The Nechako Fisheries Conservation Program: Past, Present, Future

Prepared by the NFCP Technical Committee

NECHAKO FISHERIES
Conservation Program

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https://www.nfcp.org/

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Executive Summary

The Nechako Fisheries Conservation Program (NFCP) was created under the *1987 Settlement Agreement* between Fisheries and Oceans Canada, Rio Tinto (formerly Alcan) and the province of BC, to monitor and manage the environmental effects of the proposed Kemano Completion Project (KCP). Following cancellation of the KCP in 1995, the NFCP continued to operate in anticipation of the construction of a Kenney Dam Water Release Facility to moderate river temperatures during sockeye salmon migrations. As that proposal has not yet been implemented, the NFCP has subsequently scaled back its operations to a base program that includes Nechako Chinook escapement monitoring, operation of the Summer Temperature Management Program and the Annual Water Allocation.

The *1987 Settlement Agreement* defines a Chinook salmon Conservation Goal as a measure to monitor the sustained productivity of the Nechako River under flow regulation. The NFCP Technical Committee concluded in 2016 that:

> *"… it is the opinion of the [NFCP] 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."*
>
> and
>
> *"… the Nechako Fisheries Conservation Program Technical Committee concludes that the spirit and intent of the Conservation Goal has been met."*

This conclusion implies that the NFCP has achieved its mandate and opens the door to either sunset the NFCP, maintain the ongoing base program or to broaden the focus of the program to include additional partners that address newly emerging issues within the Nechako. In 2019, the Water Engagement Initiative (WEI) was established by Rio Tinto to engage First Nations, local stakeholders, and regulators in defining a future for the Nechako and its aquatic resources. Any future institutional arrangements for the NFCP would need to complement ongoing WEI activities.

Relevant fish and water management issues described in the present report for future consideration include: 1) marine effects on Nechako Chinook survival, 2) multispecies fisheries management and the Nechako hydrograph, 3) climate change and salmon thermal ecology, and 4) First Nations engagement.

Contents

Introduction

The Kemano Project began in the 1940's when the Aluminum Company of Canada Ltd. (Alcan) conducted investigations to construct the Nechako Reservoir and a diversion tunnel into the Kemano Watershed to generate hydropower for a smelter at Kitimat. A second phase of the project, the Kemano Completion Project (KCP), was reviewed and ultimately rejected by the Province of BC. Despite its cancellation, the KCP provided the impetus to establish the Nechako Fisheries Conservation Program (NFCP) to mitigate potential fisheries and flow effects in the Nechako River. The NFCP has been operating for 35 years and this report is intended to communicate NFCP activities over this time period as well as review related Nechako fisheries issues.

The name of the Nechako River stems from the Carrier name *Netʃa Koh which means "Big River"*; the system is vitally important to the First Nations living within the watershed and who rely upon Nechako salmon as an important component of food supply, culture, and ceremonial use. The two main salmon species that are exposed to the effects of flow regulation are Chinook and sockeye salmon. While these two salmon species provide the focus for NFCP management and research activities, there are other important Nechako fish species (e.g. Nechako White Sturgeon, the Nechako River fish community) which are outside the defined scope of the NFCP but are nevertheless of major conservation concern. These latter species are briefly summarized in the present report.

The objective of this report is to provide a historical review of the effectiveness of NFCP salmon conservation activities between 1987 through to the present and to provide a snapshot of Nechako River environmental quality in relation to flow regulation. Figure 1 shows a chronological sequence of events associated with the Kemano Project and the NFCP.

CHRONOLOGY OF DEVELOPMENT

1970s 1980s Alcan continued to investigate ways to use all of the water rights granted in the 1950 agreement.

1941 Origin of the Kemano Power Project when the BC government invited the Aluminium Company of Canada Limited to investigate developing a hydroelectric power project and establishing an aluminum industry on Canada's West Coast.

1948 - 1949 Preliminary engineering studies.

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. This agreement granted Alcan a conditional water lisence for power generation.

1951 - 1956 Construction and river flow diversion; reservoir full in 1956.

1967 Completion of Kemano powerhouse and the installation of eight generators to supply power to the Kitimat aluminum smelter and neighbouring communities (i.e., Kitimat, Terrace and Prince Rupert) paralleling the construction of the aluminum smelter.

1978 BC Hydro inter-tie reached Terrace from Prince George linking Kemano to the provincial power grid and allowing Alcan to sell power to BC Hydro.

1980 The Department of Fisheries and Oceans expressed concerns about Skins Lake Spillway releases during periods of below-average inflows. The department anticipated sockeye salmon 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 affect Chinook salmon.

1980 B.C. Supreme Court specified the flows to be released until the issue could be resolved. The court urged the DFO and Alcan to work together to reach a consensus.

1985 No consensus was reached on flow discharges particularly on the water releases required to conserve Chinook salmon. Alcan to returned to court to seek resolution.

1986 While preparing for the court case, the Nechako River Working Group, a task force comprised of scientists from DFO, the provincial environment ministry and Alcan and Chaired by UBC President David Strangway, investigated whether 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.

1987 The Working Group's Summary Report became the basis for the 1987 Settlement Agreement, the legal settlement of the dispute.

1987 The Agreement also created the Nechako Fisheries Conservation Program. The immediate focus of the program (1988 – 1994) was based on the premise 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.

1991 - 1997 A number of unforeseen events occurred...

- **May 1991** Federal Court Trial Division decision requires further environmental review of the Kemano Completion Project under federal guidelines.
- **May 1991** 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 BC-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 NFCP set out in the 1987 Settlement Agreement. This work has continued to the present albeit in a reduced fashion so as to meet the terms of the 1987 Settlement Agreement.

2005 NFCP Technical Data Review completed.

2007 - 2012 First NFCP Five Year Plan completed.

2012 - 2017 Second NFCP Five Year Plan completed.

2017 - 2019 Continuation of the core functions of the NFCP including the Annual Water Allocation, the Summer Temperature Management Program and annual Nechako Chinook escapement monitoring.

2018 In collaboration with the Upper Fraser Fisheries Conservation Alliance, publication of a joint report on Chinook and Sockeye Salmon Conservation in the Netƒa Koh (Nechako) River in Northern BC.

2019 Big Bar Landslide occurred.

2019 Commencement of Water Engagement Initiative by Rio Tinto

Figure 1. Chronology of the Kemano Project and the NFCP.

Kemano Project Description

The Kemano Power Project originated in 1941 when the British Columbia government invited the Aluminium Company of Canada Limited (Alcan; now Rio Tinto) to investigate the development of a hydropower project and the establishment of an aluminum industry on Canada's West Coast. Alcan carried out preliminary engineering studies in 1948 and 1949. These resulted in a proposed development (Figure 2) that included:

1. a dam in the Grand Canyon of the Nechako River;
2. a reservoir in the Tahtsa/Eutsuk drainage;
3. a spillway at Skins Lake;
4. two new communities (Kitimat and Kemano);
5. a tunnel through Mt. DuBose to a powerhouse in Kemano;
6. a transmission line from Kemano to Kitimat; and
7. an aluminum smelter (annual capacity of 270,000 tonnes) and a deep-water port at Kitimat.

Photo: Nechako Environmental Enhancement Fund.

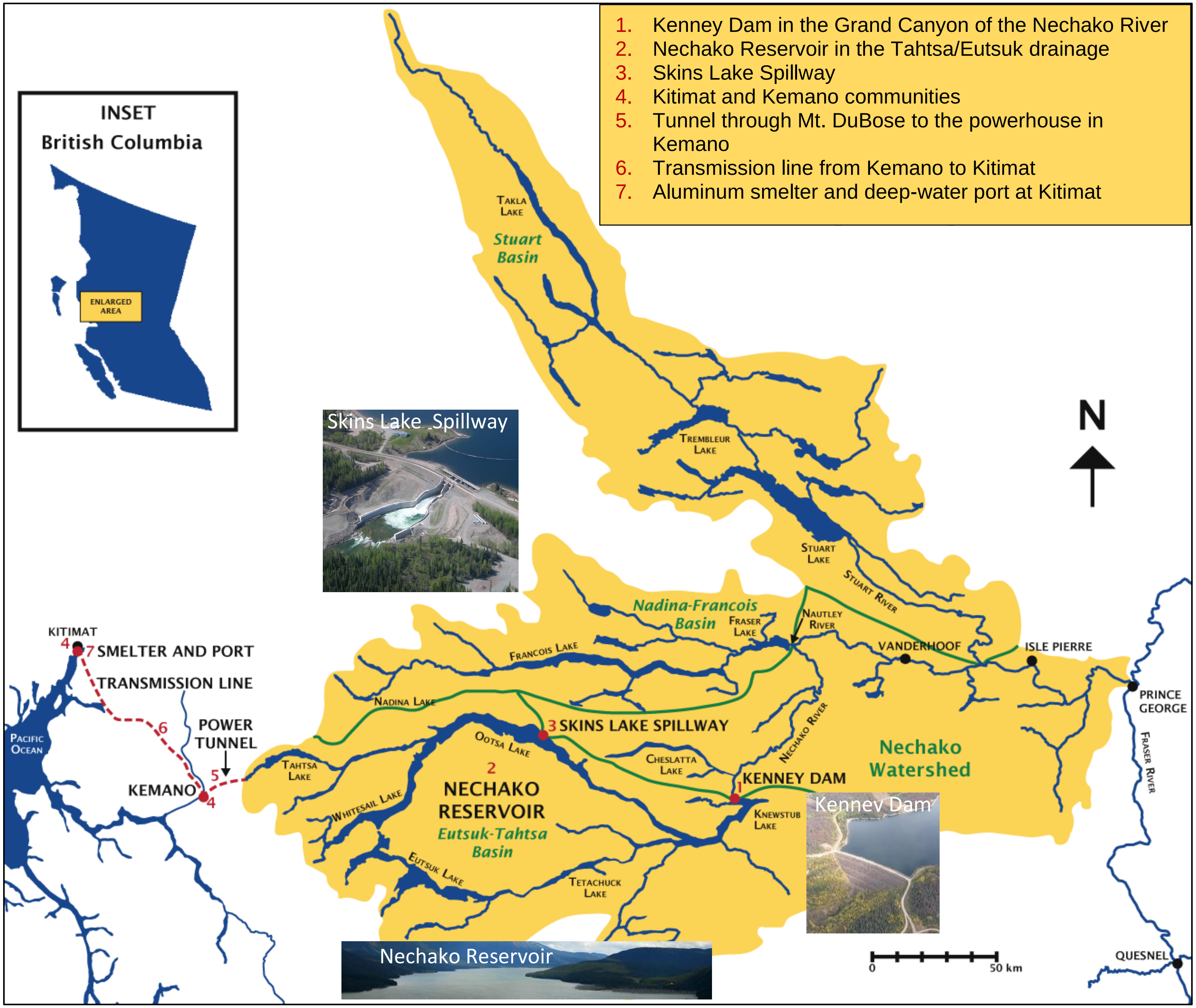

Figure 2. Nechako Watershed and Kemano Project components.

Kemano Completion Project

Alcan's conditional water license included a second phase of the development known as the Kemano Completion Project (KCP). The KCP was proposed to divert additional flows out of the Nechako and to construct diversions from the Nanika/Morice watersheds (Figure 3; part of the Skeena River Watershed) via a second diversion tunnel as well as a new powerhouse.

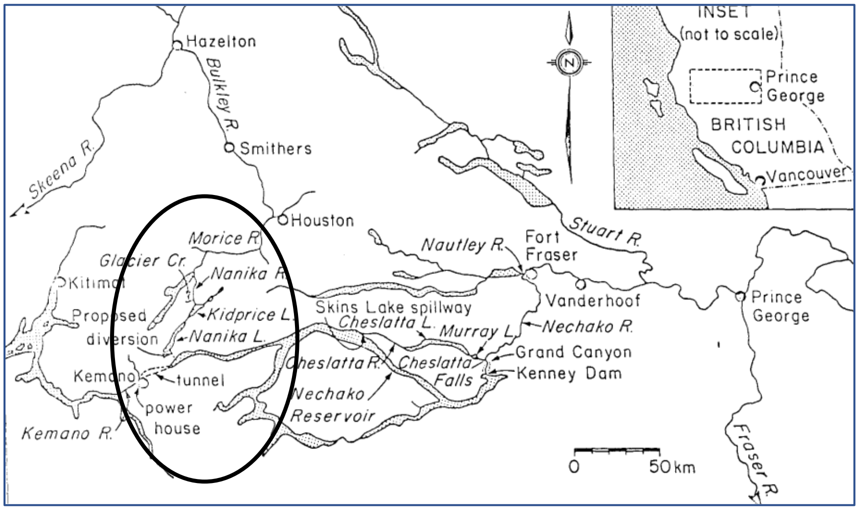

Figure 3. Map of the Nechako Reservoir and features of the Kemano Completion Proposal including diversion of the Morice-Nanika system.

Post KCP, the Project would have implemented the Proposed Long-term Release flows (orange bars on Figure 4). The additional water diversion flows would have reduced the mean annual Skins Lake Spillway discharge from 36.8 m^3/sec to 19.4 m^3/sec plus summer temperature control flows as required.

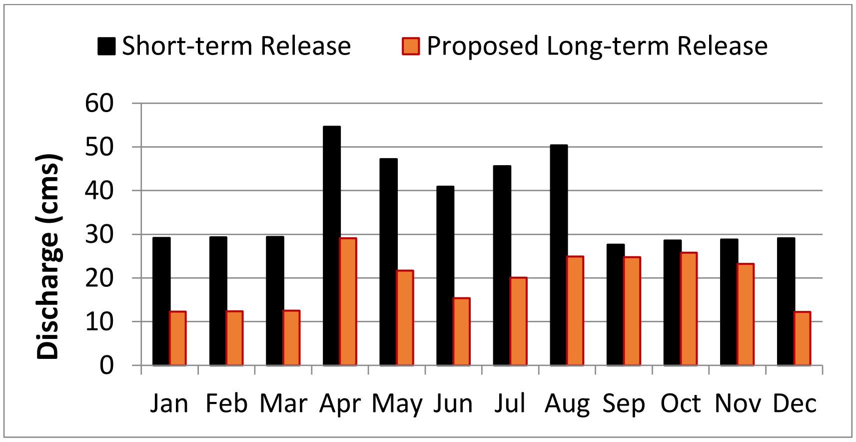

Figure 4. Water releases from the Skins Lake Spillway, not including summer cooling flows. The proposed long-term releases were never adopted as described in the 1997 BC - Alcan Agreement[1].

[1] 1997 BC - Alcan Agreement

As part of the KCP, Skins Lake Spillway releases would be reduced (Figure 4) and would follow the proposed long-term release. Following approval and partial construction of the KCP the province cancelled the project in 1995 and the established "short-term" flows became the permanent flow releases.

Effect of the Kemano Project on Nechako River Hydrology

The effect of the diversion on the hydrology of the Nechako River is shown in Figures 4 and 5. Roughly 65% of the water flow has been diverted into the Kemano drainage and 35% flows into the Nechako River via the Cheslatta watershed. There are also differences in the "shape" of the hydrograph. Prior to reservoir impoundment in 1951 the freshet peaked in June-July and following construction and the establishment of the Summer Temperature Management Program the river flow has peaked in August in most years.

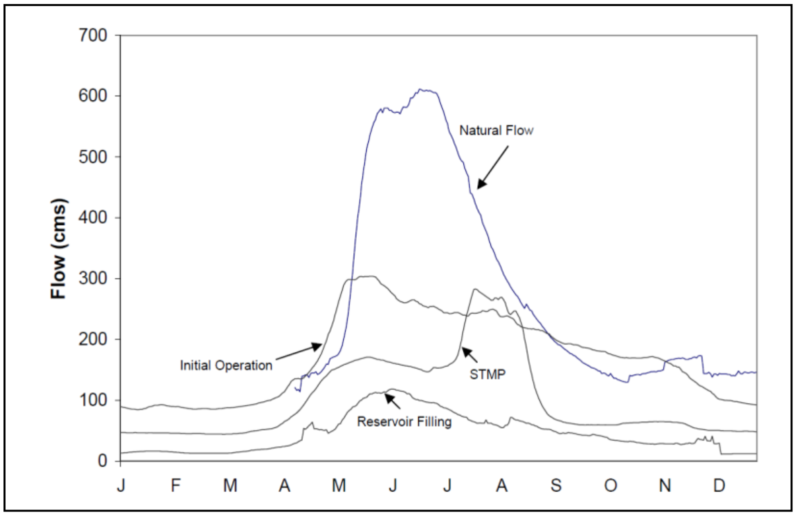

Figure 5. Mean daily discharge (cms) in the Nechako River at Vanderhoof. Data spans the pre-dam, natural flow period (1950-52), the extreme low flows when the reservoir was filling (1953-1956), the pre-STMP period during initial operation when greater water volume was released but releases where variable (1957-1982), and the present situation typified by more uniform releases of moderate volumes for a 30-day period for STMP cooling purposes (1983-2003). Source: Macdonald et al. (2007)[2].

1987 Settlement Agreement

Alcan's conditional water licence allowed the company 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[3]. The department anticipated sockeye salmon migrating through the Nechako River

[2] MacDonald et al. 2007

[3] NFCP Technical Data Report. 2005. https://www.nfcp.org/library

system would be exposed to high summer water temperatures resulting from low water flows and possibly affect Chinook salmon. Alcan and the DFO 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 be resolved.

A series of studies carried out between 1980 and 1984 attempted to resolve the issues. By 1985, a consensus still had not been reached and the parties returned to court to seek resolution.

While preparing for the court case, the Nechako River Working Group, a task force comprised of scientists from DFO, 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*, the legal settlement of the dispute.

The *1987 Settlement Agreement*[4] defined a program of measures, including water releases from the Nechako Reservoir, that were intended to ensure the conservation of Nechako River Chinook salmon and to protect migrating sockeye salmon populations. The *Settlement Agreement* specified the continued use of Alcan's operations model and associated protocols for reaching daily decisions on the volume of water to be spilled during the summer months[5]. The model was developed and implemented in the early 1980s to predict water temperatures and to calculate the volume of cooling water required to moderate water temperatures at Finmore, close to the Nechako-Stuart confluence.

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 *Nechako River Summary Report*, appended to the Settlement Agreement, states that:

> *The 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*[6]*.*

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[4] 1987 Settlement Agreement

[5] NFCP Methods

[6] The NFCP has not directly estimated Nechako Chinook harvest and en-route mortality. Escapement estimation has served as the main monitoring tool.

The Agreement also created the Nechako Fisheries Conservation Program (NFCP). The immediate focus and much of the early work of the program (1988 – 1994) was based on the premise that the Nechako River flow regime would change from the then-current "Short-Term Annual Water Allocation" to a "Long-Term Annual Water Allocation". The *Settlement Agreement* also proposed a Kenney Dam Release Facility (KDRF) designed to mitigate adverse effects of the KCP and to provide environmental benefits in the Nechako Canyon downstream of Kenney Dam and in the Murray-Cheslatta system (Appendix 1).

The Nechako Fisheries Conservation Program

The Nechako Fisheries Conservation Program (NFCP)[7] has three general goals.

- Nechako Chinook salmon conservation;
- Manage the operation of the computer models and flow release protocols necessary to protect migrating sockeye salmon in the Nechako River; and,
- Manage water releases consistent with the Annual Water Allocation in the *Settlement Agreement*

An Early Warning Monitoring Program was also developed in anticipation of the lower flows that would have resulted from the proposed KCP. The program used data from annual juvenile Chinook monitoring projects to assess trends and would be used to trigger remedial activities post-KCP if those trends suggested that adult Chinook returns four to five years later would be significantly compromised.

After 1995 when the KCP was cancelled by the Province of BC the NFCP continued to operate in anticipation of altered flows associated with a potential KDRF. Subsequently, the NFCP undertook activities in accordance with the *Settlement Agreement*, but began to reduce its level of activities starting in the early 2000's. The program was scoped down in 2005 and 2012 and most recently in 2015 when the program was re-designed to focus only on core elements: Summer Temperature Management Program (STMP), Annual Water Allocation (AWA) and Chinook monitoring. Over the years many hundreds of studies and reports have been prepared and the Nechako (Table 1) and its' salmon populations and habitats are one of the most intensively studied salmon ecosystems in BC. The tables below show the types of reports, available on the NFCP Web-site, that have been produced by the NFCP.

[7] The NFCP Technical Committee is comprised of individuals representing the Canadian Federal Government (Fisheries and Oceans Canada), the British Columbia Provincial Government (Ministry of Forests, Lands and Natural Resource Operations), Rio Tinto and one independent member who chairs the Committee. The Technical Committee maintains the NFCP web site (www.nfcp.org) which serves as a repository for Decision Records, Annual Reports, Steering Committee Briefing Documents, Technical Reports, Five Year Plans and Annual Brochures.

Table 1. Types of NFCP reports.

Type of Report	
NFCP Annual Reports	Summer Temperature Management Program
Steering Committee Annual TOR Reports	Implementation and monitoring of habitat complexes
NFCP Annual brochures	Sand mapping
NFCP 5-year plans	Pilot fertilization reports
Chinook enumeration Nechako R.	Physical data summaries
Chinook enumeration Stuart R.	Cross-sectional survey of the Nechako River
Chinook carcass recovery Nechako R.	Riparian zone
Chinook carcass recovery Stuart R.	Winter physical conditions
Chinook fry emergence	Dissolved oxygen monitoring and substrate quality
Chinook juvenile outmigration	Evaluation framework and trend analysis
Chinook winter habitat utilization	Murray-Cheslatta data collection
Flow control	Technical Data Review

Table 2. NFCP activities and reports covering the period 1988 – 2020. Reports can be accessed at https://www.nfcp.org/

Sumary of NFCP Activities

	Summer Temperature Management Program	Annual Water Allocation	Chinook Escapement Nechako	Chinook Biological Sampling	Chinook Escapement Stuart	Chinook Fry Emergence	Chinook Juvenile Outmigration	Nechako Sediment Quality	Nechako Instream Habitat Modifications	Annual Reports	Summary Reports
1988											
1989											
1990											
1991											
1992											
1993											
1994											
1995											
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1998											
1999											
2000											
2001											
2002											
2003											
2004											
2005											Technical Data Review
2006											
2007											5 yr Plan 2007-2012
2008											
2009											
2010											
2011											
2012											5-yr Plan 2012 - 2017
2013											
2014											PG Citizen
2015											Ck Escapement Trends
2016											NFCP Historical Review
2017											
2018											UFFCA/NFCP Report
2019											
2020											

Remedial Measures

Summer Temperature Management Program

The objective of the Summer Temperature Management Program (STMP) is to moderate elevated water temperatures during sockeye migrations by manipulating the timing and volume of discharge through Skins Lake releases, into the Nechako River. The 1987 *Settlement Agreement* defines specific water temperature targets and protocols using computer modelling and weather forecasts to effectively reduce temperature-related risks during the migration period (see NFCP Methods). Gate changes at the Skins Lake Spillway are used to manage flows throughout the year and water temperatures in the Nechako River from 20 July to 20 August. The goal is to minimize occurrences of water temperatures above 20 °C in the Nechako River at Finmore (upstream of the Stuart River confluence).

The Technical Data Review (NFCP 2005) evaluated the effectiveness of the STMP between 1983 - 2000 to moderate mean daily temperatures at Finmore and concluded that the program limited the frequency of occurrence of temperatures >20ºC in the Nechako River. Over this period Nechako River temperatures rarely exceeded 20ºC even though meteorological conditions warmed over the study period. It was found that that the frequency of water temperatures more than 20ºC was similar to that recorded in a cooler period prior to the implementation of the STMP. Results from more recent temperature monitoring (Figure 6) show the frequency of exceedances above 20ºC measured at Finmoore close to the Nechako-Stuart River confluence.

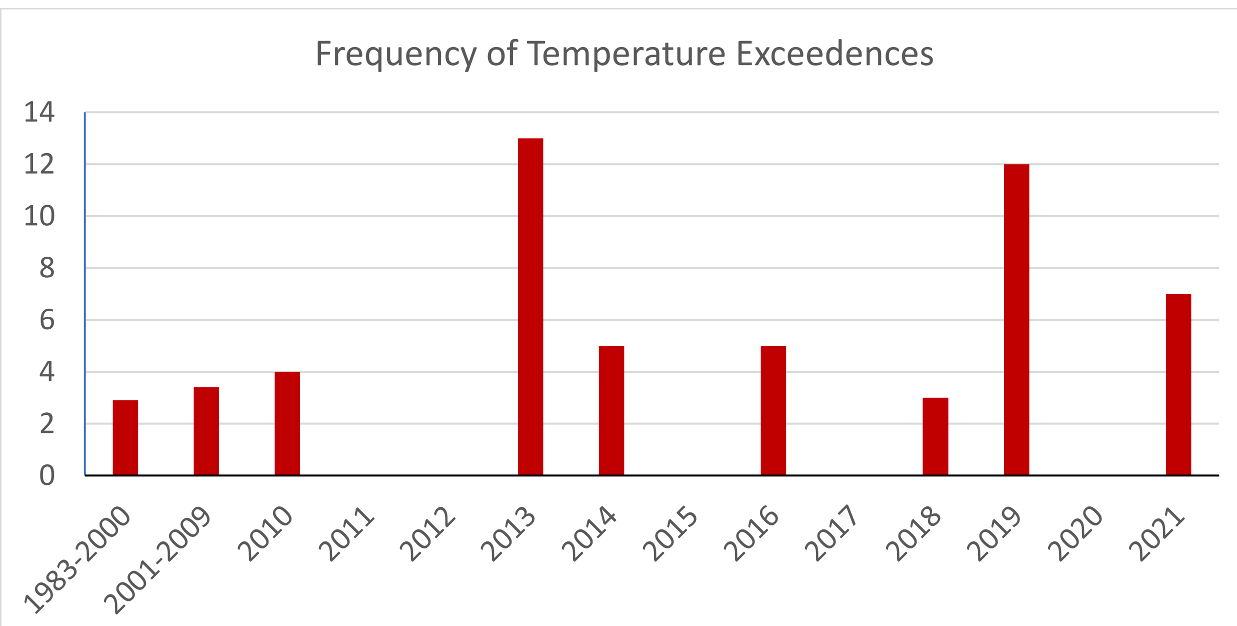

Figure 6. Temperature exceedances during the July 20 – August 20 STMP Control Period.

In some years (e.g. 2011, 2012, 2022) the STMP was not operated, as reservoir management releases due to high snow pack exceeded the STMP protocol maximum discharge in the Nechako below Cheslatta Falls for all of July and until August 20.

STMP exceedance frequency needs to be interpreted with caution due to climate change and regional warming within the Fraser Watershed in general, and the Nechako Watershed in particular. The University of Northern British Columbia (UNBC) is conducting climate change research in the Nechako Watershed and conveying its results to the Water Engagement Initiative.

The effectiveness of the STMP was demonstrated in 2019 when the BC Comptroller of Water Rights ordered Rio Tinto to suspend STMP flows to mitigate salmon passage at the Big Bar slide (Figure 7). The Nechako River temperature increased from 17.7°C on Aug. 3 to 21.5°C on Aug. 8 when the STMP was re-started. Thereafter the river temperature declined below the 20°C target. The responsiveness of river temperature to discharge volume provides support for the efficacy of the STMP, a conclusion that was also reached by MacDonald et al. (2007)[8].

Annual Water Allocation

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 was specified in the *Settlement Agreement* to ensure a post-KCP minimum mean annual discharge of 19.4 m^3/s at Skins Lake Spillway. Following KCP cancellation the flows have been maintained at a minimum mean annual release of 36.8 m^3/s. During years when there is a large snowpack mean annual releases can be significantly greater than 36.8 m^3/s.

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 Data Collection Platform Station 08JA017. Over time, the NFCP has developed a set of flow release schedules to optimize water releases via the Skins Lake Spillway.

The Technical Data Review (TDR) concluded that the protocol for flow releases from the Skins Lake Spillway has worked well. The AWA releases through the spillway have consistently exceeded 36.8 m^3/s annually, to the present. The average flow of 41.7 m^3/s at Station 08JA017 hasn't been consistently achieved due to assumption errors related to Cheslatta watershed natural inflows. The discrepancies are minor, and the TDR concluded that the biological consequences for water depth are not significant.

[8] MacDonald et al. (2007)

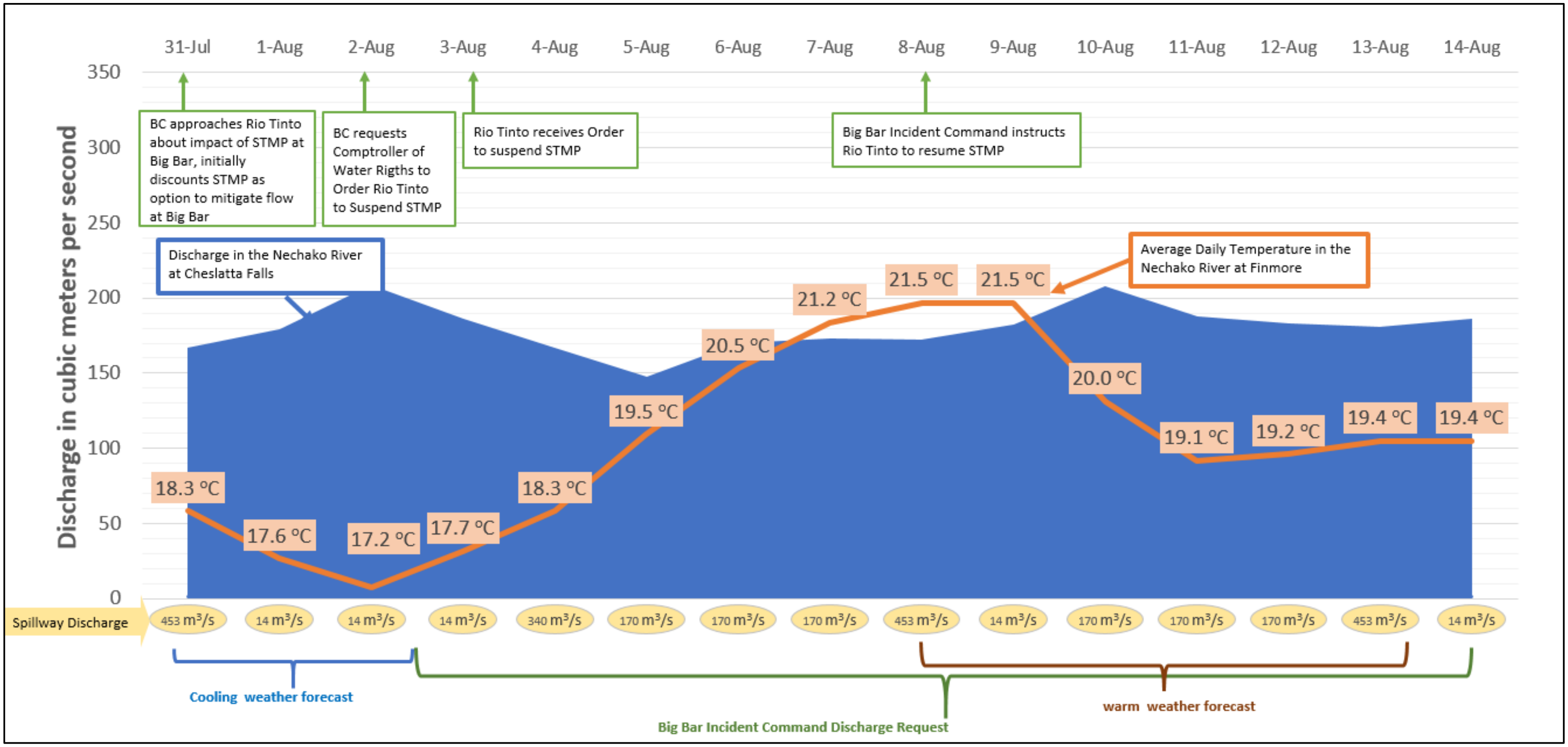

Figure 7. Spillway discharge, discharge in the Nechako River at Cheslatta Falls and average daily water temperature in the Nechako River at Finmore in August 2019. Graphic prepared by Justus Benckhuysen, former Rio Tinto Environmental Manager.

Other Remedial Measures

Previously the NFCP undertook a suite of remedial measures designed to provide capacity for ensuring Chinook conservation following implementation of the Long-Term Water Allocation of 19.4 m^3/s and the operation of a Kenney Dam Release Facility. Their effectiveness was tested to provide the means for a management response to any observed reduction in salmon productivity. The remedial measures weren't continued on a long-term basis following cancellation of the KCP.

The suite of remedial measure projects conducted by the NFCP is listed below.

Remedial Measure	Objective	NFCP Conclusion
Instream Habitat Modifications Project (Figure 8)	This project focussed on increasing Chinook rearing habitat complexity by constructing rearing habitat complexes.	Assessment of man-made structures led to a conclusion that man-made structures can be placed in the Nechako River to provide rearing habitat equivalent to natural structures.
Riparian Bank Stabilization Project	This project was undertaken in anticipation that lower flows under the Kemano Completion Project could reduce sediment transport leading to increased sedimentation and degradation of Chinook spawning and rearing habitat.	The study showed that riparian vegetation could potentially be used to stabilize the banks of the Nechako River and its tributaries, thereby reducing sediment input to the river.
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.	While the project was designed to support flow management decisions associated with the KCP, the Murray Cheslatta forecast procedure provides a useful forecasting tool that can be potentially applied for water management in the Nechako River.
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.	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.

Remedial Measure	Objective	NFCP Conclusion
Identifying and Ranking Sources Contributing Sediment to the Upper Nechako River	Develop and rank an inventory of sediment sources to use in reaching decisions on the necessity and priority of controlling sediment contributions from individual sources.	Active erosion occurred at approximately 38 sites along the upper river, but only a few sites contributed most of the annual supply. The measured Nechako River sediment loads were similar to those of other regulated or lake controlled systems.
Riverbed Survey[9]	Numerical modeling of the water surface profile of the Nechako River	The high incidence of warnings in the model output indicated that consideration should be given to adding cross sections for improved accuracy in those river reaches which appear particularly important for fisheries management.
Nechako River Sand Mapping Project	The Nechako River Sand Mapping Project involved: 1) locating major sand beds upstream of the Nautley River; 2) defining the upstream and downstream limits of major sand beds, and marking them on 1:7,500 airphoto mosaic sheets; and 3) collecting samples of riverbed material from each major sand bed and characterizing the grain size distribution.	Three types of sand beds in the Upper Nechako River were defined: major deposits, minor sand beds, and local sand beds. Major sand beds were thick and extended across the channel and for several km along the river. A previously documented minor sand bed wasn't found in 1990, suggesting that sand is mobile under the present flow regime and may form and disappear seasonally.
Literature Review: Winter Remedial Measures	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.	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.

[9] McIntosh (1991) documented river survey procedures and detailed survey results.

McIntosh, W.D. 1991. Technical Report to accompany 1990 river survey for Nechako Fisheries Conservation program (NFCP).

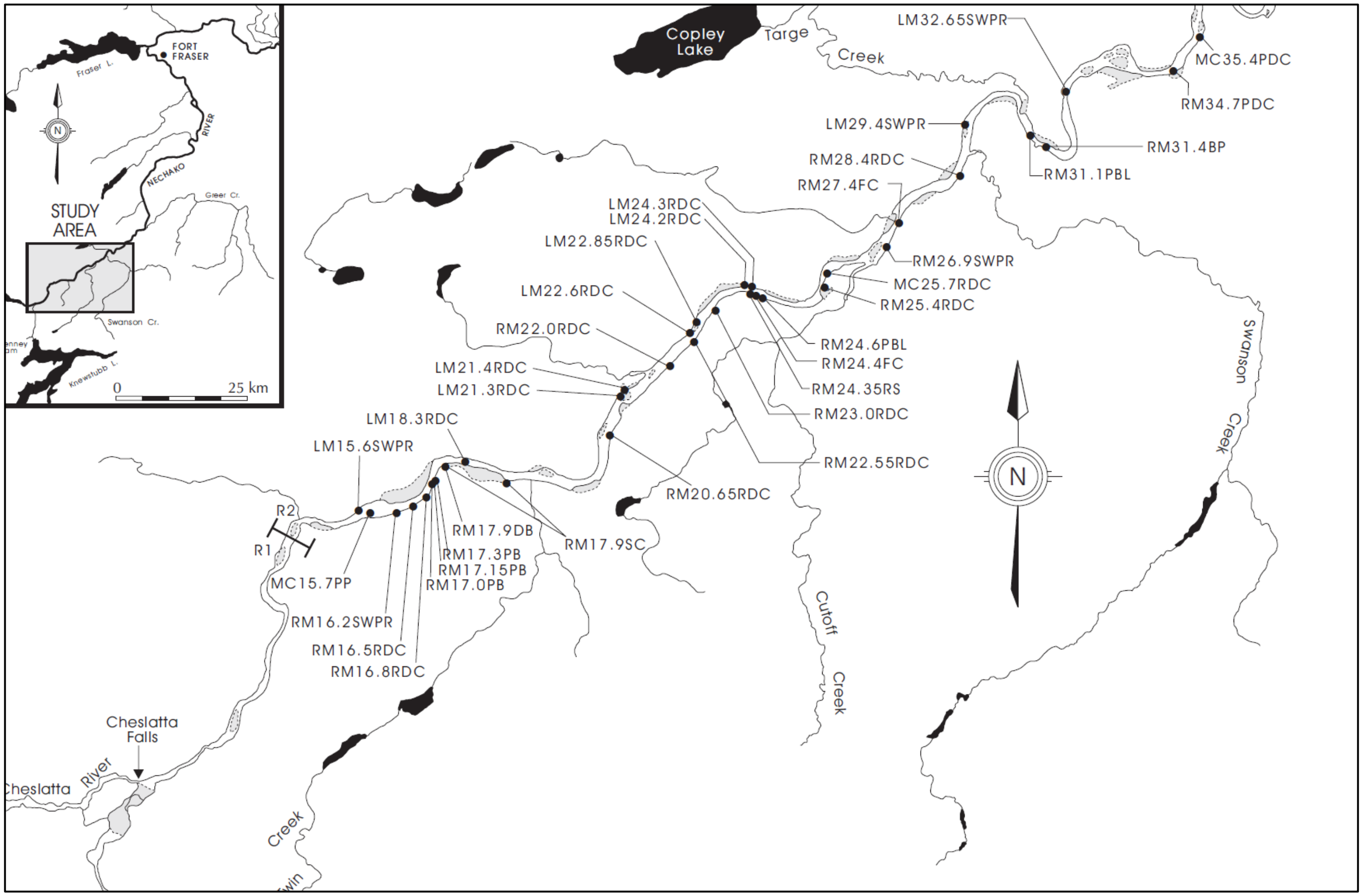

Figure 8. Location of Instream Habitat Modifications in the Upper Nechako River designed to provide managers with the ability to mitigate potential habitat losses in the Nechako Mainstem.

Structures that were tested included: 1) Debris Bundles - Rootwad Sweepers; Brush Pile; Floating Cribs; Pseudo Beaver Lodges; Deep Water Sweepers; 2) Debris Catchers - Channel Jacks; Pipe-Pile Debris Catchers; Rail Debris Catchers and 3) In-stream Modifications - Excavation of a side channel, complexed with debris bundles, and a debris boom; Construction of point bars with back eddy pools on the Nechako River shoreline.

Following testing, the structures were removed from the river.

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 NFCP Technical Committee oversaw a series of applied research projects designed to fill these gaps. The objective of the applied research was to incorporate the products of the projects into the design and implementation of the remedial measures. The following research projects were undertaken:

1. Predator/Competitor/Prey Interactions

Research was directed at identifying potential fish and avian predators, and the risk of predation on juvenile Chinook. Research was undertaken via a literature review and field studies. The research identified six of 20 resident fish species as predators and six others as potential predators. Avian predation was dominated by two species.

A literature review on competition/predation in streams with reduced flows (Bruce 1991)[10] 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.

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

[10] Bruce, J.A. 1991. Review of literature on competitive and predator-pre interactions with juvenile salmonids in the context of reduced stream flows. Aquatic Resources Ltd. Draft report prepared for the NFCP.

- rainbow trout (*Oncorhynchus mykiss*) consumed the widest range of prey, primarily drift insects (Brown *et al.* 1992)[11].

Brown (1995[12]) concluded 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.

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[13]). 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)[14]. 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).

2. Juvenile Chinook Winter Habitat Use

Over-wintering studies were carried out from 1988 to 1990. SCUBA diving and electrofishing studies were undertaken to document juvenile chinook over-wintering

[11] Brown, T.G., B. Bravender, P. Dubeau, and R. Lauzier. 1992. Initial survey: Stomach contents of potential fish predators of juvenile chinook salmon (Oncorhynchus tshawytscha) in the Nechako River, B.C. Can. MS Rep. Fish. Aquat. Sci. 2141: 33p.

[12] Brown, T.G. 1995. Stomach contents, distribution and potential of fish predators to consume juvenile Chinook salmon in the Nechako and Stuart Rivers, BC. Can. Tech. Rep. Fish. Aquat. Sci. 2077: 39 p.

[13] Brown, T.G., L. Rzen and E. White. 1995. Survey of piscivorous birds of the Nechako and Stuart Rivers, BC. Can. MS. Rept. Fish. Aquat. Sci. 2285: 26p.

[14] Brown, T.G., E. White, D. Kelly, L. Rzen, and J. Rutten. 1994. Availability of juvenile chinook salmon to predators along the margins of the Nechako and Stuart rivers, B.C. Can. MS. Rep. Fish. Aquat. Sci. 2245: 34p.

behavior throughout the upper Nechako River with overwintering more common in the uppermost section. The research was designed to assess diel behavior and activity, habitat utilization, distribution, growth and feeding behavior.

Juvenile 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. 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[15]. Stomach content analyses showed that chinook fed predominantly at dawn on aquatic insects, such as nymphs (*Ephemeroptera*) and 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[16].

3. Temperature Effects on Food and Fish Growth

There was 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. 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[17]. Benthic invertebrates, the predominant prey for chinook salmon fry, showed the most increase in abundance with the addition of nutrients.

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[15] Emmett, B., L. Convey and K. English. 1992. An early winter survey of juvenile Chinook in the Nechako River. Prepared by Archipelago Marine Research Ltd. for the NFCP. Draft report

[16] Emmett, B., L. Convey and C. Shirvell. 1990. Overwintering of juvenile chinook in the Nechako River 1989/90 Studies. Prepared by Archipelago Marine Research Ltd. for the NFCP. Draft report

[17] Perrin, C.J., and J.S. Richardson. 1997. N and P limitation of benthos abundance in the Nechako River,British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 54: 2574-2583.

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. The model would then be used to assess the effects of management actions (*e.g.*, reductions in flow, habitat enhancement, stream fertilization). 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 led to identifying individual markers for the Nechako River chinook stock. These markers may be used to define Fraser River migration 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. According to information provided by DFO 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)[18]. 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.

<u>Conclusions - Applied Research</u>

The results of the applied research projects complemented the Technical Committee's understanding of fish habitat use and species interaction on the Nechako River. While it was recognized that additional work could be done to provide more information on Nechako River ecology, with the cancellation of the KCP the applied research program was concluded.

Monitoring

Chinook are present in the Nechako River throughout the year and utilize river habitats for adult migration, spawning, egg incubation, alevin development, juvenile rearing and juvenile migration. They are potentially sensitive to flow regulation at all of these different life history stages. Following hatching the juvenile Chinook outmigrate either as fry in March - May, as fingerlings later in April - July or as yearling smolts in the following spring. Over 99% of Nechako Chinook spend their first summer and winter in freshwater before going to sea in their second year of life. 5-year-olds are the dominant age class, followed by four-year-olds. In some years,

[18] Bradford, M.J. 1994. Trends in the abundance of chinook salmon (Oncorhynchus tshawytscha) of the Nechako River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 51: 965-973.

4-year-old Chinook predominate. Small numbers of 3-year old, 6-year old and 7-year old fish also occur in the Nechako population.

Chinook spawn in the mainstem of the Nechako River between Vanderhoof and Cheslatta Falls typically between the end of August and early October. Chinook spawning locations are fairly evenly distributed, with highest numbers in the Upper Nechako about 20 km downstream of Kenney Dam.

Adult Chinook

Nechako River Chinook are monitored annually in relation to the Conservation Goal. Spawner abundance estimates after 1988 were carried out using Area-Under-the-Curve methodology. Prior to 1988, spawner counts were obtained by DFO Fishery Officers using less rigorous methods (Jaremovic and Rowland 1988[19]). The Area-under-the-Curve (AUC) method used periodic helicopter counts of spawner numbers during fall Chinook spawning and annual estimates of the time female spawners spent on the redd (residence time) in the calculation of the spawner population size. Sampling of Nechako Chinook carcasses was formerly conducted annually by the NFCP to collect biological data on age, size, life history, sex and egg retention.

The NFCP monitoring program was initially designed to comprehensively monitor all life history stages in all years. Over time, this approach was streamlined, based on experience and empirical evaluation, to create efficiencies in program delivery.

In 2007, the Technical Committee concluded that, based on the results of analyses shown in the 2007-2012 Five Year Plan, use of the mean residence time (10.6 days) in AUC calculations would suffice to produce an adequately precise estimate of the spawner population. However, if the population was to approach the minimum level (1700) included in the 1987 Settlement Agreement, the Technical Committee would re-evaluate the necessity to revert to annual estimates of residence time.

Presently, Chinook escapements are monitored annually by DFO based on two helicopter overflights and an expansion to determine spawner population size.

In 1988 and subsequently, the NFCP monitored Stuart River Chinook using mark-recapture methods to measure and compare the population trends in an adjacent unregulated river system. During the 2005 Technical Data Review preparation, DFO Science Branch and Stock Assessment personnel advised the Technical Committee that they considered the technique used to enumerate the Stuart River Chinook escapement, both in theory and in practice, was highly variable and that its value in identifying future trends in the escapement would be limited. In response the Technical

[19] Review of Chinook escapements in the Nechako River

Committee discontinued the annual Stuart River monitoring project.

The primary monitoring tool that the NFCP relies upon to determine the effects of flow regulation on Nechako Chinook is the escapement time series (Figure 9).

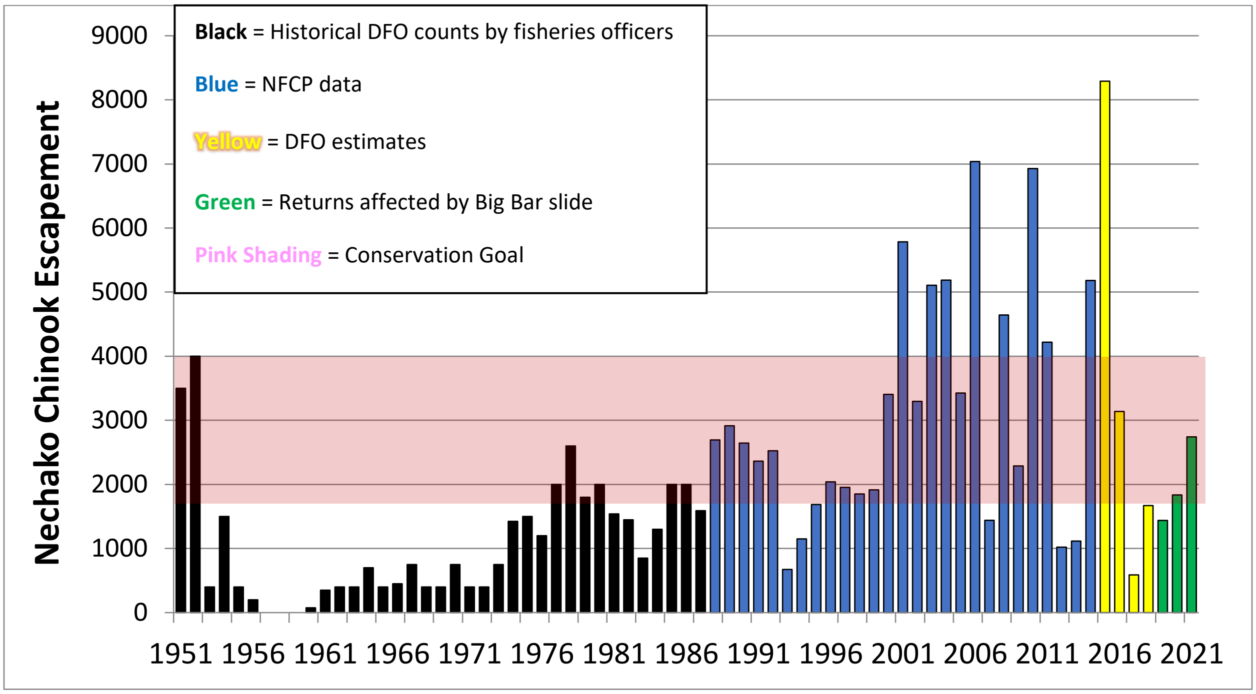

Figure 9. Nechako Chinook escapement time series between 1951 - 2021. Blue bars indicate NFCP monitoring data and black bars show pre-NFCP monitoring by DFO[20]. Yellow bars are estimates provided to NFCP by the Stock Assessment Division of DFO. The green bars are DFO estimates for returns affected by the Big Bar slide. The pink shaded area depicts the lower and upper target ranges of the Conservation Goal.

While most of the estimated escapements have occurred within the Conservation Goal target range, it remains difficult to determine the effects of water regulation on Nechako Chinook. There are no data available to determine fishing and natural mortality rates of Nechako Chinook in coastal and riverine fisheries such as those obtainable via coded wire tagging. The reason for this is the absence of a coded wire marking hatchery in the Nechako.

To address this shortcoming, the NFCP, in partnership with the Upper Fraser Fisheries Conservation Alliance (UFFCA), undertook a Chinook salmon run reconstruction to assess the sensitivity of monitoring Nechako Chinook escapement as an index of Nechako run size and the population's status. Figure 10 shows the time series of standardized run size and standardized

[20] Jaremovic and Rowland (1988)

escapement[21] estimates for both Nechako Chinook and the mean for 3 reference stocks: Cariboo, Quesnel, and Chilko.

Polynomial regressions for these data (Figure 10) reflect an upward trend in both the Nechako (black lines) run sizes and escapements relative to a polynomial curve for the standardized 3-stock run sizes and escapements. Based on the similarities in the run size and escapement patterns, the NFCP concluded that the escapement enumeration approach has provided a sensitive and reliable indicator of the status of the Nechako Chinook spawner population.

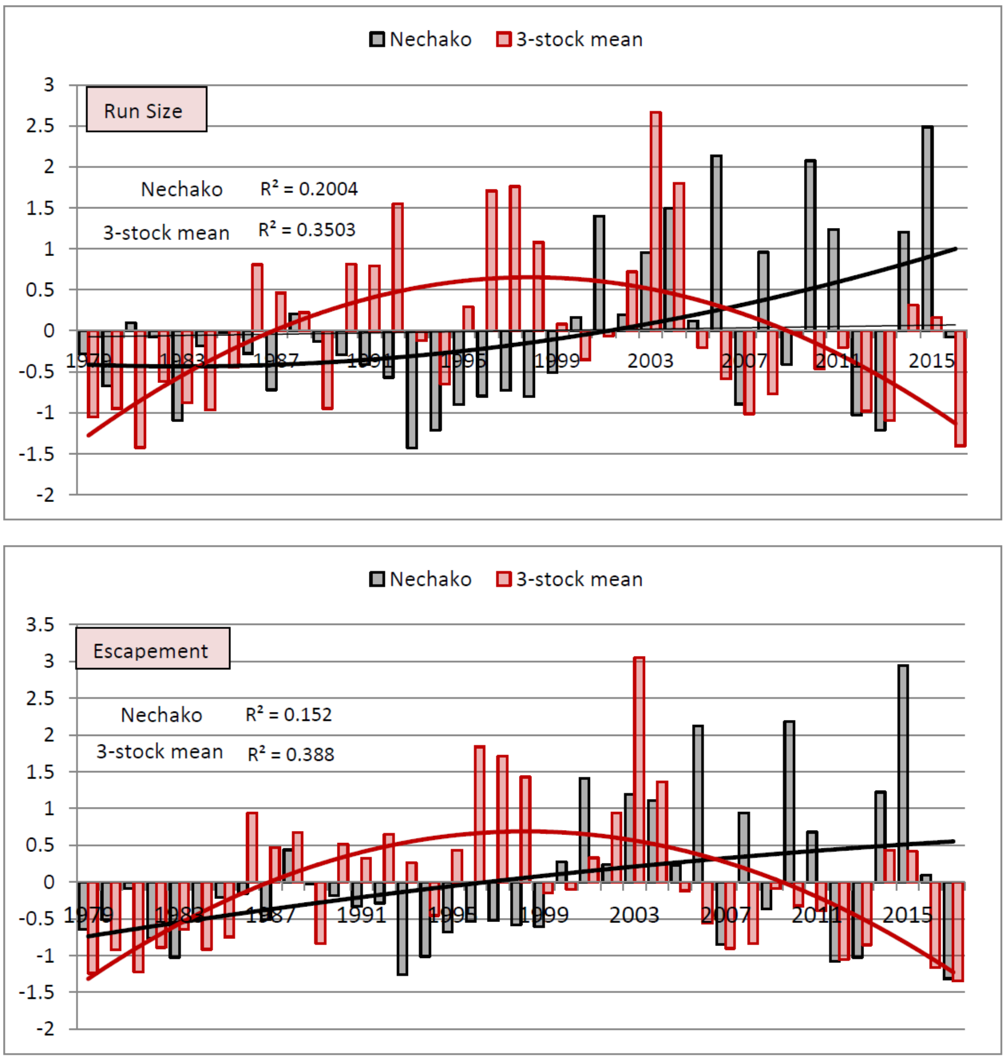

Figure 10. Standardized Chinook run size estimates and comparative 3-stock (Chilko, Quesnel and Cariboo Chinook stocks) run sizes (upper) and escapements (lower). Curves are polynomial fits to the histogram data.

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[21] a normalized value from a distribution characterized by the mean and standard deviation. This adjustment was applied to permit comparisons of escapement trends between stocks of different productivity.

Juvenile Chinook

Juvenile Chinook emerge as free-swimming fry from March to May. During previous NFCP assessments, separate programs were run to sample emergent fry in mid-March through mid-May using Inclined Plane Traps (IPTs) and migrating fingerlings between mid-April through mid-July utilizing Rotary Screw Traps (RSTs) and electrofishing.

Fry Emergence

The objectives of the Fry Emergence 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 following implementation of the Kemano Completion Project.

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

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

There was a strong linear relationship (Figure 11) between the number of female spawners in Year (x) and the index of fry emergence in Year (x+1). The R^2 value of the data set was 0.8636, a strong correlation.

The stability of the relationship over time suggests that intra-gravel habitat conditions for egg and alevin development remained suitable for fry production over the observation period and that flow regulation didn't induce a deterioration of habitat quality over time.

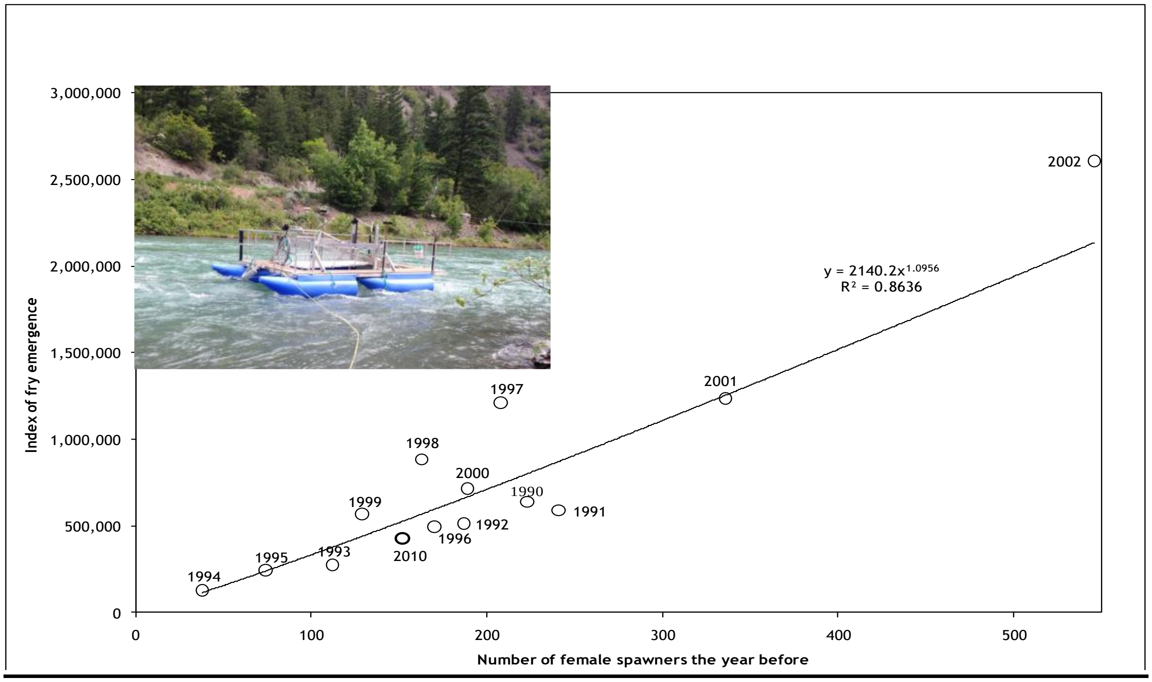

Figure 11. Index of fry emergence vs. spawner escapement during the previous year above Bert Irvine's, km 19 of the Nechako River, 1990-2002, and 2010.

Juvenile Outmigration

The Juvenile Outmigration Project was designed to monitor key components of juvenile Chinook population biology including relative abundance, average size and spatial distribution. The project was designed as an indicator for the condition of juvenile rearing habitat.

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 outmigration; 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, growth and condition.

The relationship between the number of spawners above Diamond Island and the index of juvenile outmigrants was curvilinear (Figure 12) with a R^2 value of 0.83, a strong correlation. These results suggest that rearing habitat conditions in the Nechako River remained stable over the period of observation (1992 - 2010).

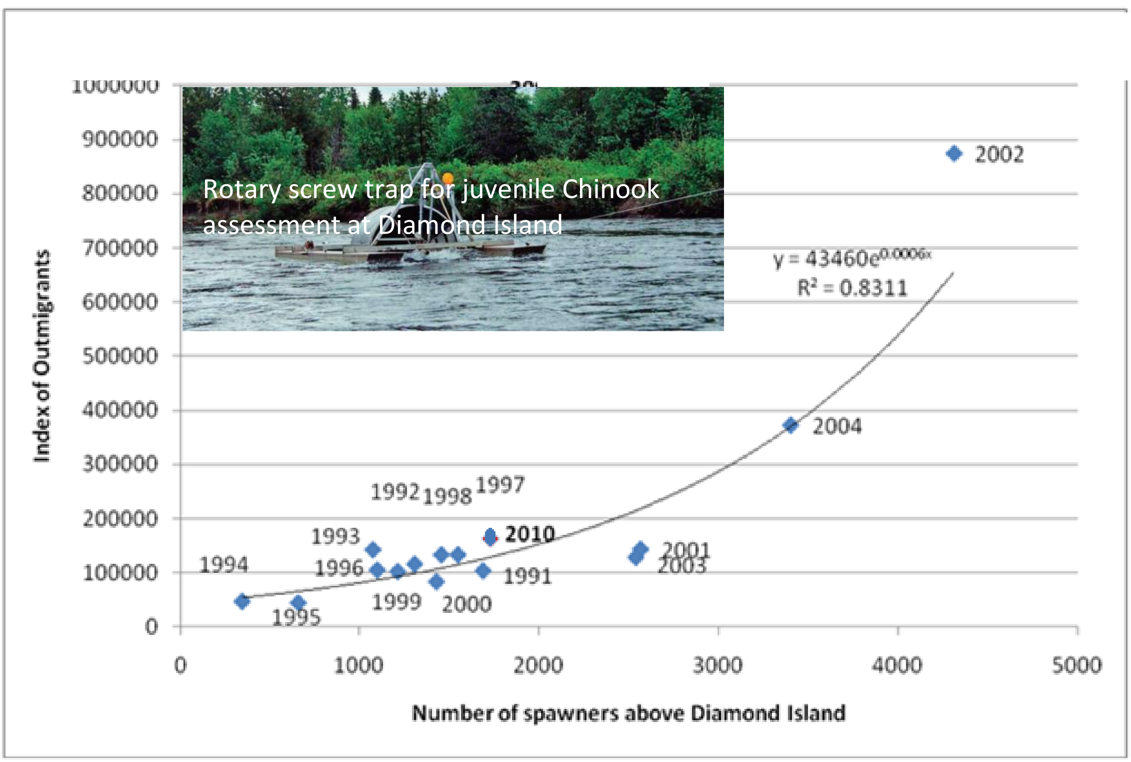

Figure 12. Index of Chinook salmon outmigrants based on rotary screw captures vs. the number of spawners above Diamond Island the previous year, Nechako River 1992-2004 and 2010.

Sockeye Salmon

The 2017 COSEWIC (Committee on the Status of Endangered Wildlife in Canada) assessment of Fraser River sockeye[22] listed eight populations (Designatable Units; DUs) as *Endangered*, two as *Threatened* and five as *Special Concern*. The 24 Fraser sockeye DUs under COSEWIC are equivalent to the 24 Fraser sockeye Conservation Units under DFO's Wild Salmon Policy.

The main sockeye protection concern associated with water regulation in the Nechako River is related to high temperature effects on migrating adults. The following sockeye DUs utilize the Nechako River as a migration corridor during upstream adult/spawner migration and downstream smolt emigration.

Status	Designatable Unit	Nechako River Utilization
Endangered	Early Stuart	Migrates through lower Nechako, up Stuart River to spawning grounds
Endangered	Late Stuart	Migrates through lower Nechako, up Stuart River to spawning grounds
Special Concern	Francois	Migrates through lower and middle Nechako, up Nautley River to spawning grounds
Not at risk	Nadina (has spawning channel)	Migrates through lower and middle Nechako, up Nautley River to spawning grounds

Nadina sockeye return in two distinct run timing groups nested within the Early Summer management unit: Early Nadina and Late Nadina.

COSEWIC suggested that the *Endangered* Early and Late Stuart Sockeye designation was associated with their exposure to marine and freshwater threats which are causing habitat quality to decline. For Early Stuart sockeye the number of mature individuals has been declining steadily for over 20 years and despite reductions in fishing mortality, productivity is currently low. For Late Stuart sockeye the number of mature individuals has been declining steadily for 3 generations yet removals by fishing have remained high.

COSEWIC further assigned a threat impact of High - Medium for Early Stuart sockeye and identified several threats:

[22] COSEWIC. 2017. COSEWIC assessment and status report on the Sockeye Salmon *Oncorhynchus nerka,* 24 Designatable Units in the Fraser River Drainage Basin, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xli + 179 pp.

- Fisheries removals "because the Sockeye population from this DU is declining and fishing is likely contributing to the decline";[23]
- Depressed marine survival also poses a medium to low level of threat to this DU;
- Freshwater temperature extremes also pose a threat to sockeye from this DU;
- The Fraser River is expected to continue to warm throughout the 21st century which could lead to severe losses during adult migrations en-route to spawning grounds; and
- Warmer winters and earlier snow melt are expected with climate change and alterations in the timing of the freshet predicted to affect this early run time DU.

There are 3 Upper Fraser sockeye conservation units (Figure 13) that migrate upstream during early summer: Early Stuart, Bowron and Nadina sockeye. Nadina is an enhanced run with a spawning channel (constructed 1973) located at the western end of Francois Lake.

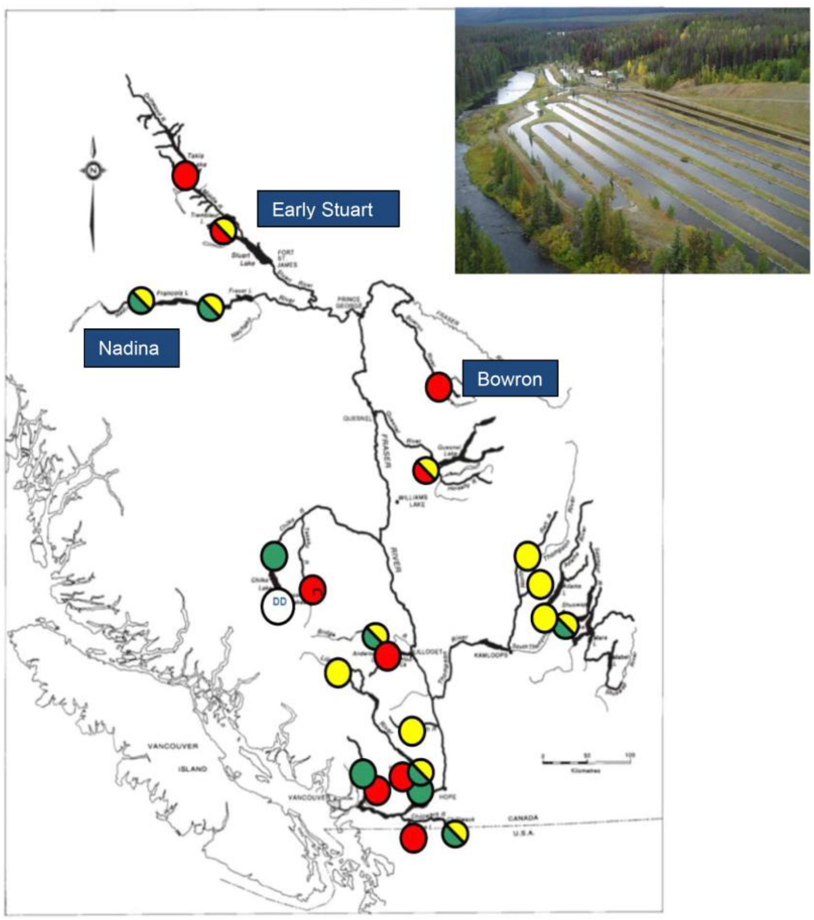

Figure 13. Three early migrating sockeye populations in the Upper Fraser: Bowron, Early Stuart and Nadina

[23] This statement in the COSEWIC report is likely inaccurate. DFO have adopted a conservative management strategy, including roiling window fishing closures, in order to conserve Early Stuart sockeye.

Fraser River Panel of the PSC (Pacific Salmon Commission) annually estimates the run timing of Fraser sockeye management groups as they migrate through Area 20 (the Straits of Juan de Fuca) and compares expected versus observed run timing in relation to previously observed cycle year median values. The run timing of the three early migrating sockeye stocks can be inferred from pre-season forecasts and post-season reconstructions (blue and red lines respectively on Figure 14) for migrations through Area 20, the Straits of Juan de Fuca. There is a time lag of approximately 10 days[24] between Area 20 and the Nechako River, exposing the tail end of the Early Stuart sockeye run to the thermal influence of the Nechako River around mid-July and the Early Summer run (including the Nadina run) between mid-July through mid-August.

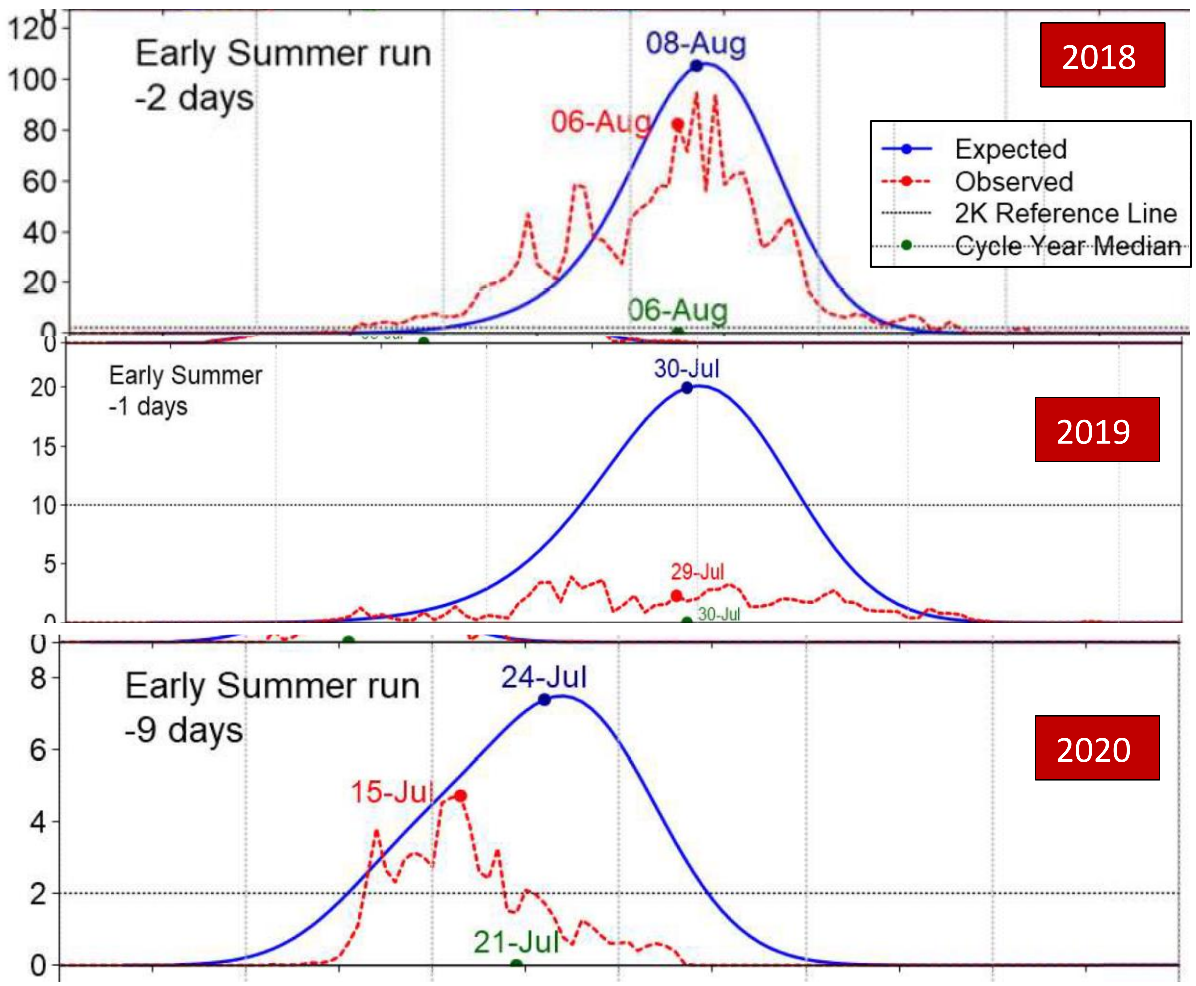

Figure 14. Area 20 (Straits of Juan de Fuca) Early Summer Sockeye run timing curves (includes Nadina sockeye) for 2018-2020. Source: Fraser River Panel of Pacific Salmon Commission.

[24] Modelling by Martens (Univ. of Northern BC) of the 795 km migration from the Fraser mouth to the Nechako and a median migration rate of the Nadina-Francois CU of 30.7 km/day yields 25.9 days and roughly 10 days can be added for passage between Area 20 and the Fraser mouth.

In terms of sensitivity and exposure to Nechako flow regulation, the Bowron population is unaffected since it is geographically separated from the Nechako and only experiences a small influence of flows from the Nechako River. The Early Stuart population is largely influenced by the Stuart River flows and to a minor extent by the Nechako River flows (Figure 15) by virtue of the higher discharge capacity in the Stuart River.

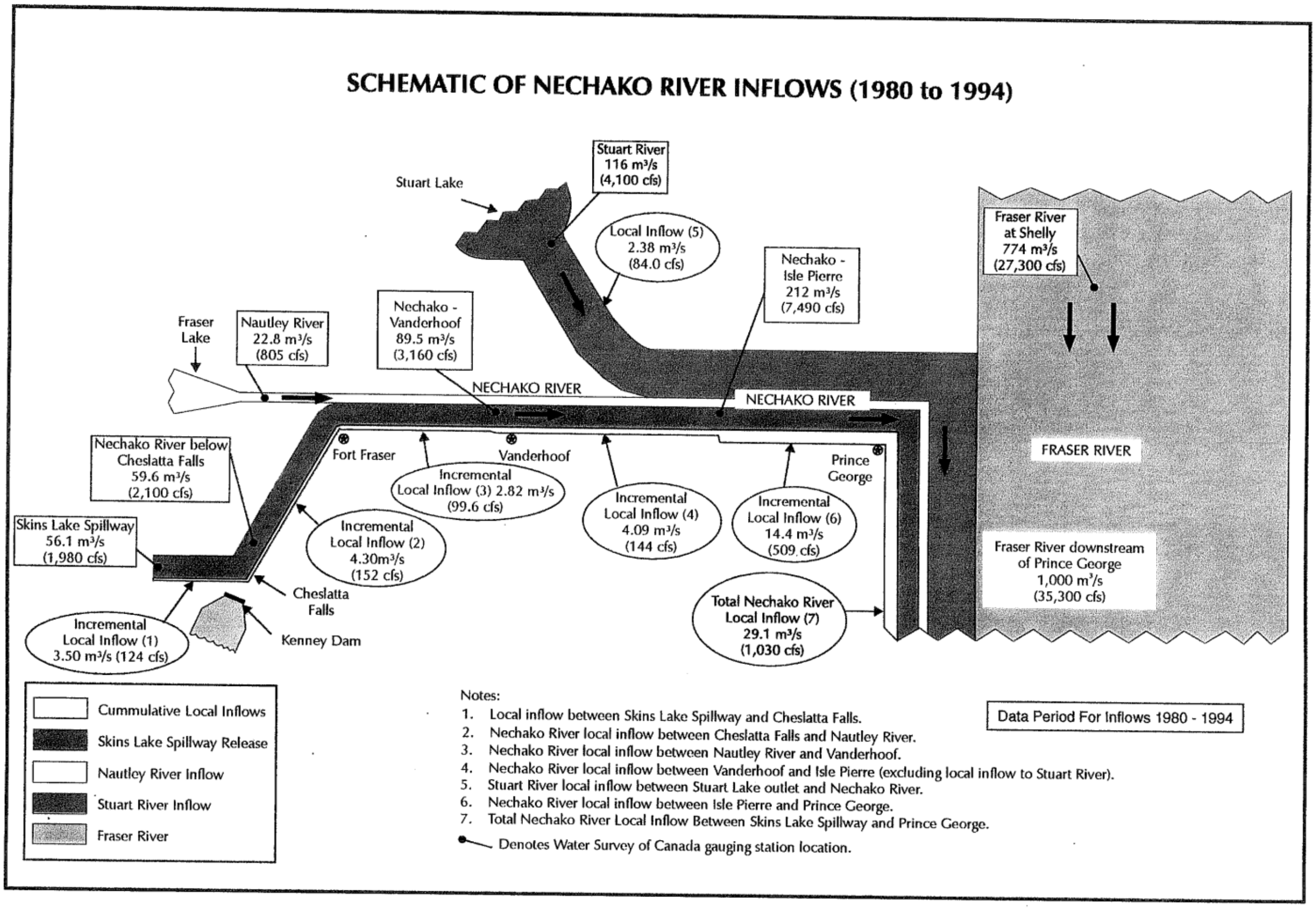

Figure 15. Schematic of Nechako River Inflows 1980 – 1994 prepared by Envirocon showing the relative contribution to the mean annual flow in each section of the Nechako River. Generally, the effect of regulation of the Nechako River inflows decreases downstream as more of the unregulated flows join the thermal influence of the Nechako River around mid-July and th

The sockeye population that is most sensitive to Nechako River temperatures is the Nadina population which migrates upstream through the Nechako River between Prince George and Fort Fraser. This DU was assessed by COSEWIC as “not-at-risk”. The STMP has the greatest influence on migration temperatures for this DU compared to other DUs. In general, after mid-August, the seasonal reduction in nighttime air temperatures moderates high water temperatures and river temperatures decrease.

The construction and operation of the Nadina spawning channel provides an opportunity to collect accurate production statistics to determine the staus of the sockeye population. Production statistics collected by DFO and the Pacific Salmon Commission (PSC) indicate that enroute loss[25] occurs within the Nadina sockeye run (red portions of histograms in Figure 16). Enroute loss data have been collected since 1992 (see footnote).

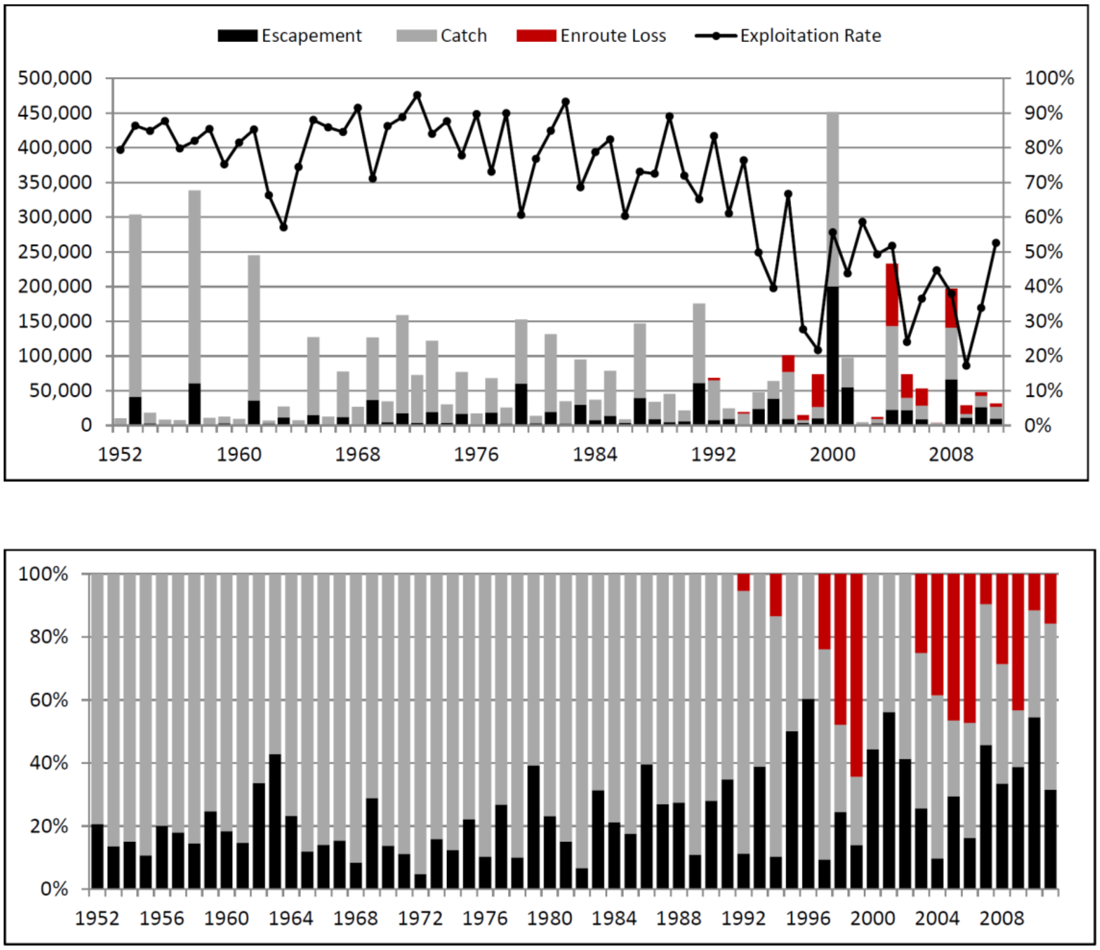

Figure 16. Time series of Nadina sockeye production statistics between 1952 - 2011. Upper and Lower Panels display absolute and relative values, respectively. The year 1992 was the first year that en route loss measurements of Fraser sockeye were initiated. Data source: Pacific Salmon Commission.

[25] DFO and the PSC refer to the differences in estimates of stock-specific abundance obtained from the Mission hydroacoustic site and those obtained from spawning grounds (after accounting for reported in-river harvest upstream of Mission) as “escapement discrepancies”. Escapement discrepancies can also arise from un-reported catch and/or through estimation errors. The Fraser River Panel of the PSC uses escapement discrepancy information to estimate the percentages of each run that are not accounted for during the migration – termed “en route loss”. En route loss began to be reported in 1992 for Early Stuart, Early summer, and Summer-runs. Hinch and Martins 2011

White Sturgeon

Photo: iStockphoto

Considerations of white sturgeon biology were not included in the 1987 *Settlement Agreement* which focussed exclusively on salmon. While planning for the KCP there were initial discussions related to the allocation of "freed-up flows" following construction of a KDRF to create a sturgeon-friendly hydrograph, however, these were preliminary in nature and ended with the cancellation of the KCP.

The conservation of Nechako White Sturgeon has been addressed during the past 20 years and the Nechako population, together with those from the Upper Fraser, Upper Columbia and Kootenay rivers, were designated as *Endangered* by COSEWIC in 2003, and listed under Canada's *Species At Risk Act* (SARA) in 2006. The endangered Nechako, Upper Columbia and Kootenay white sturgeon populations are all subject to river regulation. Information compiled by the Nechako Water Engagement Initiative suggests the Nechako population was formerly around 1600 mature adults in 1967 and had declined to 240 – 630 mature adults by 2012.

As required under *SARA*, DFO prepared a SARA-compliant Recovery Strategy (2014) which identified the primary threats to white sturgeon in the wild, including habitat loss, river regulation, harvest of prey/food, introduction of invasive non-native fish species, direct and indirect harvest, release of pollutants, and floodplain development.

It has been established that Nechako White Sturgeon have declined due to "recruitment failure". In population dynamics, recruitment is the process by which new individuals are added to a population, whether by birth or by immigration. Recruitment failure in Nechako White Sturgeon reflects that larval and post larval sturgeon survival is low, and below replacement levels, resulting in ongoing declines in population abundance. Despite the presence of fecund adult spawners in the population (up to 800,000+ eggs per female) that can repeat spawn every 3-6 years, there are relatively few post larval and juvenile white sturgeon that recruit into the adult population in the Nechako River. This is reflected in the age-distribution in the Nechako population (brown histograms in Figure 17).

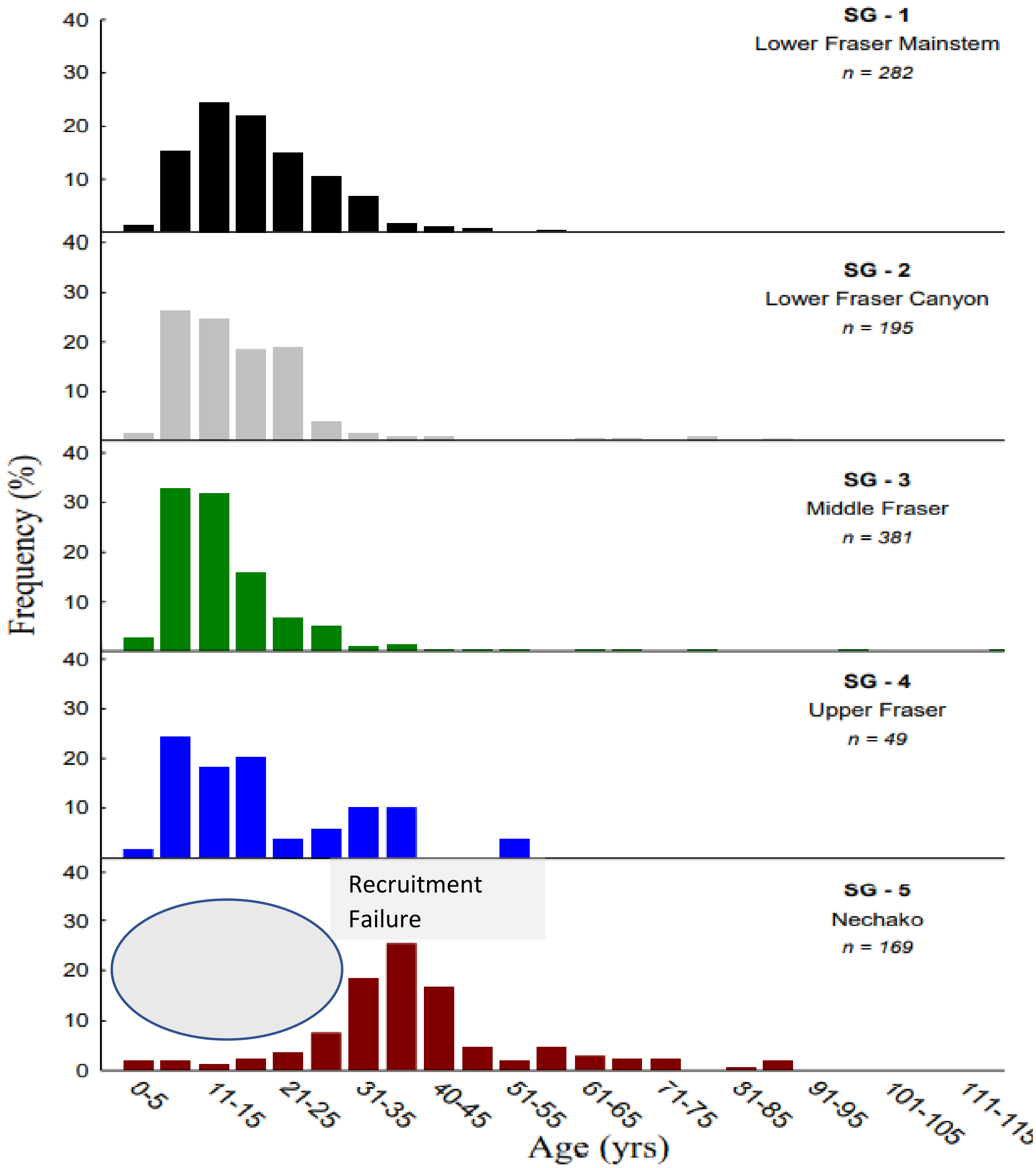

Figure 17. Age frequency distributions for five Fraser River white sturgeon populations. Unlike the upper 4 histograms, the Nechako population has low numbers of animals between 0-25 years old. Source: Nechako White Sturgeon Recovery Initiative.

White sturgeon yolk-sac larvae predominantly hide in the vicinity of spawning locations. The relationship between substrate condition and habitat use by sturgeon larvae[26] suggests there are strong effects of substrate condition on survival and that substrate degradation may contribute to recruitment limitations.

Further quantification of these linkages in relation to flow regulation[27] was undertaken via back-calculating historical recruitment which showed that recruitment was present but variable from 1946 until 1964. After 1964 there was a rapid decline, principally in 1967, and recruitment failure has continued since that time. Flow regulation, which began in 1952 with the completion of Kenney Dam, preceded recruitment failure by 15 years and the investigators concluded that flow regulation does not provide a simple unicausal explanation for recruitment failure.

The only known sturgeon spawning site in the Nechako River is adjacent to Vanderhoof. To explain the white sturgeon recruitment failure, McAdam et al. (2005) proposed that sediment input from an upstream channel avulsion in 1961, in combination with elevated flows in 1964 and 1967, led to alterations to riverbed substrates in critical white sturgeon habitat. Using air photos and specific gauge analysis, they identified a “sediment wave” in the upper Nechako River. The timing and location of avulsion sediments indicated that recruitment failure was most likely due to alteration of main channel substrates rather than the loss of off-channel habitat.

Recovery measures developed to date to improve the population status of Nechako White Sturgeon include hatchery augmentation and habitat restoration, implemented by the Nechako White Sturgeon Recovery Initiative. The NWSRI web-site[28] provides a Strategic Plan for the Nechako White Sturgeon Recovery Facility and Interpretive Centre which has been operating since 2014. The plan was prepared to secure up-front capital and a stable source of long-term funds to construct and operate a conservation aquaculture or 'recovery' facility in Saik’uz Territory in the District of Vanderhoof.

A concurrent approach to sturgeon recovery is outlined in the Nechako White Sturgeon Habitat Management Plan, developed in 2008. The plan combines active investigation of habitat requirements with a continually increasing scale of habitat rehabilitation, habitat enhancement, and habitat creation projects, towards the conservation of Nechako white sturgeon through restoration of natural in-river recruitment.

In September 2022, 11 Nechako white sturgeon were found dead in the river and there is active research underway to identify causative factors that could account for the mortalities. So far,

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[26] McAdam, S.O. 2010. Effects of substrate condition on habitat use and survival by white sturgeon (Acipenser transmontanus) larvae and potential implications for recruitment. Can. J. Fish. Aquat. Sci. 68: 812–822.

[27] McAdam, S.O., C.J. Walters and C. Nistor. 2005. Linkages between White Sturgeon recruitment and altered bed substrates in the Nechako River, Canada. Transactions of the American Fisheries Society 134:1448–1456

[28] NWSRI

provincial biologists have ruled out disease, chemical exposure or incidental mortality from angling or gill net fisheries. The fish showed no visible signs of injury. Reduced oxygen and elevated temperatures also appear unlikely since Nechako sturgeon survived under previous years of elevated river temperatures. The mortalities occurred between Vanderhoof and Prince George where effects of flow regulation are moderated by the unregulated flows that join the Nechako. Provincial biologists are actively investigating whether multiple factors could combine cumulatively to cause the mortalities in the Nechako and other reservoir-headed hydro facilities.

Other Fish Species

While salmon and sturgeon are the species of greatest conservation concern in the Nechako Watershed, there are several other members of the Nechako fish community (Levy 1991[29]), includes a total of 19 fish species, of which 4 are suckers, 6 are cyprinids (minnows), 5 are salmonids as well as prickly sculpin, burbot, white sturgeon and Pacific lamprey:

Common Name	Scientific Name
Chinook salmon	*Oncorhynchus tshawytscha*
sockeye salmon	*Oncorhynchus nerka*
rainbow trout	*Oncorhynchus mykiss*
bull trout	*Salvelinus confluentus*
Rocky Mountain whitefish	*Prosopium williamsoni*
largescale sucker	*Catastomus macrocheilus*
longnose sucker	*Catastomus catastomis*
bridgelip sucker	*Catastomus columbianus*
white sucker	*Catastomus commersoni*
redside shiner	*Richardsonius balteatus*
longnose dace	*Rhinichthys cataractae*
leopard dace	*Rhinichthys falcatus*
northern pikeminnow	*Ptychocheilus oregonensis*
peamouth chub	*Mylocheilus caurinus*
brassy minnow	*Hybognathus hankinsoni*
prickly sculpin	*Cottus asper*
burbot	*Lota lota*
white sturgeon	*Acipenser transmontanus*
Pacific lamprey	*Entosphenus tridentatus*

[29] Levy, D.A. 1991. Synthesis of a fisheries management plan for the Nechako River. Prep. for BC Ministry of Environment, Fisheries Branch. Levy Research Services Ltd. 23p.

During the investigations that were undertaken to support the development of the KCP proposal, Alcan's consultants, Envirocon[30], conducted extensive beach seine surveys of the river over a period of years. Results for 1979 and 1980 sampling campaigns (Figure 17) showed that the most numerous fish in the Nechako River were cyprinids (minnows including Northern Pikeminnow) and suckers.

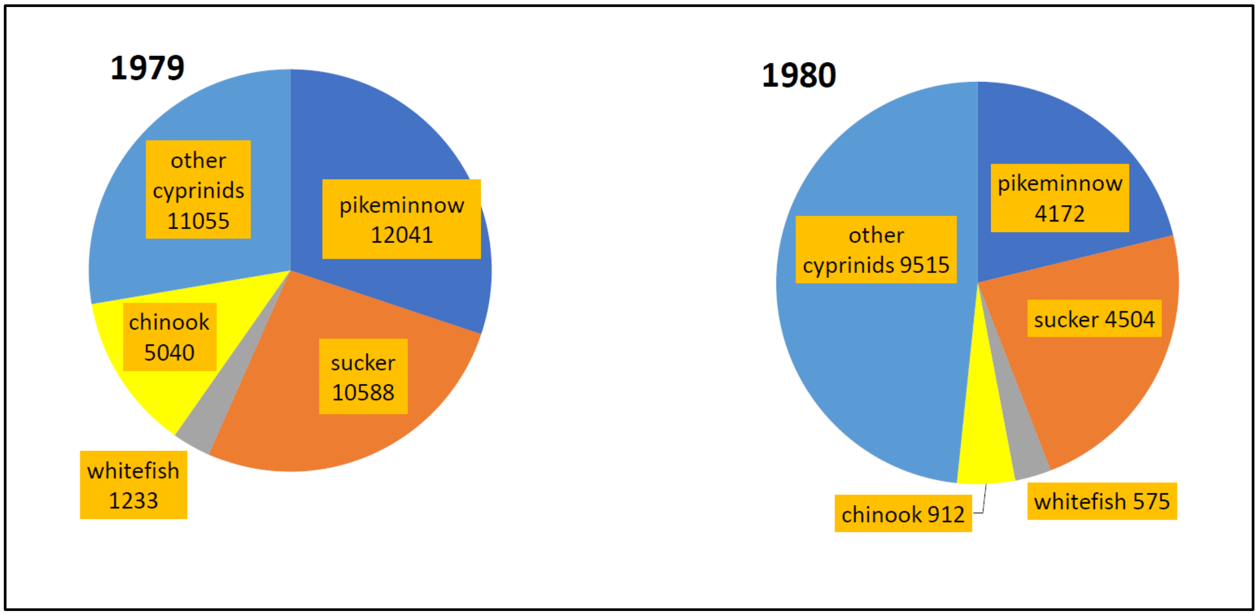

Figure 17. Total beach seine catches in the Nechako River and its tributaries by Envirocon during 1979 and 1980.

More recently, pink salmon have expanded their range and now occur in the Nechako River. The Nechako River also contains coho salmon habitat, and this species may be present in low numbers.

The province of BC has a mandate to manage sport fisheries for rainbow trout and bull trout. A sportfish habitat assessment in the Nechako River (Slaney et al. 1984)[31] identified the Upper Nechako, especially the Nechako Canyon, as having the greatest rainbow trout and char habitat capacity in the Nechako River (highest gradient and habitat complexity). The assessment found indications of depressed trout and char populations in the Upper River, including a low mean age distribution, which was interpreted as a combined result of flow alterations and overfishing.

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[30] Envirocon Ltd. 1984. Environmental studies associated with the proposed Kemano Completion Hydroelctric Development. Volume 5. Fish resources of the Nechako River system: baseline information. 416 p.

[31] Slaney, P.A., M.L. Rosenau, D.H.G. Ableson and R.L. Morley. 1984. Habitat capability of the Nechako River for rainbow trout and char and the effects of various flow regimes. BC Fisheries Branch, Fish. Tech. Circ. 63: 34p.

Slaney et al. (1984) subsequently recommended a total closure of the Upper Nechako for sport fishing; this closure was implemented between 1984-1986.

The response of the trout population to the closure was monitored[32] and steady increases in numbers, biomass, weight and size were observed. The number of catchable rainbow (>20 cm) doubled in number and tripled in biomass between 1983-1986, indicating high responsiveness of the trout population to the fishery closure. After the recovery of the trout population, restrictive sport fishery regulations were maintained for the Upper Nechako, including a catch-and-release restriction in Reach 1 (upper most reach).

NFCP Future

In 2021, the NFCP discussed four future options for the program:

Proposed NFCP Structure	Status
Maintain the original mandate of the NFCP	This was rejected in the early 2000's
Sunset the NFCP and create a new agreement	Still on the table
Reduce the scope of the NFCP to a bare minimum	This is the current model in relation to flow and temperature management (Rio Tinto data) as well as Chinook escapement estimation (DFO data)
Set new objectives and renew the NFCP as a stewardship partnership with the same three principle partners, but under a new name and modified mandate, that may include additional participants.	Still on the table but needs to factor in the active operation of the Rio Tinto-sponsored Water Engagement Initiative (WEI). NFCP doesn't participate in the WEI but maintains informal contact with the initiative.

The latter option could also include a mechanism for implementing watershed and water use planning[33].

NFCP discussions addressed:

- The scope of activities that have historically been conducted by the NFCP are of interest to First Nations and fall within scope of matters regarding which the crown would need to consult with First Nations.
- The NFCP mandate is primarily focussed on sockeye and chinook salmon and limited to the impacts of Rio Tinto operations in the Nechako River on sockeye and chinook salmon.

[32] Slaney, P.A. 1986. An assessment of the rainbow trout (Salmo gairdneri) population in the Upper Nechako River and the effects of a sportfishery closure. BC Fish. Mgmt. Rept. 89: 38p.

[33] It is not clear which agency would have a mandate to lead the development of a Water Use Plan and what legal arrangements would be required to develop future Nechako hydrographs that deviate from the *1987 Settlement Agreement*.

- Climate change is already influencing environmental conditions and salmon conservation in the Nechako River, as well as conditions for the majority of salmon life history outside of the Nechako watershed.
- Conservation of the aquatic environment in the Nechako watershed would benefit from a broader scope of considerations than is afforded by the NFCP biological or geographical restricted mandate.
- Local and regional governments, non-profit organizations and members of the public have expressed a desire to be involved in and/or support a broad-based watershed stewardship approach.
- The Rio Tinto WEI, which is modelled after the Province of BC's Water Use Planning program, is active and includes up to 40 representatives in the region with concerns and interests related to water management, climate change, and aquatic resources.
- The Rio Tinto WEI forum provides an opportunity to work with First Nations, governments, regulators and other stakeholders to develop an environmental stewardship program that reflects the interests and issues relevant to the Nechako Watershed.
- There are many environmental issues impacting the Nechako Watershed not directly related to or caused by Rio Tinto operations, such as climate change, land development and forestry. The parties need to work together to appropriately scope a Nechako conservation program that reflects today's environmental realities.

The results of a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis for the NFCP (Figure 17) and a NFCP-determined watershed priorities are shown in Figures 17 and 18, respectively.

Figure 17. Results of a SWOT analysis for the NFCP.

Nechako Watershed priorities identified by the NFCP are reflected in Figure 18.

Figure 18. Summary of future management priorities identified by the NFCP.

Emerging Issues

The previous sections of this report summarize past and present responsibilities and initiatives conducted by the NFCP. The sections described below are not part of the NFCP mandate, nevertheless, the world has changed considerably since 1988 when the program was initiated, and consideration of new conservation initiatives is required. The NFCP does not have a mandate to develop a future program; that responsibility lies with the 3 principals of the NFCP: DFO. the Province of BC and Rio Tinto.

Marine Effects on Nechako Chinook Survival

The 1987 Settlement Agreement recognized that it was only practical to monitor freshwater survival of Nechako Chinook in relation to flow regulation. Marine survival could not be considered due to the absence of survival data and information on Nechako Chinook distribution and migration patterns in the marine environment.

More recent analysis (Appendix 2) demonstrated that low early marine survivals during the first year of marine residence were key drivers of recent Southern BC Chinook productivity decreases[34] and both local and larger scale oceanographic conditions are likely involved. Other factors considered by an Independent Panel (harvests, freshwater habitats, hatcheries, pathogens, and climate change) were considered as possible secondary contributors. The Independent Panel noted that, consistent with the Pacific Salmon Treaty, harvest rate reductions have been imposed to rebuild North Pacific Chinook stocks. Simultaneously, reductions in marine productivity have undermined rebuilding efforts so the effect of reduced harvest rate has been counterbalanced by reduced marine productivity of juvenile and possibly sub-adult Chinook. The Panel could not attribute causes to the declines other than inferring that low early marine survivals and climate variations have been primary contributing factors and there have likely been secondary contributions from each of the other factors considered during the analysis (harvests, freshwater habitats, hatcheries, pathogens, and climate change and variation).

This conclusion implies that interpretation of Nechako Chinook survival based on escapement must be undertaken cautiously since ocean conditions represent a “black box” that can confound the interpretation of Nechako Chinook survival in relation to flow regulation. While escapement data can provide a coarse indicator of overall Chinook survival, the marine survival component remains largely unknown.

[34] Chinook Independent Advisory Panel Report

Multispecies Fisheries Management and the Nechako Hydrograph

The NFCP concluded in several reports that the sustained achievement of the Conservation Goal described in the 1987 Settlement Agreement has been met as reflected by the annual escapements which have remained reasonably productive between the 1970's through to the present (Figure 9).

Sockeye salmon vulnerability to warm temperatures during migration has been partially mitigated by the effective operation of the Summer Temperature Management Program, although there are ongoing exceedances of the 20^{o}C temperature target as monitored at the confluence of the Nechako and Stuart Rivers. The responsiveness of river temperature to discharge volume provides support for the efficacy of the STMP.

To date there has been little consideration of a river hydrograph that considered the production of Nechako White Sturgeon at various points of their life cycle. It is unknown whether trade-offs would be required to simultaneously maximize salmon, sturgeon and sport fish production and how these could be optimized. Further, there is a question as to which agency would have the legal authority to revise the hydrograph specified in the Settlement Agreement.

The 1987 Settlement Agreement recognized that it was only practical to monitor freshwater survival of Nechako Chinook in relation to flow regulation. Marine survival could not be considered due to the absence of survival data and information on Nechako Chinook distribution and migration patterns in the marine environment.

The future challenge for Nechako fisheries managers is how to simultaneously optimize the production of Chinook, sockeye and sturgeon in the face of flow regulation. Each of these species has different distributions and habitat requirements and creating an optimal hydrograph is challenging. This hypothetical hydrograph needs to also consider the requirements of different ecosystem components. To advance a new hydrograph will require a modelling approach and/or Structured Decision Making.

Climate Change and Salmon Thermal Ecology

Climate change is an established fact of the 21st Century (Figure 19) and salmon and other cold water fish species are highly sensitive to temperature changes within their habitats. While the STMP is effective at moderating temperatures in the Nechako associated with flow regulation, the predicted scale of future climate warming may undermine STMP effectiveness.

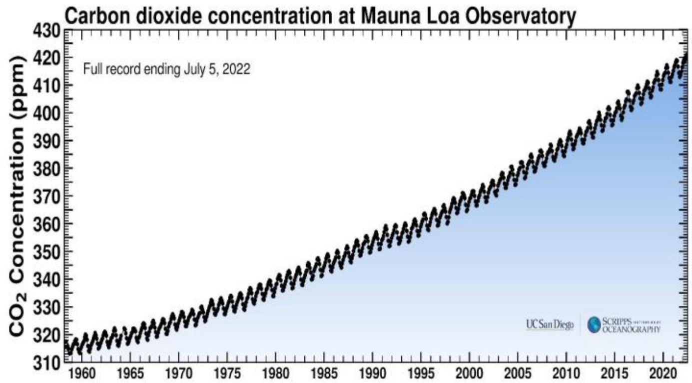

Figure 19. This graph, known as the Keeling Curve, depicts the upward trajectory of carbon dioxide in the atmosphere as measured at the Mauna Loa Atmospheric Baseline Observatory by NOAA and the Scripps Institution of Oceanography.

As measured by the DFO Ewatch Program, during recent years there have been warm temperature conditions in the Fraser River and lower than average flows necessitating the application of Management Adjustments (measures to compensate for adverse migration conditions) that anticipate *en route* mortality to ensure that spawning escapement targets are met. Adult migrating sockeye are particularly sensitive to Fraser River temperature conditions between Hope and Upper Fraser spawning grounds. In particular, female sockeye survival can be reduced during passage through hydraulically difficult parts of the migration such as Hell's Gate and Big Bar. Sockeye that experience elevated temperatures (>19^{o}C) between Hope and Prince George can experience further temperature stress during the final stretches of migration prior to reaching their spawning grounds in the Upper Fraser[35]. Cumulative exposure to high temperature coupled with upstream passage through hydraulically constricted reaches create stress that can be manifested as prespawning mortality which occurs on the spawning ground as well as *en route* mortality which occurs during upstream migration.

Long-distance migrating sockeye populations that swim through the Nechako (e.g. Early and Late Stuart sockeye) are vulnerable to migration mortality (*en-route* loss) associated with climate-related temperature increases upstream of Hope. This is one of several mechanisms associated with climate change that can affect salmon in the Fraser Watershed[36]. Predicted reductions in Late Stuart sockeye survival due to incremental warming are estimated between 9-16% by the end of this century[37].

While the effects of climate change on Nechako salmon cannot be accurately predicted at present, Nechako salmon are long distance summertime migrators making them vulnerable to

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[35] Reduced Sockeye Survival Due to High Temperature

[36] Effects of Global Warming on Fraser Salmon

[37] Effects of Temperature and Climate Warming on Survival of Fraser Sockeye

future changes in temperature and altered discharge associated with climate change. Many of these effects will occur downstream of the Nechako River and will create cumulative effects as the fish migrate upstream, particularly in hydraulically constricted areas e.g. Hell's Gate.

First Nations Engagement

First Nation salmon fisheries are currently managed by DFO, First Nation communities, the Carrier Sekani Tribal Council[38] and the Upper Fraser Fisheries Conservation Alliance[39]. First Nations concerns were excluded from the development and management of the Kemano Project which had adverse impacts on many First Nation communities within the Nechako Watershed. At the time, the interests of First Nations were considered a fiduciary obligation of the Federal and Provincial Crown but that approach does not acknowledge established or asserted Aboriginal Rights of the communities. Many of those rights were legally defined after the Kemano Project was developed. This conflict has led to ongoing litigation particularly in relation to fish harvesting and water management.

While the CSTC and the UFFCA provide invaluable support services to the Nations, these organizations are not the holders of aboriginal rights. Rather, aboriginal rights belong to the individual Nations implying that any future engagement in Nechako fisheries and environmental management needs to be conducted on a bilateral (government-to-government) basis. A blanket approach to First Nations engagement[40] is unlikely to be effective and engagement efforts need to be focussed on individual nations.

Various First Nations, including the seven members of the Carrier Sekani Tribal Council (CSTC) are engaged Nechako fisheries and environmental management. The seven Nations include:

- Ts'il Kaz Koh First Nation (Burns Lake Band)
- Nadleh Whut'en
- Saik'uz First Nation
- Stellat'en First Nation
- Takla Lake First Nation
- Tl'azt'en Nation
- Wet'suwet'en First Nation

Additionally, there are other First Nations e.g. Cheslatta Carrier Nation, that aren't part of CSTC but who participate actively in Nechako fisheries management.

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38 CSTC Fisheries Program

39 UFFCA Fisheries Program

40 First Nations refer to this approach as "Drive-by consultation"

Appendices

1. Proposed Kenney Dam Surface Water Release Facility

A key element within the *1987 Settlement Agreement* was the construction, by Alcan, of a Kenney Dam Release Facility to mitigate the effects of the modified flow regime on Chinook and sockeye salmon in the Nechako watershed. The facility would be constructed as a multi-level water release facility at Kenney Dam. However, the Long-Term Water Allocation protocol, a component of the *1987 Settlement Agreement,* was rejected in 1995. Subsequently, the *B.C. Alcan Agreement* (1997) established the Nechako Environmental Enhancement Fund (NEEF) whereby Alcan agreed to contribute, on a matching basis, up to $50 million to the fund.

The NEEF Management Committee (MC) was tasked with reviewing, assessing and reporting on the options for the downstream enhancement of the Nechako watershed area. The Committee released its' assessment report on June 7, 2001. The main incentive to construct the KDRF was to more efficiently utilize the water budget, to rewater the Nechako Canyon downstream of Kenney Dam and to generate "freed-up flows" due to the elimination of the STMP flows to benefit aquatic resources throughout the Nechako River. In the event that a cold-water facility was to be constructed then a series of potential benefits could be achieved ranging from re-watering of the Nechako Canyon below Kenney Dam, re-shaping of the Nechako River hydrograph, restoration of the Cheslatta System and providing beneficial habitat for sturgeon.

At an early stage of the assessment of a KDRF it was determined that downstream enhancement could only be achieved via the establishment of a more natural flow regime in the Nechako River. A KDRF was identified as the preferred option for downstream enhancement because it had potential to address a broad range of interests. If the KDRF was designed to access cooler water from lower levels of the reservoir then less water would be required to meet summer temperature management requirements for fish in the Nechako River. This would free-up water that could be redistributed across the year to mimic a more natural flow regime, meet other downstream needs and allow for rehabilitation of the Cheslatta system.

Secondary considerations included rewatering the Nechako Canyon without seasonal interruptions, ability to generate hydropower at Kenney Dam and ability for maintenance shutdowns of the spillway without interrupting flows to the Nechako Canyon or requiring all flows to pass through the Cheslatta system.

The NEEF MC considered 5 different KDRF designs in relation to:

- capacity to release high water flows;
- ability to intake water from the surface of the water and/or at greater depths where the water is colder;
- ability to regulate the temperature of the water; and
- ability to release water into the Nechako as required and at all times of the year.

Ultimately the Management Committee recommended a design (Option E) that fulfilled the requirements (Figure 21).

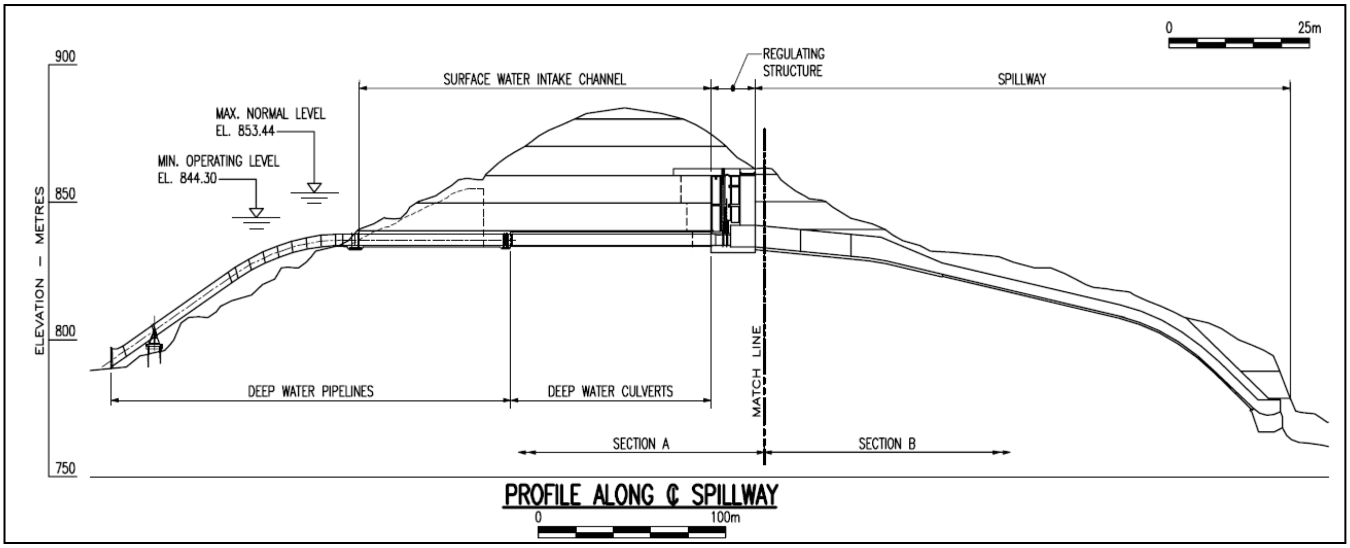

Figure 20. Profile along the spillway of a proposed Kenney Dam Cold Water Release Facility: Updated Option E. Source: NEEF MC (2001[41]).

The design specifications for the KDRF Option E are:

- a surface-water intake channel;
- a deep-water intake and pipelines;
- a high-level outlet regulating structure, capable of releasing water from surface and deep sources either one at a time or together, and a surface spillway with a flip bucket energy dissipator; and,
- a low-level outlet with the capability of releasing water from surface and deep sources either one at a time or together and equipped with one or more hollow-cone valves for energy dissipation and dissolved gas control.

Total cost (2001 dollars) for KDRF construction, a Cheslatta fan meandering pilot channel construction, a Nechako Watershed Council Trust Fund ($3 million) and an Independent Scientific Panel Review was $100 million.

The Management Committee recommended that a Cold Water Release Facility be constructed at Kenney Dam to enable downstream enhancement of the Nechako Watershed. A number of outstanding issues were identified including water temperature uncertainty, movement of water through the Cheslatta Fan, total gas pressure (TGP), temperature shear and re-watering of the Nechako Canyon. The Committee also identified a meandering pilot channel as a cost-effective solution to moving water through the Cheslatta Fan. A number of recommendations were

[41] NEEF 2001. Report of the Nechako Environmental Enhancement Fund Management Committee. 34p.

provided for the Cheslatta system including the identification of fish habitat rehabilitation as a primary objective with tourism and recreation as secondary objectives.

The NEEF MC developed an implementation strategy that would engage the NFCP, Nechako Watershed Council (now defunct) and an independent objective scientific body to propose an optimal flow regime that would result in a healthy, more natural Nechako River. The Committee also addressed ownership and operations of the KDRF and recommended a public/private joint venture partnership to ensure that the KDRF is constructed in an efficient, cost-effective and timely manner. As the KDRF would be subject to an environmental assessment under the provincial and/or federal processes it would be necessary to identify a proponent to assume responsibility for the preparation of an environmental impact assessment.

The NEEF Management Committee was reconvened in November 2011 with new members who were asked to reconsider previous decisions and review all options for environmental enhancement including a surface water release facility. During consultations, a number of people and organizations, including the Nechako Watershed Council, expressed their support for building a KDRF. Additionally, the Cheslatta Carrier Nation proposed the Cheslatta Carrier Nation Nechako River Legacy Project to design, permit, construct and operate a KDRF in association with their industry partner, Surespan. It was concluded that the facility is the only way to facilitate large scale rehabilitation of the Cheslatta system. This option would remove most of the high flows currently being routed through the Cheslatta system thereby reducing erosion and potentially increasing productivity over time. It would also re-water the 9 km long Nechako Canyon and restore high value fish habitat and could potentially enable greater downstream temperature control.

Outstanding issues identified by the Management Committee that would need to be addressed include:

1. Secured funding
2. Preparation of a Project Description
3. Completion of an Environmental Impact Assessment
4. Resolution of technical issues described in reports commissioned by NEEF between 2003-2009
5. Reduction of risks associated with sediment transfer downstream of the Cheslatta Fan
6. Resolution of uncertainties regarding the amount of flow required to rehabilitate the Cheslatta watershed

The Management Committee decided that NEEF would be used for a KDRF at Kenney Dam as well as additional environmental enhancement options. However, since the earlier NEEF MC report in 2001, costs associated with KDRF increased substantively and a current cost estimate is unavailable. Moreover, no party has been identified to invest in the project.

The committee decided that for a 5-year period following release of the NEEF report, 80% of the total potential NEEF be available for constructing a KDRF subject to the following milestones:

a) By the end of Year 1 a proponent is identified and an acceptable Project Description is prepared and submitted to regulatory agencies;
b) By the end of Year 2 an Environmental Assessment has commenced; and,

c) By the end of Year 5 the Environmental Assessment process is complete and construction has commenced.

In support of a future Environmental Assessment, the Committee decided that a total of $1 million of the NEEF funds would be available by way of an annual allocation over a period of 5 years, on a matching fund basis to facilitate the preparation and completion of an Environmental Assessment of the KDRF option.

The benefits of a KDRF remain uncertain. A hydrology study by DFO (MacDonald et al. 2007[42]) showed that:

> *"Current temperature targets at Finmoore can be achieved with the release of smaller amounts of cooler water from Kenney Dam but may result in warmer conditions in the lower Nechako and cooler conditions in the upper Nechako compared to conditions under the current temperature management regime."*

The impact of such changes would need to be carefully evaluated, and, if necessary, mitigated. Further, according to the DFO model, with anticipated climate change and the tendency of reduced volumes of water to warm more quickly, then the water savings would be modest. It will be necessary to verify the environmental benefits of a KDRF for river temperature control before the project could proceed.

2. Production Declines in Southern BC Chinook Populations

In response to growing evidence that Southern BC Chinook salmon are declining, DFO and the Fraser River Aboriginal Fisheries Secretariat convened a scientific workshop between May 22-24, 2013. As part of the investigation, an Independent Advisory Panel was convened to evaluate the relative importance of different factors that may have affected the abundance and productivity of southern BC Chinook salmon[43]. The Independent Panel included six pre-eminent fisheries scientists who reviewed the available evidence related to the underlying causes for the Chinook decline. Potential causal factors were analysed as part of the review.

<u>Harvest Rates</u>

Catches of BC Chinook have declined over time primarily due to a reduction in commercial landings. Coded Wire Tagging data for Indicator stocks demonstrated that exploitation rate of Southern BC Chinook declined from an average of 75% to an average of 45% between 1973 and 1993. In spite of the reductions in exploitation rate many Chinook stocks have continued to

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[42] Macdonald,J.S., Morrison, J, Patterson, D.A., Heinonen, J., and Foreman, M. 2007. Examination of factors influencing Nechako River discharge, temperature, and aquatic habitats. Can. Tech. Rep. Fish. Aquat. Sci. 2773: vii + 32 p.

[43] Southern BC Chinook Independent Advisory Panel Report

decline. Evidence suggests that most southern BC stocks have experienced reductions in marine survival that have undermined stock productivity, implying that even reduced harvest rates may be too high and are contributing to additional declines in escapements. The Panel suggested methods that may permit more rigorous assessment of Chinook productivity changes in future.

Freshwater Habitat

Freshwater habitat degradation could potentially cause a decline in Chinook productivity either via natural causes and/or negative interactions with human-induced stressors e.g. pollution, habitat alienation. Southern BC Chinook Conservation Units (CUs) show a synchronous decline in freshwater productivity, so there would need to be large-scale freshwater environmental forcing to cause coherence in decreased spawning and freshwater rearing habitat quality.[44] Therefore it seems unlikely that freshwater stressors are sufficient to explain the Southern BC Chinook decline and should be considered as secondary modifiers of production. The Panel indicated that stream discharge and water temperatures can be impacted by flow regulation in many rivers, particularly on Vancouver Island, but the impacts on Chinook production were difficult to elucidate. They concluded that there are no obvious freshwater environmental drivers that could explain recent trends in Chinook salmon spawner abundance.

The main freshwater information gaps included the linkage between river temperature and flow conditions and the survival of spring and summer Chinook smolts, especially in view of future climate change projections[45].

Marine Habitat

With the exception of the Thompson River summer CU and other salmon stocks with early (prior to May) or late (July or later) entry timing into the Strait of Georgia, Southern BC Chinook have shown a synchronous decline implying a mortality factor or production bottleneck in a shared habitat. This implicates marine habitat conditions as the main driver of Chinook productivity variations.

Climate indices, e.g. the North Pacific Gyre Oscillation (NPGO), show cyclic variation over time and influence conditions in marine habitats occupied by salmon. The patterns of the NPGO correlate strongly with a widely shared trend in marine survival derived from dynamic factor analysis. The analysis is complicated since physical and biological oceanographic conditions vary greatly at regional and local scales. Both local and basin-scale oceanographic conditions affect marine survival. Conditions in the marine environment during the first year of marine residency of Southern BC Chinook salmon appear to act as a key driver in survival and

[44] A similar conclusion was reached by the Cohen Inquiry on Fraser sockeye salmon with respect to freshwater habitat conditions.

[45] The Nechako is somewhat unique in the Fraser Watershed as river temperatures and flows are closely monitored by the NFCP. The Summer Temperature Management Program collects relevant Nechako River data during the sockeye migration period, however, to date this information hasn't been utilized for Mid-Fraser Spring and Summer Chinook fisheries management.

productivity trends. There is strong evidence of direct effects of local marine conditions on the survival of Chinook salmon, especially within the Salish Sea.

Chinook predators may directly affect salmon survival. A number of Southern BC marine mammal predator populations e.g. seals and sea lions, have increased significantly in recent decades. The Panel concluded that marine mammal predation may now be a more significant mortality factor than fishery removals for Southern BC Chinook salmon, however, total mortality rate due to both predation and fishing is considerably lower in recent years than pre-1990. The Panel concluded that because total mortality rates from both these sources declined substantially from approximately 1980 through 2003, it is unlikely that these combined factors were driving the general decline in Southern BC Chinook abundance since 1995.

The life history phase most likely to explain the decline in productivity of Southern BC Chinook salmon is the first year of ocean residency. Better understanding of ecological processes affecting juvenile life history in the marine environment could contribute to improved Chinook fisheries management practices. The Salish Sea Marine Survival Project, operated by the Pacific Salmon Foundation carried out a 6-yr integrated research program (2012-2018) to investigate juvenile salmon ecology in the Salish Sea designed to provide relevant information to inform future management response strategies for Southern BC Chinook. This includes tracking juvenile Chinook marine survival via coded-wire tagging and tag recovery of hatchery indicator stocks. The Panel commented that coded-wire tagging of selected wild stocks should also be considered in future to provide information on marine survival for CUs that are not represented by hatchery indicator stocks. They called for better estimates of mortality rates and their inter-annual variability to provide insight into the mechanisms affecting marine survival.

<u>Hatcheries</u>

The Panel referred to the WSP that requires hatchery management in a manner which is consistent with the conservation of wild salmon populations. The evaluation identified concerns related to the compatibility and coordination of the DFO Salmonid Enhancement Program with the objectives of the WSP. Serious risks were identified for "wild" populations where there are high hatchery proportions in the enhanced populations and low proportions of wild salmon as well as straying of hatchery fish into “wild” unenhanced populations. This is a major concern in West Coast Vancouver Island and Strait of Georgia Chinook CUs that have extensive hatchery programs. In the Middle-Upper Fraser River, Thompson River, and Lower Fraser CU groups, hatchery programs have been reduced to levels where risk is small. The Panel called for an independent comprehensive assessment of hatchery programs cutting across the range Southern BC Chinook salmon CUs to improve monitoring programs and develop the essential actions needed to reform hatchery operations.

The Panel concluded that there was insufficient information to assess the degree to which hatcheries have been a stressor and contributor to observed declines in Southern BC Chinook salmon. A suite of monitoring strategies and research activities were proposed to improve the ability to understand and manage the interactions between hatchery practices and wild Chinook salmon production.

Pathogens

Existing information was insufficient for the Panel to draw any conclusions on whether pathogens and associated diseases have contributed to the reduction in Chinook production in Southern BC. A number of plausible mechanisms were identified e.g. effects on swimming ability, growth and reproduction, but appropriate quantitative evidence regarding the distribution, magnitude and frequency of either direct or indirect impacts was unavailable.

The Panel recommended improvements in monitoring of pathogens and disease occurrence in both hatcheries and natural populations particularly for Chinook pathogens. Additionally, more research was identified to address the dynamics of disease expression, interactions with environmental conditions and the potential role of hatcheries in the persistence of pathogens and risk of transmission to natural populations. The Panel also recommended more in-depth consideration of the interaction between salmon farm pathogens and the hatchery and natural populations of Chinook salmon.

Climate Change

The Panel concluded that it is highly likely that climate variation and change has been a factor influencing Chinook productivity in the past and will have increasing impacts in the future. Effects are likely mediated through changes in temperature, stream flow volume and seasonality, reductions in glaciers, increases in pathogens, non-indigenous species and contaminants as well as changes in the marine environment. Climate change effects in the Fraser River mainstem include an earlier-timed freshet and a significant increase in summer temperatures. Further, most Southern BC Chinook populations have been faced with increasingly stressful thermal conditions during return migrations and projected future warming will increase stress on Southern BC Chinook populations.

The Panel recommended an analysis of past and potential future impacts of climate change on Southern BC Chinook salmon that considers the diversity of life history types, the complex topography of Southern BC and diversity of stream types and the potential for behavioural adaptation of Chinook to respond to changing conditions. The need for a strategic plan and an effective monitoring design was identified. A detailed assessment would include designation of ‘indicator stocks' or populations strategically situated to represent the major life history types of Chinook salmon. Other factors that would need to be considered include annual variation in freshwater and marine survival; exploitation estimates including total fishing mortality by age; quantitative monitoring of spawning escapements by age (including losses during up-stream migration, retention of eggs and pre-spawning mortality of females), and hatchery produced first-generation returns.

Overall Conclusions

Southern BC Chinook are in decline. Low early marine survivals during the first year of marine residence were identified as a key driver of recent productivity decreases[46] and both local and larger scale oceanographic conditions are likely involved. Other factors considered by the Independent Panel (harvests, freshwater habitats, hatcheries, pathogens, and climate change) were considered as possible secondary contributors. The authors noted that, consistent with the Pacific Salmon Treaty, harvest rate reductions have been imposed to rebuild North American Chinook stocks. Simultaneously, reductions in marine productivity have undermined rebuilding efforts so the effect of reduced harvest rate and has been counterbalanced by reduced marine productivity of juvenile and possibly sub-adult Chinook.

As a component of the work of the Independent Panel was undertaken on the productivity (adult returns per spawner) for 24 wild Chinook stocks between Oregon and Western Alaska[47]. The investigators documented shared time trends in productivity that were most closely associated with oceanographic factors, in particular the North Pacific Gyre Oscillation and the location of the bifurcation in the North Pacific Current as it reaches the west coast. They concluded that Chinook productivity patterns of separate populations have become more synchronous in recent years, reinforcing the conclusion of the Independent Panel that early marine survival, where different populations of juvenile Chinook share similar marine habitats, is a key driver affecting Southern BC Chinook productivity.

Within Southern BC, the clearest indication of the decline in Chinook salmon is within the Fraser River. However, the Panel could not attribute causes to the declines other than inferring that low early marine survivals and climate variations have been primary contributing factors and there have likely been secondary contributions from each of the other factors considered at the workshop (harvests, freshwater habitats, hatcheries, pathogens, and climate change and variation). Due to the complexity associated with the fisheries assessment process, it was not possible to quantitatively assess the relative likelihood of different factors contributing to trends in the productivity of Southern BC Chinook salmon stocks. The Panel did, however, identify factors that likely contributed to the decline in spawning abundance over the past 12 to 15 years.

Habitat considerations included freshwater, estuarine and marine habitats and freshwater habitats utilized for spawning, rearing and migration. However, there was no evidence to suggest that the variation in patterns of decline or increase observed in recent years among CUs is related to land-use activities and water uses. For marine habitats, environmental conditions during the first year of marine residency of Southern BC Chinook salmon were considered to be key drivers of recent trends in survival and productivity. Both local and larger scale oceanographic conditions are likely involved. In general, smaller fish have higher natural

[46] Chinook Independent Advisory Panel Report

[47] Covariation of Chinook Productivity

mortality rates than large fish which supports the Panel's primary research recommendation to focus on early marine periods.

The highest priority follow up from the Advisory Panel analysis was for DFO and collaborating entities to undertake a critical review of available assessment data and to identify future data and research needs. To monitor the status of CUs and explain causation, a strategic design was identified for an evaluation framework that includes an integrated evaluation of status, ocean conditions, hatcheries, pathogens, freshwater habitat, and harvest for Southern BC Chinook that is scaled to a monitoring level that can be maintained annually. The Panel recommended new, more collaborative and inclusive processes to address these needs integrating the strengths and resources of First Nations, universities, and other NGOs and communities within a well-designed assessment and monitoring framework. They envisaged the establishment of an integrated network of communities to support DFO and help to maintain abundant and productive Chinook salmon population.