with higher spawner numbers for escapements observed between 1988 and 2000 (range 664 to 3,436). The length, weight and condition of juvenile chinook were similar in most years with differences in size related to emergence timing and to water temperature regimes. However, in 2001 the number of spawners returning to the river exceeded the upper bounds of the target population that is part of the Conservation Goal by almost 40%. As a result of this large return, the progeny from the 2001 spawners may have resulted in a saturation of upper river juvenile rearing habitat. More fry per spawner left the river than usual while the rearing index did not increase beyond the maximum values seen previously. This cannot be assessed until spawners return in 2005 and 2006.

The methodology provided a useful surrogate measure for in-river rearing conditions over the range of flows and temperatures experienced in the sampling period. The program is satisfactory for monitoring changes in body size, relative abundance of juvenile chinook in the river, spatial distribution, and an index of the number of out-migrants under the present flow and temperature regimes. Based on the consistency of the two relationships (rearing fry per spawner and juvenile out-migration per spawner), the capacity of the available rearing habitat in the upper Nechako River appears to be adequate for the number of spawners identified in the Conservation Goal.

Future Considerations: The project has proven useful in interpreting variations in escapements to the Nechako River and as an indicator of habitat conditions. The need to continue monitoring juveniles under flows experienced since 1988 should be reviewed. This review should assess the value of both the juvenile out-migration component and the electrofishing index component of this project.

10.5.2 Spawners

Objectives: Obtain spawner estimates to determine the influence of habitat change on the Nechako River chinook population.

> As stated in the introduction to this section, the Technical Committee recognized the limitations inherent in relying solely on escapement estimates to assess the success of meeting the Conservation Goal. Consequently, the committee initiated various monitoring projects to obtain indices of habitat quality at various stages of chinook life-history.

Methods: Multiple aerial counts combined with estimates of residence time were used on an annual basis to calculate an "area-under-the-curve" spawner estimate. This methodology has been used since 1988. [See *ss.5.1.1.1 "area-under-the-curve"*]

Data were also collected on sex ratio and spawner distribution, and the age at return and the condition of spawners returning to the Nechako River was assessed through a carcass recovery program. In addition, adult Nechako River chinook returns were compared to adult returns in the Stuart River—a geographically close but unregulated stream—to gauge extrinsic effects on population[91].

Results and Conclusions: Until 1992, the number of chinook that returned to the Nechako River was greater than the number of spawners that produced them. There were significant downturns from 1993 to 1995. Although a direct comparison of trends between the Nechako and Stuart Rivers needs to be approached cautiously, data indicate that the declines occurred within both the Nechako and Stuart River stocks, suggesting that they were the result of extrinsic

[91] Although Nechako and Stuart River stocks both use the Nechako River downstream of the Stuart River confluence, research has shown this period to be short-term as fry from both systems are actively migrating downstream to Fraser River habitats

factors — they occurred outside of the natal streams. In 1996 and 1997 approximately as many fish came back as there were parents and there was a significant increase in the ratio of returning fish to spawners in 1999 and 2000. The Nechako River escapements trends were also compared to escapements to other unregulated upper Fraser River and the comparison supported the conclusion that the effect observed on the Nechako was related to "extrinsic" factors.

Spawner age classes generally reflected the contribution from the respective parent year (*i.e.,* 1995 spawners are the offspring of 1990 parents). The one exception was 1996, which showed an even distribution of four- and five-year olds (*i.e.,* 1991 and 1992 spawners). This could be the result of offspring from the 1991 brood having a lower survival rate; however, the results from juvenile chinook investigations gave no indication of this occurring.

The results of the secondary monitoring projects suggest that current in-river conditions have resulted in linear relationships for spawners to emergent fry, spawners to rearing fry, and spawners to out-migrants over the study period indicating that there is consistency in fry and juveniles produced per spawner. In addition, observations of Nechako and Stuart River chinook over the study period have indicated:

- the timing of spawning activity is consistent year to year;
- pre-spawning mortality has been consistently low;
- spawners continue to be dominated by five-year old fish with 1 year of freshwater residency;
- there have been no noticeable changes in the length of spawners over the years, and their size appears to be similar to that of other upper Fraser River chinook stocks; and
- analysis of age-at-return data shows a normal distribution of offspring from brood years, once again suggesting that any change in the numbers of spawners resulted from factors outside the natal stream.

10.6 APPLIED RESEARCH

Recognizing that overall chinook production is affected by all life-history stages — including factors such as freshwater rearing outside of the Nechako River, ocean survival, ocean and in-river harvesting and upstream migration survival — the Technical Committee intended to develop a life-history limiting factors model. However, as the study progressed it became apparent that critically important extrinsic information is unavailable. That said, research projects were undertaken to provide additional information on both in-river life-history factors for Nechako River chinook, as well as to identify life-history factors outside of the river that could affect the population.

Work undertaken by the committee has shown that while a minority of juvenile chinook over-winter in the Nechako River using habitat complexes — including artificial habitats — the majority migrates out of the upper Nechako River by late spring or early summer. DNA analyses indicate that these fish move into rearing areas in the mainstem of the Fraser River where their distribution is similar to that for Stuart River juvenile chinook.

Research projects also provided data on predators that pose a threat to rearing chinook on the Nechako River. While preyed on by both fish and birds[92], chinook do not appear to be preferentially selected under the current flow regime.

[92] Additional information on predation by birds, specifically mergansers, is needed to better understand the risks faced by chinook.

Future considerations: As noted in ss 9.1 (*Predator/Competitor/Prey Interactions*), progress has been made on answering some of the applied research questions posed in the Nechako Working Group's *Summary Report*. While canceling the Kemano Completion Project reduced the importance of these questions, any significant future changes to flow patterns will bring them to the forefront. Changes in flow conditions may also require a re-assessment of predator/chinook relationships.

Increased information from ongoing research outside of the Nechako River on factors affecting salmonid survival will lead to a better understanding of Nechako River chinook production. For example, current initiatives using DNA are beginning to develop tools that can be used to help understand ocean survival and mortality associated with harvest. It may be appropriate to reconsider developing the Nechako River chinook life-history model when this information becomes available.

10.7 THE CONSERVATION GOAL

During its initial work, the Technical Committee recognized that sufficient time would need to elapse after the implementation of the Kemano Completion Project before it could assess whether the Conservation Goal had been achieved. The timeframe identified by the committee to ensure that the Nechako River chinook population was stable and within the target value established by the *1987 Settlement Agreement* was 20 to 25 years, or four to five complete chinook life-cycles. However, with the cancellation of the Kemano Completion Project (and, consequently, no change in flows) and the completion of almost three spawning cycles, the committee believes that it is now possible to assess the relevance and appropriateness of the Conservation Goal, and to interpret the success of the program in achieving the goal.

The Conservation Goal is:

> *… the conservation on a sustained basis of the target population of Nechako River chinook salmon including both the spawning escapement and the harvest as referred to in paragraph 3.1 of the Summary Report….*

Paragraph 3.1 of the *Summary Report* states that:

> *The total population of chinook salmon to be conserved is that represented by the average escapement to the river plus the average harvest during the period 1980-1986. DFO escapement records during this period averaged 1,550 with a range of 850-2,000. In view of the known inaccuracies in spawner count data the working group recognizes that the estimated escapement is on average 3,100 spawning chinook but ranges from 1,700 to 4,000. This number is referred to as the target population.*

Early in its deliberations, the committee recognized the need for more clarity in defining the number of chinook to be conserved. For example:

- both "total population" and "target population" are used in the same directive;
- both the number "3,100" and the range "1,700 to 4,000" are referred to as the "target population"; and
- the number of returning adults recorded for the period 1980 to 1986 was based on various counting methods, each with a different level of precision and accuracy. Recognizing this uncertainty, the authors of the *Summary Report* multiplied the escapement estimate by a factor of two to better reflect what was, in the author's opinion, a more likely range of returning adults for the 1980-86 period.

To overcome some of the uncertainty in the definition of the "target population," and recognizing the potential for extrinsic factors to result in significant annual and multi-year variations in the number of chinook returning to spawn in the Nechako River, the Technical Committee has assessed the annual escapements against the range of "1,700 to 4,000" spawners per year to be the "target population" described by the Conservation Goal. The "total population" of Nechako River chinook is made up of two groups, the adults that return to the Nechako River to spawn and those fish harvested in the ocean or in fresh water on their way to the Nechako River. It has not been possible to develop accurate data on the harvested group of salmon.

The committee recognized that a counting method more rigorous than that used in the past was an important part of assessing trends in Nechako River chinook production. After some deliberation, the "area-under-the-curve" (AUC) method was selected. Among other things, this method provided a peak count that could be compared to the data used to establish the Conservation Goal. Trends developed using the AUC estimates were also compared to the returns from the Stuart River chinook.

The returns to the Nechako River have been generally within the range for the target population set out in the *1987 Settlement Agreement*. The exceptions to that general statement are thought to be the results of factors not related to the Nechako River. This is supported by similar trends in the Stuart River chinook stock.

Future Considerations: The "total population" of Nechako River chinook is made up of two groups, the adults that return to the Nechako River to spawn and those fish harvested in the ocean or in fresh water on their way to the Nechako River. It was not possible at the time the Agreement was drafted, nor is it possible now, to develop accurate data on the harvested group of salmon.

An alternative method that has been explored is to compare trends in escapement between the Nechako River chinook population with other Fraser River basin chinook populations that share similar spawning run timing and, presumably, similar harvest rates[93], in addition to the Stuart river population used by the committee. Similar changes in trends among several stocks would indicate some commonality in experience (*i.e.,* outside of the natal rivers). This is a variant of the "index stream" method that has been applied with varying degrees of success to salmon stocks throughout British Columbia.

10.7.1 Monitoring Habitat Quality as a Surrogate for the Conservation Goal

In 1986, the Department of Fisheries and Oceans adopted *Policy for the Management of Fish Habitat* (DFO 1986, updated in 2003). This policy, which includes a hierarchy of preferences for protecting or replacing the productive capacity of fish habitat, helped establish the context of the *1987 Settlement Agreement*.

One of the objectives of the NFCP has been to use indirect indicators to evaluate the capacity of Nechako River fish habitat (or habitat quality) in the context of the Conservation Goal. Estimating fry emergence [see *ss. 6.1 Fry Emergence Project*] and juvenile out-migration [see *ss. 6.2 Juvenile Chinook Out-migration Project*] are two examples of this approach. While the expected changes in flow contemplated as part of the proposed Kemano Completion Project have not occurred, the indices developed to evaluate the effects of

[93] There was general agreement at the February 1998 NFCP Workshop that as an alternative or additional method the NFCP could compare trends in Nechako chinook escapement with those of other Fraser River stocks.

flow changes can be used as a means of assessing the stability of the habitat of this regulated river. The relationships developed over the program period serve this purpose.

Analysis of the indices indicates that from incubation through rearing to the returning adult spawners, the in-river conditions since the inception of the NFCP in 1987 have been consistent. For example:

1) Egg-to-fry survival
- emergent fry indices increase proportionately with the number of spawners upstream of the trapping site (there is no density dependence) indicating that the spawning habitat does not appear limiting;
- based on hatching time, size at emergence and condition, chinook life-history parameters appear normal; and
- based on the relationship between spawner numbers and emergent fry, and the gravel quality results, the quality of the incubation environment in the upper Nechako River has not shown any degradation over the study years and appears to be stable.

2) Egg-to-juvenile survival
- the timing of juvenile chinook out-migration has been consistent over the duration of the program;
- the number of fry leaving the system is directly and positively related to the number of spawners the previous year;
- the numbers of fry rearing in the river as reflected by catch-per-unit effort values is directly and positively related to the number of spawners the previous year; and,
- the numbers of fry produced in the Nechako River have generally resulted in numbers of return spawners within the values identified in the Conservation Goal.

This report presents the results of nearly two decades of intensive sampling and monitoring of Nechako River chinook salmon; it represents one of the most extensive data sets of its kind. The Nechako Fisheries Conservation Program's mandate to protect and conserve chinook salmon was implemented, and its mandate to achieve the 'Conservation Goal' was defined, in anticipation of the significantly reduced 'Long-Term Flows' that were expected to be released into the Nechako River as part of the Kemano Completion Project. However, that project was effectively cancelled in January 1995, and flows to the Nechako River will not be reduced to the level of the long-term regime. Regardless, monitoring should be considered as part of any future program, as the possibility exists that in-river conditions could change over time.

In spite of uncertainties associated with the considerable variability that exists external to the Nechako River (*i.e.,* ocean conditions and harvest rates), the habitat capacity of the upper Nechako River as measured through various indices has been shown to support reproduction and the early life stages of chinook salmon at numbers that result in the return of chinook salmon at the levels of abundance identified in the *1987 Settlement Agreement*. Consequently, it is the opinion of the Nechako Fisheries Conservation Program Technical Committee that the current in-river conditions examined by the committee are sufficient to sustain a population of chinook salmon that fluctuates generally within the "target population" range identified by the Conservation Goal.

The Nechako Fisheries Conservation Plan Steering and Technical Committees continue to function in their respective roles, managing the annual water allocation, implementing the Summer Temperature Management Program, enumerating chinook salmon returns to the river, and, as needed, continuing to evaluate the capacity of Nechako River fish habitat through fry emergence and out-migration projects in the context of the Conservation Goal. This work will continue until an alternate agreement, organizational structure or mandate is established.

Given that a defined schedule of water releases into the Nechako River has been established since 1980, and given the results of the work described in this report, the Nechako Fisheries Conservation Program Technical Committee concludes that the intent and spirit of the Conservation Goal has been met.

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