Historical Review of the Nechako Fisheries Conservation Program: 1987 - 2015

Prepared by:

Nechako Fisheries Conservation Program Technical Committee

July, 2016

Executive Summary

The Nechako Fisheries Conservation Program (NFCP) was established to implement the *1987 Settlement Agreement* between Canada, B.C. and Alcan The Agreement anticipated modified flows in the Nechako River associated with the Kemano Completion Project (KCP) and the construction of a Kenney Dam Release Facility (KDRF). The Program was developed to implement an integrated set of monitoring, applied research and remedial measures to ensure the conservation of Nechako Chinook and sockeye salmon that utilize the river as a migration corridor. When the KCP was cancelled by the Province of BC in 1995, the NFCP continued its work in anticipation of altered flows associated with a potential KDRF. Since the early 2000's, the program has continued its operations, albeit with a reduced level of activity. A notable milestone during the programs' development was the preparation of a Technical Data Review (TDR) in 2005 that evaluated NFCP results collected between 1988 - 2002. The present report updates the information to 2015, provides a historical synthesis of key findings and describes the evolution of the NFCP.

Since the TDR was completed 10 years ago the more recent NFCP results demonstrate:

1. the streamlined monitoring program that was initiated in 2007 has been effective and data integrity has been maintained. The streamlining was primarily associated with the use of mean residency time (10.6 days) for generating Chinook spawner population estimates coupled with reduced helicopter overflight frequencies (5 flights per year);

2. there was a 61% increase in Chinook spawner population size over the period 2003-2014 when compared with the TDR data set covering 1988-2002;

3. in 2010, juvenile Chinook habitat productivity indices were consistent with previous monitoring results obtained between 1990 - 2002;

4. the Summer Temperature Management Program was operated in most years to minimize water temperature exceedances above a 20^{o}C temperature target measured at the Nechako/Stuart confluence. Over the past 10 years there was an average of 2.25 exceedances of the temperature target per year;

5. the Annual Water Allocation (AWA) flow objective (mean annual flow above 36.8 m^3/sec) has been consistently achieved; and,

6. escapements have met the target population of 3100 spawning Chinook in most years and there is continued support for the conclusion that the Conservation Goal is being met.

Based upon the above conclusions, in 2015 the NFCP decided to terminate the biological monitoring component of the program that commenced in 1988 and ran until 2014. DFO is presently undertaking Nechako Chinook escapement monitoring following procedures that are routinely applied in large Chinook salmon rivers in BC. The flows in the Nechako River, as specified in the *1987 Settlement Agreement*, will continue to be managed by the NFCP and implemented by Rio Tinto.

Contents

Introduction

In 1950 Alcan signed an agreement with the province of BC that led to the Kemano Project including construction of the Kenney Dam on the Nechako River and the formation of the Nechako Reservoir. The agreement included a conditional water license for hydro development so as to provide a power source for Alcan's smelter at Kitimat (Figure 1).

During the 1980's, in response to water management issues related to flow releases from the Skins Lake Spillway, the Nechako River Working Group was formed to address water flow requirements for salmon downstream of the reservoir. The Working Groups' report became the basis for the *1987 Settlement Agreement* (Appendix 1) that was prepared to provide certainty with respect to water flows.

Under the terms of the 1950 agreement with the province, Alcan received rights to divert additional water from the Nechako Reservoir to an expanded powerhouse at Kemano, a project known as the Kemano Completion Project (KCP). The additional water diversion flows were specified in the *1987 Settlement Agreement* and 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. That agreement also established the mandate for the Nechako Fisheries Compensation Program (NFCP) which was to undertake an integrated set of monitoring programs and to design remedial measures for the benefit of Nechako Chinook and migratory sockeye salmon. The Settlement Agreement also proposed a Kenney Dam Release Facility (KDRF) which would be constructed 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.

Following partial construction of the KCP the province cancelled the project in 1995 and the established "short-term" flows became the permanent flow releases. 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 requirements, but began to reduce its level of activities starting in the early 2000's. The program was scoped down in 2005 and 2012 and more recently in 2015. Over the years many hundreds of studies and reports have been prepared and the Nechako and its' salmon populations are one of the most intensively studied salmon ecosystems in BC.

During 2005 the NFCP prepared a Technical Data Review (NFCP 2005) that described the technical program between 1988 - 2002. In view of the need to evaluate recent data collected to 2015, this report was prepared by the NFCP Technical Committee to update the status of the program particularly in reference to what has been learned since the Technical Data Review was released more than 10 years ago. The report summarizes key NFCP results in a single volume and describes the evolution of the program from 1987 through to the present.

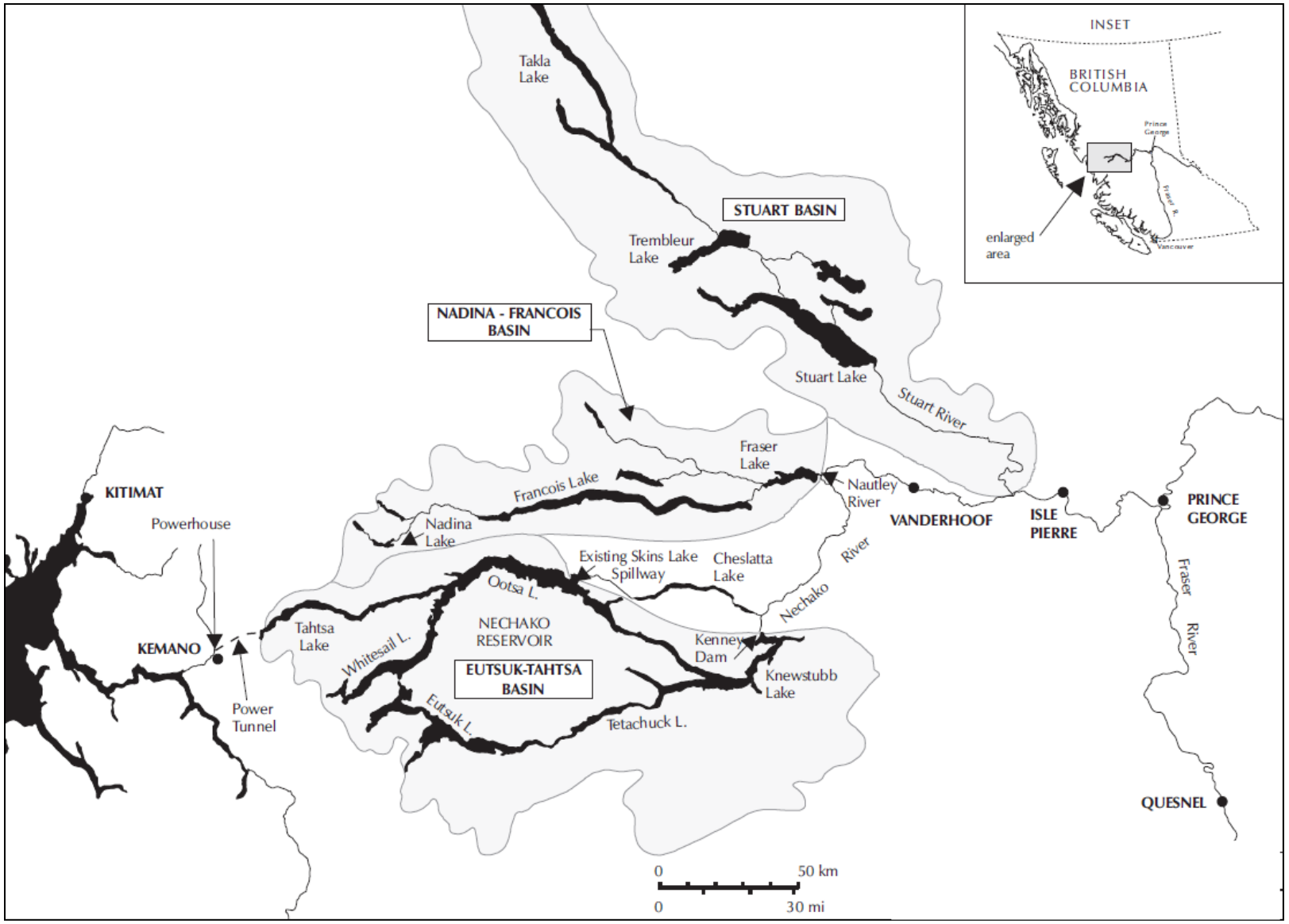

Figure 1. Location of the Kemano Project and the Nechako River in northern BC. Source: NEEF (2001).

Kemano Project History and the Origins of the NFCP

Background

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 developing a hydroelectric power project and establishing an aluminum industry on Canada's West Coast. Alcan carried out preliminary engineering studies in 1948 and 1949. These resulted in a proposed development that would include:

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

The effect of the diversion on the hydrology of the Nechako River is shown in Figure 2. 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 1951 the freshet peaked in June-July and following construction and the establishment of the Summer Temperature Management Program the river flow peaked in August.

The 1950 agreement and conditional water licence allowed Alcan to reduce releases at the Skins Lake Spillway during periods of below average inflows to the Nechako Reservoir. However, in June 1980 the Department of Fisheries and Oceans expressed concern over the volume of water released. The department anticipated sockeye salmon 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. Although Alcan was committed to releasing water to protect the fish, the company and the Department of Fisheries and Oceans 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, Alcan voluntarily agreeing to a renewal of the 1980 injunction in each of these years. Considerable progress was made during this period on methods to be used for the conservation of migrating sockeye salmon. However, by 1985, a consensus still had not been reached — particularly on the water releases required to conserve Chinook salmon — and Alcan returned to court to seek resolution.

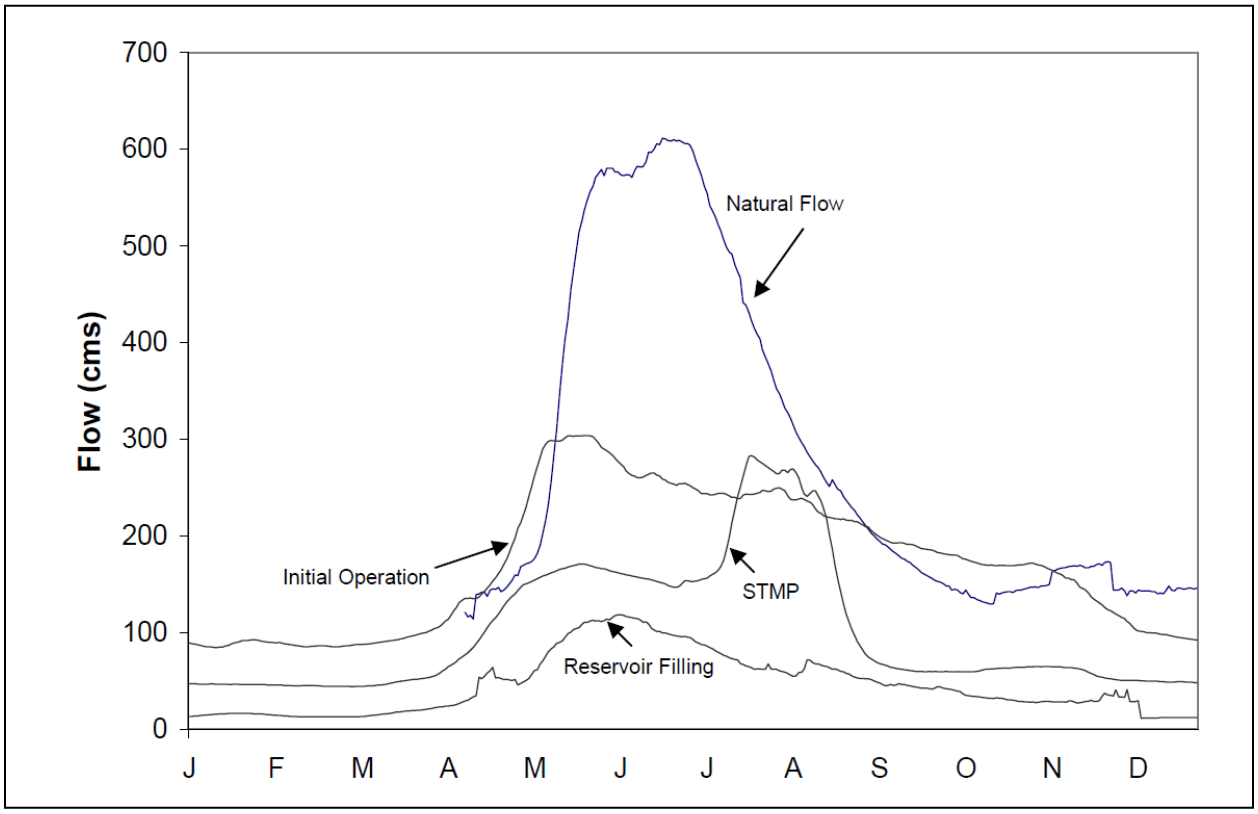

Figure 2: Mean daily discharge (cms) in the Nechako River at Vanderhoof. Data spans the pre-dam, natural flow period (1950-52), the extreme low flows when the reservoir was filling (1953-1956), the pre-STMP period during initial operation when greater water volume was released but releases where variable (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).

While preparing for the court case, the Nechako River Working Group, a task force comprised of scientists from the Department of Fisheries and Oceans, the provincial environment ministry and environmental consultants from Alcan, was asked if there was a technical basis for reaching an out-of-court settlement that could, with an acceptable level of certainty, conserve the Chinook salmon that use the Nechako River. The Working Group's *Summary Report* (1987) became the basis for the *1987 Settlement Agreement* (Appendix 1), the legal settlement of the dispute.

The terms of the Agreement provided Alcan the certainty it needed to start work on the KCP. Under the terms of the 1950 agreement with B.C., the Completion Project could divert additional water from the Nechako Reservoir to an expanded powerhouse at Kemano.

The Agreement also created the Nechako Fisheries Conservation Program. The immediate focus and much of the early work of the program (1988 – 1994) was based on the premise 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 KCP) was constructed by Alcan at Kenney Dam.

Accordingly, the Nechako Fisheries Conservation Program developed projects to collect baseline data and carry out research on the Nechako River basin. The objective of this research was to fill important gaps in knowledge in anticipation of lower water flows resulting from construction of the KCP.

Despite the uncertainty created by the court challenges and the province's cancellation of the KCP, the Technical Committee continued to fulfill the mandate for the NFCP set out in the *1987 Settlement Agreement*. This program was maintained in anticipation of potential flow changes associated with a proposed KDRF and has continued to the present, albeit with a reduced level of activity. The scope of the present program is described in subsequent sections of this document.

The 1987 Settlement Agreement

The *1987 Settlement Agreement* 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 Agreement provided direction to the parties for the periods prior to and following construction of the Kemano Completion Project and the KDRF. For example, the Agreement specified a schedule of short-term water releases to be carried out until the completion of the project, as well as a schedule of long-term releases to be carried out once the release facility was operating (Figure 3).

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

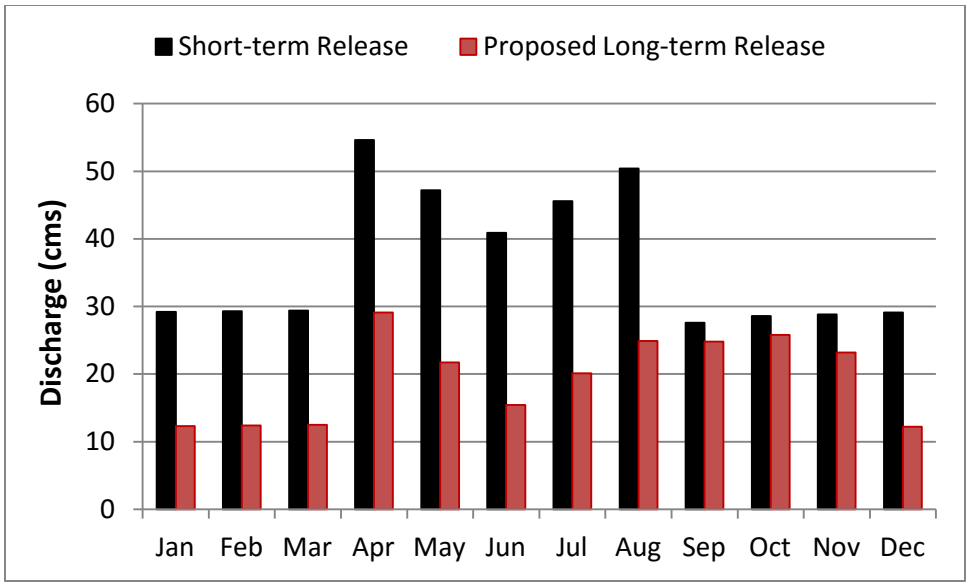

Figure 3. Water releases from the Skins Lake Spillway, not including summer cooling flows. The proposed long-term releases were never adopted as reflected in the 1997 BC - Alcan Agreement[1].

Conservation Goal

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

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

Paragraph 3.1 of the *Nechako River Summary Report*, appended to the 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[2].

[1] http://neef.ca/uploads/agreements/BC-Alcan_1997_agreement.pdf

[2] The NFCP has not directly estimated Nechako Chinook harvest and en-route mortality due to the absence of coded wire tagging data for the population. Escapement estimation has served as the main monitoring tool.

The Nechako Fisheries Conservation Program

The Nechako Fisheries Conservation Program (NFCP)[3] has three general goals.

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

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

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

An Early Warning Monitoring Program was also implemented 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 lower.

After 1997 when the KCP was cancelled, the Technical Committee focused on three primary activities.

- Managing water releases from the Nechako Reservoir into the Nechako River. This includes both the Annual Water Allocation (AWA) as specified in the *Settlement Agreement* and releases made during the summer months to protect migrating sockeye.
- Collecting Chinook utilization data in the upper Nechako River.
- Compiling, analyzing and reporting of technical data to ensure that NFCP objectives are met and to establish the basis for future NFCP-related activities.

[3] 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.

Chinook and Sockeye Utilization of the Nechako River

Chinook Salmon

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. To evaluate the sensitivity of the Chinook population to flow regulation it is important to understand Nechako Chinook life history to provide context for NFCP monitoring activities

A comprehensive summary of Chinook life history (Healey 1991) provides general biological information on Chinook salmon across their geographical range. Chinook are divided into 2 different races: "ocean-type" and "stream-type" depending on whether they emigrate to the ocean as fry or as yearling smolts. Nechako Chinook are stream-type animals (Bradford 1994) and have juveniles that reside in the Nechako during their first year or in the Fraser River mainstem (Levings and Lauzier 1991), or in non-natal streams (Murray and Rosenau 1989) before outmigrating to the ocean.

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 e.g. 2014, 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.

Sockeye Salmon

Sockeye salmon that utilize the Nechako River as a migratory corridor include:

Sockeye Run	Management Group
Nadina	Early Summer
Early Stuart	Early Stuart
Late Stuart	Summer
Stellako	Summer

The main sockeye protection concern associated with water abstraction is related to high temperature effects on migrating adults.

Time series of sockeye production (includes both harvest and escapement) between 1952 - 2011, the period of reservoir operation, are shown in Figure 4. Sockeye production is highly variable between years due to cyclic dominance.

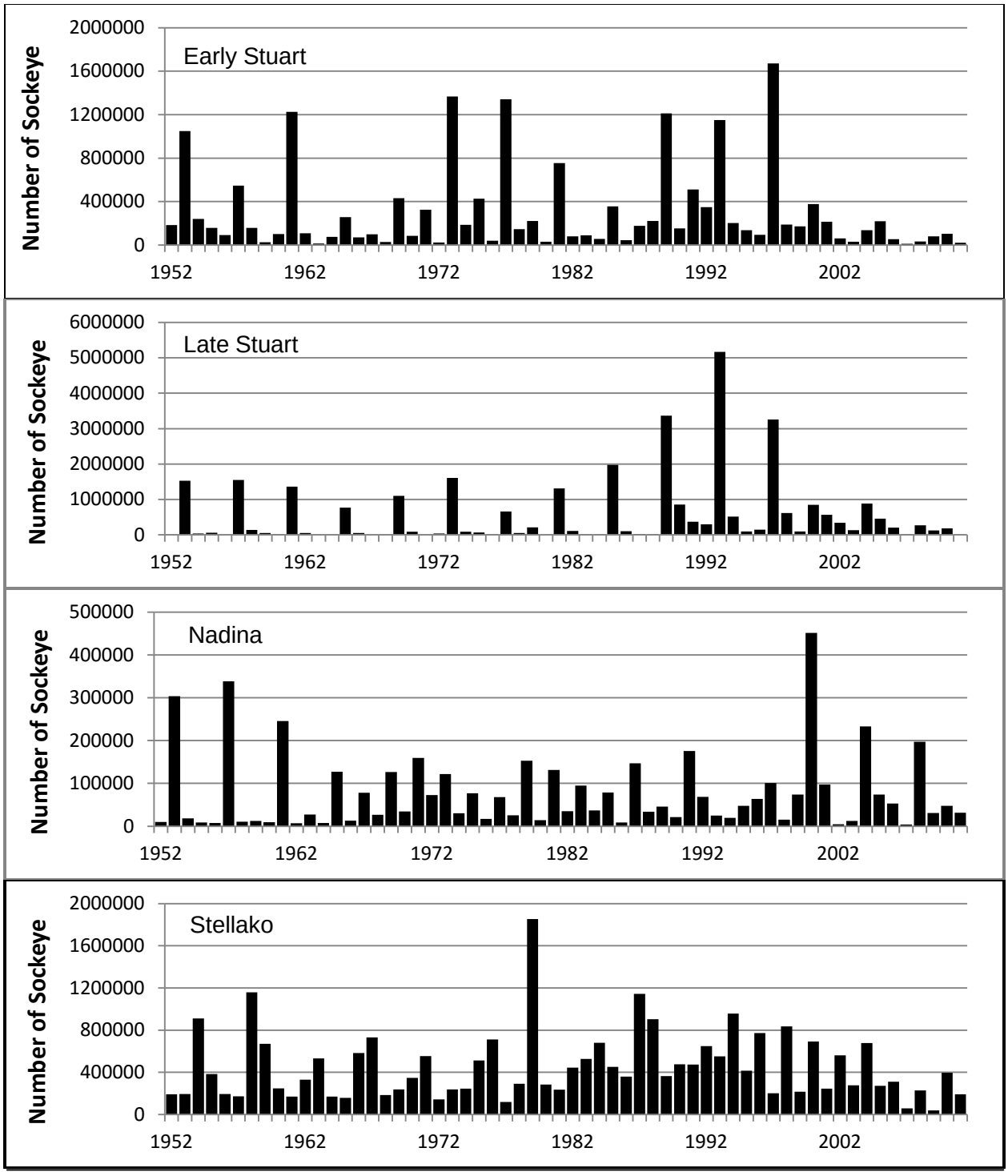

Figure 4. Sockeye production time series in 4 populations exposed to Nechako River discharges. Data source: DFO. Currently available data span the years 1952-2011.

Scope of NFCP Technical Activities

Monitoring

Chinook Salmon Adult Enumeration

Nechako River Chinook have been monitored annually in relation to the Conservation Goal. Spawner abundance estimation has been carried out using Area-under-the-Curve methodology since 1988 (Hill 1997); prior to then, spawner counts were obtained by DFO Fishery Officers using stream-side visual counts (Jaremovic and Rowland 1988).

The Area-under-the-Curve (AUC) method uses both periodic helicopter counts of spawner numbers during fall Chinook spawning and estimates of the time female spawners spend on the redd (residence time) in the calculation of the spawner population size. Detailed sampling procedures are described in the Technical Data Review (NFCP 2005). During the early stages of the Chinook monitoring program, the enumeration data were fitted using a trapezoidal approach to "connect-the-dots" of the sequential helicopter observations. Since the mid-2000's the population has been estimated by means of a Maximum Likelihood Approach to fit a normal curve to the flight observations.

Sampling of Chinook carcasses has been conducted annually by the NFCP to collect biological data on age, size, life history, sex and egg retention. The following data are routinely collected.

- sex
- condition
- post-orbital hypural length
- egg retention and fecundity
- scale samples for aging purposes

Almost all Chinook spawning activity in the mainstem of the Nechako occurs between Cheslatta Falls and the community of Vanderhoof. To analyse spawner distribution, the Technical Committee divided this portion of the river into 16 sections aggregated into three regions, the upper, middle and lower river (Figure 5).

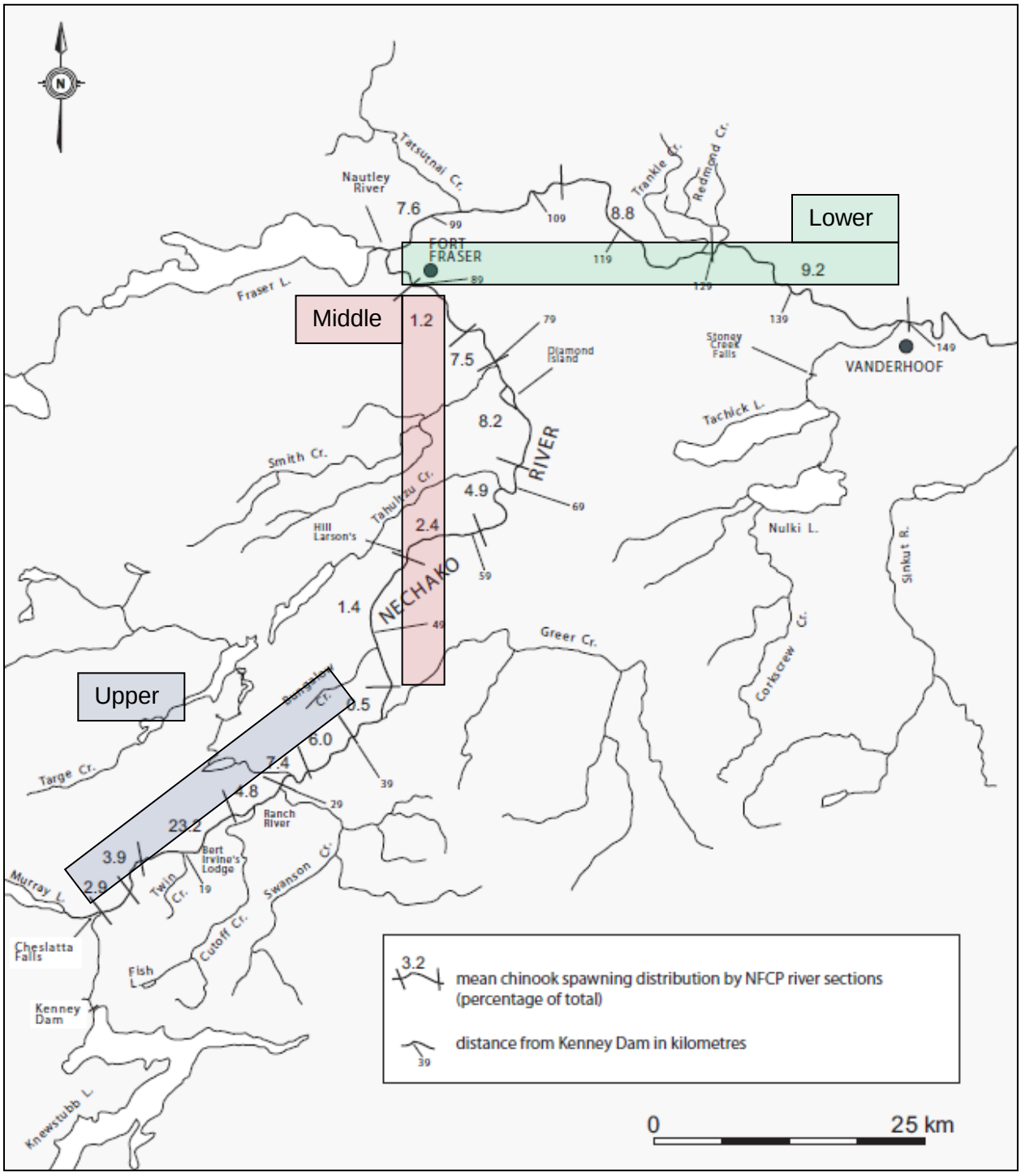

Figure 5. Chinook spawning distribution by river section between 1988 - 1998.Numbers indicate percentage of observed Chinook spawners. Source: NFCP (2005).

While Chinook spawning occurs throughout the river, largest numbers spawn in the upper river between Cheslatta Falls and the confluence of the Nechako River and Greer Creek (river km 0-40 in Figure 5).

The Carcass Recovery program collected samples for the determination of age composition, sex ratio, fecundity and size distribution. NFCP data shows that:

- Nechako Chinook are primarily 5-yr old fish with a smaller proportion of 4-yr olds and 6-yr olds;
- Female:male sex ratios were 1.37 (n=21 years)[4];
- Fecundity of Chinook averaged 5769 eggs per female (n=8 years);
- Nechako Chinook averaged 70.2 cm (postorbital hypural length) and are relatively large when compared with other Fraser River populations

With the exception of body size, there were no notable differences in adult characteristics between the Chinook from the Nechako River and those from the unregulated streams of the upper Fraser River basin. The age structure of Nechako River Chinook closely resembled the age structure found on the unregulated Stuart River and was not markedly different from the age structure of combined Fraser River basin stream-type Chinook.

Between 1989 and 2004, residence time was measured annually in the lower river and the upper river, as well as for early vs. late spawners, and showed a low level of variation. Residence time is a critical parameter for estimating spawner abundance by the area-under-the-curve method and varied between 8.9 days in 1994 to 12.5 days in 2004.

The Technical Data Review (NFCP 2005) compiled all of the Nechako River Chinook escapement data that has been collected since 1951 (Figure 6). Based on information from Jaremovic and Rowland (1988), the largest chinook escapements to the mainstem of the Nechako River prior to the inception of the NFCP were recorded in 1951 (3,500) and 1952 (4,000) prior to construction of Kenney Dam and the regulation of the upper river. Escapements fell ten-fold with the closure of the dam (1952), but between 200 and 1,500 spawners were reported in the next four years (1953 to 1956) as the last progeny of the pre-dam era returned from the sea to spawn. By the fifth year, 1957, no spawners were reported and none were observed in 1958 and 1959. Then in 1960 a total of 75 spawners were reported; escapements slowly increased thereafter. In recent years escapement has exceeded the recorded pre-dam escapements.

The trend in Chinook escapement since 1988 when the NFCP began to enumerate spawners (Figure 6) indicates that the Conservation Goal has generally been met with the exception of 5 years: 1994, 1995, 2007, 2012 and 2013. The observations of relatively high escapements between 1996 and 2006 indicate that the Chinook population is resilient and deviations below the lower target don't appear to create sustained reductions in subsequent year-classes. The highest escapement over the duration of NFCP monitoring (1988 - 2015) occurred in 2015 when 8,291 Chinook spawners were enumerated.

[4] In the Squamish River, Chinook female:male sex ratios vary between 0.82 - 2.48 (Evanson 2009).

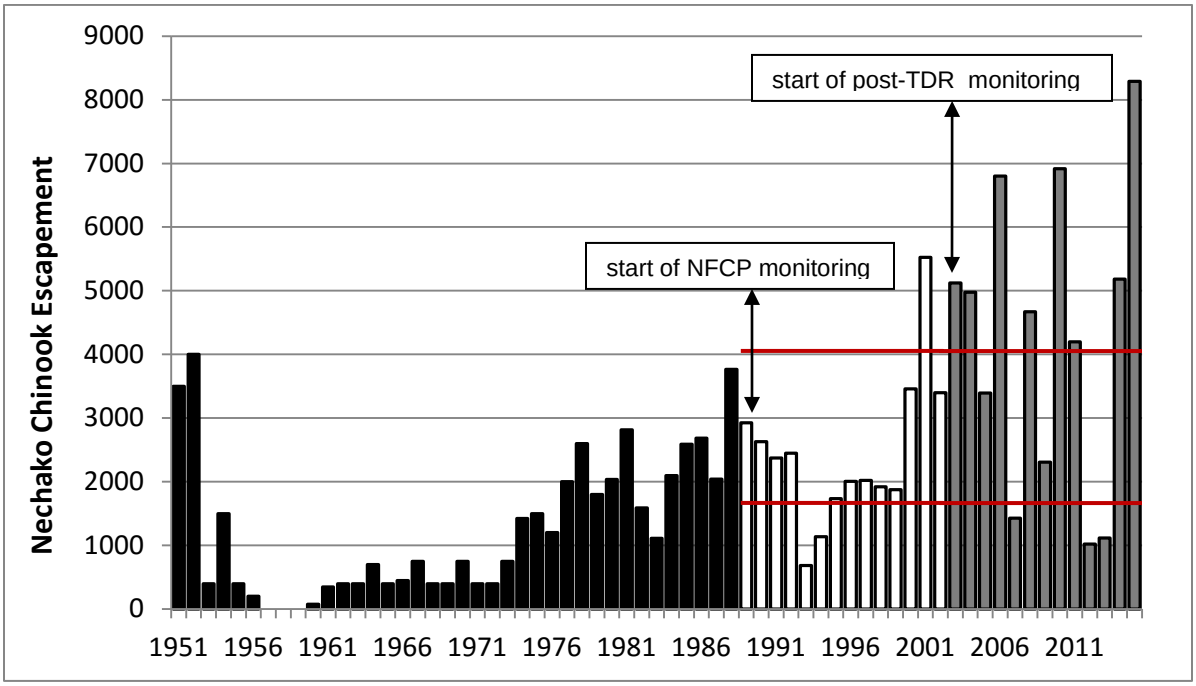

Figure 6. Time series of Chinook escapements to the Nechako River between 1951 - 2015. Black shaded bars indicate data from Jaremovic and Rowland (1988), white bars indicate NFCP monitoring results analysed in the TDR (NFCP 2005) and grey-shaded bars indicate NFCP monitoring results collected after the TDR evaluation (NFCP 2015). Horizontal red lines indicate the upper and lower limits of the Conservation Goal established following the 1987 Settlement Agreement.

During 2015 analyses were undertaken (NFCP 2015) to compare escapement trends in 2 successive periods: prior to, as well as after the Technical Data Review analysis. The mean escapements are compared in Table 2[5].

Table 2. Comparison of Chinook escapement over the period 1988 - 2015.

Time Period	Description	Mean Escapement
1988 - 2002	start-up of NFCP monitoring until end of TDR analysis	2527
2003 - 2015	recent period incorporating modifications described in 5 year Plans for 2007-2012 and 2012 - 2017	4264

[5] The NFCP/DFO methodology for estimating Chinook escapement has evolved over time and has included the following approaches: 1) pre-NFCP counts between 1951-1987; 2) Area-Under-the-Curve (5 helicopter flights) between 1988-2007; Maximum Likelihood Analysis (5 helicopter flights) between 2008 - 2014; and 5) Maximum Likelihood Analysis (2 helicopter flights) in 2015. The evolution of the NFCP methodology is further described in Technical Report Decision Record 2016-2017 #1.

The analysis indicated 69% higher escapement in the 2003-2015 period and further strengthened the 2005 Technical Data Review conclusion that "the spirit and intent of the Conservation Goal have been met."

As a complement to escapement monitoring, an alternative approach utilized in numerous salmon assessment programs is to calculate recruits per spawner as a measure of salmon productivity. "Recruits" represent escapement as well as catch and en-route mortalities during upstream migration. Catch mortality is usually estimated from head tag recoveries of hatchery marked juveniles. As there is no head tag recovery program for Upper Fraser Chinook, this approach cannot be applied.

An alternative approach relies upon calculations of "escapement-per-escapement" estimates to evaluate the escapement returns of specific brood years (Figure 7). The calculation accounts for differential age at return and shows a polynomial relationship. Peak escapement-per-escapement occurred between the late 1990's and the early 2000's. The results imply a higher productivity over this period although the underlying mechanism for this trend is unclear.

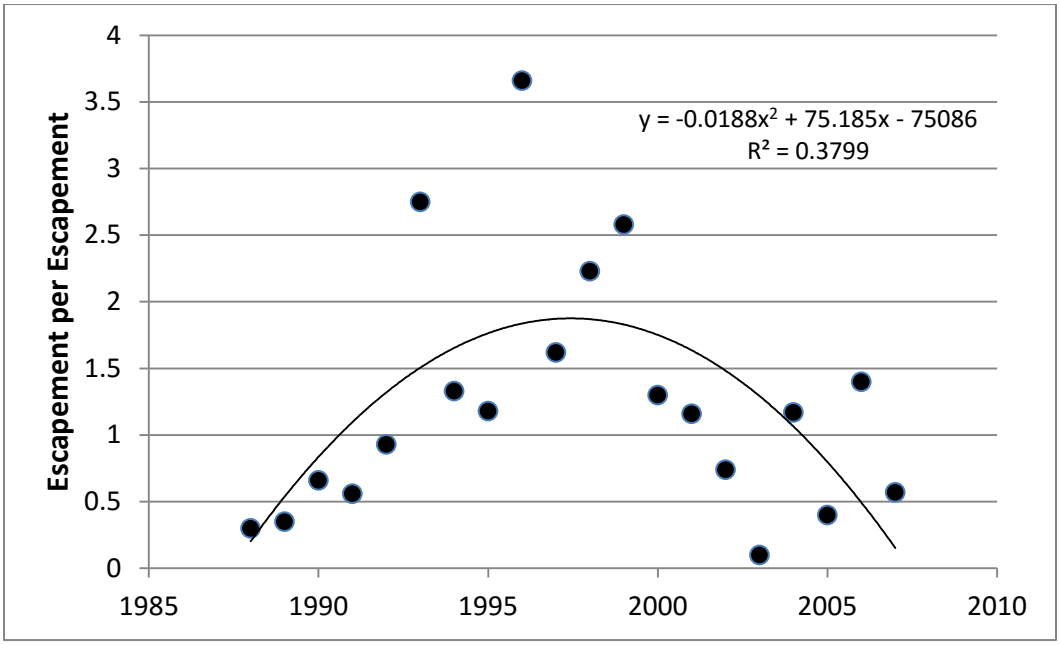

Figure 7. Trends in escapement-per -scapement for brood years between 1988 - 2007.

Juvenile Chinook Monitoring

Juvenile Chinook monitoring has been undertaken to assess in-river habitat quality and to potentially trigger remedial activities in the event of habitat degradation in relation to flow changes. Between 1990 - 2002 this activity was undertaken annually. The frequency was scoped down to once every 5 years during the 2007-2012 period, and was terminated in 2015 when NFCP monitoring was suspended. The last measurements took place in 2010.

During NFCP juvenile assessments, separate programs were run to sample emergent fry in mid-March through mid-May using 4 Inclined Plane Traps (IPTs) in the Upper River adjacent to Bert Irvine's Lodge and migrating fingerlings between mid-April through mid-July utilizing 3 Rotary Screw Traps (RSTs) and electrofishing, also in the Upper River. Detailed methodology for the Fry Emergence and Juvenile Outmigration projects is available in Triton (2010 A,B) and the Technical Data Review (NFCP 2005).

Fry Emergence Project

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.

Specific tasks included monitoring:

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

The daily index of fry emergence from the substrate was estimated from the proportion of discharge sampled by each IPT and its wings, and the number of Chinook counted in each IPT. Data for all IPTs were combined for each day because statistical independence among IPTs could not be assumed. Consequently, the index of fry emergence was the sum of all four IPTs expanded daily catches weighted by the water volume filtered by each trap.

An 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 8) between the number of female spawners in Year (x) and the index of fry emergence in Year (x+1). The most recent data point (2010) fell close to the regression line and the R^2 value was 0.8636, a strong correlation.

The stability of the relationship over time suggests that intra-gravel habitat conditions for egg and alevin development have remained suitable for fry production and that flow regulation hasn't induced to a deterioration of habitat quality over time.

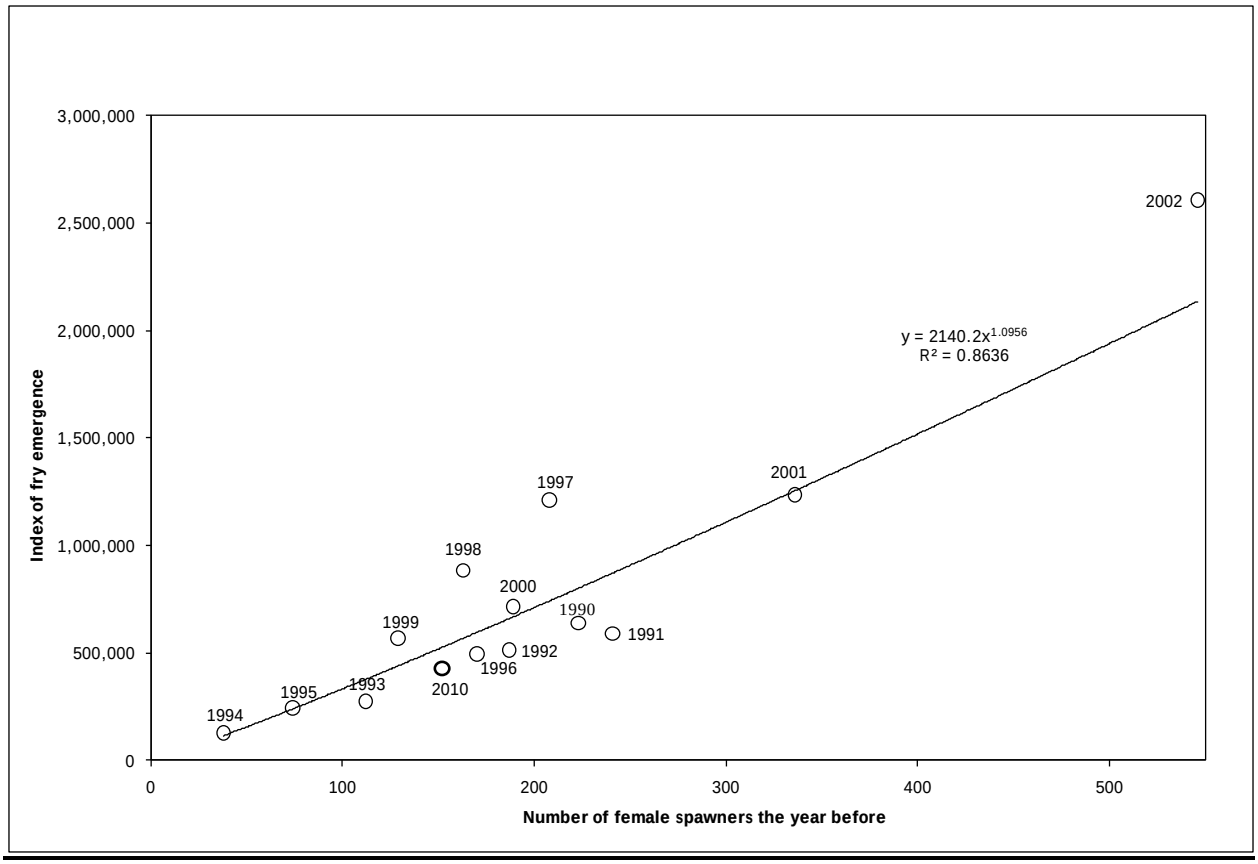

Figure 8. Index of fry emergence vs. spawner escapement during the previous year above Bert Irvine's, km 19 of the Nechako River, 1990-2002, 2010 (circled data point). Source: Triton (2010A).

Juvenile Out-migration Project

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 to act as an indicator of the condition of juvenile rearing habitat.

The specific objectives of the project were to:

- monitor temporal and spatial changes in juvenile Chinook abundance from spring to autumn within the upper 90 km of the Nechako River;
- monitor juvenile Chinook body size, growth and condition;
- develop a standardized index of the number of juvenile Chinook salmon leaving the upper Nechako River;
- measure the timing of juvenile Chinook 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 number of juvenile Chinook passing Diamond Island (RST sampling site) in a day was estimated by multiplying the total number of fish caught in an RST in a given time period (day or night) by the ratio of the total flow of the river to the flow that passed through the RST. Since there were 3 RSTs, there were 3 estimates of the total number of downstream migrants each day. The best estimate of the total index number of Chinook out-migrants was the mean of the 3 estimates weighted by the flow passing through each trap.

The seasonal pattern in Chinook outmigration in the Nechako River (Figure 9) indicates a unimodal distribution with highest numbers migrating during the month of May.

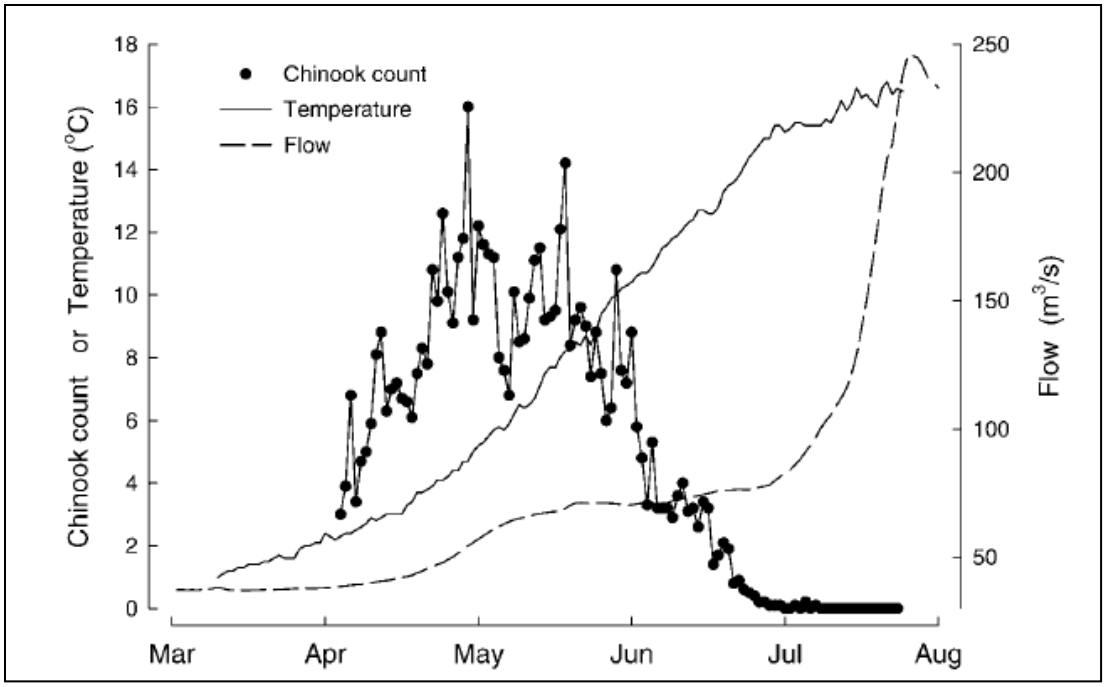

Figure 9. Outmigration of Chinook fingerlings in the Nechako River. Graphic shows average daily Chinook salmon captures, average flow and average temperature in the upper Nechako River for the period 1992 - 2004. Source: Sykes et al. (2009).

The relationship between the number of spawners above Diamond Island and the index of juvenile outmigrants appeared to be curvilinear (Figure 10) with a R^2 value of 0.83, a strong correlation. These results suggest that rearing habitat conditions in the Nechako River have remained stable over the period of observation (1992 - 2010).

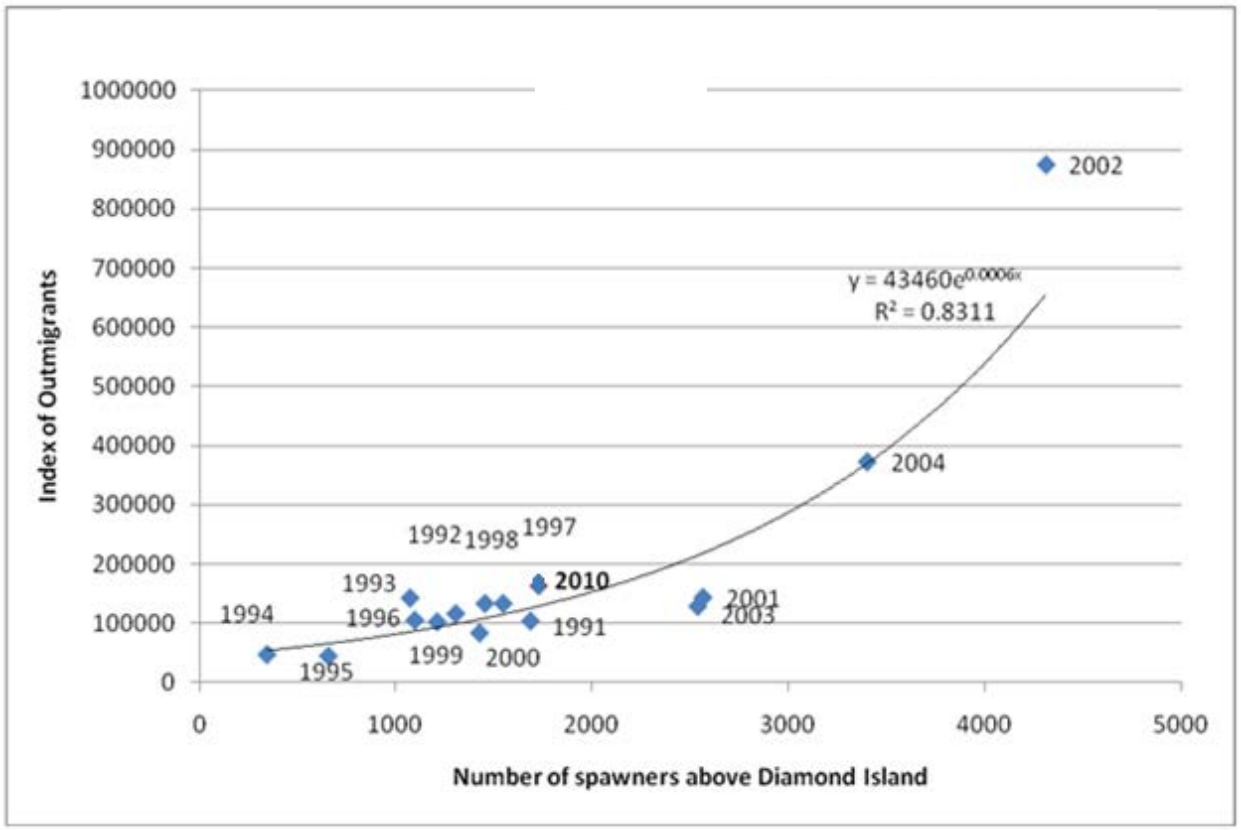

Figure 10. Index of Chinook salmon outmigrants based on rotary screw captures vs. the number of spawners above Diamond Island the previous year, Nechako River 1992-2004, 2010. Source: Triton 2010B.

Remedial Measures

Summer Temperature Management Program

The objective of the Summer Temperature Management Program (STMP) is to moderate elevated water temperatures during sockeye migration by manipulating the timing and volume of reservoir water, 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. 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 >20^{o}C in the Nechako River. Over this period Nechako River temperatures rarely exceeded 20^{o}C even though meteorological conditions warmed over the study period. It was found that that the frequency of water temperatures in excess of 20^{o}C was similar to that recorded in a cooler period prior to the implementation of the STMP. Results from recent years are shown in Table 3.

Table 3. Annual frequency of water temperatures exceeding 20^{o}C in the Nechako River at Finmore during the STMP period between July 20 - August 20.

Year	Exceedances above 20^{o}C between July 20 - August 20	Commentary
1953-1979	3.2	Annual average
1983-2000	2.9	Annual average
2001-2009	3.4	Annual average
2010	1	Mean daily water temperatures in the Nechako River above the Stuart River confluence exceeded 20°C on July 10 through July 13 and July 28 reaching a maximum temperature of 20.1°C on July 28. There were three exceedances that occurred prior to the water temperature control period and the latter occurred when the river discharge was at the maximum permitted under the operating protocol.
2011	0	The STMP was not operated in the summer of 2011 as reservoir management releases exceeded the STMP Protocol maximum discharge in the Nechako River below Cheslatta Falls for all of July and until August 25 (later than required under the STMP).
2012	0	The STMP was not operated in the summer of 2012 as reservoir management releases exceeded the STMP Protocol maximum discharge in the Nechako below Cheslatta Falls for all of July and until August 20.

2013	13	The STMP was operated in the summer of 2013 in accordance with the Protocol referenced in the 1987 Settlement Agreement. Generally, the summer of 2013 was warmer than average and releases from the Skins Lake Spillway were required to maintain the discharge in the Nechako River below Cheslatta Falls at or near the maximum discharge of 283 m^3/s for 23 of the 31 days in the control period (July 20 to August 20).
2014	5	The STMP was operated in the summer of 2014. The summer of 2014 was generally average when compared to previous years, and as a result, the discharge of the Skins Lake Spillway was increased above minimum levels on several occasions in response to warming trends. Due to the above average temperatures, the maximum flow target of 283 m^3/s at the Nechako River below Cheslatta Falls was exceeded 5 days during the temperature control period (July 20 – August 20).
2015	0	The STMP was operated in the summer of 2015. Due to the higher than normal reservoir level, discharge at the Skins Lake Spillway was higher than typical years at the start of the water temperature operational period (July 10 – August 20).

Comparison of the earlier results from the TDR with more recent observations (Table 3) indicates that the exceedances above 20°C increased in 2013 and 2014, possibly in response to a regional warming trend in BC. Increased summer water temperatures have been observed throughout the Fraser River watershed and are monitored by DFO via the Environmental Watch Program and have also been observed prior to July 20, the start date of the STMP.

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 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 and this result has continued 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 consequence for water depth is not significant.

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 measures projects is listed below and is summarized in the TDR.

Remedial Measure	Objective	NFCP Conclusion
1. Instream Habitat Modifications Project	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.
2. 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.
3. Cheslatta and Murray Lakes Inflow Investigations	The objective of the Cheslatta and Murray Lakes Inflow Investigations was to develop a method of forecasting both the timing and volume of the spring freshet into the upper Nechako River from the Cheslatta Lake and Murray Lake watersheds.	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.
4. Inorganic Fertilization Project	The objectives of the Inorganic Fertilization Project were to determine optimum nutrient enrichment ratios and loading rates, assess the effect of fertilization on the benthic community and collect periphyton baseline data.	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.
5. Identifying and Ranking Sources Contributing Sediment to the	Develop and rank an inventory of sediment sources to use in reaching decisions on the necessity and priority of controlling sediment contributions	Active erosion occurred at approximately 38 sites along the upper river, but only a few sites contributed most of the annual supply. The

Upper Nechako River	from individual sources.	measured Nechako River sediment loads were similar to those of other regulated or lake controlled systems.
6. Riverbed Survey	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.
7. 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.
8. 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.

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.

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 behavior throughout the upper Nechako River. The research was designed to assess diel behavior and activity, habitat utilization, distribution, growth and feeding behavior.

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.

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.

Conclusions - Applied Research

The results of the applied research projects complemented the Technical Committee's understanding of fish habitat use and species interaction on the Nechako River. 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.

Evolution of the NFCP Technical Program

The NFCP monitoring program was initially designed to comprehensively monitor all Chinook life history stages in all years. Over time, this approach was streamlined, based on experience and empirical evaluation, to create efficiencies in program delivery. This section of the report provides a description of key management decisions that have guided the evolution of NFCP program activities.

Modifications to scheduled reservoir releases have been undertaken, as required, based on consensus decisions of the NFCP Technical Committee. For example, Skins Lake spillway discharge is normally increased from the base winter flow level to the spring discharge level of 49 cms in the last few weeks of April. In years when the water level increases quickly during the spring thaw there is a risk of drowning beaver that could get trapped under the ice cover due to an absence of breathing holes. Under these circumstances the spring discharge is delayed until the ice on Cheslatta Lake has cracked free from shore around the perimeter of the lake.

Other flow modifications are undertaken as needed to maintain the reservoir within the operating limits during high inflow years. Increased flow releases have occurred either during spring/summer or else during the fall/winter in order to minimize risk of a forced spill in spring.

When the KCP was cancelled in 1995 the NFCP program continued in anticipation of potential flow changes associated with the construction of a KDRF. During the 2000's and subsequently the technical program was scoped down and, since 2007, has been guided by two 5-year plans.

The first 5-year plan covered the period between 2007 - 2012 (NFCP 2007). Key program refinements reflected in this plan included:

- core water management activities including the Annual Water Allocation (AWA) and Summer Temperature Management Program (STMP) remained unchanged;
- adult and juvenile Chinook monitoring were reduced and streamlined so as to improve overall program efficiency via:
    - reductions in helicopter overflight frequency during annual abundance surveys;
    - adoption of the long term average residency time for scaling adult Chinook numbers (10.6 days);
    - reduced frequency of fry emergence and juvenile outmigration surveys; and,
    - adult carcass surveys were continued to provide biological supporting data for the Chinook population counts and to provide linkage to the historic data set.

The second 5-year plan was prepared to cover the period between 2012 - 2017 (NFCP 2012) and includes:

- core water management activities including the Annual Water Allocation (AWA) and Summer Temperature Management Program (STMP) remained unchanged;
- adult Chinook would continue to be monitored annually using 5 helicopter overflights scheduled in September into early October[6];
- the long term average residency time for scaling adult Chinook numbers (10.6 days) would be adopted and measured once during the 5 year period;
- juvenile Chinook monitoring would be measured once over the 5 year period consistent with the previous five-year plan; and,

[6] annual overflight frequency was reduced to 2 flights in 2015 - see below

- adult carcass surveys would continue to provide biological supporting data for the Chinook population counts and to provide linkage to the historic data set.

During 2015 the Technical Committee decided to transfer the responsibility for adult Chinook monitoring to Fisheries and Oceans Canada as part of their routine stock assessment activities in large BC Chinook rivers. The rationale was documented in a report that reviewed trends in Nechako Chinook adult escapement over 26 years of NFCP monitoring (NFCP 2015). The evaluation considered 2 monitoring periods: 1) 1988 - 2002, covering the data set analysed during the 2005 Technical Data Review, and 2) 2003 - 2014. The intent was to determine whether the conclusions in the TDR remained valid by comparing the respective escapements in the 2 periods. Results showed that Chinook escapements in the recent period increased on average by 61% compared to the earlier period, thus supporting the earlier conclusions contained in the TDR.

In view of the documented increase of the Nechako Chinook population between 2005 - 2014, the Technical Committee concluded that the adult Chinook monitoring could be further streamlined. A decision was taken to reduce the helicopter overflight frequency (from 5 flights to 2 flights) as documented in a formal Decision Record:

> *The Chinook escapement monitoring program, previously undertaken between the last week of August and throughout September, will be taken over by the Stock Assessment Division of DFO as part of the province-wide escapement monitoring of large Chinook rivers in BC. Other NFCP water management functions, including the Annual Water Allocation (AWA) and the Summer Temperature Management Program (STMP), will continue to be operated as set out in the 1987 Settlement Agreement.*

Presently the NFCP program no longer operates an adult chinook monitoring program but continues to carry out core remedial measures including the AWA and the STMP.

Evaluation of the NFCP

In general the NFCP has functioned effectively since 1987 and the collaboration between DFO, BC FLNRO and Rio Tinto has successfully fulfilled the programs' mandate as defined in the Settlement Agreement. The original focus of the NFCP was to prepare for lower flows that would result from the KCP. Following the cancellation of the KCP in 1995 the program continued to operate in anticipation of altered flows associated with a potential KDRF.

The NFCP focus has been directed towards the Nechako Chinook population and the migratory sockeye that utilize the Nechako River Corridor. Monitoring has demonstrated that the Nechako Chinook population is healthy and meets the Conservation Goal in most years. Additionally, monitoring of fry emergence and juvenile outmigration has shown that the incubation and fry rearing habitats in the Nechako have remained stable in the Nechako River. The numbers of fry produced are sufficient to generate a return of spawners within the Conservation Goal range.

The scope of the NFCP mandate relative to sockeye conservation is to operate the STMP. It is evident that the STMP has limited the frequency of mean daily temperatures that have exceeded 20^{o}C at the Nechako-Stuart confluence and effectively mitigates warming effects on sockeye salmon that are associated with flow regulation. Warming water temperatures have occurred in the Upper Fraser region and temperature-related mortality of sockeye salmon remains an ongoing concern throughout the drainage basin.

Following thorough review, the TDR concluded in 2005 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."*

Since the TDR was completed 10 years ago the more recent NFCP results demonstrate:

1. the streamlined monitoring program that was initiated in 2007 has been effective and data integrity has been maintained. The streamlining was primarily associated with the use of mean residency time (10.6 days) for generating Chinook spawner population estimates coupled with reduced helicopter overflight frequencies (5 flights per year);

2. there was a 61% increase in Chinook spawner population size over the period 2003-2014 when compared with the TDR data set covering 1988-2002;

3. continued fry and juvenile habitat stability as reflected by the 2010 sampling results;

4. over the period 2010-2015 daily exceedances of the 20^{o}C temperature target measured at the Nechako/Stuart confluence ranged between 0-13[7].

5. the AWA flow objective (mean annual flow above 36.8 m^3/sec) has been consistently achieved; and,

6. continued achievement of the Conservation Goal.

[7] The summer of 2013 was warmer than average and releases from the Skins Lake Spillway were required to maintain the discharge in the Nechako River below Cheslatta Falls at or near the maximum discharge of 283 m³/s for 23 of the 31 days in the control period (July 20 to August 20). This resulted in 13 exceedances of the temperature target.

During its initial work the Technical Committee recognized that sufficient time would need to elapse after the implementation of the KCP before it could assess whether the Conservation Goal had been achieved. The timeframe identified by the committee to ensure that the Nechako River Chinook population was stable and within the target value established by the *1987 Settlement Agreement* was 20 to 25 years, or 4-5 complete Chinook life cycles. By 2015, the NFCP had completed 27 years of adult Chinook monitoring equivalent to more than 5 complete Chinook life cycles. The program has therefore collected sufficient data to evaluate and confirm that the spirit and intent of the Conservation Goal has been met.

In view of the 2015 transfer of Chinook monitoring responsibility to DFO, the NFCP in future will continue to annually carry out core remedial measures programs including the AWA and the STMP. Fisheries flows in the Nechako River will continue to be managed by the NFCP and implemented by Rio Tinto. This arrangement will ensure that the 1987 Settlement Agreement provisions will continue to be met.

References

Evanson, M. 2009. Chinook salmon population dynamics and life history strategies in the Squamish River Watershed, B.C., Canada. Ph.D. Thesis. Department of Environmental Science and Engineering, University of California Los Angeles. 142p.

Healey, M.C. 1991. Life history of Chinook salmon *(Oncorhynchus tshawytscha)* p. 310 - 393. *In* C. Groot and L. Margolis (ed.) Pacific salmon life histories. University of British Columbia Press, Vancouver, B.C.

Hill, R. A. 1997. Optimizing aerial count frequency for the Area-under-the-Curve method of estimating escapement. N. Am. J. Fish. Mgmt. 17: 461-466.

Jaremovic, L. and D. Rowland. 1988. Review of Chinook salmon escapements in the Nechako River, British Columbia. Can. MS Rept. Fish. Aquat. Sci. 1963. 135p.

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

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.

Murray, C.B. and M.L. Rosenau. 1989. Rearing of juvenile Chinook salmon in nonnatal tributaries of the lower Fraser River, British Columbia. Trans. Am. Fish. Soc. 118: 284-289.

Nechako Fisheries Conservation Program. 2005. Technical Data Review 1988 - 2002. 319p. Vanderhoof, B.C.

Nechako Fisheries Conservation Program. 2007. 5 Year Plan: 2007-2012. Prep. by NFCP Technical Committee.

Nechako Fisheries Conservation Program. 2012. 5 Year Plan: 2012-2017. Prep. by NFCP Technical Committee.

Nechako Fisheries Conservation Program. 2015. Trends in Adult Chinook Salmon Escapements in the Nechako River: Results from 26 Years of NFCP Monitoring. Vanderhoof, B.C. 17p.

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

NEEF 2012. Report of the Nechako Environmental Enhancement Fund Management Committee. 27p.

Nechako River Working Group. 1987. Summary report of the Nechako River Working Group. Appended to the 1987 Settlement Agreement.

Sykes, G.E., C.J. Johnson and J.M. Shrimpton. 2009. Temperature and flow effects on migration timing of Chinook salmon smolts. Trans. Am. Fish. Soc. 138: 1252 - 1265.

Triton. 1997. NFCP 10 Year Review: Background Report. Prep. for NFCP.

Triton. 2010A. Nechako River fry emergence project 2010. Prep. for NFCP. 44p.

Triton. 2010B. Size, distribution and abundance of juvenile Chinook salmon of the Nechako River, 2010. Prep. for NFCP. 63p.

Triton. 2013. NFCP flow-related decision criteria. Prep. for Rio Tinto Alcan.

Appendix. 1987 Settlement Agreement