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Natural Resource Consultants

Nechako Coldwater Release Facility Year 1 Pre-Engineering and Environmental Studies – Nechako Canyon and Cheslatta Fan

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EXECUTIVE SUMMARY

The construction of Kenney Dam has significantly altered the discharge and sediment regimes of the Nechako Canyon by diverting the Nechako River flows into the Cheslatta River system. This has left the first 9 km of the former Nechako River essentially dry, except for local inflows, and eliminated sediment transport through the Nechako Canyon. The operation of the Nechako Reservoir has also altered the flow and sediment regimes of the Nechako River below the Cheslatta confluence by reducing average and peak flows and by redistributing the timing of low and high flows.

It is the objective of this study to evaluate the plan for returning the diverted flows to this dried-up reach of the Nechako River. The study is in two parts because the affected river reach consists of two very different sections, with 7 km of bedrock canyon followed by 2 km of alluvial sediment (the Cheslatta Fan) created by a post-diversion channel avulsion.

Nechako Canyon

Sediment accumulations in Nechako Canyon are principally located in the first 4 km of channel downstream of Kenney Dam. These deposits consist of fans that have formed the mouths of two small streams, an eroding spoil pile near the dam, fine sediment and organic materials found in or behind beaver dams and locally derived colluvium. The location and volume of potentially mobile sediment has not changed significantly since Triton's previous study in 1991. Their volume estimate of 28,000 m^3 of unconsolidated clay, silt, sand and pond materials appears reasonable for planning purposes.

The study team recommends that the deposited sediment be flushed out of the canyon using flows from the Cold Water Release Facility. If required, sediment loads could be reduced by protecting the toe of the spoil pile near the dam from erosion, and possibly pre-excavating materials from the vicinity of the two fans. It would not be feasible to remove other sediment in the canyon. Hydraulic and sediment transport calculations confirm that the deposited sediment would be mobilized and transported out of the canyon by relatively small flows during the earliest stages of canyon flushing, likely creating high suspended sediment concentrations and turbidity.

Plant material subject to removal would be biomass accumulated since dewatering of the Canyon in the 1950's. The trees found in the canyon are generally less than 22 cm in diameter at breast height and shorter than 15 m in height. These sizes, in relation to the width of the channels, are not expected to create massive accumulations of woody debris that could suddenly break and release. The presence of the mobilized vegetation, large or small, is not expected to have significant adverse impacts on the aquatic ecosystem. It is very unlikely that removal of this vegetation would result in the loss of rare or endangered plant species.

Rainbow trout that have become established in the canyon will likely be displaced. Larger flows will create high velocity migration barriers to fish traveling upstream.

Wildlife in the canyon was predominantly beaver and waterfowl, with some use by otter and moose in the canyon. These would be displaced with the rewatering of the canyon.

Cheslatta Fan

Hayco reviewed 14 options in the NEEFMC report, Options for Passing Flows through the Cheslatta Fan, and recommended the Meandering Pilot Channel concept. The EDI study team concurs with the elimination of 12 of the 14 concepts, but retained the Meandering Pilot Channel and the River-cut Channel (Options 12 and 13) for more detailed assessment. The River-cut Option was modified slightly, and two variations of this concept were evaluated in this report. Option A includes bank stabilization involving bioengineering in the area where the future bank would likely form, and careful channel commissioning using an adaptive management approach. The other variation, Option B, is the same as Option A except that a short pilot side channel, two herms and a short revetment have been added.

The evaluation confirmed that all three options are feasible. However, the Meandering Pilot Channel Option proposed hy Hayco is not recommended. Option A is the best choice, with Option B a close second. Each of the four independent additional elements of Option B (the pilot side channel, the two berms and the revetment) offers a modest environmental benefit at a modest cost. If required, any one or more of these additional features could be added to Option A.

The construction cost of Hayco's Meandering Pilot Channel concept was re-estimated at $1.41 million. Option A has no construction cost associated with it, and Option B was estimated to cost $0.67 million. However, these estimates do not include the costs of water with which to commission the channels, bioengineering for hank stabilization, environmental studies, permits, approvals, and monitoring, all of which are similar for all three options.

Commissioning

The EDI study team recommends a series of progressively larger flow releases from the Cold Water Release Facility to flush sediment from Nechako Canyon and to commission the proposed channel across Cheslatta Fan. These flows should be manipulated to ensure that exposures to turbidity or suspended sediment concentrations would not cause mortality to fish by applying new criteria that would be based on recent research by the B. C. government (Newcombe and Jensen, 1996; Newcombe, 2003).

The commissioning flows should be released during the period from May 15 to August 20, and preferably in the early part of that period, when pre-Kenney Dam flows were high and turbid. The first set of commissioning flows should involve only small discharges (to a maximum of 60 m^3/s) and should be used as an intensively monitored test case to provide data for planning subsequent releases. After these commissioning flows have peaked, they should be reduced in steps to determine the maximum discharge from the Kenney Dam that does not entrain significant amounts of fine sediment. This should allow the Cold Water Release Facility to become at least partially operational immediately after the initial set of commissioning flows.

To dilute the suspended sediment and to keep it in suspension as long as possible, large quantities of clean water flushing flows should be released from Skins Lake spillway to coincide with the commissioning flows. These high flows should be sustained longer than the travel time for the water to flow from Cheslatta Falls to Prince George, and they should have some fluctuations to dissipate sands and finer material from the riverbed to the channel margins.

It is not possible to calculate or reliably predict the rates of sediment transport along the bed of the river or the concentrations of suspended sediment that would occur as a result of the initial stages of the commissioning process. It appears likely that instantaneous sediment concentrations could reach 10 g/L at the mouth of the canyon and on the fan prior to dilution at Cheslatta Falls, however these concentrations could not be sustained for long due to the limited volume of fine material to be flushed out.

The configuration of the river systems allows clean water dilution and flushing flows to be released via the Skins Lake spillway and the Cheslatta River during channel commissioning. These flows would make large dilution ratios possible when the initial low flows with high sediment concentrations are discharged from the canyon and fan.

The volume of water required to commission the Option A or B channels cannot be estimated with any certainty in advance, since the volume required would partly depend on the concentrations of suspended sediment generated, and on the rules for flow releases at Kenney Dam that would be developed during the adaptive management process. A series of assumed flow release scenarios that would occur over four separate years suggest that net additional water volumes ranging from 7% to 12% of the total average annual inflow to the Nechako Reservoir in each of these four years may be adequate to fully commission the channel. This 4-year total is 2.4 billion m^3 of water, or about 3 m of depth in the reservoir.

It must be recognized that if suspended sediment criteria with stringent maximum limits on concentration are to be applied to this project, then the Cold Water Release Facility cannot be built. There is no way to remove the fine sediment from Nechako Canyon, nor to create a natural self-enlarging channel across Cheslatta Fan, without exceeding such criteria by a large margin for short periods of time. Research by Newcombe and others has shown that juvenile and adult salmon can tolerate short-term exposures to suspended sediment concentrations that are much higher than some of the upper limits set by regulatory criteria in the past without suffering mortality.

It must also be recognized that implementing any of the self-enlarging channel options will involve some risk of higher sediment loads, unexpected sediment deposition patterns downstream, and/or greater water volume requirements than might be anticipated in studies prior to commissioning. However, it is the unanimous opinion of this study team that the risks of short-term negative environmental impacts associated with rewatering the Nechako Canyon and allowing the creation of a self-enlarging natural channel across the Cheslatta Fan would be significantly outweighed by the substantial long term environmental benefits. More natural annual flow patterns on the Nechako River and restoration of the Cheslatta River can only be achieved by building the Cold Water Release Facility.

We recommend forwarding Option A to the next stage of study and evaluation, subject to a clear indication from all the regulatory agencies involved that they will be willing to accept alternative suspended sediment concentration-duration criteria for the purpose of evaluating this project. Such willingness is absolutely essential for the Cold Water Release Facility project to proceed.

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1.0 INTRODUCTION AND OBJECTIVES

In the early 1950s, Alcan began construction of its Kemano Project, which included the construction of a dam on the southern arm of the Nechako River and the creation of a reservoir system. The purpose of the project was to divert water to the Pacific drainage to generate hydroelectric power (Figure 1.1-1). The construction and operation of the Kenney Dam has resulted in the diversion of a portion of the Nechako River's mean annual flow and the alteration of the hydrologic regime of the river.

In the 1980's Alcan, Canada, and the Province of British Columbia reached an agreement on, among other things, the flow releases from the Nechako Reservoir for the conservation of chinook salmon (*Oncorhynchus tshawytscha*) salmon and a downstream temperature protocol for the protection of migrating sockeye salmon (*O. nerka*) (the "1987 Settlement Agreement).

After the 1987 Settlement Agreement was signed, Alcan proceeded with its Kemano Completion Project (KCP). A coldwater release facility at Kenney Dam was included in the 1987 settlement agreement. The objectives of the water release facility were (Rescan 1999):

- Provide long-term water allocation release as specified in the 1987 Settlement Agreement.
  - Annual annualized base flow of 19.6 m^3/s.
  - Provide additional cooling water in July and August to maintain downstream water temperature objectives for migrating sockeye salmon. Temperatures were not to exceed 20°C for more than 3.88 days per year on average.
- Total gas pressure control for all releases to less than 103% at 1 km below Kenney Dam to avoid exposure of fish to elevated levels of dissolved gas.

With the cancellation of the KCP, the concept of a water release facility was in flux. In 1997, the Province of British Columbia and Alcan signed the BC-Alcan 1997 Agreement. Among other things, this Agreement established the Nechako Environmental Enhancement Fund (NEEF) and a NEEF Management Committee (NEEFMC). The NEEFMC was given the mandate to review, assess and report on options that may be available for the downstream enhancement of the Nechako River watershed (NEEF 2001). In June 2001, after a series of public workshops and consultations, the NEEFMC issued a report, which included two decisions and five recommendations. The NEEFMC decided that the NEEF should be used to construct a water release facility at Kenney Dam. The beneficial outcomes that were considered to be of importance were:

- Establishment of a more natural year-round flow in the Nechako River by redistributing the current high summer flows; and
- Reducing flows in the Murray-Cheslatta to expedite environmental rehabilitation and to manage flood flows.

The NEEF (2001) report identified a preferred option for construction of the water release facility, although, there were several areas of uncertainty. The NEEFMC felt that additional studies were required to examine the issues of:

- water temperature;
- movement of water through the Cheslatta Fan;
- total gas pressure; and
- re-watering of the Nechako Canyon.

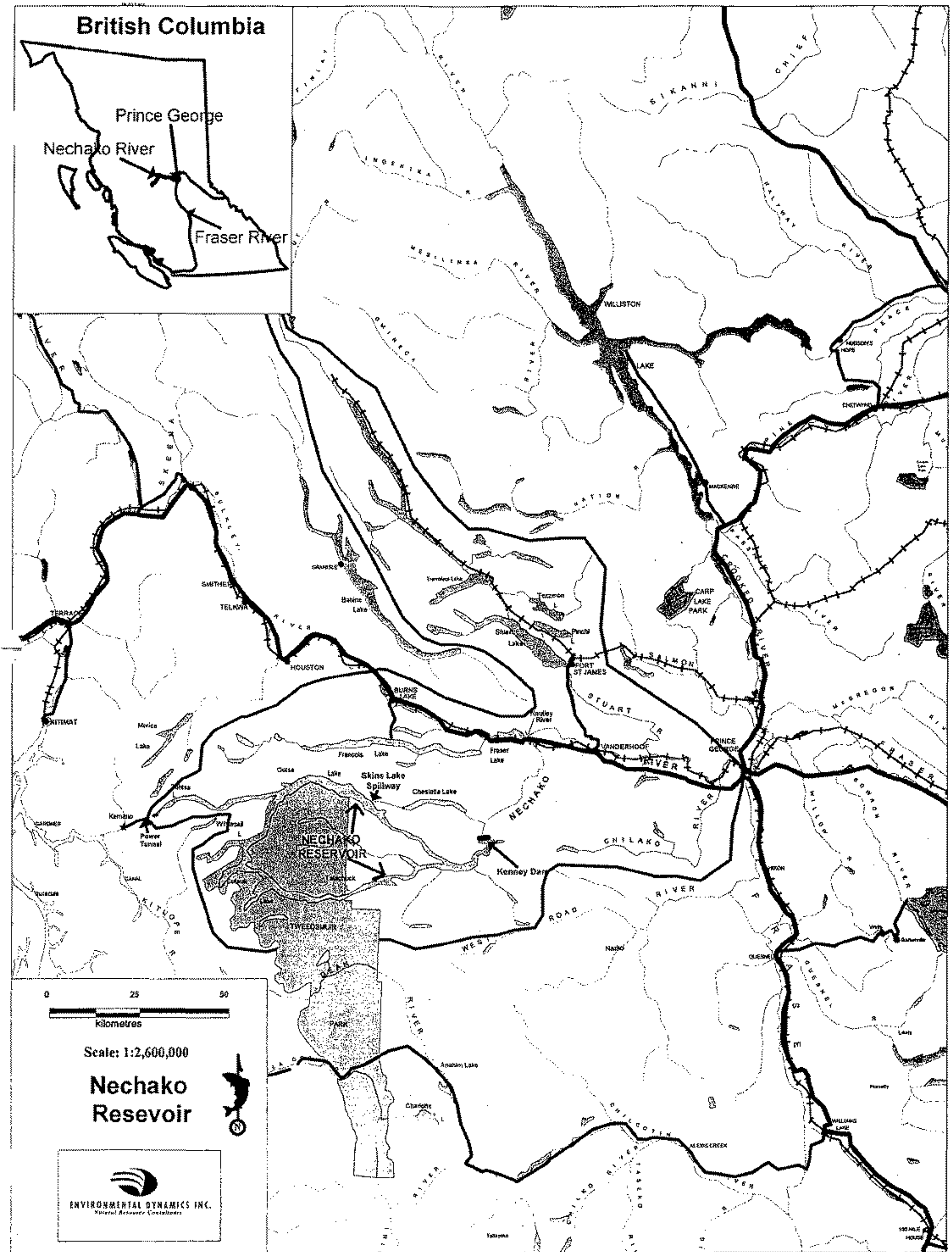


Figure 1.1-1 Nechako River watershed and Nechako Reservoir

1.1 The Nechako Watershed Council Work Plan

In 1998 the Nechako Watershed Council (NWC) was formed to bring together the various non-governmental organizations (NGOs), communities, and government agencies. The NWC was to work towards addressing many of the long-standing issues related to water management in the Nechako River watershed.

The NWC developed a work plan for constructing a cold water release facility (CWRF) at the Kenney Dam (NWC 2002). This NWC outlined a three-phased approach to the project: planning, pre-engineering and environmental review, and implementation (Table 1-1.1). The NWC work plan identifies 14 activities that need to be completed over a 10-year period to have the CWRF operational by approximately 2012 (NWC 2002).

1.2 Year 1 Activities of a 10-Year Project

The Province of British Columbia and Alcan formed the Nechako Enhancement Society (NES), which would oversee the implementation of the NWC work plan. In July 2002, the NES issued a request for proposal (RFP) for initiating some of the Year 1 activities identified in the NWC work plan. This request for proposal included the appointment of a Project Manager to undertake or coordinate the work associated with the following activities outlined in the NWC work plan:

- Activity#3: Information & Communication
- Activity#4: Compilation of Background Information
- Activity#5: Assessment of Benefits
- Activity#6: Pre-engineering and environmental reviews

EDI Environmental Dynamics Inc. (EDI), Prince George, BC, and its study team were awarded the contract to undertake the Year 1 activities. Aspen Communication and Denis & Muntener Advertising of Prince George, BC have undertaken the completion of Activity 3 (Read and Rogers 2003). Robinson Consulting and Associates (Victoria, BC) has completed a framework for assessing potential benefits (Activity 5) that may arise from the CWRF (Robinson 2003). Environmental Dynamics Inc. and Western Ecological Services Ltd. (Victoria, BC) prepared the bibliography of background information for Activity 4 (Bradley and Peterson 2002).

A team consisting of EDI, Kellerhals Engineering Services Ltd. (Heriot Bay, BC), M. Miles and Associates Ltd. (Victoria, BC), Western Ecological Services Ltd. (Victoria, BC), and UMA Engineering Ltd. (Victoria, BC) carried out the tasks for the pre-engineering and environmental reviews (Activity 6).

1.3 Engineering and Environmental Review in Year 1 Activities

There are two components to Activity #6 that are to be completed in Year 1, (i) the review of the Cheslatta Fan Pilot Channel concept and (ii) the plans for removal (flushing) of sediment from the Nechako Canyon (Figure 1.3-1).

Table 1.1-1 Summary of NWC Work Plan activities

NWC Work Plan Activity	Year 1 2002/03	Year 2 2003/04	Year 3 2004/05	Year 4 2005/06	Year 5 2006/07	Year 6 2007/08	Year 7 2008/09	Year 8 2009/10	Year 9 2010/11	Year 10 2011/12
PHASE 1 PLANNING										
1. Establish Management System*	◆									
2. NEEFMC Report Deliverables*	◆									
3. Information and Communication Program	◄	─	─	─	─	─	─	─	─	►
• **Prepare Communication Plan**	◆									
• **Ongoing Communication Program**		◆	◆	◆	◆	◆	◆	◆	◆	◆
4. Compilation of Background Information	◆									
5. Assessment of Benefits	◄	►								
• **Evaluation of methods**	◆									
• **Determination of benefits**		◆								
PHASE 2 PRE-ENGINEERING AND ENVIRONMENTAL REVIEW										
6. Pre-Engineering and Environmental Evaluation	◄	─	─	─	─	►				
• **Review Cheslatta Fan Pilot Channel Conceptual Design**	◆									
• **Nechako Canyon Flushing**	◄	►								
• **Fish Entrainment at the CWRF**		◆								
• **Release Water Temperature Criteria**		◆								
• **Reservoir Hydrothermal Structure**		◄	►							
• **Total Gas Pressure**		◆								
7. Preliminary Engineering of a Pilot Channel at Cheslatta Fan				◆						
8. Preliminary Engineering of a Coldwater Release Facility				◆						
9. Environmental Review and Permitting					◄	►				
PHASE 3 IMPLEMENTATION										
10. Detailed Engineering and Construction of the Cheslatta Fan Pilot Channel							◆			
11. Detailed Engineering of a CWRF								◆		
12. Coldwater Release Facility Construction									◄	►
13. Coldwater Release Facility Commissioning										◆
14. Adaptive Management										◆
PROPOSED PROJECT MANAGEMENT										
Environmental Dynamics Inc.	◄	─	─	─	─	►				
UMA Engineering					◄	─	─	─	─	►

*To be completed by NES.

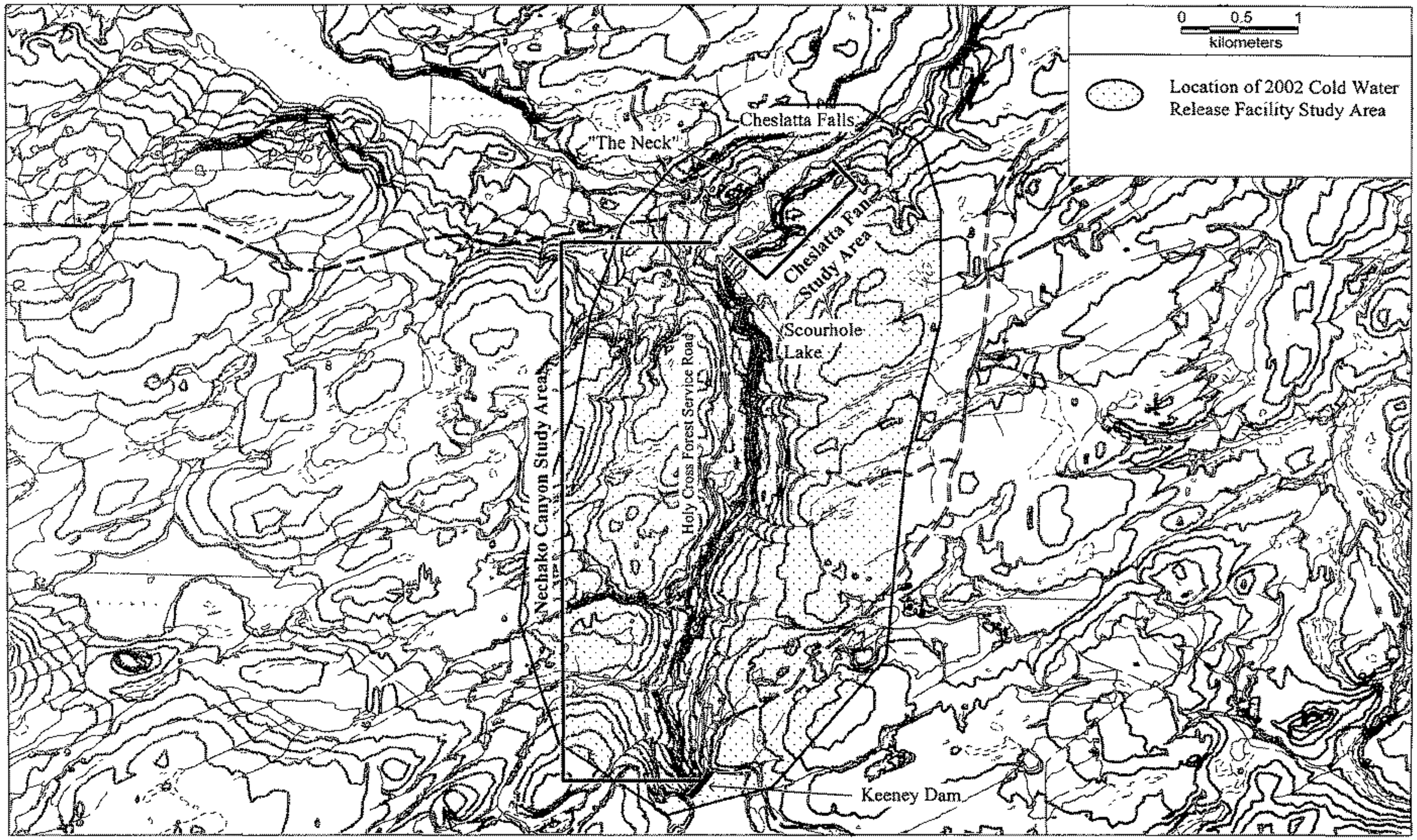


Fig .3-1 Nechako cold water release facility study area - 2002

The objectives for the Cheslatta Fan Pilot Channel concept review were to assess the concept for developing a pilot channel in the Cheslatta Fan and to select an alternative that had the least economic and environmental cost. Parameters that were to be considered in the assessment included (NWC 2002):

- The feasibility of constructing the pilot channel proposed by the NEEFMC.
- The likelihood of the channel concept developing as proposed by the NEEFMC when all geotechnical information was considered.
- Determination of the expected timeframe for the channel to develop under the operating or commissioning constraints.
- The likely duration and magnitude of downstream sediment concentrations in view of the likely form and timing of channel development.
- Determination of the cost-competitiveness of the concept with other options and the likelihood for approval of the concept by agencies given the current regulations and standards in effect for sediment concentrations.

The objective of the Nechako Canyon flushing portion of Activity 6 was to assess the feasibility of flushing accumulated sediment and vegetation from the Nechako Canyon when water is re-introduced to the canyon. Parameters that were to be considered in the assessment included (NWC 2002):

- Document the current state of sediment deposits and vegetation growth in the Nechako Canyon.
- Compare and contrast current conditions with conditions documented by Triton (1991).
- Evaluate the plan for flushing sediments and vegetative debris from the canyon in light of the present design and regulatory requirements.

The NWC work plan (NWC 2002) outlines the Activity 6 studies as two distinct work streams. Due to the contiguous physical location of the two areas to be examined and the linked hydrological and geomorphological processes that affect the two areas, the projects objectives were undertaken in a closely integrated manner. The information presented in the present report summarizes the result of the Year 1 projects for the pre-engineering and environmental reviews for both Activity 6 assignments.

2.0 ENVIRONMENTAL SETTING

2.1 Physical Conditions

2.1.1 Physiography

The Nechako watershed drains the east side of the Coast Mountains (specifically the Kitimat Ranges) and the Nechako Plateau. The headwaters of the Nechako watershed reach elevations of 2280 m asl at the height of land in the Kitimat Ranges. The Nechako Plateau has a much gentler relief and typically ranges in elevation between 740and 1200 m asl.

The total watershed area upstream of the Kenney Dam is approximately 14,100 km^2. This is a third of the total drainage area of Nechako River at the confluence with Fraser River at Prince George (Table 2.1.1-1). At present, the spillway for the Nechako Reservoir flows through the Skins Lake drainage and the Cheslatta River (including Cheslatta and Murray Lakes) before entering Nechako River 9 km downstream of Kenney Dam (this is 265 km upstream of the Fraser River confluence). The total basin area of the Cheslatta system (excluding the Nechako Reservoir) is approximately 1,300 km^2 or 3% of the total watershed area at Prince George.

Table 2.1.1-1 Watershed areas

Watershed	Basin Area (km^2)	Elevation (m)		Relief (m)
		Maximum	Minimum	
Nechako Reservoir upstream of Kenney Dam	14,078	2200	860	1340
Stream 1 at Nechako Confluence	5.9	960	780	180
Stream 2 at Nechako Confluence	55	960	760	200
Local drainage (excluding Streams 1 and 2) between Kenney Dam and Cheslatta Confluence	19.8	1160	740	420
Cheslatta River at Nechako Confluence	1,328	1252	740	512
Nechako River downstream of Cheslatta Confluence	15,487	1252	720	532
Nautley River at WSC Gauge	6,030	1340	680	660
Stuart River at WSC Gauge	14,653	1465	640	825
Chilako River at WSC Gauge	1,801	1427	600	827
Nechako River at Fraser River confluence	42,554	2200	580	1620

There are two principal tributaries to Nechako River in the area between Kenney Dam and the Cheslatta River. These streams, which enter the mainstem channel 1.3 and 2.6 km downstream of the dam, have been informally referred to as Streams 1 and 2 (Watershed Code 180-557700), respectively. Their basin areas are 5.9 and 55 km^2. The total drainage area between the dam and the Cheslatta River confluence is 81 km^2.

There are three major tributaries to the lower Nechako River. The Nautley, Stuart and Chilako Rivers enter approximately 90, 180 and 240 km downstream of the dam. These watersheds have basin areas of approximately 6,000, 14,700 and 1,800 km^2, respectively. The locations of these drainages are indicated on Figure 2.1.1-1.

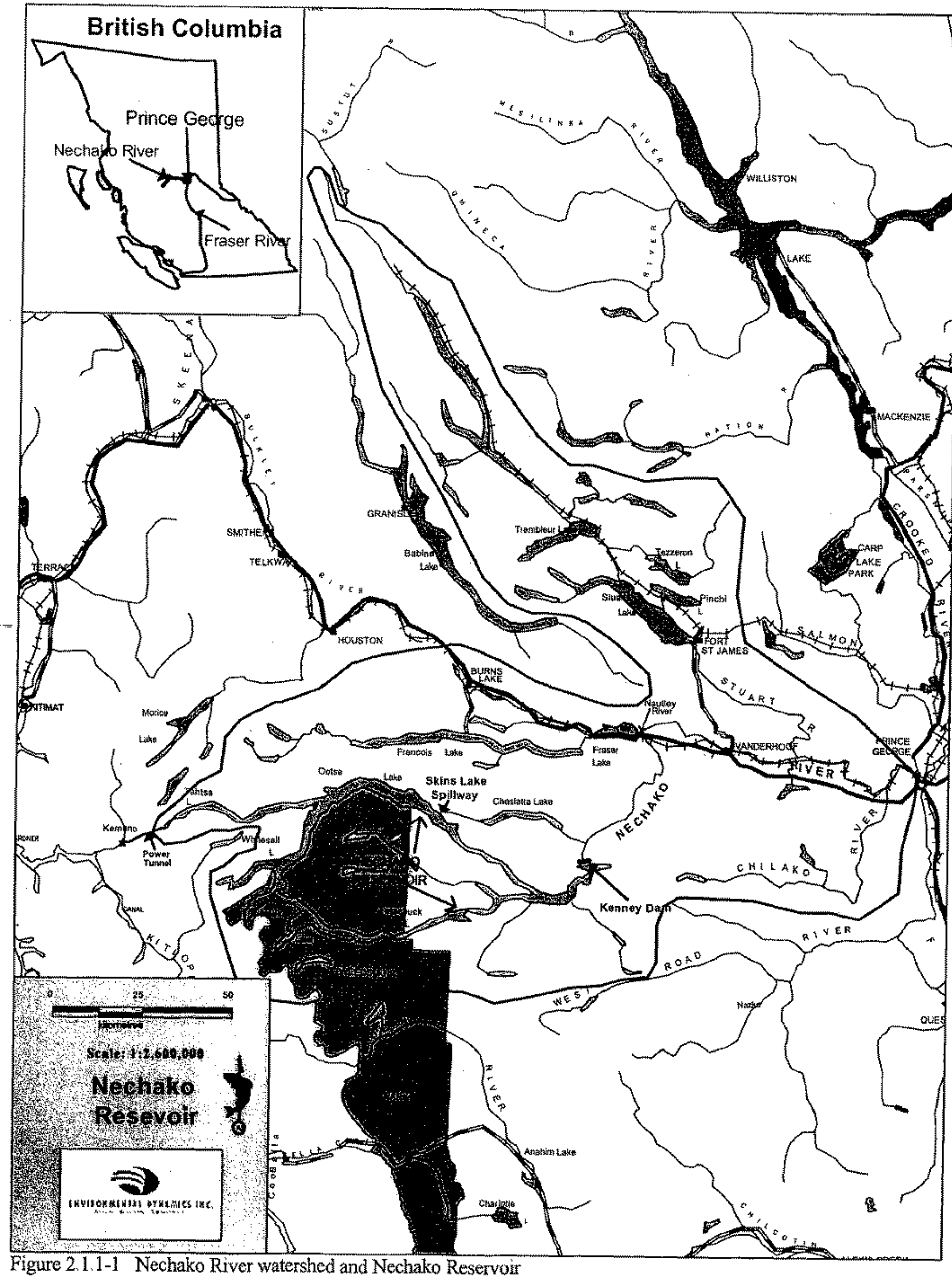


Figure 2.1.1-1 Nechako River watershed and Nechako Reservoir

A long profile of the lower Nechako River and its principal tributaries is shown on Figure 2.1.1-2. These data illustrate that the channel gradient generally decreases downstream of the Nechako Canyon-Cheslatta confluence until approximately Km 60 when the channel again adopts a steeper slope.

2.1.2 Geology

Tipper (1963); Williams et al. (1997); Diakow et al. (1997); Journeay et al. (2000); Lowe et al. (2001) and Plouffe and Williams (2001) have investigated the regional bedrock geology. The study area is located within the Endako Group, which is predominantly comprised of andesite and basalt with minor occurrences of breccia, tuff, gabbro, dacite, rhyolite, conglomerate, sandstone and shale. Mapping by Lowe et al. (2001) shows a northwest trending fault located southeast of Knewstubb Lake. This fault, named the Chedakuz Fault by Diakow, et al. (1997), appears to extend in a northerly direction through the Nechako Canyon.

The study by Lowe et al. (2001) identifies two large slope instability features. One is located on the right or south bank of Nechako River, 2.5 km downstream of Kenney Dam. The second is located on the right bank of Cheslatta River approximately 5 km upstream of the Nechako River confluence. Both sites are thought to be presently inactive.

Soils mapping (Cotic et al. 1976) indicates that the surficial materials along the Nechako Canyon are principally comprised of gravelly glaciofluvial deposits, colluvium and glacial till. The surficial materials at the mouth of the Cheslatta River include gravelly glaciofluvial deposits, colluvium, glacial till, and thick glaciolacustrine sediments.

2.1.3 Climate

The Meteorological Service of Canada (MSC) has 7 climate stations in the vicinity of the study area (Table 2.1.3-1). Station locations are shown on Figure 2.1.3-1. "Fraser Lake North," "Wistaria" and "Ootsa Lake Skins Lake Spillway" are all located in the Nechako Plateau. Data from these sites indicate summer temperatures are typically in the range of 5 to 20°C while mid-winter values are typically -5 to -15°C. Extreme temperatures can range as low as –45°C and as high as +35°C (Figure 2.1.3-2).

Precipitation data, shown on Figure 2.1.3-3, indicates there is a substantial difference between the reservoir headwaters and the area near the outlet. Specifically, the average annual precipitation at "Tahtsa Lake West" (which is located at the west end of the reservoir) is over 2,000 mm, about half of which falls as snow. In contrast, average annual precipitation near the east end of the reservoir ranges between 417 and 503 mm with 38 to 43% falling as snow.

The seasonal variation in extreme 1-day rainfall and total precipitation is shown on Figure 2.1.3-4. This analysis indicates that 1-day rainfall intensities on the Nechako Plateau are of modest size. The maximum observed values of 50 to 63 mm are below Caine's (1980) criteria which indicates values of 100 mm/day are generally required to cause shallow landslides or debris flows in susceptible material.

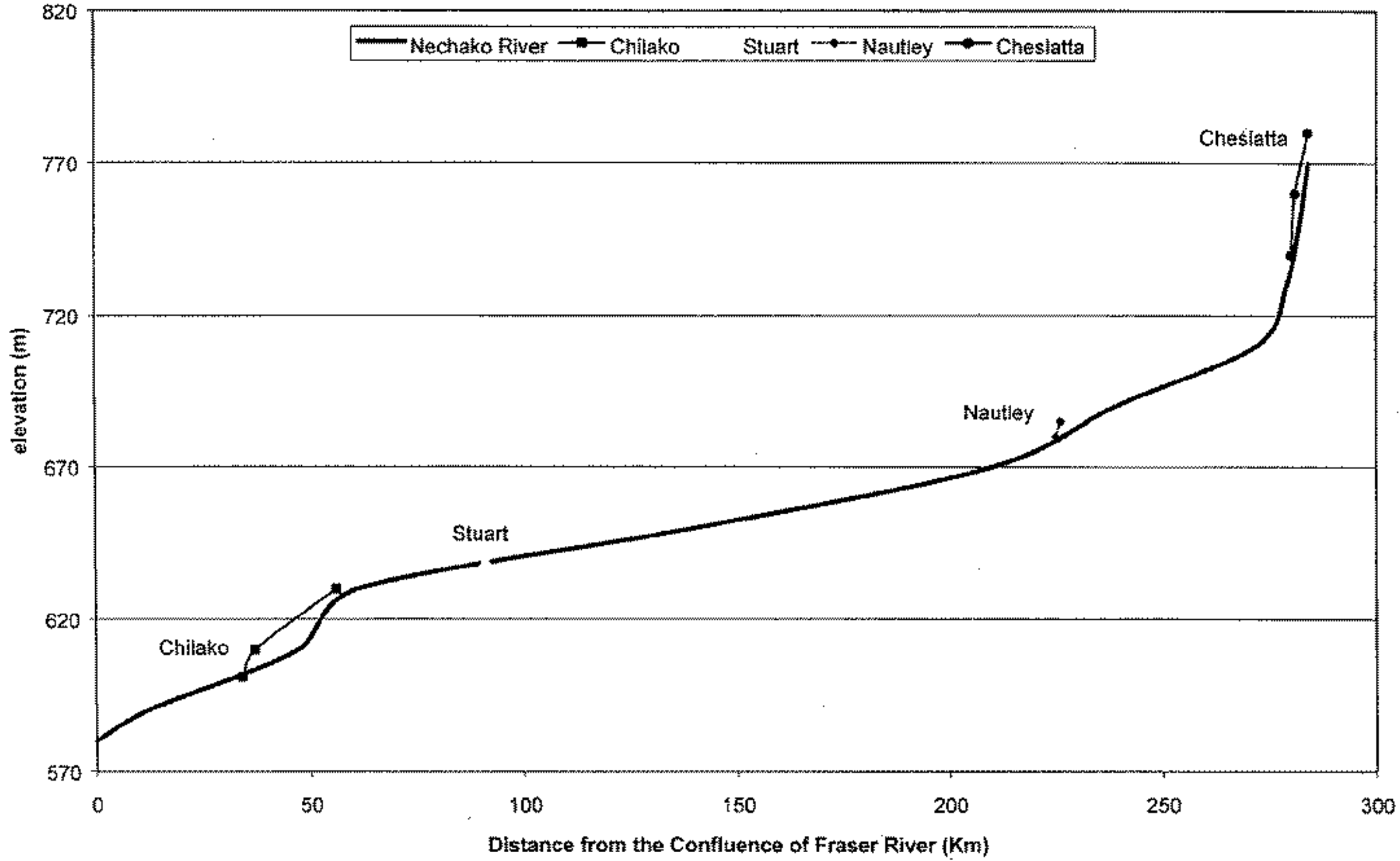


Figure 2.1.1-2 Longitudinal profile of Nechako River downstream of Kenney Dam

Table 2.1.3-1 Regional Meteorological Service of Canada climate stations

STATION NUMBER	STATION NAME	ELEVATION (m asl)	PERIOD DF RECORD	YEARS OF RECORD	AVAILABLE DATA							
					TEMP	PRECIP	RATE OF PRECIP	WIND	SUN	EVAP	NIPHER	NORMALS
109C0LF	Fraser Lake North Shore	674	1965 –	36	@	@						X
1085415	Nechako River (AUT)	715	1990 –	12								
1085835	Ootsa L Skins L Spillway	861	1956 –	45	@	@						X
1087950	Tahtsa Lake West	863	1951–2000	50	@	@						X
1087974	Takysie Lake	884	1987 –	15	X	X						
1088970	Wistaria	na	1926-1991	75	@	@						
			1991 –		X	X						X
1098D90	Vanderhoof	638	1980 –	22	@	@						

FRDM: http://scitech.pyr.ec.gc.ca/climhydro/main_frames_bc.htm

ABBREVIATIONS:

TEMP	Temperature
PRECIP	Precipitation
RATE OF PRECIP	Rate of Precipitation
SUN	Sunshine
EVAP	Evaporation
NIPHER	Nipher Snow Gauge
X	Yes, in general
@	Incomplete information

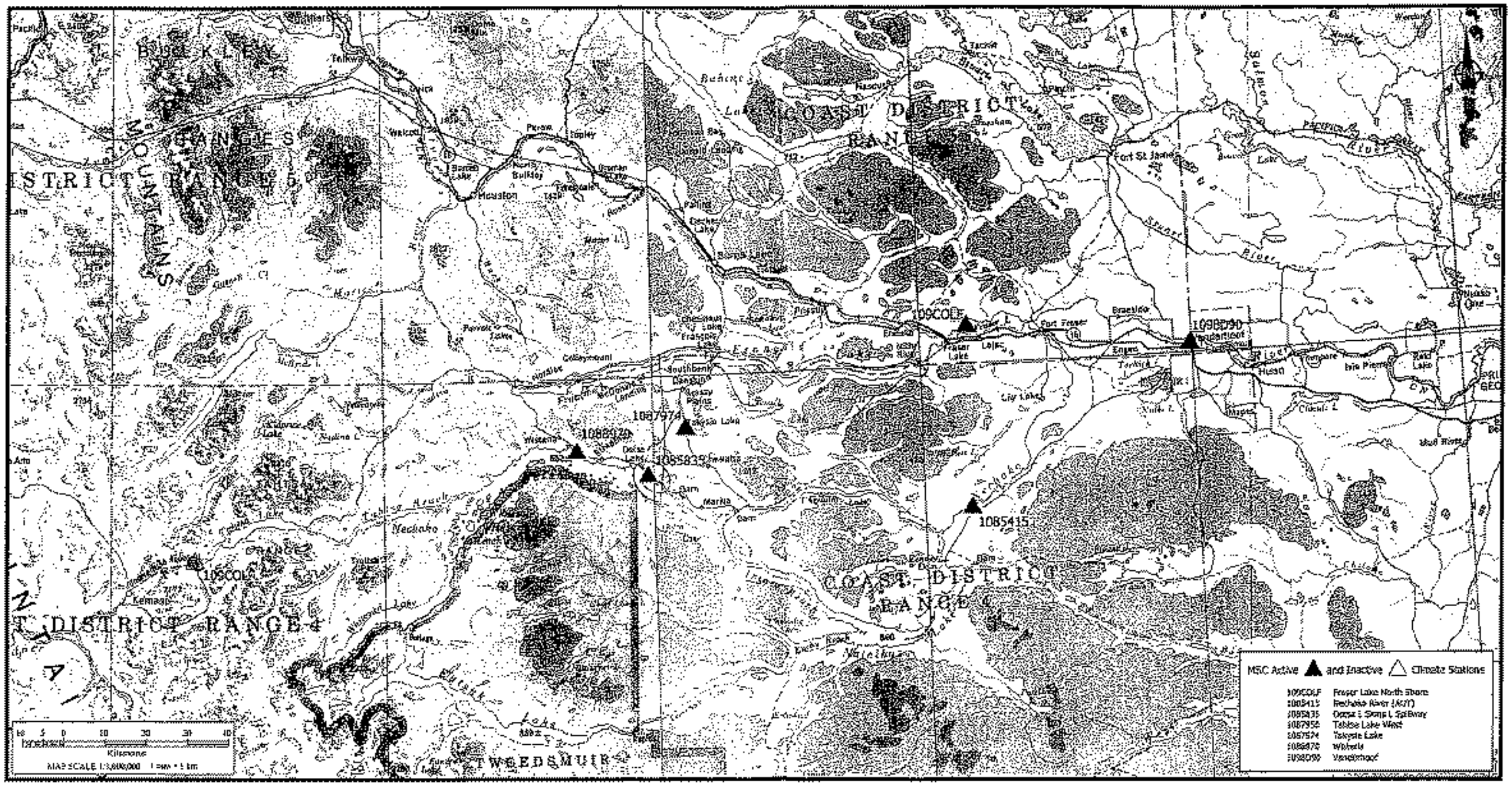


Figure 2.1.3-1 Climate station location map.

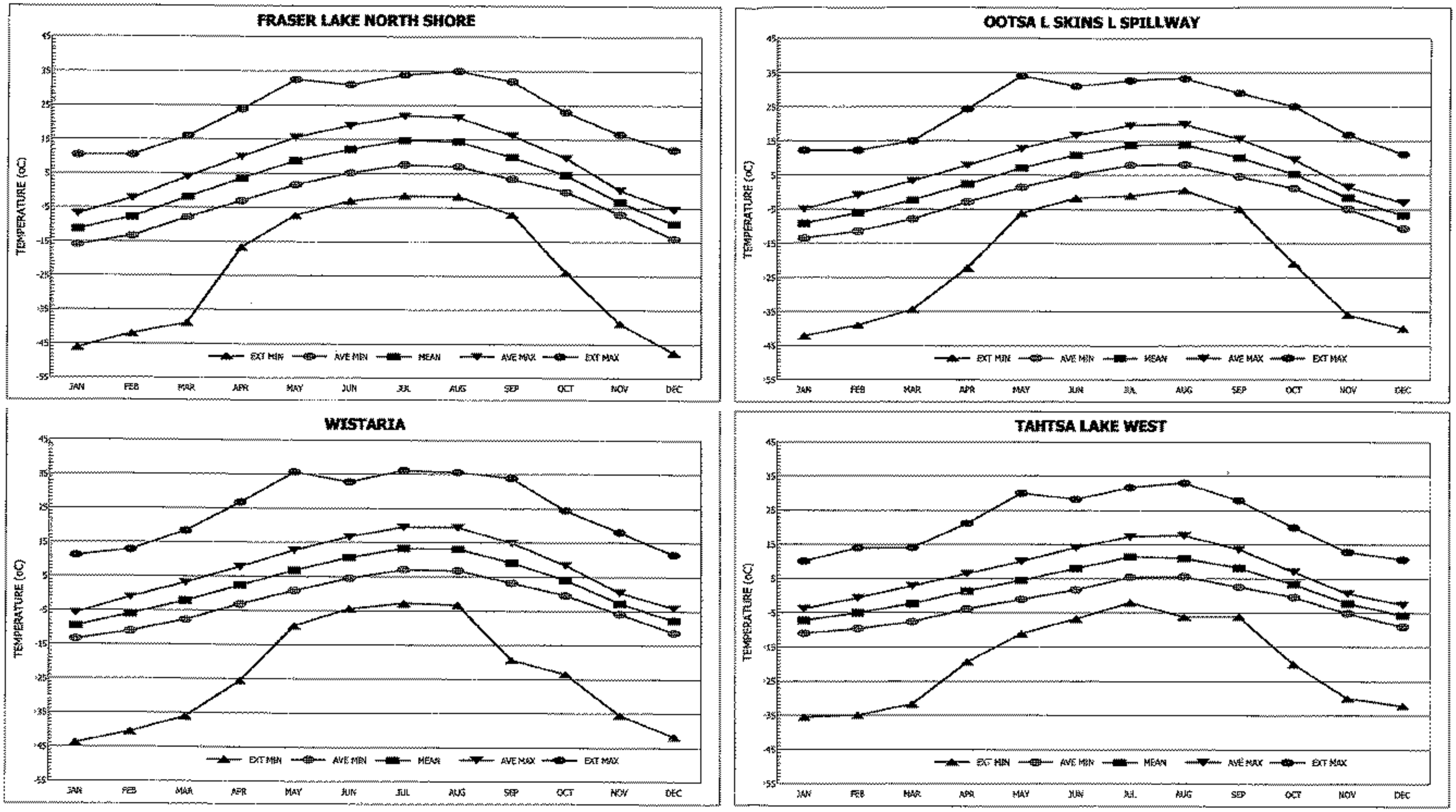


Figure 2.1.3-2 Seasonal variation in temperature (from 1961-1990 normals)

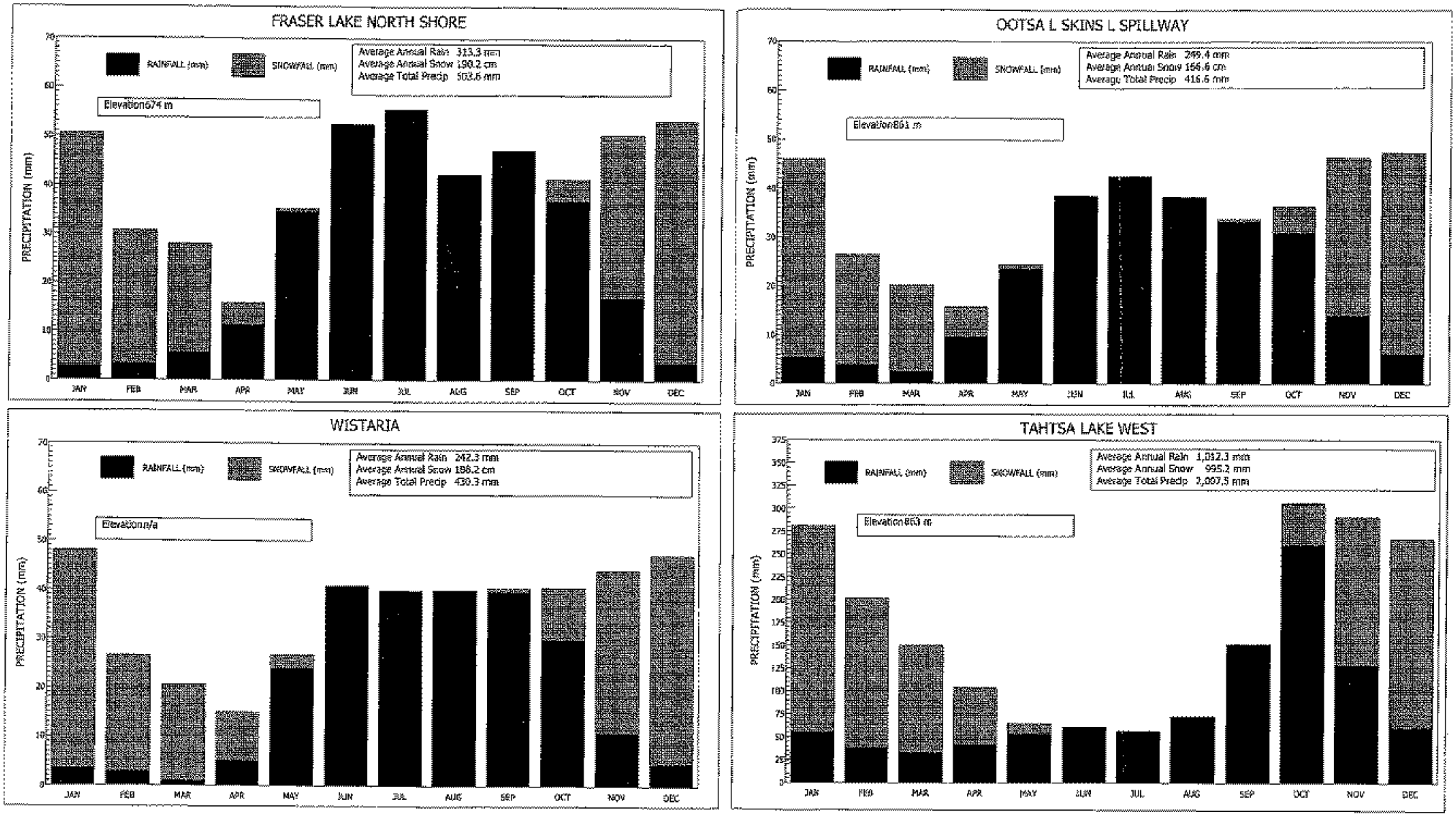


Figure 2.1.3-3 Seasonal variation in mean monthly precipitation (from 1961 to 1990 normals).

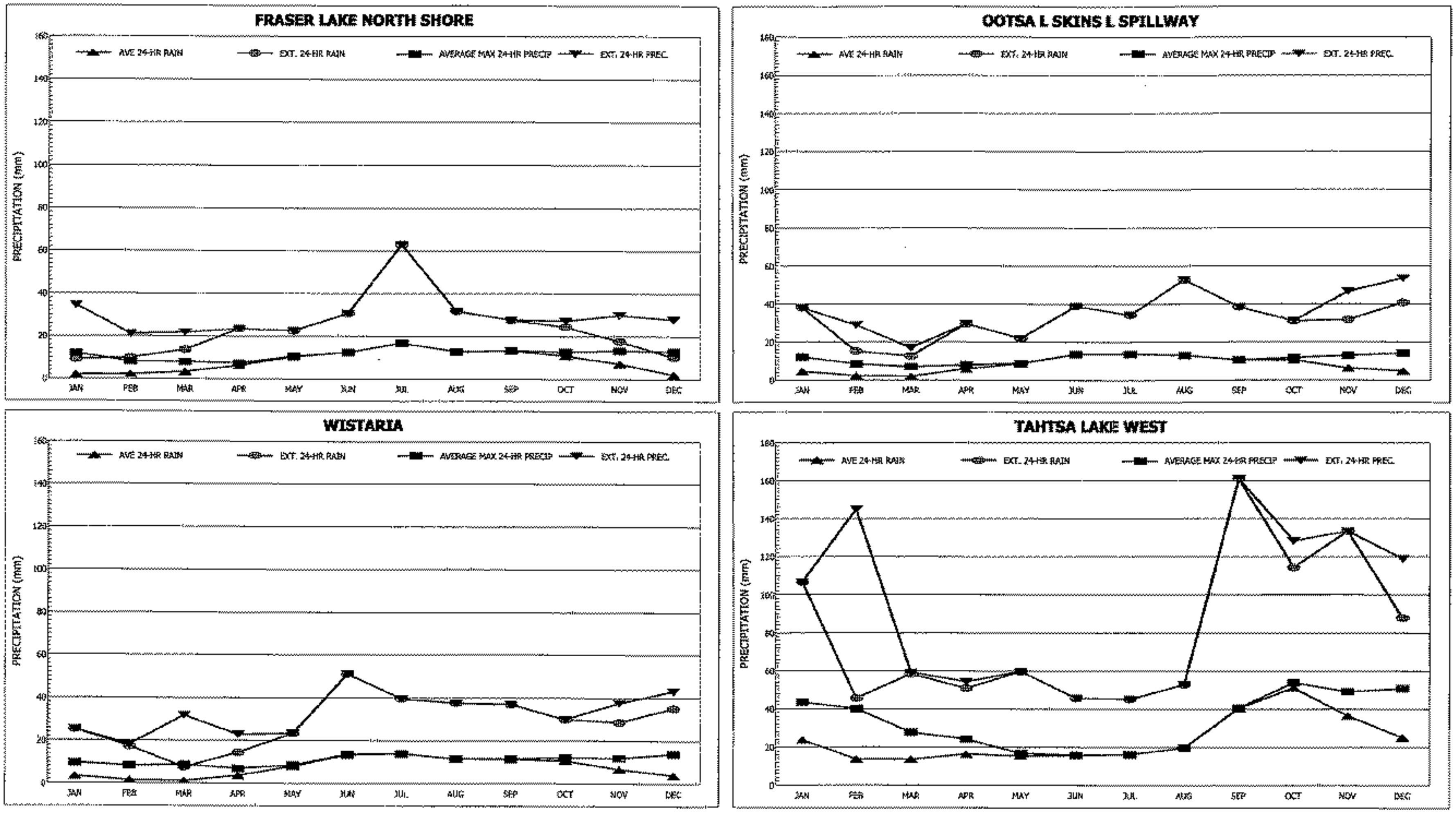


Figure 2.1.3-4 Seasonal variation in extreme 1-day rainfall and total precipitation (from 1961 to 1990 normals).

The historical variation in annual extreme 1-day rainfall is shown on Figure 2.1.3-5. This analysis indicates that there is substantial regional variation in the 1-day rainfall events. As a consequence, heavy rainfall has generally not occurred simultaneously at the three Nechako Plateau sites. This suggests that maximum rainfall intensities are associated with local convective activity rather than larger frontal systems. Data from the "Ootsa Lake Skins Lake Spillway" indicates that the maximum 1-day rainfall occurred in 1978 and had an average return period of approximately 100 years (see Table 2.1.3-2). A larger event (having a return period of 200 years) occurred at Wistaria in 1993.

The BC government, in cooperation with Alcan, operates a series of snow survey sites in the vicinity of the Nechako Reservoir (Table 2.1.3-3). Station locations are shown on Figure 2.1.3-6. Snow pillow data for Mount Wells is shown on Figure 2.1.3-7 and illustrates that snow typically begins to accumulate in early October, reaches a maximum in April or May and has melted by the end of June. A frequency analysis of regional snow course data has been compiled in Table 2.1.3-4. These results indicate that the average water equivalent of the snow pack in the vicinity of Skins Lake is 118 mm. This value increases westward to 1207 mm at the Tahtsa Lake snow pillow. The historical variation in annual maximum snow accumulation at representative sites is shown on Figure 2.1.3-8. These data indicate that an unusually deep snow pack occurred in 1997 at both "Bird Creek" and "Skins Lake." A frequency analysis (summarized on Table 2.1.3-4) indicates the average return period for this event ranges between 10 and 40 years. Depending on location, unusually heavy snowpacks have also occurred in 1976, 1991 and 2002.

2.1.4 Hydrology

The hydrology of the Nechako River and the operating regime of the Nechako Reservoir will both affect the design of the proposed project. Flood magnitude determines the size of the channel across Cheslatta Fan. The volume of water available from the reservoir at the time of project start up affects the ability to flush sediment downstream and the ability to dilute the flushing flows with clean water from Skins Lake Spillway. In the longer term, available water volumes will determine Alcan's ability to re-establish a more natural flow regime and provide suitable water temperatures in the lower Nechako River. These are substantive issues requiring detailed analysis during project design. It is appropriate at this stage of the project to summarize the available data, investigate how reservoir operation has affected the flow regime, review flood history and state the design flow criteria used in our analyses of the proposed channel across Cheslatta Fan.

2.1.4.1 Available Information

The Water Survey of Canada (WSC) has operated nine stream gauging stations on Nechako River (Table 2.1.4-1) and three sites within the Cheslatta River drainage (Table 2.1.4-2). The locations of these gauging sites are shown on Figure 2.1.4-1. There have also been numerous hydrological reports prepared on the Nechako watershed. Reference for these studies are presented in the bibliography prepared by Bradley and Peterson (2002).

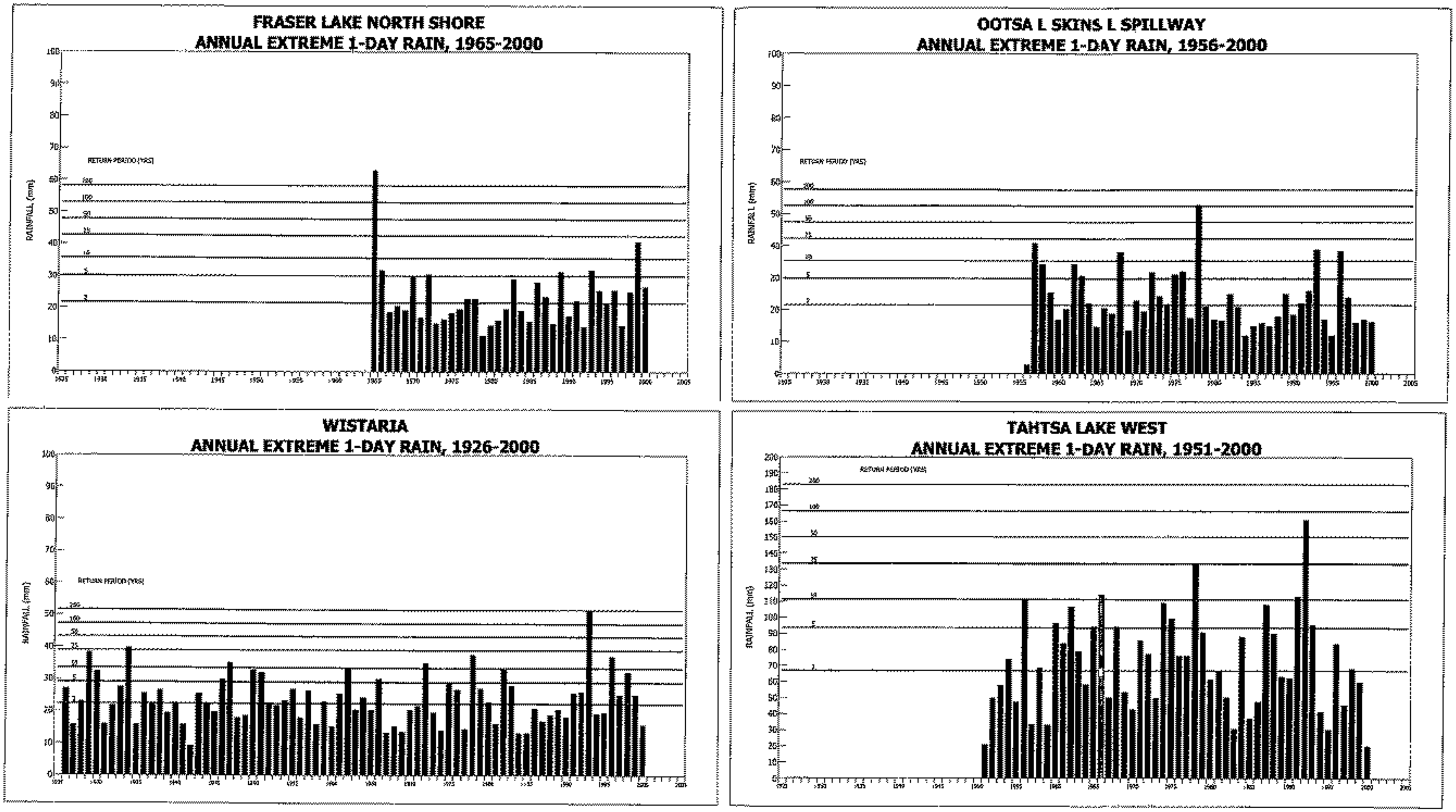


Figure 2.1.3-5 Historical variation in annual extreme 1-day rainfall.

Table 2.1.3-2 Frequency analysis of annual extreme one day rainfall and precipitation intensities

AES STATION NAME	PERIOD OF RECORD	ELEVATION (m asl)	TYPE OF RECORD	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION	MAXIMUM OBSERVED VALUE			SPECIFIED RETURN PERIOD EXTREME ONE DAY PRECIPITATION (mm)						
							YEAR	VALUE	RETURN PERIOD	2 YRS	5 YRS	10 YRS	25 YRS	50 YRS	100 YRS	200 YRS
Fraser Lake North Shore	1965-2000	674	rainfall	36	23.2	9.5	1965	63.0	384.4	21.6	30.0	35.6	42.6	47.8	53.0	58.2
			precipitation	36	24.9	9.0	1965	63.0	406.6	23.4	31.4	36.6	43.3	48.2	53.1	58.0
Ootsa L Skins L Spillway	1956-2000	861	rainfall	45	23.0	9.4	1978	52.8	104.4	21.5	29.8	35.3	42.2	47.4	52.5	57.6
			precipitation	45	25.1	9.9	1957	53.6	72.0	23.5	32.2	38.0	45.3	50.8	56.2	61.5
Wistaria	1926-2000	na	rainfall	75	23.4	7.6	1993	51.2	194.7	22.2	28.9	33.3	38.9	43.1	47.2	51.4
			precipitation	75	25.0	7.1	1993	51.2	202.8	23.8	30.1	34.3	39.5	43.4	47.3	51.1
Tahtsa Lake West	1951-2000	863	rainfall	50	71.8	30.2	1992	161.0	79.2	66.8	93.5	111.2	133.5	150.1	166.5	182.9
			precipitation	50	82.1	28.1	1992	161.0	65.8	77.5	102.3	118.8	139.5	154.9	170.2	185.5

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

Table 2.1.3-3 Regional snow course stations

STATION NUMBER	STATION NAME	ELEVATION (m asl)	PERIOD OF RECORD		YEARS OF RECORO	AVERAGE MAXIMUM SNOW COVER (mm water equivalent)
			FROM	TO		
1B05	Skins Lake	880	1964	2002	39	124.6
1A23	Bird Creek	1180	1990	2002	13	151.1
1B02	Tahtsa Lake	1300	1952	2002	51	1217.3
1B02P	Tahtsa Lake	1300	1963	2002	12	1273.6
1B08P	Mount Pondosy	1400	1963	2002	12	B4B.9
1B01	Mount Wells	1490	1952	2002	51	530.5
1B01P	Mount Wells (Pillow)	1490	1963	2002	12	586.6
1B07	Nutli Lake	1490	1976	2002	13	541.8
1B06	Mount Swannell	1620	1989	2002	14	321.6

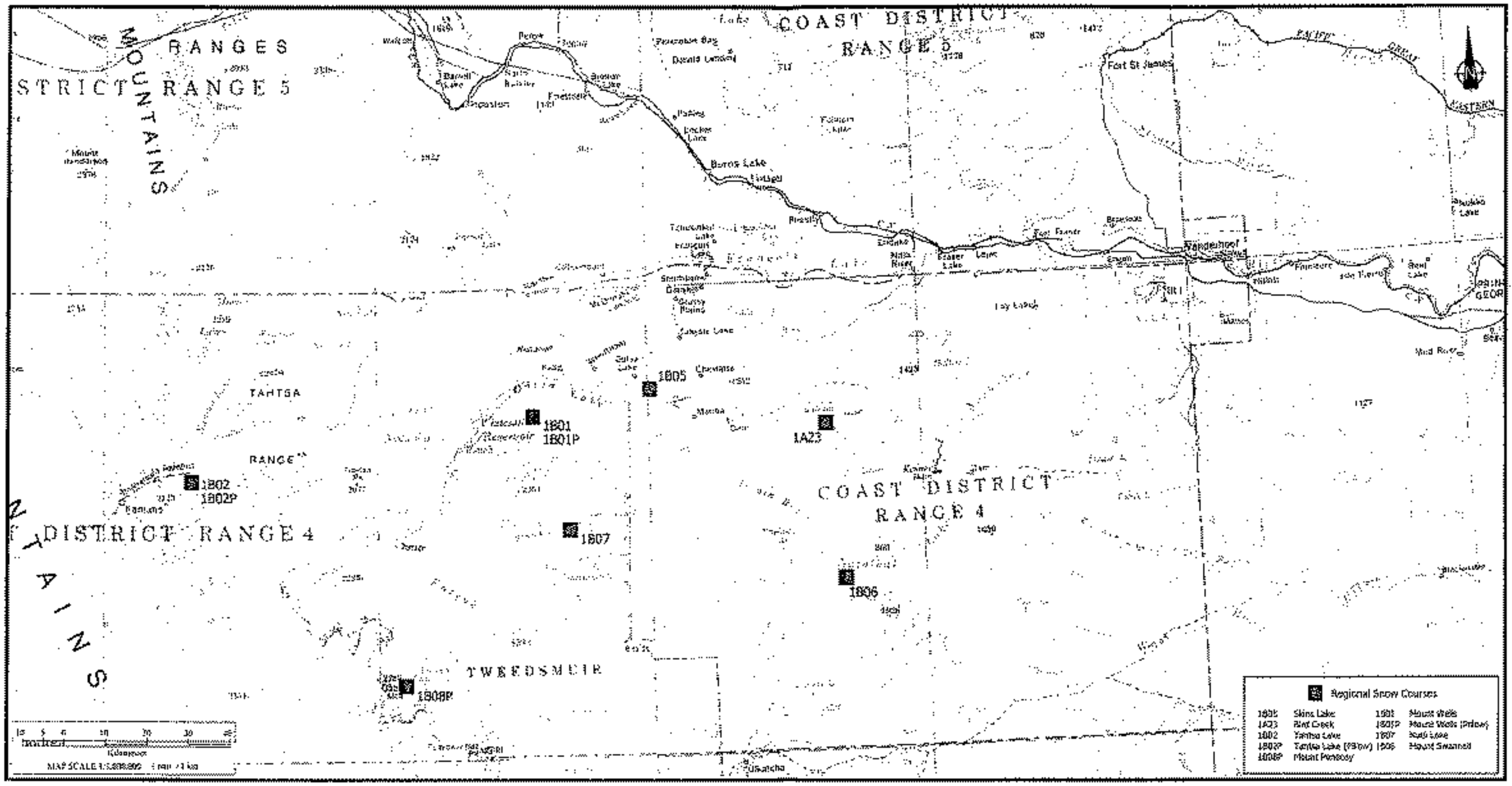


Figure 2.1.3-6 Regional snow course location map

Snow Pillow Data 2002-2003
Mount Wells - 1B01P

Drainage:	Nechako	Yrs of Record:	10	Elevation:	1,490 m
Latitude:	53°44'	Longitude:	126°25'	Type:	Pillow

Snow Water Equivalent (in millimetres)

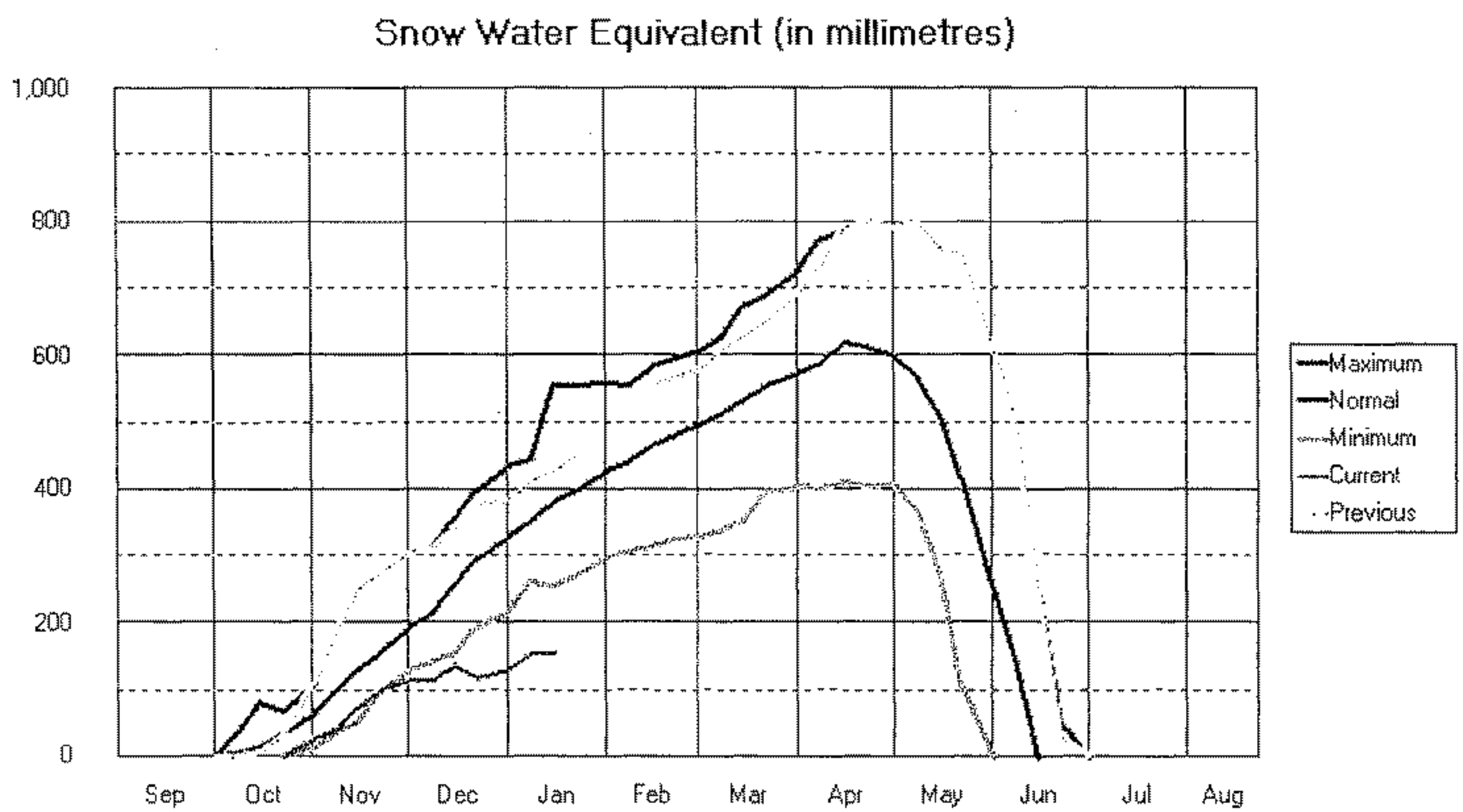


Figure 2.1.3-7 Seasonal variation in snow cover at the Mount Wells snow pillow

Table 2.1.3-4 Frequency analysis of annual maximum snow accumulation

SNOW COURSE	PERIOD OF RECORD	ELEVATION (m asl)	YEARS OF RECORD	MEAN VALUE (mm)	STANDARD DEVIATION (mm)	MAXIMUM OBSERVED VALUE			PREDICTED SNOW WATER EQUIVALENT (mm) FOR A RETURN PERIOD OF						
						YEAR	VALUE (mm)	RETURN PERIOD (YEARS)	2 YRS	5 YRS	10 YRS	25 YRS	50 YRS	200 YRS	200 YRS
Bird Creek	1990 -	1180	13	151.1	48.2	1997	270.0	42.6	143.2	185.8	214.0	249.6	276.0	302.3	328.4
Nutli Lake	1976 -	1490	13	541.8	163.1	2002	806.0	14.7	515.1	659.1	754.6	875.2	964.6	1053.4	1141.8
Tahtsa Lake Pillow	1963 -	1300	12	1273.6	405.3	2002	1798.0	9.9	1207.1	1565.0	1802.5	2102.0	2324.1	2545.0	2764.7
Mount Pondosy Pillow	1963 -	1400	12	848.9	225.6	2002	1277.0	20.8	811.9	1011.1	1143.3	1310.0	1433.7	1556.6	1678.9
Mount Wells Pillow	1963 -	1490	12	586.6	121.8	1997	792.0	16.0	566.6	674.2	745.5	835.6	902.3	968.7	1034.7
Mount Wells	1952 -	1490	51	530.5	112.7	1976	960.0	236.8	512.0	611.5	677.6	760.9	822.6	884.0	945.1
Tahtsa Lake	1952 -	1300	51	1217.3	218.3	1976	1770.0	46.3	1181.5	1374.3	1502.2	1663.5	1783.1	1902.1	2020.4
Mount Swannell	1989 -	1620	14	321.6	92.5	1991	489.0	18.6	306.4	388.1	442.3	510.7	561.4	611.8	661.9
Skins Lake	1964 -	880	39	124.6	42.7	1974	226	37.9	117.6	155.3	180.3	211.9	235.3	258.5	281.7

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

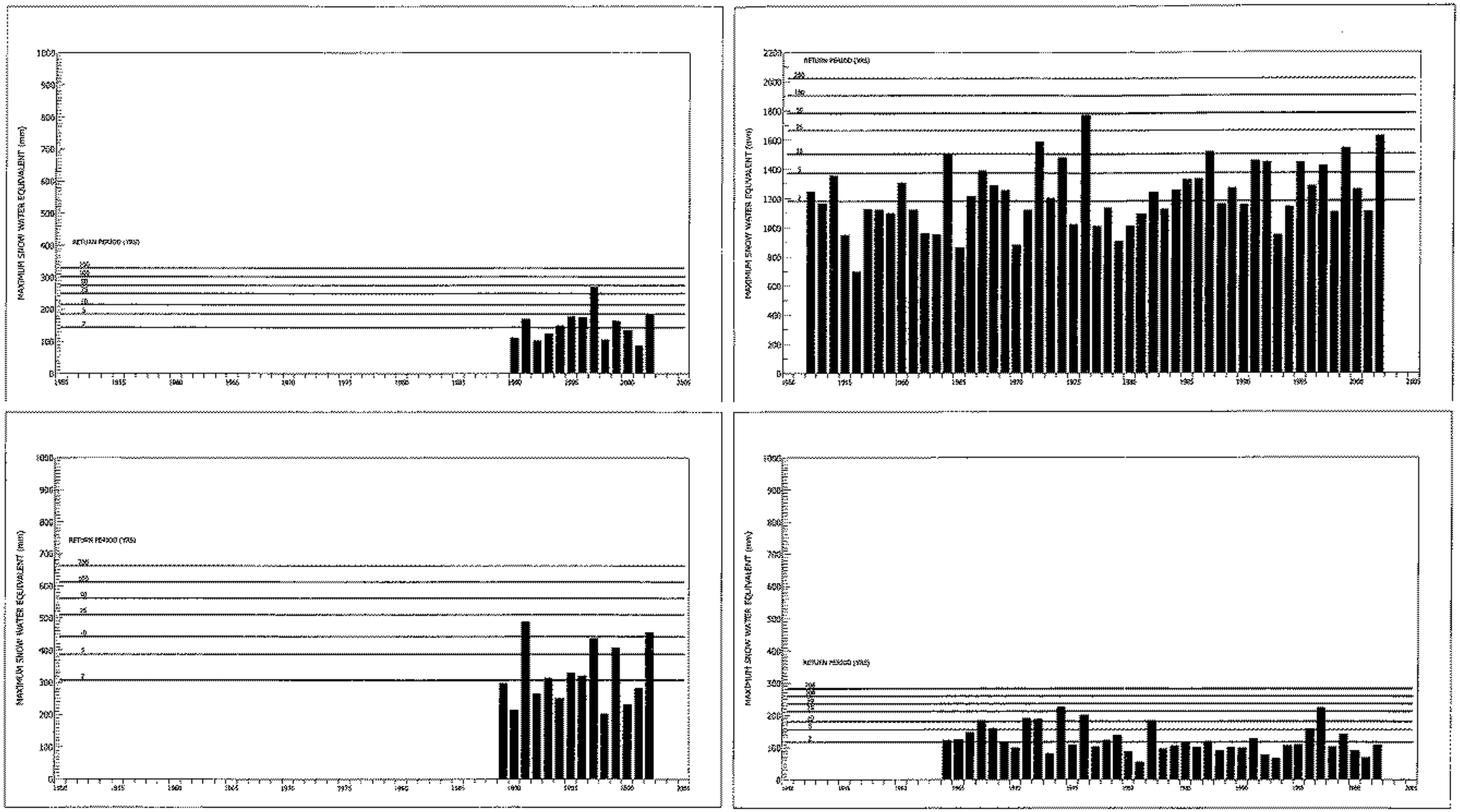


Figure 2.1.3-8: Historical variation in annual maximum snow water equivalent.

Table 2.1.4.1 Water Survey of Canada (WSC) stream gauging stations on Nechako River

STATION NUMBER 08...	STATION NAME	BASIN AREA (km2)	TYPE OF RECORD		TYPE OF FLOW	PARAMETER	YEARS OF RECORD
JA007	Nechako River at Outlet of Natalkuz Lake	12,100	30#; 32 MS; 33 M#		NAT	A	
						B	
JA011	Nechako River Near Ootsa Lake	?	49-50 MS		NAT	A	
						B	
JA010	Nechako River Near Big Bend	13,900	50-52 RC		NAT	A	
						B	
JA017	Nechako River Below Cheslatta Falls	15,600	80-2002 RC	7	REG 52	A	23
						B	23
JA001	Nechako River at Fort Fraser	17,700	15-17 MS; 29-30 MC; 31-53 MS; 54-60 M#		REG 52	A	24
						B	
JC001	Nechako River at Vanderhoof	25,100	15 MS; 16 M#; 48-55 MS; 56-85 MC; 86-2002 RC	6	REG 52	A	54
						B	17
JC002	Nechako River At Isle Pierre	42,500	50-2002 RC	5	REG 52	A	
						B	
JC004	Nechako River Above Isle De Pierre Rapids	?	55 *MS	1	REG 52	A	
						B	
JC003	Nechako River Below Isle De Pierre Rapids	?	55* MS	1	REG 52	A	
						B	

Inland Waters Directorate, 1996

NOTES:

*	stage only	REV	Data to 19__ have been reviewed	1	Data not published
#	miscellaneous measurements	NAT	Natural Flow	5	Water Quality Data Available
M	manual gauge	REG	Regulated Flow with date of regulation - if known	6	Sediment Data Available
R	recording gauge			7	Satellite Data Collection Platform Installed
S	seasonal operation	NA	Not Available	10	Minimum Flows
C	continuous operation - numbers refer to years (e.g. 09 is 1909)			A	Annual Maximum Daily Flows
				B	Annual Instantaneous Flows

Table 2.1.4.2 Water Survey of Canada (WSC) stream gauging stations on the principal tributaries Nechako River

STATION NUMBER 0B...	STATION NAME	BASIN AREA (km²)	TYPE OF RECORD	TYPE OF FLOW	PARAMETER	YEARS OF RECORD
JA013	Skins Lake Spillway, Nechako Reservoir	?	55#; 56-2002 PC	REG	A	48
					B	--
JA018	Cheslatta Lake at West End	?	81-2002 * RC 7	REG	A	
					B	
JA009	Cheslatta River Near Ootsa Lake	1,580	50 R#; 51 RS	NAT	A	
					B	
JB003	Nautley River Near Fort Fraser	6,030	45 M#; 50-51 MS; 52-73 MC; 74-75 M#; 76-91 RC	NAT	A	
					B	
JC005	Chilako River Near Prince George	3,390	15 M#; 60-63 MC; 64-65 MS; 66-74 MC	NAT	A	
					B	
JE001	Stuart River Near Fort St. James	14,600	29-31 MS; 32 M#; 33-34 MS; 35-41 MC; 42-47 MS; 48 MC; 49-50 MS; 51-86 MC; 87-91 RC 5	NAT	A	
					B	

Inland Waters Directorate, 1996

NOTES:

*	stage only	REV	Data to 19__ have been reviewed	1	Data not published
#	miscellaneous measurements	NAT	Natural Flow	5	Water Quality Data Available
M	manual gauge	REG	Regulated Flow with date of regulation - if known	6	Sediment Data Available
R	recording gauge			7	Satellite Data Collection Platform Installed
P	power plant	NA	Not Available	10	Minimum Flows
S	seasonal operation			A	Annual Maximum Daily Flows
C	continuous operation - numbers refer to years (e.g. 09 is 1909)			B	Annual Instantaneous Flows

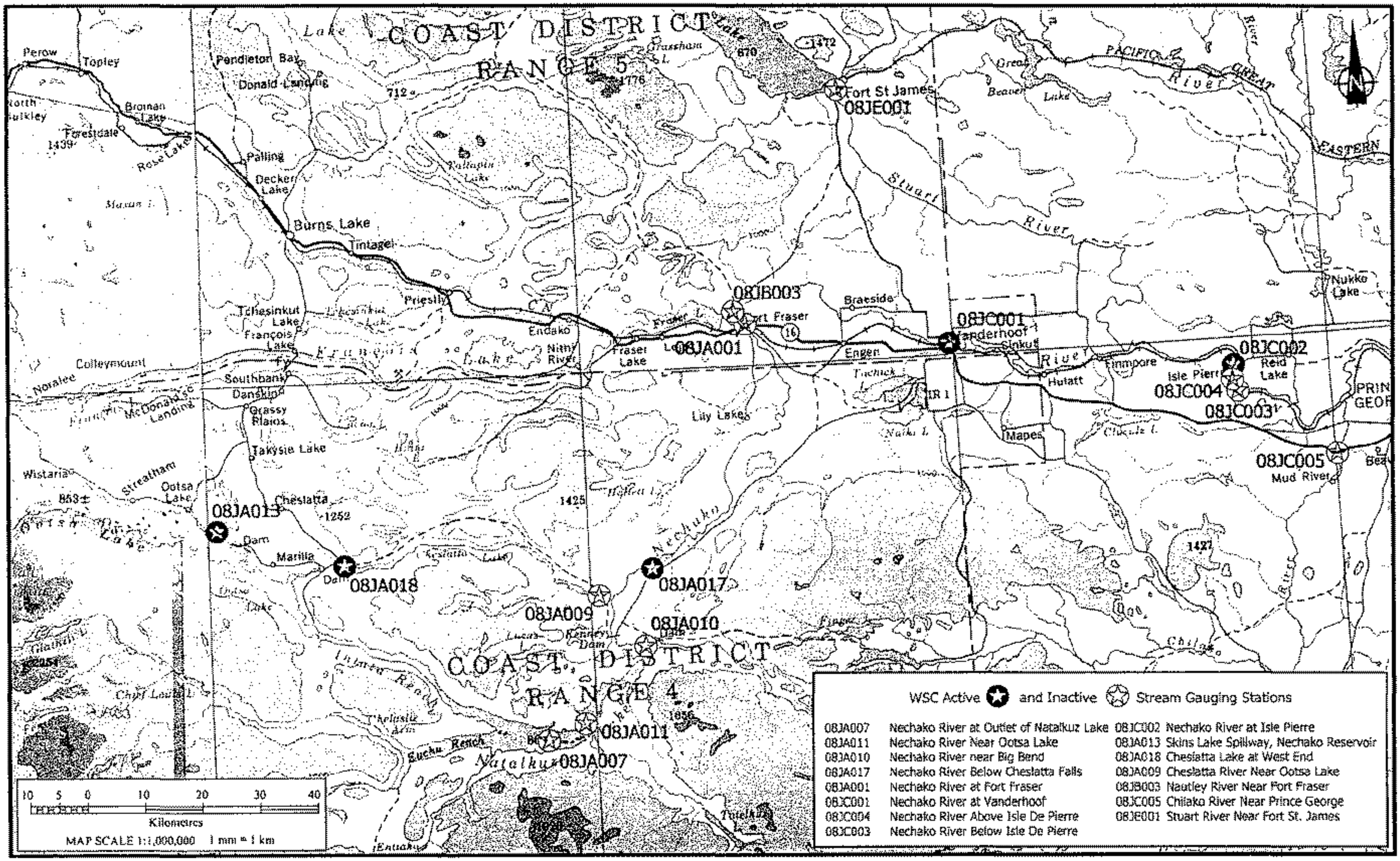


Figure 2.1.4-1 Map showing the location of relevant Water Survey of Canada stream gauging stations

The now discontinued Nechako River stations at the "outlet of Natalkuz Lake", "near Big Bend," and "near Ootsa Lake" provide miscellaneous short-term data from the pre-1953 period. Pre-regulation data are also available from two sites on the lower river, "Nechako River at Fort Fraser" and "at Vanderhoof." The longest term data within the post-regulation period are from the Nechako River stations "at Vanderhoof" and "at Isle Pierre". There is also post-1980 data available from the "below Cheslatta Falls" site, which is the closest mainstem station to the proposed project area.

Within the Cheslatta River drainage, the WSC monitors stream flow at "Skins Lake Spillway" and miscellaneous pre-regulation data area available from the site "near Ootsa Lake." Water levels are also available from "Cheslatta Lake at the West End."

2.1.4.2 Seasonal Variation in Flow

The pre-regulation streamflow regime on Nechako River is illustrated on Figure 2.1.4-2, based on data from the "outlet of Natalkuz Lake," "near Big Bend," "near Oootsa Lake" and "at Vanderhoof" gauging stations. These short-term data indicate that snowmelt derived runoff in May, June, July and early-August used to be the dominant hydrologic event of the year. Rain or rain-on-snow events caused comparatively small increases in early-winter streamflow.

The post-regulation hydrographs from the Cheslatta River and Nechako River stations predominantly reflect the operating regime of the Skins Lake Spillway. Figures 2.1.4-3 to 2.1.4-7 show the maximum, average and minimum daily flows observed over the period of record. These data illustrate the altered characteristic of the annual hydrograph but are difficult to interpret as the spillway operating regime has varied over the life of the development. The daily flows at the "Skins Lake Spillway," "Nechako River below Cheslatta Falls," and "Nechako River at Vanderhoof," along with daily water levels for "Cheslatta Lake at West End," have been compiled[1]. The "Skins Lake Spillway" data illustrate the change in timing and discharge that occurred following the adoption of the "short-term" cooling regime in 1980[2]. Average monthly discharges generally decreased post-1980, although flows are regularly released from the reservoir starting in April and larger releases (of up to 450 m^3/s) occur annually in mid-July to mid-August to provide cooling flows to the lower river. 1997 is anomalous as more substantive releases were undertaken throughout the summer to reduce water levels in the reservoir during this unusually wet year.

The reservoir releases described above dominate the post-1980 water levels of Cheslatta Lake and the flows at "Nechako River below Cheslatta Falls." The flow regime on "Nechako River at Vanderhoof" also shows substantive changes due to the operation of the Nechako Reservoir. In the period between 1980 and 2001, the mean annual discharge at "Nechako River at Vanderhoof" and "at Isle Pierre" was 48% and 58% of the average pre-regulation value, respectively.

[1] This information is available from M. Miles and Associates Ltd, Victoria, BC, upon request.

[2] The 1978 and 1979 flow regimes "on Skins Lake" are also significantly different from those which occurred in the period between 1955 and 1977. The "short-term" cooling flow regime was instigated in 1980. This required flows of 170 to 283 m^3/s to be maintained at the gauge "Nechako River below Cheslatta Falls" between July 15 and August 15 (Triton 1991).

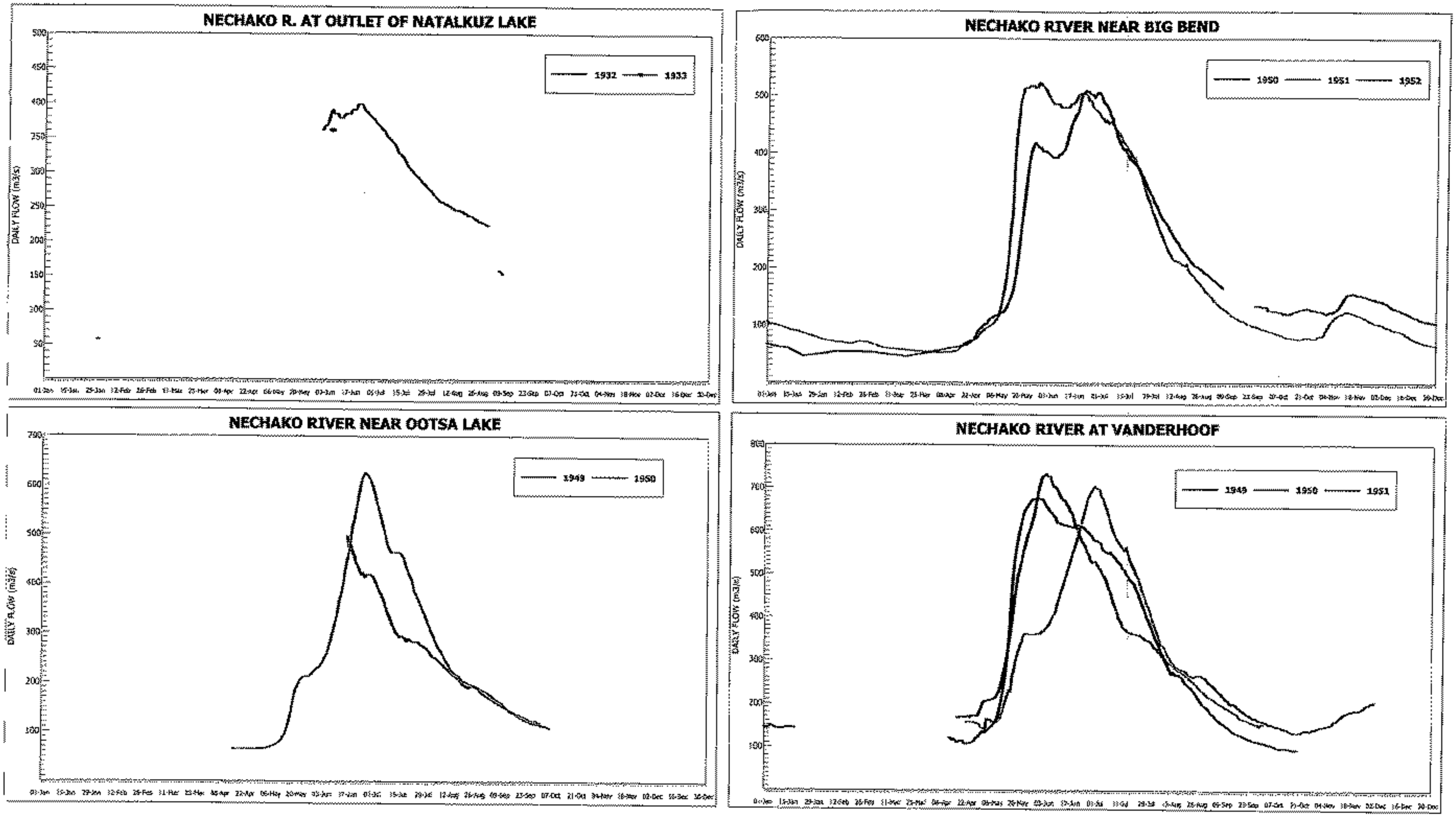
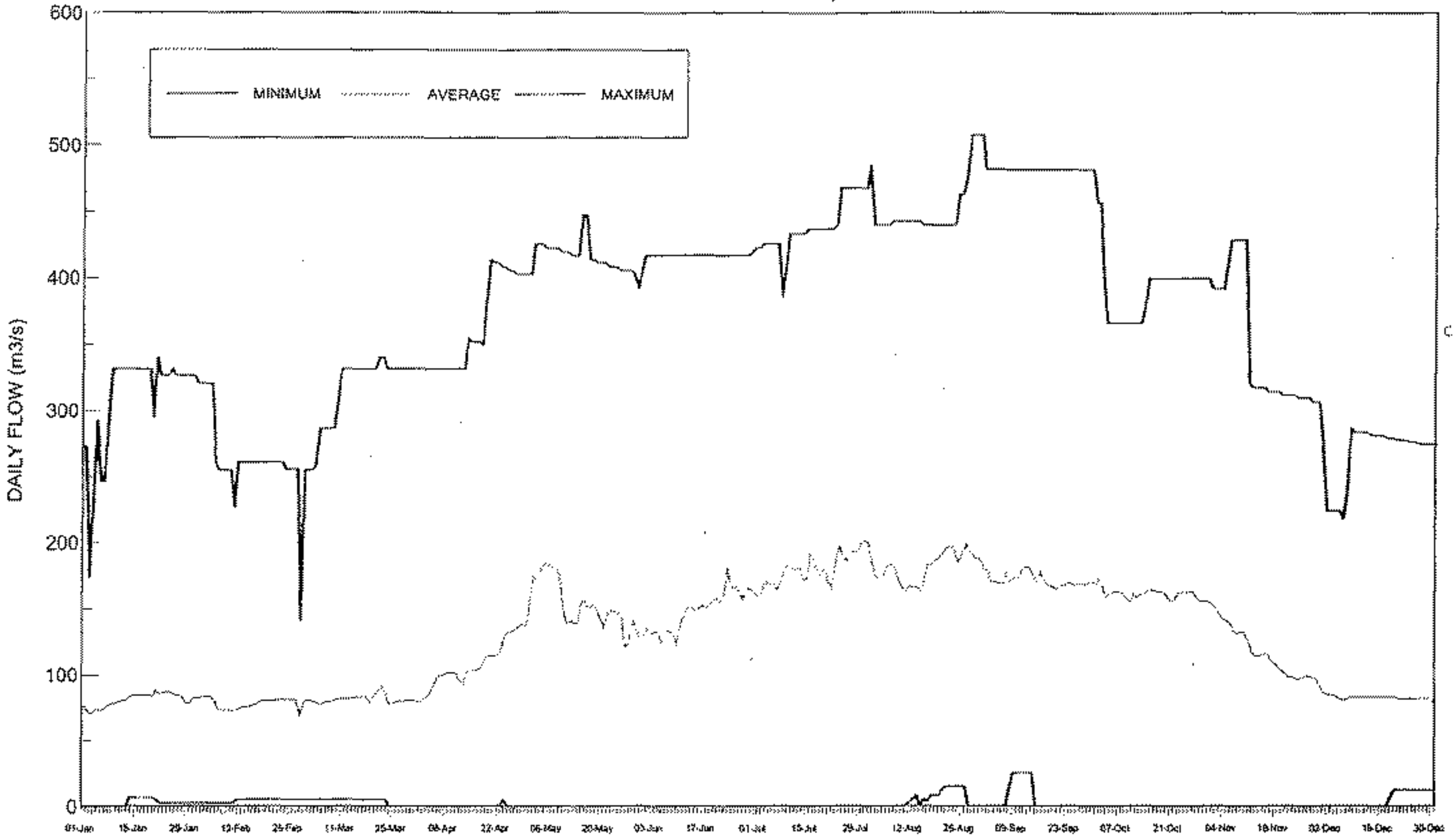


Figure 2.1.4-2 Seasonal variation in pre-regulation stream flow at WSC streamgauging stations on Nechako River.

SKINS LAKE SPILLWAY, 1955-1979



SKINS LAKE SPILLWAY, 1980-2001

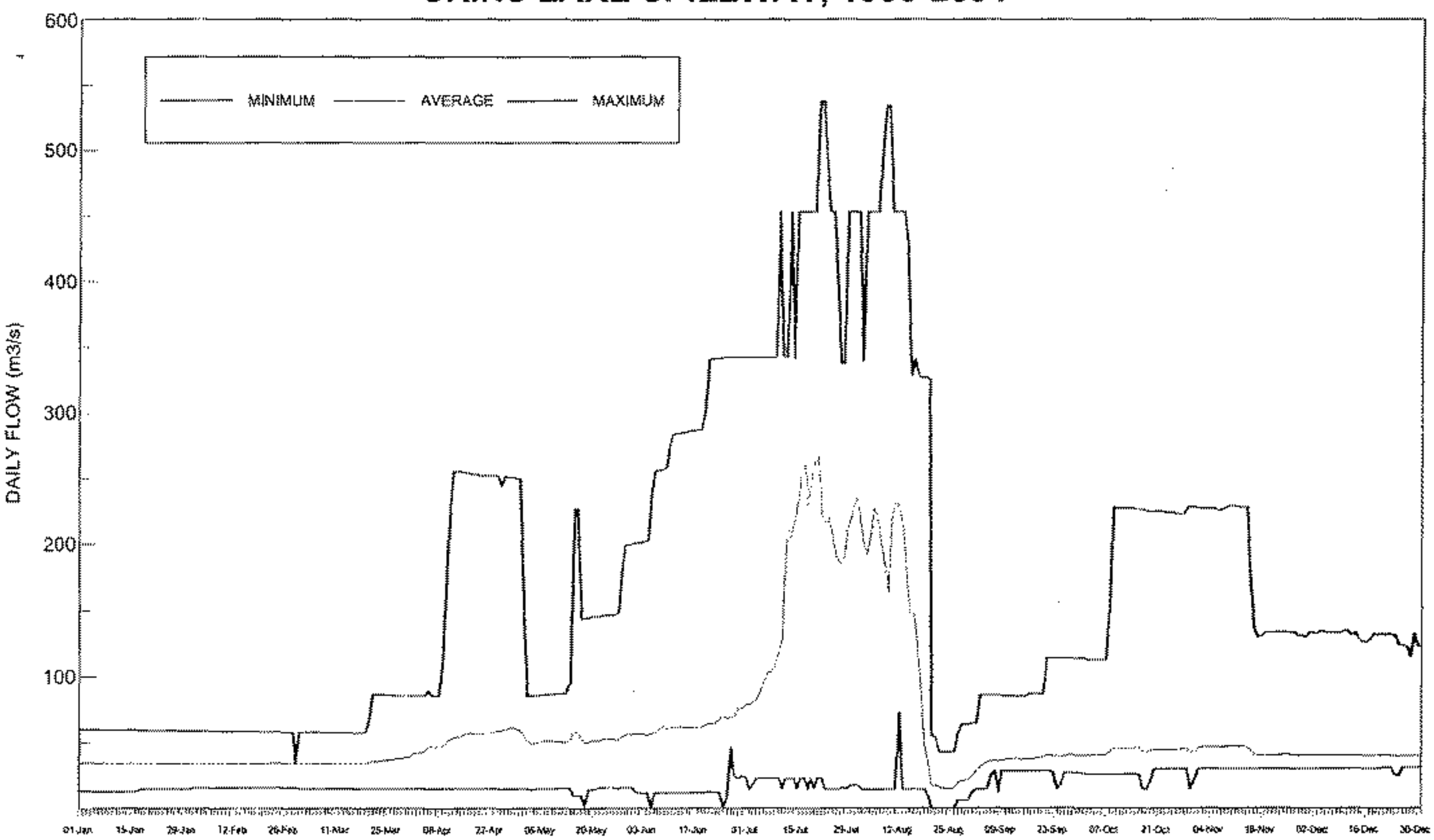


Figure 2.1.4-3 Seasonal variation in streamflow on Skins Lake Spillway, Nechako Reservoir, 1955 to 1979 and 1980 to 2001.

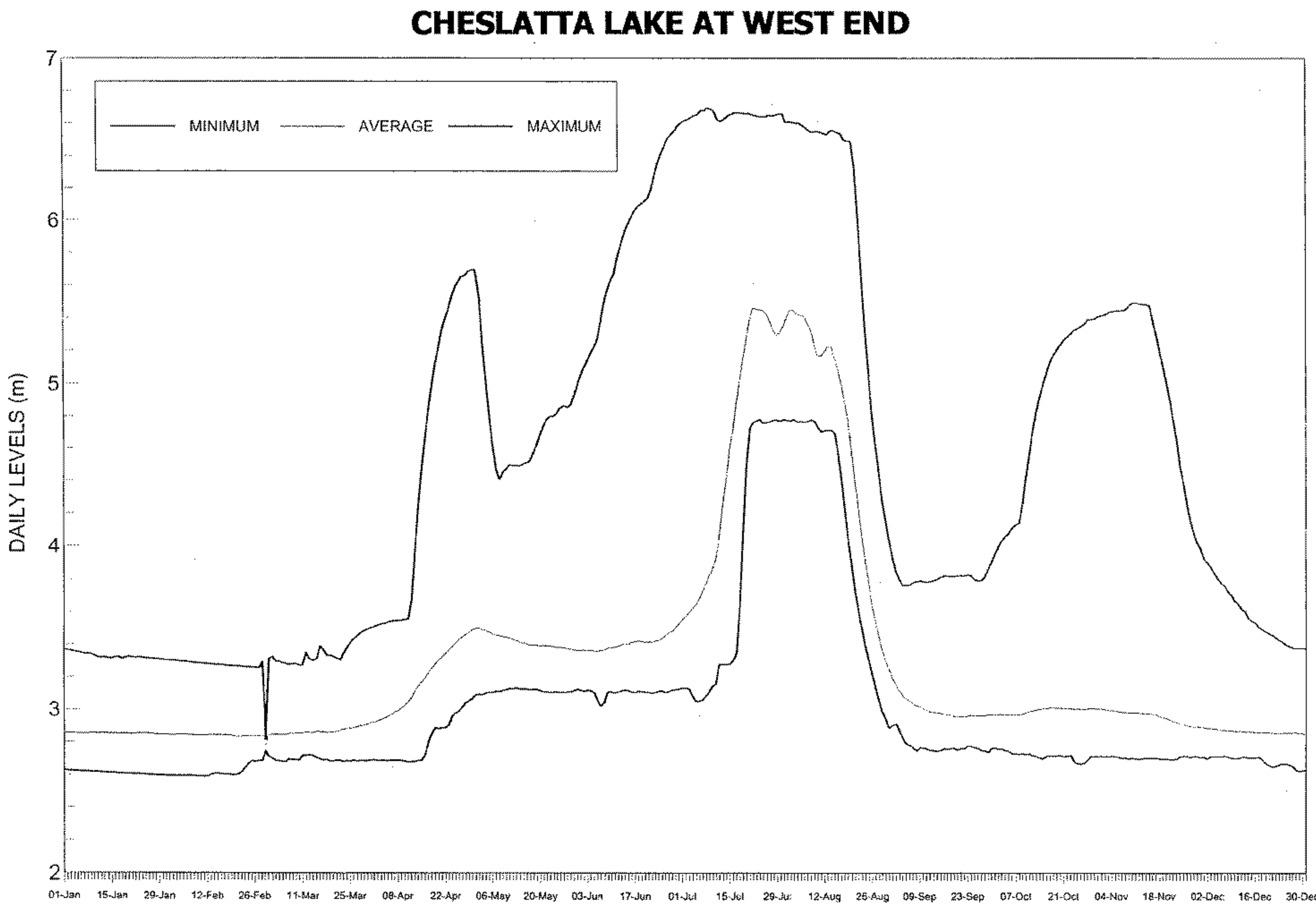


Figure 4-4 Seasonal variation in levels on Cheslatta Lake at West End, 1981 - 2002.

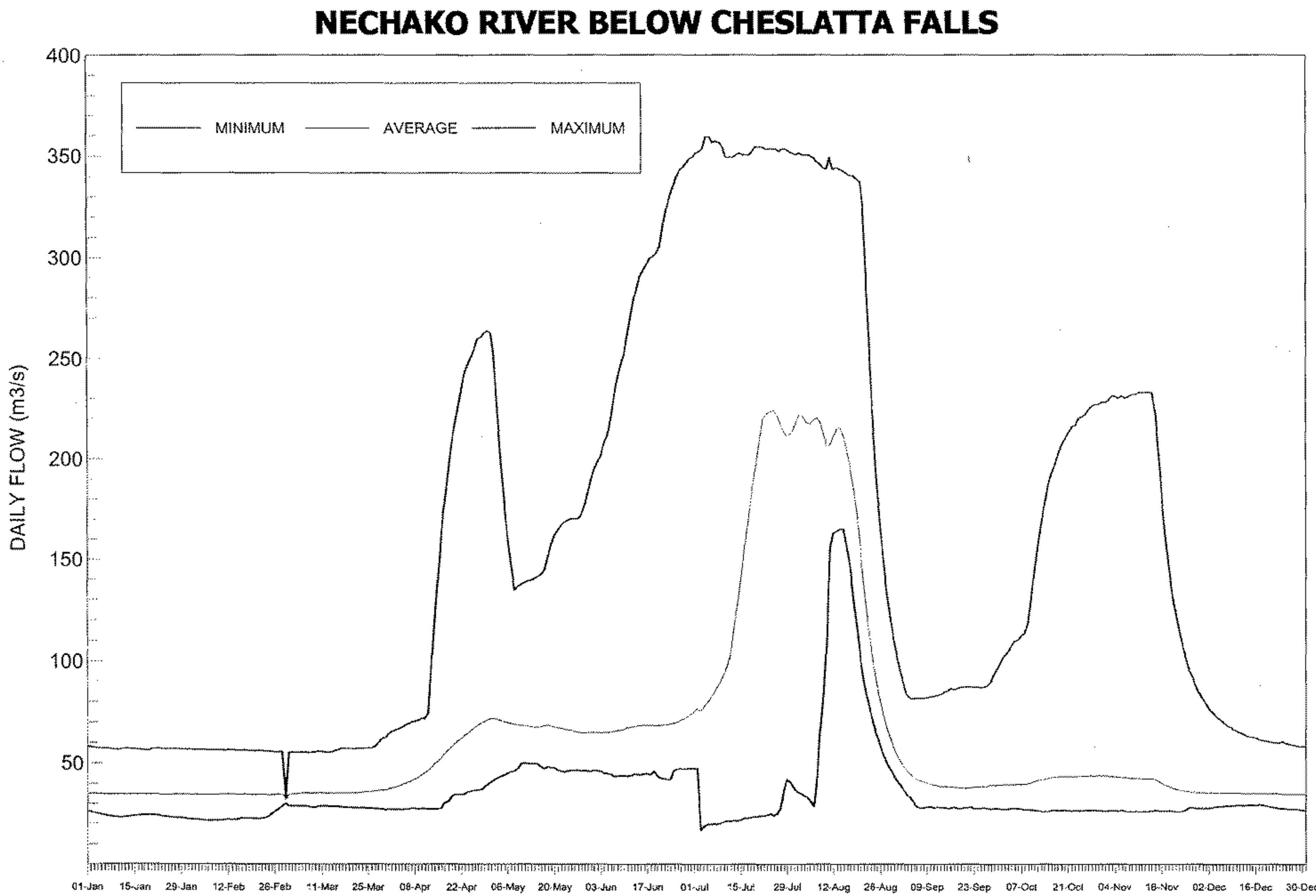
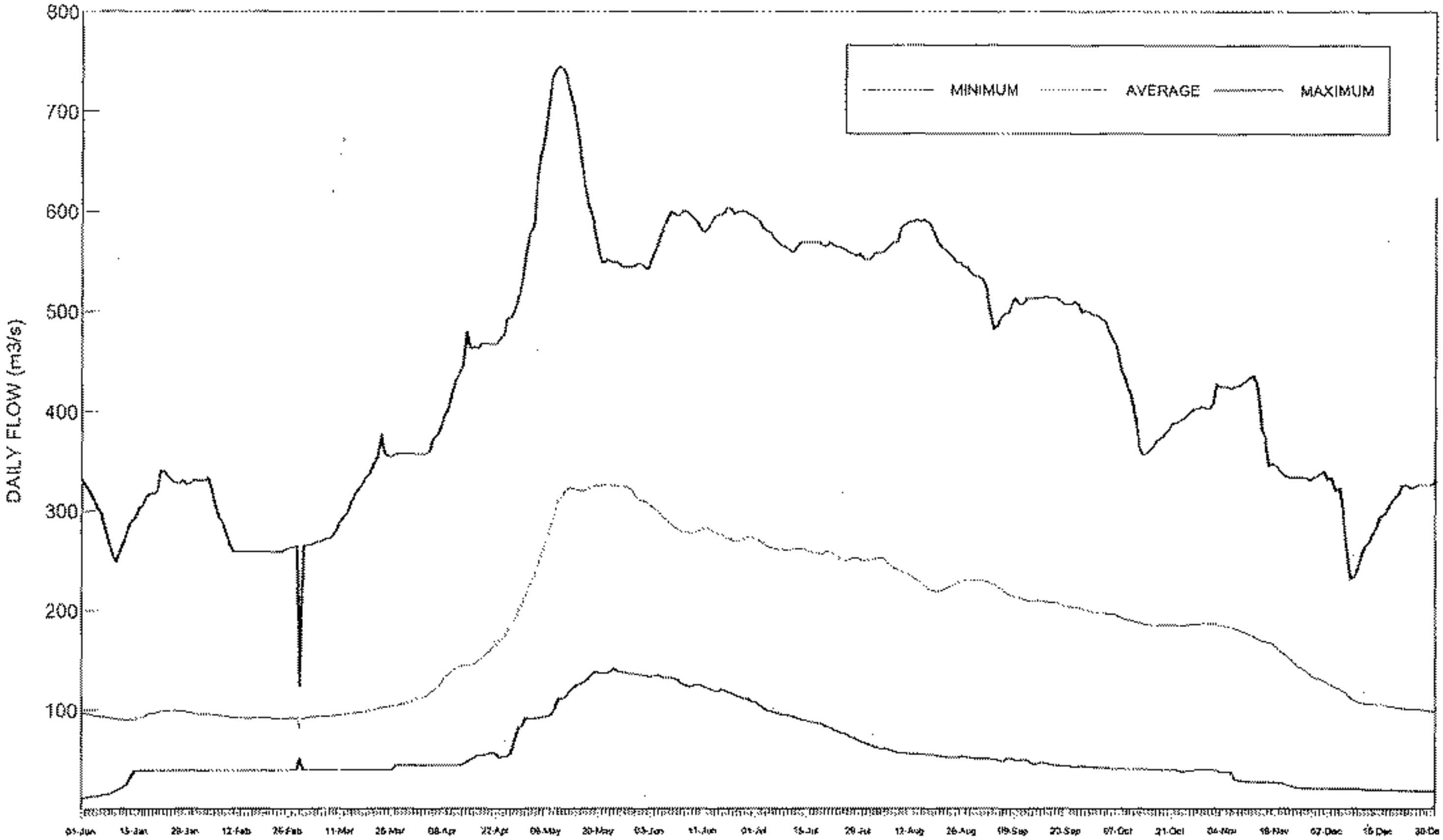


Figure 2.1.4-5 Seasonal variation in streamflow on Nechako River Below Cheslatta Falls, 1980 - 2002.

NECHAKO RIVER AT VANDERHOOF, 1957-1979



NECHAKO RIVER AT VANDERHOOF, 1980-2001

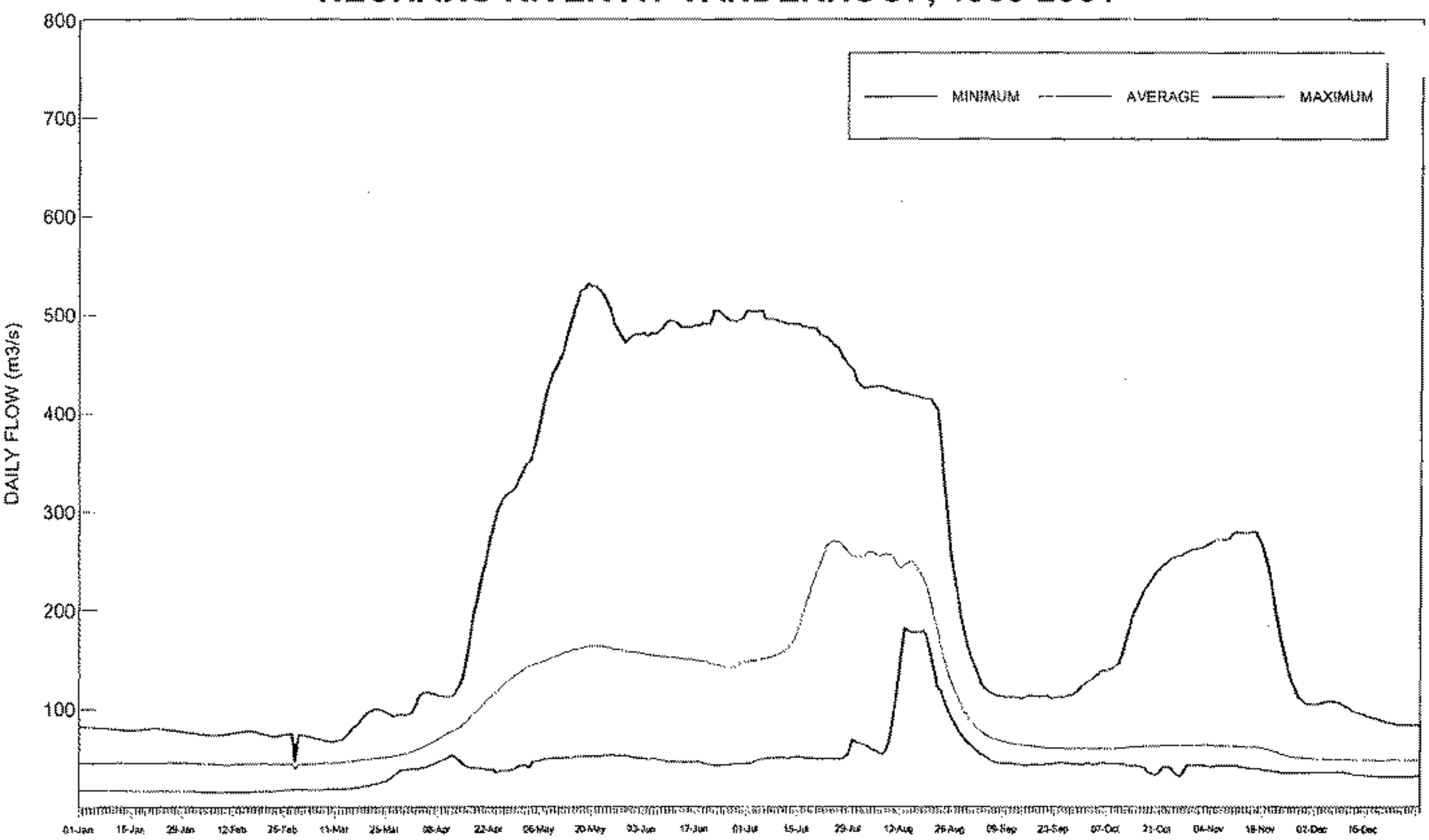


Figure 2.1.4-6 Seasonal variation in post-regulation streamflow on Nechako River at Vanderhoof, 1957 to 1979 and 1980 to 2001.

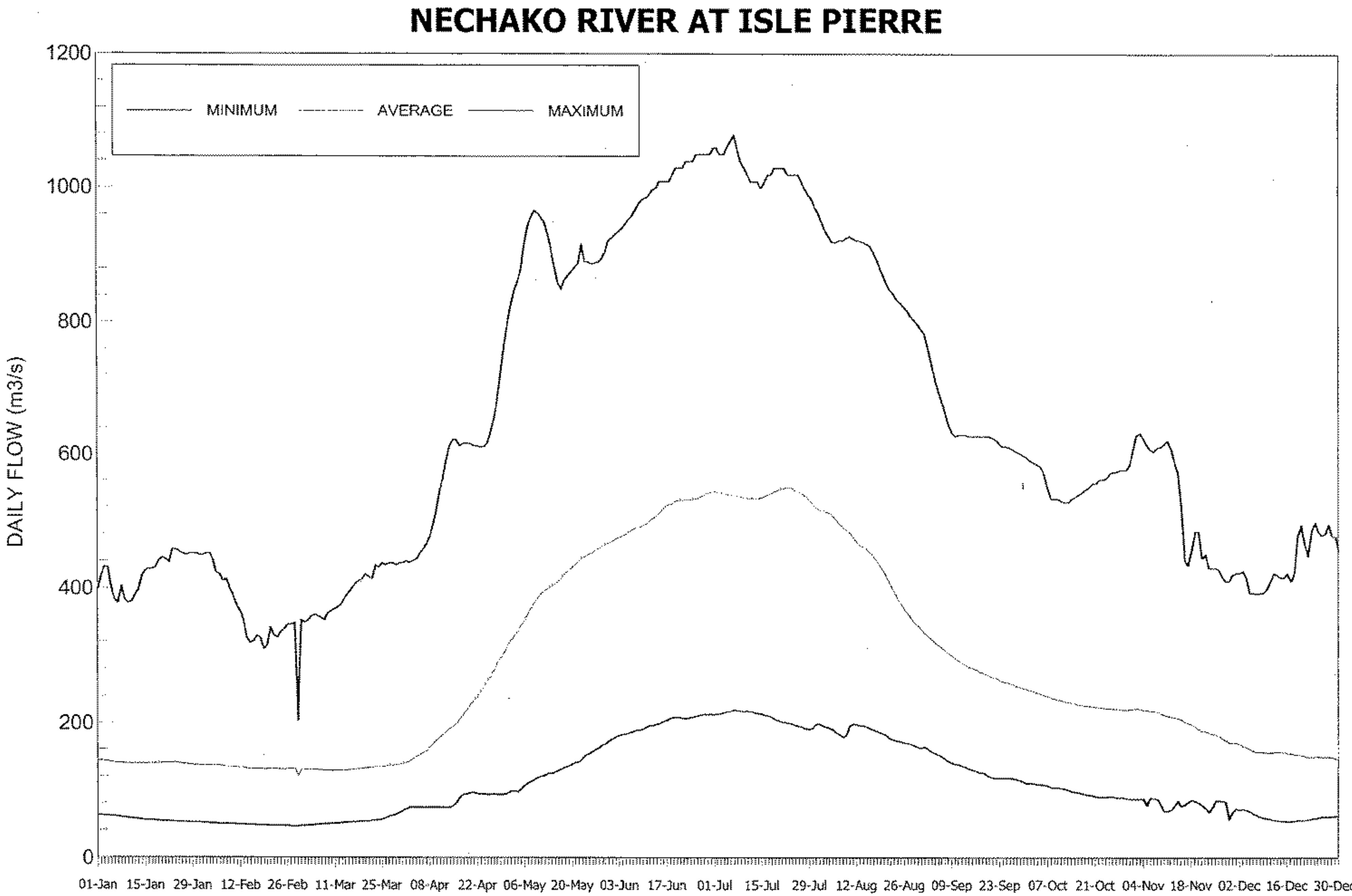


Figure [illegible]-7 Seasonal variation in streamflow on Nechako [illegible]ver At Isle Pierre, 1957 - 2001.

2.1.4.3 Flood Discharges

The pre-project discharge data shown on Figure 2.1.4-2 suggest that the mean annual maximum daily discharge at Nechako Canyon was approximately 550 m^3/s prior to construction of Kenney Dam.

The historical variation in annual maximum daily discharges released though "Skins Lake Spillway" is shown on Figure 2.1.4-8. Flows in the 1956 to 1979 period were quite variable in comparison to post-1980 values, which are generally 450 m^3/s. The maximum flow of record occurred in 1981 and reached a value of 538 m^3/s. The annual maximum water levels of Cheslatta Lake (Figure 2.1.4-9) are also comparatively uniform except for 1997 when long duration releases from the reservoir resulted in unusually high water.

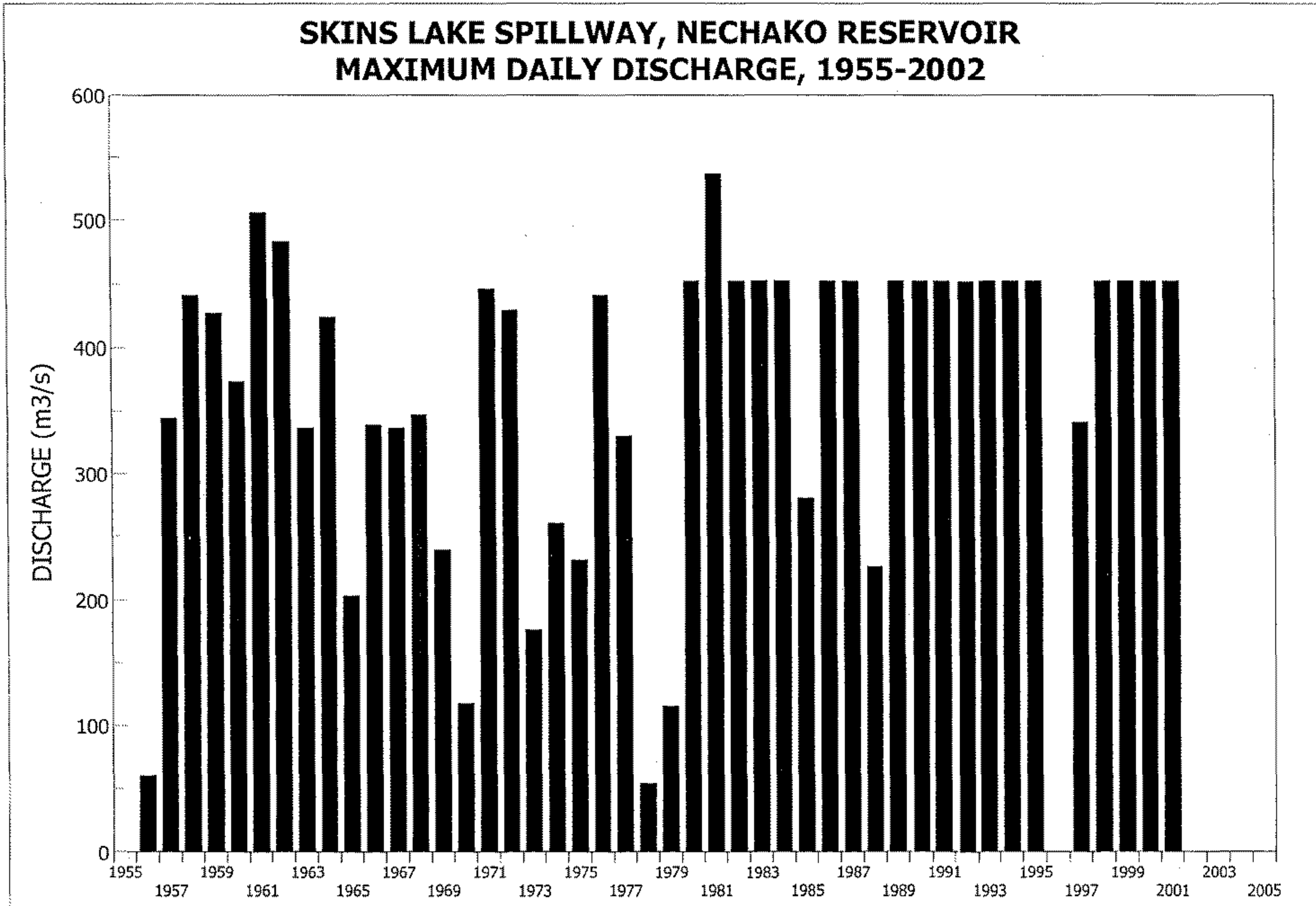
Discharge data from "Nechako River below Cheslatta Falls" (Figure 2.1.4-10) indicates that the average post-1980 annual maximum daily discharge is 281 m^3/s. This is half of the estimated pre-regulation value. Unusually high events occurred in both 1981 (350 m^3/s) and 1997 (360 m^3/s).

Pre-regulation discharge data from "Nechako River at Fort Fraser" (Figure 2.1.4-11) indicate that the two-year return period annual maximum daily flow was approximately 541 m^3/s. This value is slightly smaller than the previously estimated mean annual maximum daily flood flow at the inlet to the Nechako Canyon. This discrepancy reflects the scarcity of pre-regulation data.

Discharge data from "Nechako River at Vanderhoof" (Figure 2.1.4-12) indicate that the average annual maximum daily discharge in the period between 1949 to 1952 was 687 m^3/s. This value, which is larger than that computed from the gauging data "at Fort Fraser," appears reasonable given the increase in basin area between these two sites (17,700 and 25,100 km^2). The average annual maximum flows between 1953 and 1956 were reduced to 132 m^3/s as a result of reservoir filling. Annual maximum flows in the period between 1957 and 1979 ranged between 166 and 745 m^3/s with the average value being 426 m^3/s, which is 62% of the average pre-regulation value. Annual maximum flows in the 1980 to 2002 period have ranged from 207 m^3/s in 1988 to 532 m^3/s in 1997. The average maximum discharge in this period was 327 m^3/s, which is 48% of the pre-regulation value. Information provided by the BC Ministry of Water, Land and Air Protection indicated the following relationship between discharge and flooding potential at Vanderhoof (Larson pers. comm.):

Natural boundary	280 m^3/s
Property begins to flood	400-450 m^3/s
Buildings flood	630 m^3/s

The temporal pattern in annual maximum flood flows at "Nechako River at Isle Pierre" (Figure 2.1.4-13) is similar to that observed at Vanderhoof. The pre-regulation mean annual daily maximum discharge was 998 m^3/s. This decreased to 656 m^3/s in the period between 1951 and 1979 or 66% of the pre-regulation average. Mean annual maximum daily flows further decreased to 578 m^3/s or 58% of the pre-project average in the post-1980 period.



Figur 1.4-8 Historical variation in maximum daily dischar Skins Lake Spillway (1955 to 2001).

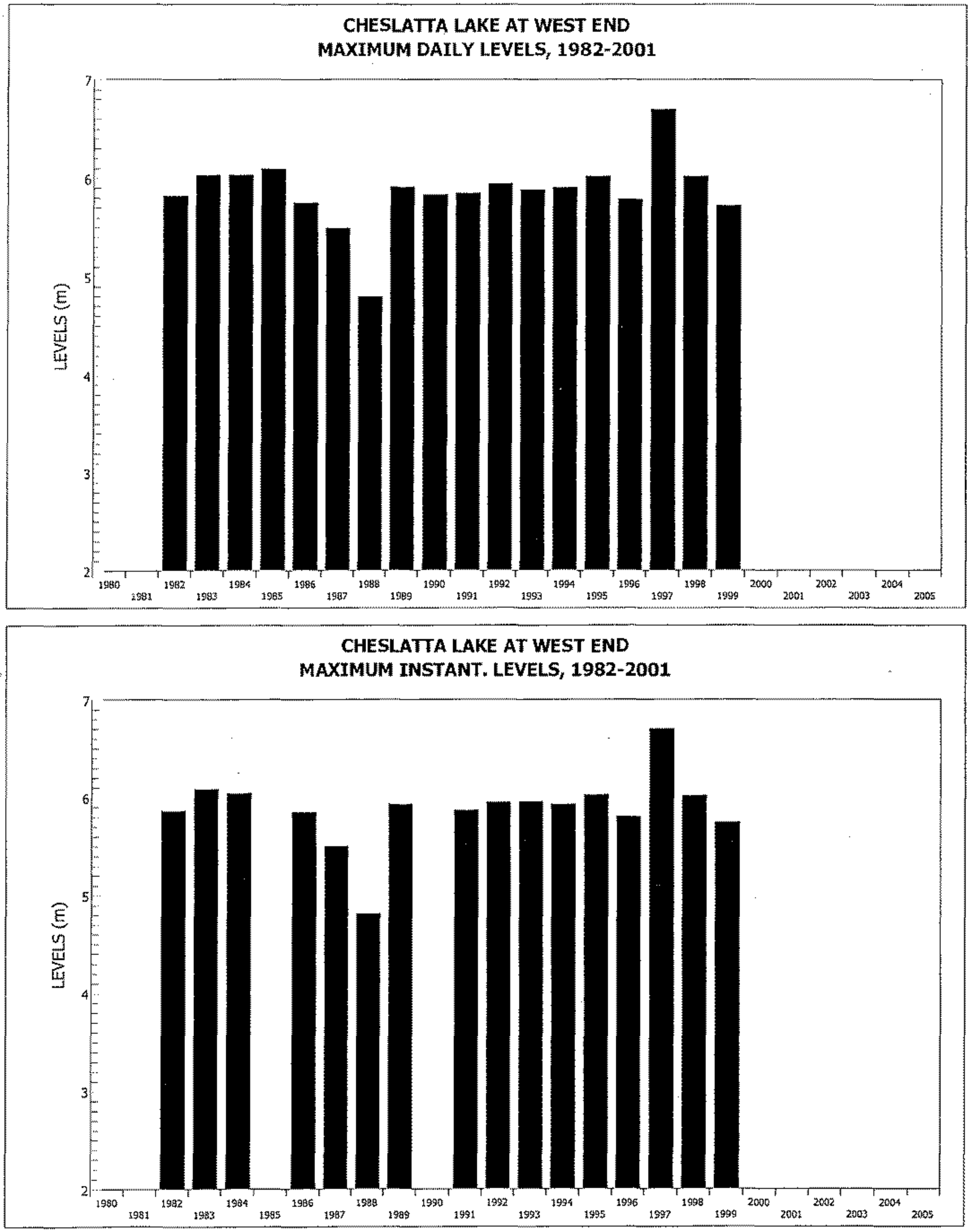
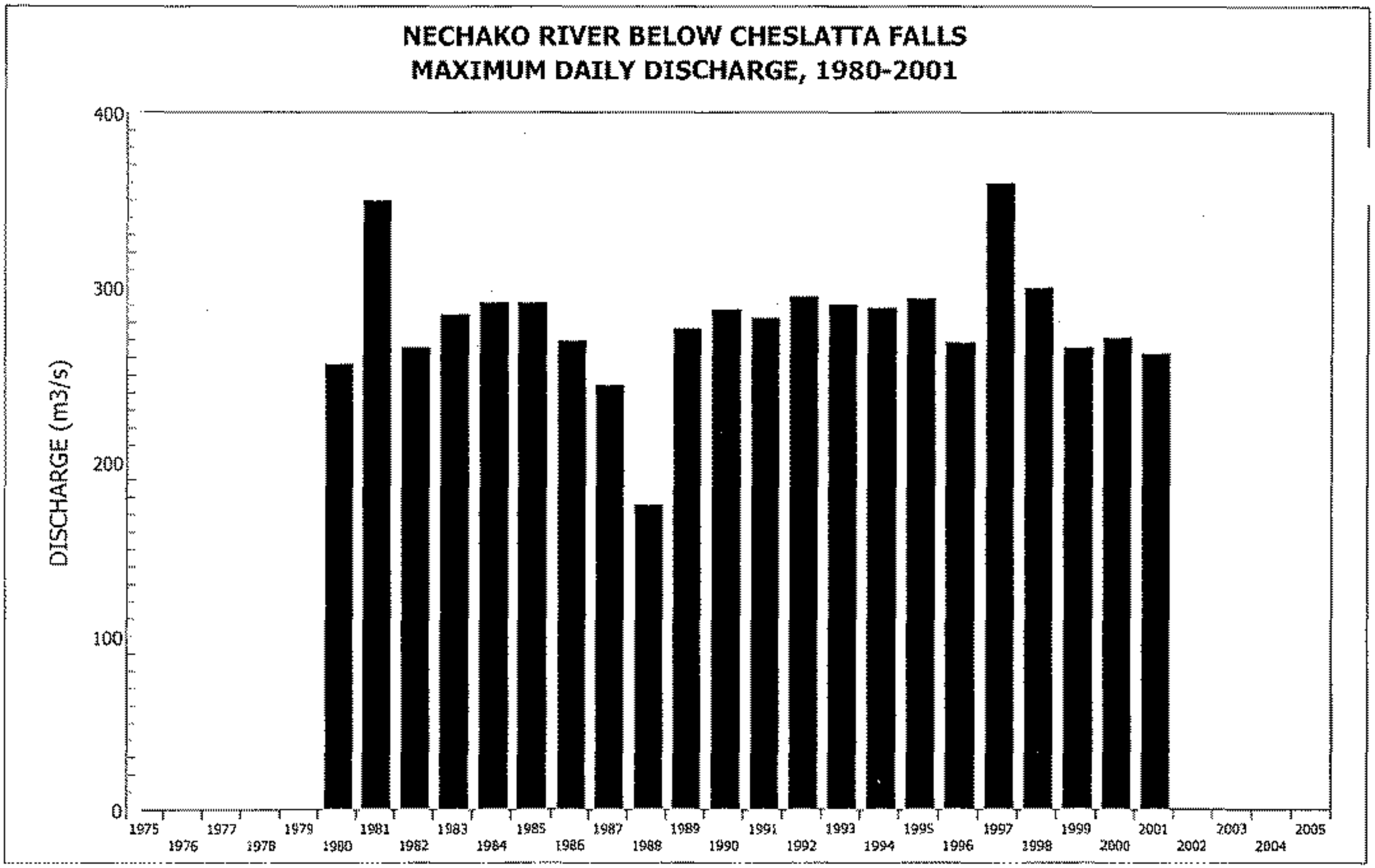


Figure 2.1.4-9 Historical variation in annual maximum daily and instantaneous water levels, Cheslatta Lake at West End, 1982 - 2001.



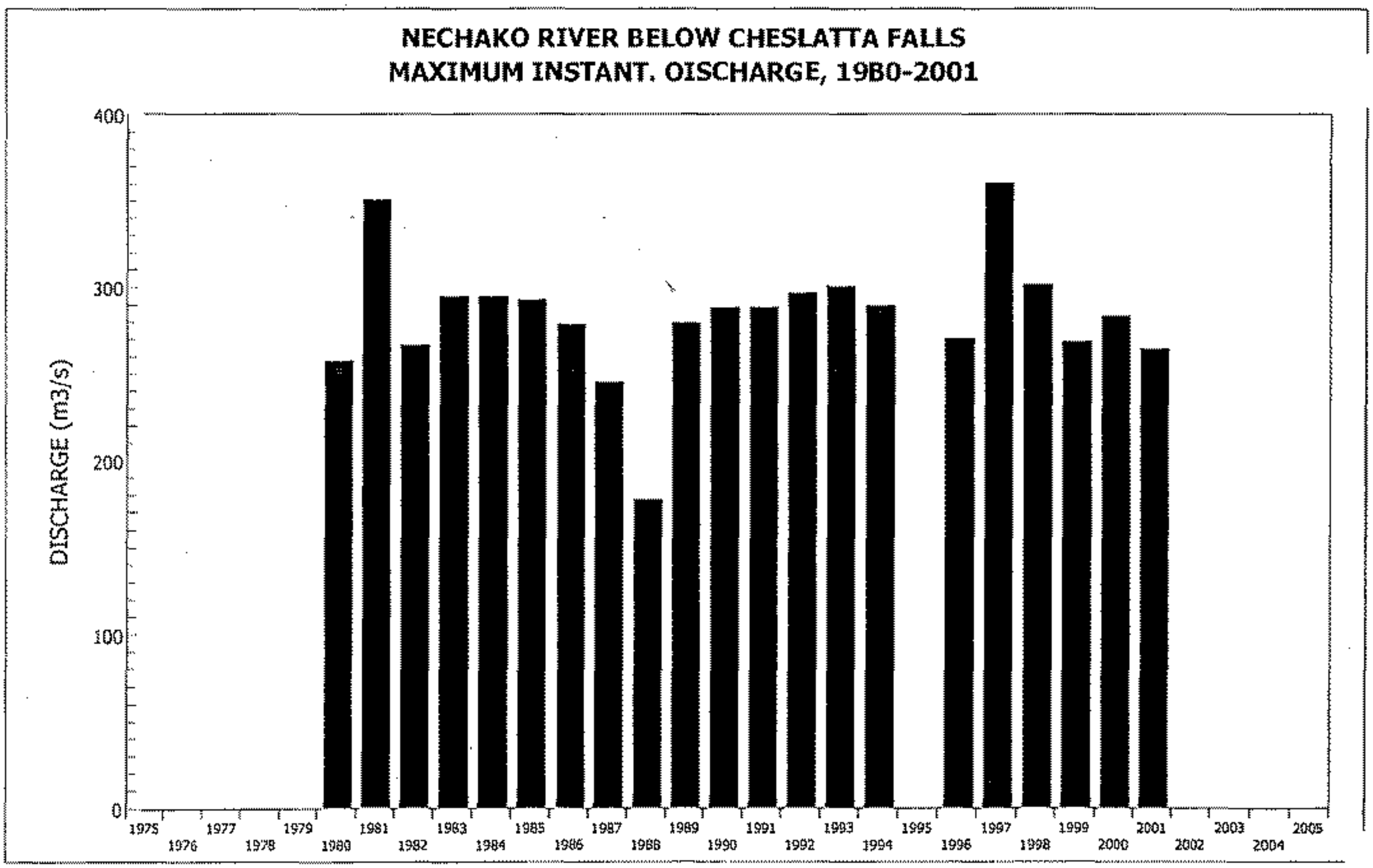


Figure 2.1.4-10 Historical variation in annual maximum daily and instantaneous discharge, Nechako River Below Cheslatta Falls (1980-2001).

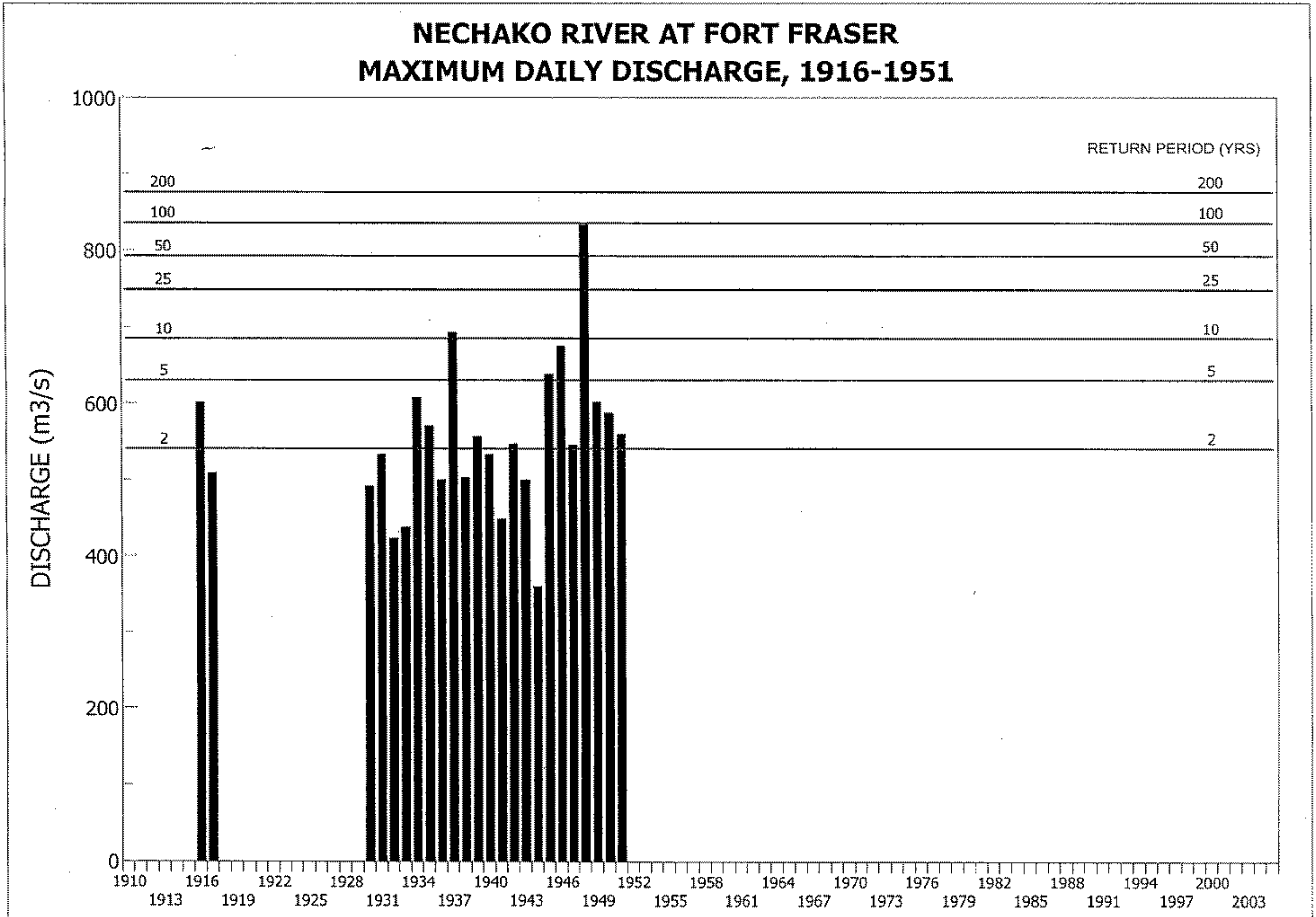
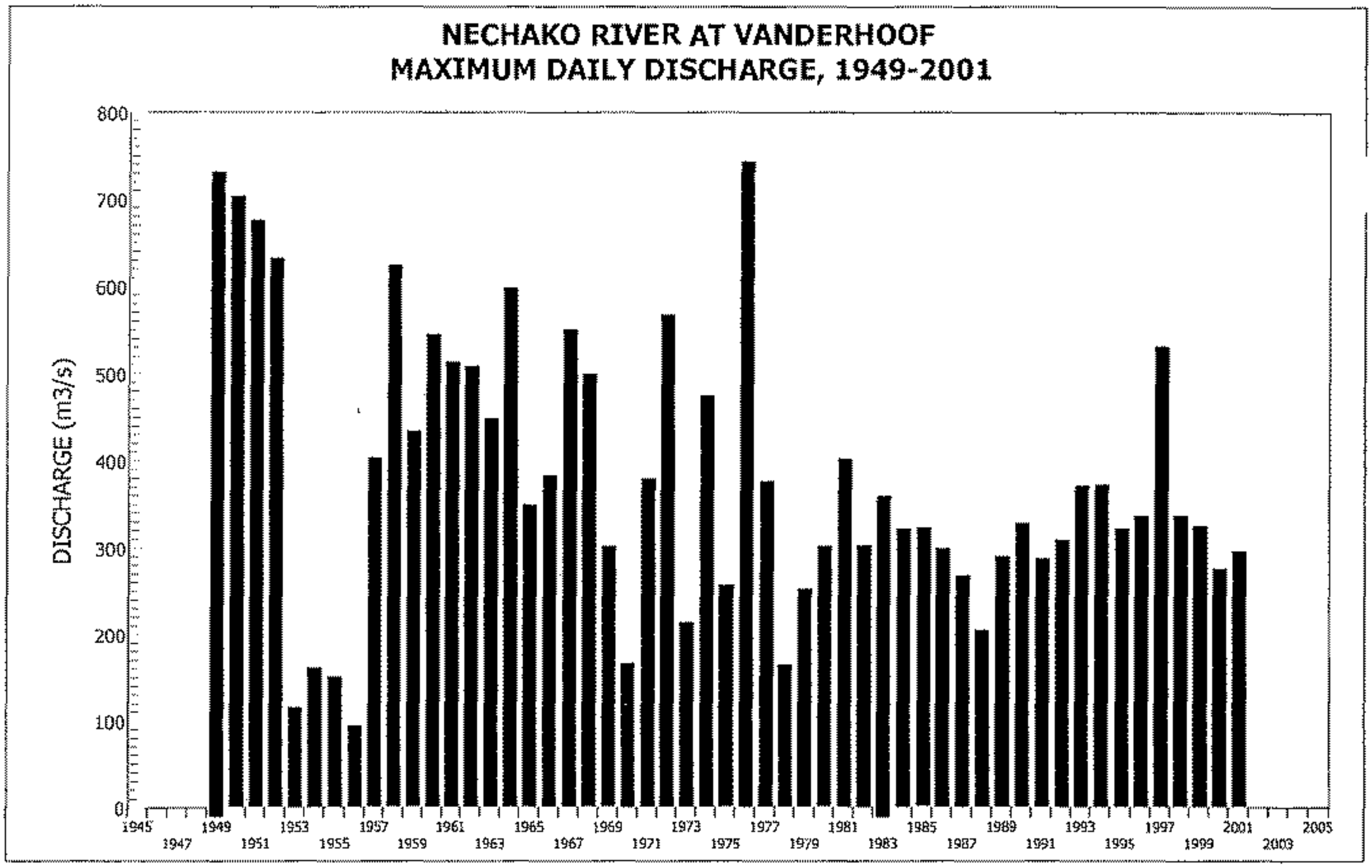


Figure 2.1.4-11 Historical variation in maximum daily discharge, Nechako River at Fort Fraser, (1916-1951).



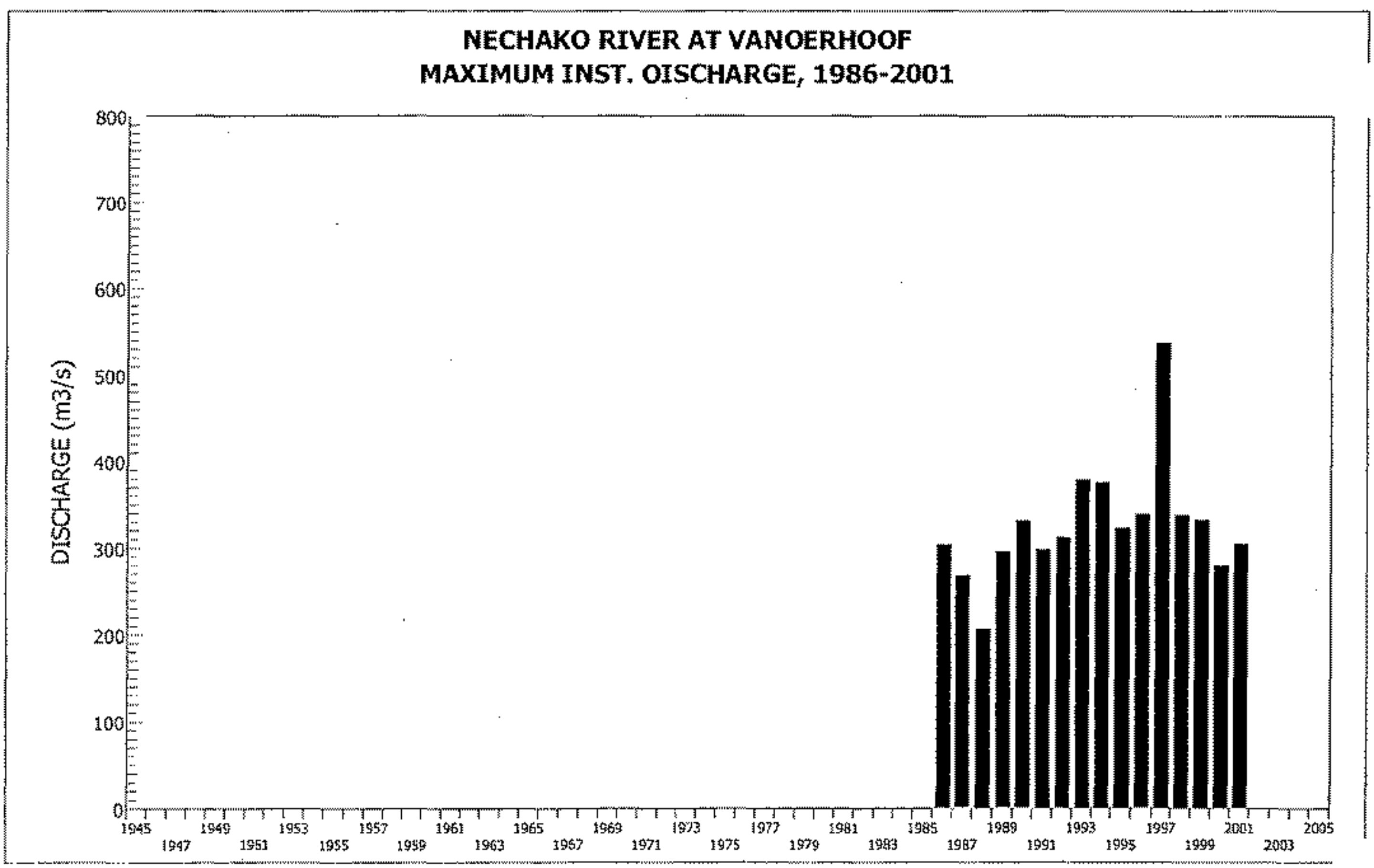


Figure 2.1.4-12 Historical variation in annual maximum daily and instantaneous discharge, Nechako River at Vanderhoof, 1949-2001.

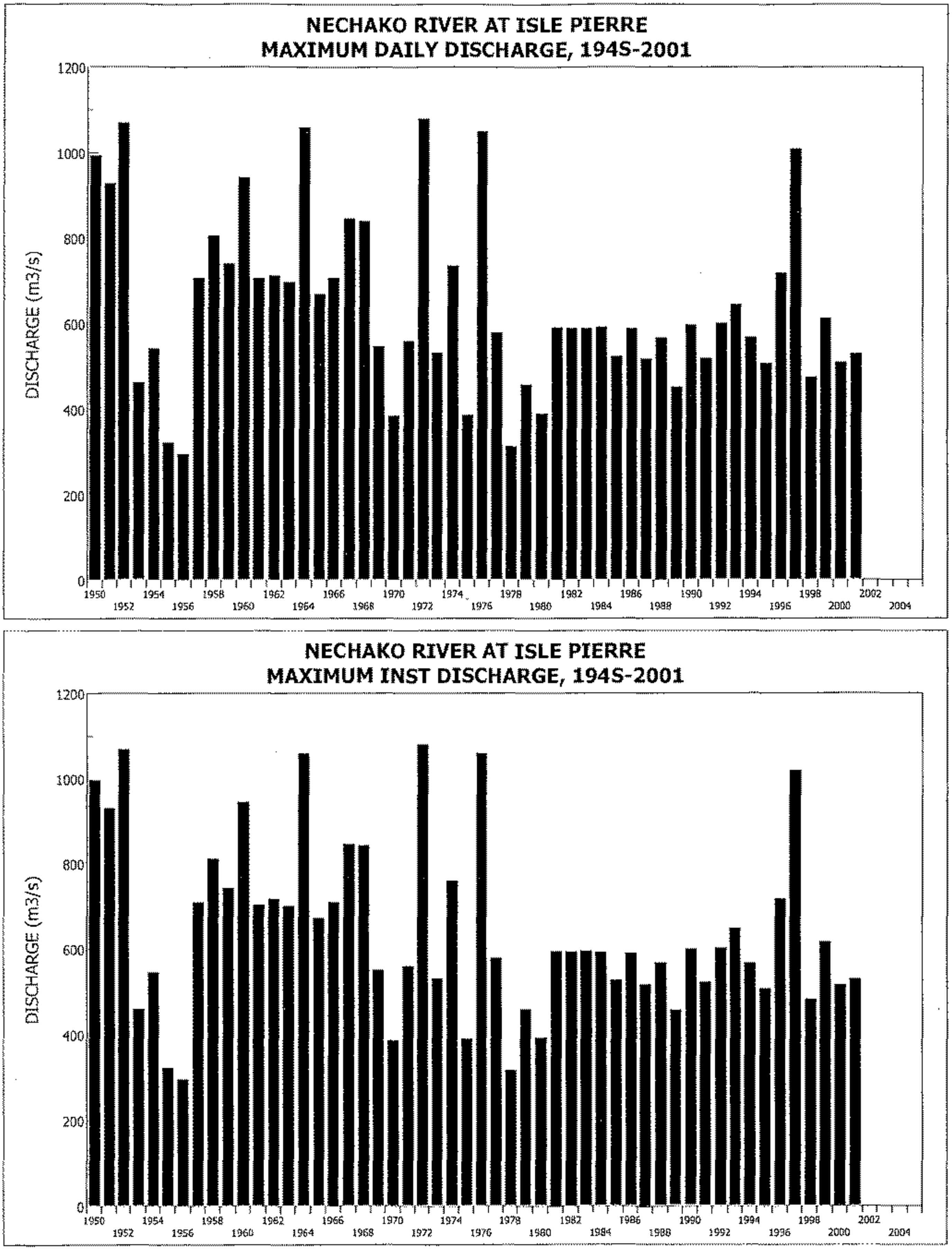


Figure 2.1.4-13 Historical variation in maximum daily and instantaneous discharge, Nechako River at Isle Pierre, 1945-2002.

2.1.4.4 Design Discharge Criteria

Klohn Leonoff and Triton (1991) designed the Kenney Dam Release Facility [KDRF] on the basis of a 170 m^3/s design flow. Related studies to assess how these flows could be routed past Cheslatta Fan (Klohn Leonoff 1991a and b) were "checked" using a flow of 210 m^3/s, which included a local inflow of 40 m^3/s.

The KDRF was no longer required following the BC-Alcan 1997 Agreement (refer to Section 1.0). A somewhat different structure, the Water Release Facility or WRF, was subsequently proposed (Triton 2000, Klohn Crippen 2001). The WRF would have the capacity to release 170 m^3/s as cooling flows and the ability to manage excess inflows to the reservoir of up to 450 m^3/s. Hayco (2000) used this larger value, along with a local inflow of 40 m^3/s (for a total design flow of 490 m^3/s) in the most recent assessment of the proposed Cheslatta Fan channel. We have adopted these WRF design flows for the present study[3].

The design flow of 450 m^3/s at Kenney Dam is the typical post-1980 annual maximum discharge observed at the "Skins Lake Spillway" (refer to Figure 2.1.4-8), but is smaller than the 1981 value of 538 m^3/s. The 450 m^3/s value is also somewhat smaller than the estimated average pre-regulation annual maximum daily flood flows of around 540 to 550 m^3/s (refer to Section 2.1.4-3). Releasing this flow directly into Nechako River (rather than routing it through Cheslatta and Murray Lakes) would result in larger downstream flows in comparison to the present operating regime, which achieves an average annual maximum daily flow of 290 m^3/s at "Nechako River below Cheslatta Falls."

The previously recommended local inflow of 40 m^3/s in the area between Kenney Dam and Cheslatta River (which has a total area of approximately 80 km^2) corresponds to a unit discharge of 500 L/s/km^2. The recent report by Obedkoff (2001) indicates that there are substantial regional variations in flood runoff within this portion of the Nechako Plateau (Hydrologic Zone m). On the basis of his regional envelope curve, the predicted 10-year return period instantaneous flood is 360 L/s/km^2 or 29 m^3/s. The proposed 40 m^3/s value is 1.4 times this value. Using Obedkoff's procedures, this corresponds to a flood with an average return period ranging from at least 25 years to possibly as much as 200 years, depending on runoff characteristics of the watershed. Given the small snow packs and modest rainfall intensities documented in Section 2.1, the use of a 40 m^3/s local inflow value may be excessively conservative as extreme local runoff is unlikely to occur simultaneously with maximum reservoir releases.

2.1.5 Channel Morphology

A series of colour air photo mosaics have been prepared to illustrate conditions along the 17 km of river channel downstream of Kenney Dam. These photos, which were taken in September 2000 and have been enlarged to a scale of 1:5,000 from 1:20,000 originals. They are presented in Appendix 1.

Kenney Dam is located at the head of Nechako Canyon[4], which is a 7 km long, bedrock confined, fault controlled channel. Following construction of Kenney Dam, the only water supply to the canyon

[3] The value of 450 m^3/s is slightly larger than an earlier estimate of the 200-year flood flow for the Kenney Dam Spillway (see Reksten 1994).
[4] The Nechako Canyon actually extends upstream approximately another 9 km, but this area is now submerged by the reservoir.

consists of local drainage. The drainage area at the canyon outlet has been decreased from 14,160 to 80 km^2. As a consequence, this section of Nechako River consists of a very small residual channel that is generally flowing over cobbles or bedrock. A number of beaver dams, sediment deposits (principally at the confluence of Streams 1 and 2) or bedrock sills locally block the channel and have formed a series of small ponds. These occur most commonly in the upper 4 km of channel. A large scour pool (Scour Hole Lake[5]) occurs at the canyon outlet.

Cheslatta River joins Nechako River at Km 9. A post-diversion channel avulsion resulted in the deposition of a large fan in the Nechako Valley between Km 7.4 and 9.0. This channel relocation initially occurred in 1961 (see Rood and Neill 1987), with significant additional reworking being reported to have occurred in 1972 (see Hayco 2000). Alcan then forced the Cheslatta River back into its original channel over Cheslatta Falls with the construction of a small saddle dam.

A bedrock constriction occurs downstream of the Cheslatta Fan at Km 8.25. This constriction, which is informally referred to as the "Neck," appears to locally control the stream gradient at high flow.

The outlets of Murray and Cheslatta Lakes are located in the Cheslatta drainage approximately 3 and 14 km upstream of the Nechako confluence, respectively. Lower Cheslatta River consists of a single thread gravel bedded channel that is frequently confined by bedrock or surficial materials. The bedrock controlled Cheslatta Falls occurs at the Nechako River confluence.

Immediately downstream of the Cheslatta confluence the Nechako River consists of an irregular, gravel bed channel with occasional islands. A bedrock constriction occurs between Km 9.5 and 10.25 and this also appears to cause backwater effects during periods of high flow. Unconfined sections of channel are now laterally stable and riparian vegetation is becoming well developed along the channel margins and bars that were more active prior to river regulation.

2.1.6 Channel Stability

A series of historical air photos showing how stream channel conditions have changed over time is presented in Appendix 2. Original air photos taken in 1953, 1971, 1990 and 2000 have been digitally scanned and presented at a common scale of 1:10,000 for the area between Kenney Dam and the outlet of Nechako Canyon. Additional air photos taken in 1950, 1961, 1974 and 1978 have also been compiled for the area around Cheslatta Fan[6].

Prior to inundation, Nechako River upstream of the Nechako Canyon (including the 9 km of the canyon that was flooded by the reservoir) consisted of an irregularly meandering channel flowing within a moderately wide valley flat (see Figure 2.1.6-1). The channel contained well developed point bars indicating that mainstem bank erosion, possibly augmented by sediment production from four sizeable tributary streams to the approximately 35 km of channel downstream of Lake Natalkuz, resulted in a significant sediment load. Inspection of the historical air photos in Appendix 2 indicates this material was, in large measure, transported through Nechako Canyon. The first sizeable area available for sediment deposition was located upstream of the constriction at Km 8.25 (the "Neck"). Channel

[5] This lake has been referred to as the Devil's Punchbowl, Scour Hole Lake, and as Scourhole Lake. The lake will be referred to as Scour Hole Lake in this report.
[6] Photography is also available from 1949 but has not been compiled for this report.

conditions in this area are illustrated on Figure 2.1.6-2 on the basis of 1949 air photos. The pre-regulation sediment deposits upstream of the Km 8.25 constriction are easily recognizable; as is a sizeable scour hole and additional sediment deposits in the downstream channel.

There has been relatively little change in channel conditions in Nechako Canyon in the post-regulation period (this will be discussed further in Section 3.3.2); however, as indicated by Figure 2.1.6-3, substantial changes have occurred at the Cheslatta confluence. Cheslatta River breached its right bank just downstream of the Holy Cross Forest Service Road bridge and cut a massive gully through a thick unconsolidated sequence of glaciofluvial gravels, lacustrine sediments and till thus by-passing Cheslatta Falls. The eroded materials were redeposited in the form of a large alluvial fan on the floor of the Nechako Valley, both upstream and downstream of the constriction at Km 8.25. A saddle dam was constructed at the entrance to the diversion channel in the mid 1970's (Dhaliwal pers. comm.) and the Cheslatta River was forced back over Cheslatta Falls. Rood and Neill (1987) estimate that approximately $0.9 \times 10^6 m^3$ of sands and gravels were eroded by this channel relocation and that 0.4 to $0.5 \times 10^6 m^3$ was deposited in Nechako River above Cheslatta Falls. The remainder of the material has been carried downstream. The historical air photos in Appendix 2 (Sheets 5 and 6) provide a good illustration of how this feature has changed in the period since 1950.

Post-regulation changes in channel stability in Nechako River downstream of Cheslatta River have generally been limited to sediment deposition and vegetation encroachment within the original channel boundaries (Rood and Neill 1987). Some side channels have been abandoned due to vegetation encroachment, sediment deposition and lowered water levels (northwest hydraulic consultants 2002a). In addition, there is evidence of local fine sand deposition within areas of cobble bed materials (northwest hydraulic consultants 2002b).

2.2 Riparian Conditions

The study area lies within the Sub-Boreal Spruce (SBS) Biogeoclimatic Zone. Forests of the SBS Zone are broadly transitional between the montane forests of Douglas-fir to the south, the drier and colder pine-spruce forests to the southwest, boreal forests to the north, and subalpine forests at higher elevations (Meidinger et al. 1991). The Nechako Canyon-Cheslatta Fan area lies within one of the relatively dry subzones (the SBSdk) that is centred around Francois Lake, extending from Trembleur Lake in the north to Ootsa Lake in the south, and east to include the Nechako Canyon area. On the uplands adjacent to the canyon, the dominant tree species listed on polygons of the Forest Cover Map Series, Map 93F.066, are lodgepole pine, spruce (hybrids between white and Engelmann spruce), and aspen. Scattered paper birch and black cottonwood also occur in these upland forests stands. All of tbese upland tree species occur within the Nechako Canyon and in the vicinity of Cheslatta Fan.

As outlined in Sections 3.3.1 and 4.3.2, there is not a conspicuous riparian zone in the canyon or on the fan area, in contrast to the distinct cottonwood-dominated floodplain sites that occur along the Nechako River downstream of Cheslatta Falls. Black cottonwood is present on portions of the Cheslatta Fan but is uncommon in the dewatered areas within Nechako Canyon.

Air Photos: A11282 #144 September 13, 1947 A11292 #2 September 22, 1947
A11288 #41 September 17, 1947 A11293 #37 September 20, 1949

Figure 2.1.6-1: 1947 & 1949 air photos illustrating pre-regulation channel conditions upstream of Nechako Canyon.

A11293 #34		September 20, 1949 Air Photo			
REFERENCED DRAWING NO.		REFERENCED DRAWING DESCRIPTION			
A	Nov. 1, 2002	Issued For Discussion	SG	MM	
B	Jan. 23, 2002	Issued For Report			

APPROXIMATE SCALE:	1:5,000
DATE:	November 1, 2002
DRAWN:	S. Gibbins
DESIGNED:	S. Gibbins
CHECKED:	M. Miles
APPROVED:	M. Miles

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CLIENT: NECHAKO ENHANCEMENT SOCIETY

PROJECT: NECHAKO RIVER COLD WATER RELEASE FACILITY

TITLE: NECHAKO RIVER AIR PHOTO MOSAIC SHOWING CONDITIONS IN 1949

FIGURE 2.1.6-2

PROJECT NO. 219
Km NO. 7 to 9
REV: A

30BCC00020 #59		September 22, 2000 Air Photo				APPROXIMATE SCALE: 1:5,000	M. MILES AND ASSOCIATES LTD. 645 ISLAND ROAD, VICTORIA, BC, V8S 2T7 Phone: 250-595-0653 Fax: 250-595-7367 email: mmaa@coastnet.com	PROJECT: NECHAKO RIVER COLD WATER RELEASE FACILITY	
						DATE: August 26, 2002			
REFERENCED DRAWING NO.		REFERENCED DRAWING DESCRIPTION				DRAWN: S. Gibbins		TITLE: NECHAKO RIVER AIR PHOTO MOSAIC SHOWING CONDITIONS IN 2000	
A	Aug. 26, 2002	Issued For Discussion	SG	MM		DESIGNED: S. Gibbins			
B	Jan. 23, 2003	Issued For Report				CHECKED: M. Miles	CLIENT: NECHAKO ENHANCEMENT SOCIETY	FIGURE 2.1.6-3	PROJECT NO. 219 / Km NO. 7 to 9 / REV: A
						APPROVED: M. Miles			

Although not directly applicable to either the site conditions exposed as a result of dewatering of the Nechako Canyon or the sites created by deposition of Cheslatta Fan, a regionally representative floodplain site series for the study area is typified by the following description by Banner et al. (1993): The Black Cottonwood-Dogwood-Prickly Rose site series occurs on active floodplains adjacent to major rivers. Shrub layers are tall and vigorous with red-osier dogwood, alders, and willows present. The herb layer characteristically includes bluejoint, American vetch, blue wild-rye, sweet-cicely, and palmate coltsfoot. Mosses are sparse or lacking. Soils are Regosols and Brunisols with thin, loose litter layers; this site series generally shows evidence of repeated flooding. This description of a typical floodplain site series is for the SBSdk Biogeoclimatic Subzone along the southeastern limit of the Prince Rupert Forest Region, the eastern limit of which is in the vicinity of Kenney Dam.

In the vegetation resources baseline information prepared for Alcan by Envirocon Limited (1984a) the study area closest to Nechako Canyon was monitoring site NEC-01 along the Nechako River near River Ranch, approximately 25 km downstream from the Cheslatta Fan area. Side channels and fluvial bar sites were examined at that location, where there was a diversity of wetland and upland vegetation types, including a grass/willow plant community near the Nechako River and aspen-spruce mixed wood forest on drier portions of the floodplain. The 1984 vegetation descriptions from site NEC-01 are not summarized here because the Nechako River floodplain in that study area is not representative of conditions in the Nechako Canyon; however, site NEC-01 may serve as a guide for long-term potential development of vegetation adjacent to a reestablished channel along the eastern flank of the Cheslatta Fan.

If future stands of cottonwoods are to be encouraged adjacent to a new channel between Scour Hole Lake and the Cheslatta Falls area, there is substantial information available on relations between fluvial processes and cottonwood development in floodplain ecosystems similar to those in the Nechako-Cheslatta study area. These key information sources include reports that deal with black cottonwood or balsam poplar ecosystem dynamics from several study locations: British Columbia generally (McLennan 1991; McLennan and Mamias 1992; Simard and Vyse 1992; Massie et al. 1994; Peterson at al. 1996; McLennan and Johnson 1999); Skeena River floodplain (Beaudry et al. 1990); Beatton River floodplain in northeastern British Columbia (Nanson and Beach 1977); Morice River floodplain (Gottesfeld and Gottesfeld 1990); Blaeberry River floodplain in southeastern British Columbia (Fyles and Bell 1986); alluvial sites in the Fraser River valley (Brink 1954); and river bars along the Tanana River in Alaska (Krasny et al. 1988a, 1988b). Porter (1990) described willow species typical of alluvial and other riparian sites in the SBS Zone.

2.3 Fisheries

The following is a brief summary of information related to the fish resources of the Nechako River. This is not intended to be an exhaustive review, but rather to provide enough information to put fisheries issues into context.

2.3.1 Resident Fish Species

Resident fish species documented within the Nechako River include brassy minnow (*Hybognathus hankinsoni*), bull trout (*Salvelinus confluentus*), leopard dace (*Rhinichthys falcatus*), longnose sucker

(*Catostomus catostomus*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), pygmy whitefish (*Prosopium coulteri*), rainbow trout (*Oncorhynchus mykiss*), redside shiner (*Richardsonius balteatus*), slimy sculpin (*Cottus cognatus*), sucker (Catostomus spp.), white sturgeon (*Acipenser transmontanus*), and white sucker (*C. commersoni*) (FISS 2003). Of the species identified in the Nechako River, bull trout and brassy minnow are provincially blue listed species, while the white sturgeon is a red listed species.

2.3.1.1 Resident Salmonids

The primary focus of fisheries research in the Nechako River has been on salmon species and in more recent years, white sturgeon. Consequently, very little information could be located on non-salmon species of salmonids or any other fish species. For example, only 12 references could be located on non-salmon species (principally rainbow trout), whereas, there were 69 reports that referred specifically to juvenile chinook salmon (Bradley and Peterson 2002).

Therefore, the life-history of non-salmon species of salmonids (and non-salmonid fish species) in the Nechako River remains virtually unknown. Rainbow trout are an important resident sport fish in the river, primarily due to angler use. The productivity of rainbow trout is limited in some reaches by the availability of tributary rearing habitat (Rescan 1999). Adult rainbow trout use the mainstem of the Nechako River for holding and feeding. Adults appear to move into the tributaries to spawn. Rainbow trout fry (i.e., Age-0) rear almost exclusively in the tributaries, whereas older juveniles (referred to as parr by Envirocon 1984b) use both the mainstem and tributary streams (Envirocon 1984b).

Bull trout were the least abundant fish species captured during the baseline fisheries studies for the Kemano Completion Project (Envirocon 1984b). The distribution of bull trout in the Nechako mainstem appears to be limited to areas downstream of Envirocon's Reach 6 (downstream of the Trankle Creek confluence; Envirocon 1984b).

Mountain whitefish occurred in low abundance in the sampling conducted in 1979-80, comprising approximately 3% of total catch.

2.3.1.2 White sturgeon

Historically, white sturgeon have only been documented downstream of the Nautley confluence (Cadden 2000). There are concerns about the reproductive success of white sturgeon in the Nechako River and the population of white sturgeon in the Nechako River is believed to be in danger of extirpation. Evidence suggests that there is a potentially severe juvenile recruitment problem in the Nechako River stock. Although, the exact cause for the recruitment decline is not known, it is believed by many that if steps are not taken to reverse this trend, the Nechako River stock may be lost. BC Ministry of Water, Land and Air Protection has initiated steps towards identifying the causes of recruitment decline as well as developing recovery strategies. One favored strategy proposed involves monitoring experimental flow regimes that would return the Nechako River hydrograph to more natural conditions with stronger seasonality (Korman and Walters 2001). The use of conservational aquaculture has also been suggested as a possible short-term measure to ensure the genetic diversity and integrity of the population (Korman and Walters 2001).

2.3.1.3 Non-salmonid Resident Species

Non-salmonid species made up between 84 and 92% of the catch during the 1979-80 sampling. The majority of the non-salmonid catch consisted of suckers (species not identified), redside shiner, and northern pikeminnow (Envirocon 1984b). Non-salmonid species were found through out all reaches sampled. There appeared to be a peak in relative abundance in Envirocon's Reach 5 (Nautley River confluence to the Trankle Creek confluence) and Reach 7 (Sinkut River confluence to Stuart River confluence), due to a large number of redside shiners captured in each of tbese reaches (Envirocon 1984b). It is presumed that all life-stages of these species will utilize habitat in the Nechako River.

2.3.2 Anadromous Fish Species

Historically, chinook salmon (*Oncorhynchus tshawytscha*) and sockeye salmon (*O. nerka*) are well documented within the Nechako River watershed. Department of Fisheries and Oceans enumeration data for spawning chinook exists from early to mid 1900's. Although, chinook and sockeye salmon make up the vast proportion of salmon species composition within the river, there have also been isolated reports of pink salmon (*O. gorbuscha*) and coho salmon (*O. kisutch*) within the mainstem.

2.3.2.1 Chinook Salmon

Adult chinook salmon enter the Nechako River in August and September to spawn. Many of these fish will travel part way up the Nechako to enter the Stuart River, while the remaining salmon are left to compose the Nechako River stock. In 1998, the number of chinook returning to spawn in the Nechako River was estimated to be 1,868 fish (Van Schubert and Compton 2001). The adult chinook salmon spawn in various sections of the river between the community of Vanderhoof and Cheslatta Falls. Evidence from chinook enumeration reports suggest that the majority of spawning activity takes place in the Upper Nechako River (between Greer Creek and Cbeslatta Falls). In 1988, 1989, 1990, 1991, 1994, 1995, 1996, 1997, and in 1998, the highest proportion of chinook salmon on redds were observed in the Upper Nechako River (Van Schubert and Compton 2001). A report prepared by Envirocon (1984b), stated that the greatest concentration of spawners occurs within a 7 Km section of river near Irvine's Lodge, upstream of the confluence of Cutoff Creek. This area is in the Upper Nechako River, approximately 5 km downstream of Cheslatta Falls.

2.3.2.2 Sockeye Salmon

The sockeye salmon is the most significant fisheries resource in the Nechako River watershed, representing over 99% of all salmon in the Nechako system (Rescan 1999). Sockeye use the Nechako River as a migration corridor during the summer/fall migration to spawning grounds in the Nadina-Francois and Stuart-Takla tributary drainages. There are five major runs of sockeye salmon: early and late Stuart River runs, early and late Nadina runs, and the Stellako run. Although sockeye use the Nechako River as a migration corridor, very few sockeye actually spawn in the river; however, an area downstream of the outlet of Targe Creek (located 31 km downstream of Kenney Dam) has been identified as a primary site for sockeye redds in the Nechako River mainstem (Van Schubert and Compton 2001). The peak number of spawning sockeye in the mainstem (n=325) was observed during the 1998 Nechako and Stuart rivers chinook spawning enumeration, which was considerably higher than in previous years (Van Schubert and Compton 2001). In 1993, during a dominant run year, a record escapement of 2.7 million sockeye spawners were recorded within the Nechako basin (Rescan 1999).

2.4 Wildlife Habitat

The area of the canyon and fan is known to support moose (*Alces alces*), black bear (*Ursus americanus*), mule deer (*Odocoileus hemionus*) and small mammals and fur bearers (Government of BC 1997). During the site visit in late September 2002 there was evidence of beavers (*Castor canadensis*) in the upper part of the canyon as well as adjacent to and downstream of the Cheslatta Fan. A family group of otters (*Lontra canadensis*) was observed in one of the ponds in the upper part of the canyon. Signs of moose browsing were evident at all locations surveyed during September 2002.

2.5 Existing Land Use

The key land uses in the vicinity of Nechako Canyon and Cheslatta Fan, in no intended order of importance, include the following:

- Cheslatta'ten and Saikuz First Nations people have used this region for many centuries. Over 130 archaeological sites have been documented in the vicinity of Nechako Canyon Protected Area and Cheslatta Falls, including a former village site near the falls where pit depressions from dwellings and former food caches have been documented. (http://wlapwww.gov.bc.ca/bcparks/explore/parkpgs/nech_can.htm).
- The Holy Cross Road, a major north-south artery that runs approximately 0.5 km west of and parallel to the western rim of Nechako Canyon, serves as an important forestry haul road as well as recreational access to the region. To the southeast of the canyon-fan area the Kenney Lake Road also serves as an important regional access for recreational and other land uses.
- In July 2000, the 1,246-hectare Nechako Canyon Protected Area was established along the 7 km canyon of the Nechako River. Recognized special features of this protected area are the impressive gorge, rock walls, overhanging cliffs, and other hydraulic erosional features in the dewatered portion of the canyon. (www.luco.gov.bc.ca/lrmp/vanderhf/images/protectedareas.jpg)
- There are no park facilities at Nechako Canyon, but the Cheslatta River Forest Recreation Site is located to the west side of the Nechako Canyon Protected Area, adjacent to the Holy Cross Forest Service Road. This recreation site is a popular camping area located on land owned by Alcan.
- A 1.2 km B.C. Forest Service recreational trail follows the Cheslatta River from the Forest Recreation Site to the Nechako River at Cheslatta Falls.
- There is four-wheel drive vehicle access from the Holy Cross Road east to the Cheslatta Fan, providing recreational access to features in the fan area, Cheslatta Falls, and the Nechako River just downstream from the falls.
- A recreational hiking trail parallels the east rim of Nechako Canyon from the vicinity of Nechako Lodge downstream to viewpoints opposite Cheslatta Falls.
- A 'Fish and Wildlife Reserve' designated on Forest Cover Series Map 93F.066 occurs along the eastern side of the Cheslatta Fan area.
- Forest harvesting and subsequent silviculture activities have occurred in cutblocks on uplands both east and west of Nechako Canyon.

Land uses in the study area are influenced by several provincial planning procedures. For example, the Vanderhoof Land and Resource Management Plan specifies that the intent of the Upper Nechako River Resource Management Zone (RMZ) is to provide for maintenance of the fisheries, wildlife, scenic views, and cultural values of the Nechako River Corridor. This RMZ extends from Kenney Dam northeast to the agricultural area just south of Fort Fraser. Some examples of recommended strategies for this RMZ that would relate to plans for rewatering the Nechako Canyon-Cheslatta Fan are listed below (refer to www.luco.gov.bc.ca/lrmp/vanderhf/229.htm and www.luco.gov.bc.ca/lrmp/vanderhf/2211.htm):

- Establish Forest Practices Code riparian reserves on the Nechako River as appropriate.
- Explore the potential to enhance salmonid habitat via increased water flows, colder water temperatures, and reduced siltation in the Nechako River.
- Recognize this area as a high priority for watershed assessment.
- Support foreshore inventory and classification of the Nechako River main stem for delineation of fisheries sensitive zones prior to development.
- Identify archaeological sites.
- Consider establishing campsites along the river for canoeists.
- Manage the Nechako River as a scenic area.
- Manage natural habitat for waterfowl and raptors.
- Retain a broadleaf deciduous tree component for wildlife values.
- Retain the cottonwood component along the river.
- Explore the potential for planting broadleaf deciduous trees along the river.
- Develop different aspen retention strategies for minor versus major broadleaf deciduous stands.
- Allow a variety of public recreational access points to the Nechako River valley from the Kenney Dam road.

Another planning initiative relating to land uses in the study area is provincial monitoring of the status of riparian ecosystems (http://wlapwww.gov.bc.ca/soerpt/14-1-riparian-ecosystems.html). The province uses the status of riparian ecosystems on forestlands as one of the indicators for State of the Environment Reporting. The main riparian management tools include: the Forest Practices Code that requires riparian reserve zones and management zones around larger streams containing fish; and the Identified Wildlife Management Strategy that enables habitat protection for species not adequately protected by general riparian and biodiversity measures under the Forest Practices Code.

3.0 THE NECHAKO CANYON

The Nechako Canyon extends for approximately 7 km downstream of the Kenney Dam and empties into Scour Hole Lake immediately upstream of the Cheslatta Fan and Cheslatta River confluence. The canyon is the result of the Nechako River incising itself across a volcanic rock barrier on the Nechako Plateau.

3.1 Principal Issues

Normal river flows have been absent from the Nechako Canyon since the completion of the Kenney Dam in 1953, as releases from the Nechako Reservoir occur via Skins Lake Spillway and the Cheslatta River. Flows have been limited to local groundwater sources and several small tributary streams. Sediment has accumulated on the riverbed and vegetation has become established within the former high-water channel of the river due to the reduced flows in the canyon (Triton 1991).

There has been concern about the potential downstream effects that might result from mobilizing accumulated sediment when flows are re-established in the canyon following the completion of CWRF. There have also been concerns that uprooted vegetation could cause debris jams if the vegetation was not removed prior to initiation of discharges from the cold water release facility. There was also some uncertainty as to how best to address the sediment and vegetation accumulations in order to mitigate downstream impacts.

3.2 Previous Studies

To begin to address the concerns noted above, Triton and Klohn Leonoff (1991) surveyed the sediment and vegetation accumulations in the canyon as part of the Kemano Completion Project assessments. Triton (1991) conducted an assessment of the amount of material that would be mobilized by flows of up to 200 m^3/s in the canyon. Based on the flushing scenarios that were examined at that time, Triton (1991) concluded:

- If vegetation were allowed to remain in place, uprooted vegetation 5 to 15 cm in diameter could cause debris jams. There was concern that this could result in unanticipated downstream effects.
- The 19 beaver dams could affect flows and the ability to control the release of sediment.
- Approximately 28,100 m^3 of sediment could be mobilized from the canyon at flows of 200 m^3/s. 77% of the material would consist of silt-sized and finer materials, which are located at the lowest elevations in the canyon.
- The more course sand fraction would be deposited in Scour Hole Lake, while the finer silt and clay fraction would be transported downstream.
- Peak sediment concentrations in the Nechako River would be between approximately 900 to 1300 mg/L, depending upon the flushing flow scenario. It would take 3-4 days to flush the majority of the accumulated sediment out of the canyon.

In response to these conclusions Triton (1991) recommended that:

- Trees 5 to 15 cm in diameter be cut and burned;
- Some of the beaver dams be loosened and burned prior to start of flushing flows;
- Flushing flows be designed to ensure fine sediments are transported at least as far as the Nautley River confluence; and

- Flushing should coincide with the summer temperature maintenance program releases to take advantage of the high flows from Skins Lake/Cheslatta River and thereby aid in the dilution of sediment concentration.

3.3 Results of Field Inspection in 2002

A field inspection was made by the study team on 28-29 September 2002 to make qualitative assessments of current conditions and to assess options for rewatering the Nechako Canyon. The vegetation and sediment accumulations were examined and compared to conditions documented by Triton and Klohn Leonoff (1991) and Triton (1991). Current condition of beaver dams was also considered. The height and age of vegetation along the river channel were assessed in order to define the former bankfull width of the channel and to assess the potential for disturbance by post-CWRF flows.

3.3.1 Riparian Vegetation

In terms of dominant tree species, Nechako Canyon vegetation is similar to that on adjacent slopes and plateau sites, with lodgepole pine, spruce (hybrid white spruce-Engelmann spruce), and aspen as the dominant species. Lesser amounts of black cottonwood and paper birch are present, especially in the area immediately downstream of Kenney Dam (Plate 3.3.1-1). Based on field observations on 28-29 September 2002, some of the key features of vegetation in the Nechako valley between Kenney Dam and Scour Hole Lake are outlined below.

Near Kenney Dam there is a well-developed forest cover characterized hy small spruce that established along the valley floor after the channel was dewatered, with abundant broadleaf deciduous species (aspen, birch, and black cottonwood) on surfaces disturbed during construction of Kenney Dam (Plate 3.3.1-1). Some of the early succession broadleaf forest cover shown in Plate 3.3.1-1 is on relatively unstable construction-related slopes.

A two-aged forest stand structure is evident along much of the length of Nechako Canyon. Plate 3.3.1-2 shows small spruce (generally under 5 m height) on surfaces exposed as a result of canyon dewatering, with older and larger conifer and broadleaf deciduous forest stands occupying the slopes above pre-Kenney Dam flood levels.

Spruce is the dominant small conifer on valley bottom sites of the canyon where there is mineral or organic soil accumulation, as shown at the far edge of the pond in Plate 3.3.1-2. Lodgepole pine is the dominant small conifer where there are gravel or boulder surfaces in the dewatered zone (Plate 3.3.1-3). Both Plates 3.3.1-2 and 3.3.1-3 demonstrate the small sizes of trees that would be subject to removal during flushing of the canyon. Some of the young spruce stands that have developed near some of the beaver dams or near other ponds on the valley floor have a relatively dense tree cover (Plate 3.3.1-2). In contrast, most of the pines that have established on boulder surfaces are not only small but also sparsely spaced (Plate 3.3.1-3).

Plate 3.3.1-1 Well-developed forest cover approximately 0.4 km downstream from Kenney Dam.

Well-developed forest cover 0.4 km downstream of Kenney Dam. Small, young spruce were established along the valley floor after the channel was dewatered. Valley slopes in this area are dominated by broadleaf deciduous tree species that established on surfaces disturbed during Kenney Dam construction. An area of unstable vegetation occurs at the base of the eroding slope that dates from the dam construction period (See also Plate 3.3.2-1).

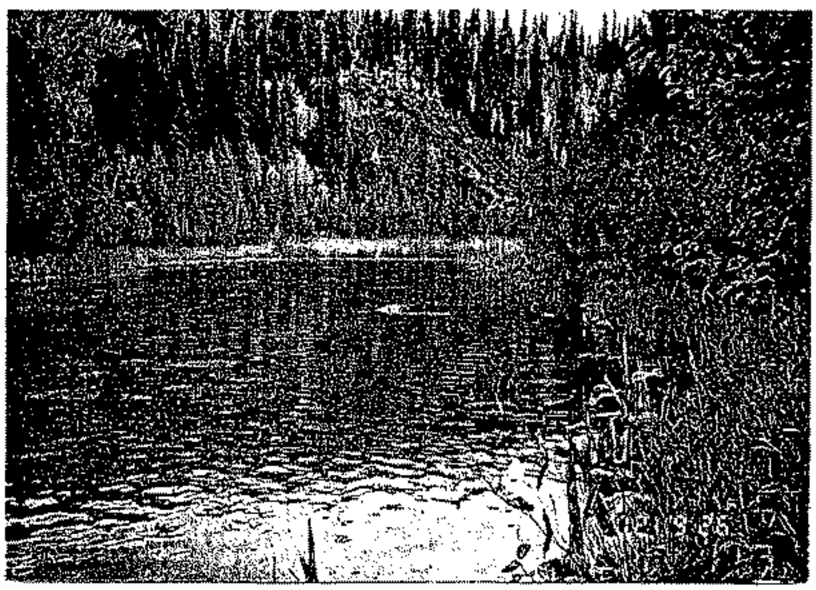


Plate 3.3.1-2 Two-aged forest stand structure in Nechako Canyon.

Two-aged forest stand structure in Nechako Canyon, with small spruce (generally under 5 m height) on surfaces exposed as a result of canyon dewatering, with older and larger conifer and broadleaf deciduous forest stands occupying the slopes above pre-Kenney Dam flood levels. Location: floor of Nechako Canyon, viewed to northwest over north end of pond approximately 0.6 km downstream of Kenney Dam.

Plate 3.3.1-3 Vegetation accumulations on dewatered bars in the Nechako Canyon.
Relatively sparse woody biomass accumulation is typical of much of the dewatered area in the Nechako Canyon, with many of the spruce and lodgepole pine less than 5 m tall. Location: floor of Nechako Canyon approximately 0.7 km downstream from Kenney Dam.

Large areas of the dewatered canyon floor contain no tree cover at all. Our impression from field observations in September 2002 is that there is less woody material accumulated in Nechako Canyon since it was dewatered than is implied in the Triton (1991) report. Concern by previous investigators that there is a risk of trees forming debris jams in narrow sections of the canyon during a flushing program was based on the assumption that any such jams would be formed primarily of large trees. As one would expect, the field reconnaissance in September 2002 did not reveal the presence of large trees below the high water line of pre-Kenney Dam river flows. The currently anticipated flushing flows are expected to be substantially less than the extreme natural flows experienced through the canyon before dam construction. Therefore, we do not visualized that flushing flows to prepare for a cold water release facility would remove any large trees that grow above the high water line of the pre-dam era.

Table 3.3.1-1 lists five trees sampled in September 2002 that could be at locations subject to canyon flushing. These sample trees are some of the largest trees established since the canyon was dewatered. The largest sample tree in the canyon that is potentially subject to removal by flushing is a 49-year-old spruce tree 21.7 cm diameter at breast height and an estimated 14.8 m tall (tree no. 4 in Table 3.3.1-1). For comparison, some of the largest sampled trees in the Nechako Canyon and Cheslatta Fan area that occur just above pre-dam flood levels, and presumably are not susceptible to removal by flushing, are listed in Table 3.3.1-2.

Table 3.3.1-1 Samples of some of the largest Nechako Canyon/Cheslatta Fan trees that were established since the canyon was dewatered in the 1950s.

Sample tree no.	Km downstream from dam	UTM grid location 1:20,000 Forest Cover Map	Species	Diameter at breast height (cm)	Age at breast height (yr)	Estimate height (m)*	Comments
1	0.6	N 5939100 E 370730	Pine	17.8	38	12.5 (12.3)	See note 1
3	2.6	N 5940820 E 370920	Spruce	20.8	38	11.4 (11.6)	See note 2
4	2.6	N 5940820 E 370920	Spruce	21.7	49	14.8 (14.7)	See note 3
6	7.5	N 5945020 E 371600	Pine	20.3	50	15.0 (15.0)	See note 4
8	7.9	N 5945390 E 371940	Pine	33.4	49	25.0 (25.0)	See note 5

* Height estimates are based on site index curves and tables for age at breast height on a medium quality site (site index 15). Unbracketed height estimates are from interior British Columbia site index tables by Thrower et al. (1994), and bracketed height estimates are for comparable tables from Alberta (Huang et al. 1994). For sample tree no. 8, estimated height is based on growth rates for an excellent site (site index 25) because this pine was growing on a moist seepage slope with no apparent bedrock limitations to soil rooting volume.

Note 1. This pine is an example of medium sized woody material that would be removed from the dewatered zone of the Nechako Canyon during initial flushing flows.

Note 2. Similar to sample tree no. 1, this 38-year-old spruce also occurs on a floodplain bench that was formerly flooded before Nechako Canyon was dewatered and would presumably be part of the woody biomass removed during flushing.

Note 3. During the limited reconnaissance of Nechako Canyon in September 2002, sample tree no. 4 was the largest spruce observed within the dewatered zone of Nechako Canyon.

Note 4. Sample tree no. 6 is an example of a medium sized pine in the forest stand at the southeastern edge of Cheslatta Fan (see Plate 4.3.2-2). The degree to which trees in this location would be disturbed by establishment of a selfforming natural channel in the vicinity of this forest stand has not been determined.

Note 5. Sample tree no. 8 is the largest tree observed in a zone that may have been periodically flooded before Kenney Dam was built. This relatively large pine is at a location considered to have high erosion potential if a selfforming natural channel is established along the southeast side of Cheslatta Fan (Y. Shumuk, pers. comm., 2002).

Table 3.3.1-2 Samples of some of the largest Nechako Canyon/Cheslatta Fan trees at elevations just above pre-Kenney Dam flood levels.

Sample tree no.	Km downstream from dam	UTM grid location, 1:20,000 Forest Cover Map	Species	Diameter at breast height (cm)	Age at breast height (yr)	Estimated height (m)*	Comments
2	0.6	N 5939100 E 370730	Spruce	29.6	95	24.2 (24.6)	See note 1
5	2.6	N 5940820 E 370920	Spruce	44.2	65	18.8 (18.8)	See note 2
7	7.6	N 5945080 E 371740	Spruce	49.1	113	27.0 (27.0)	See note 3
9	8.3	N 5945580 E 371940	Spruce	38.8	135	29.3 (29.4)	See note 4

* Height estimates are based on site index curves and tables for age at breast height on a medium quality site (site index 15). Unbracketed height estimates are from interior British Columbia site index tables by Thrower et al. (1994), and bracketed height estimates are for comparable tables from Alberta (Huang et al. 1994). These estimates of tree height basedon breast height age and site index would differ from tree heights predicted from only diameter at breast height, as in individual tree volume tables compiled by Huang (1994).

Note 1. This spruce was located about 2 m upslope from a boulder field that marked the upper limit of pre-Kenney Dam flooding. It is assumed that trees of this size, from locations above the pre-Kenney Dam floodplain, would not be removed during maximum flushing flows.

Note 2. At a location further downstream in Nechako Canyon, this sample tree is similar to sample tree no. 2. Its location a short distance upslope from the pre-Kenney Dam floodplain suggest that it would not be subject to downstream transport during flushing of the canyon.

Note 3. This sample spruce in the Cheslatta Fan area is potentially the largest diameter tree available for transport downstream if this remnant stand of trees (see Plate 4.3.2-2) were to be eroded by a selfforming channel on the eastern flank of the forest stand.

Note 4. This sample spruce in the Cheslatta Fan area (near the 'Neck' area shown in Plate 4.3.2-3) is at an elevation that escaped previous high water levels in the Nechako River valley. Whether this large sample tree would be subject to flooding during maximum flushing has not been detemined.

The plant material subject to loss by Nechako Canyon flushing would be almost entirely biomass that has accumulated on new surfaces that were exposed by dewatering of the canyon in the 1950s. This suggests that there is no need for concem about loss of rare or endangered plant species, many of which typically occur in ecosystems and habitats that have been free of disturbance for a long time. Plant species that have sufficiently successful reproductive strategies, through seeds or vegetative reproduction, to be able to occupy the newly exposed surfaces in the Nechako Canyon after it was dewatered do not fit the concept of rare or endangered species. Such species, with aggressive reproductive capahilities, are not threatened at a regional scale. For this reason, no surveys are proposed for assessing whether there would be losses of rare or endangered plant species if Nechako Canyon were rewatered.

3.3.2 Channel Conditions and Sediment Accumulation

As discussed in Section 2.1.6, a series of historical air photos have been compiled (and presented in Appendix 2) to determine how channel conditions in the Nechako Canyon have varied over time. An analysis of this information indicates that little or no substantive changes in valley wall stability or tributary sediment production have occurred since Triton Environmental Consultants Ltd. undertook their sediment accumulation studies in 1991 (Klohn Leonoff and Triton 1991 and Triton 1991).

Our field studies included both an aerial helicopter overflight and ground studies at three representative locations. Approximately three hundred 35 mm photographs were taken from the air to document channel conditions. Digital video imagery was also taken of the entire canyon.

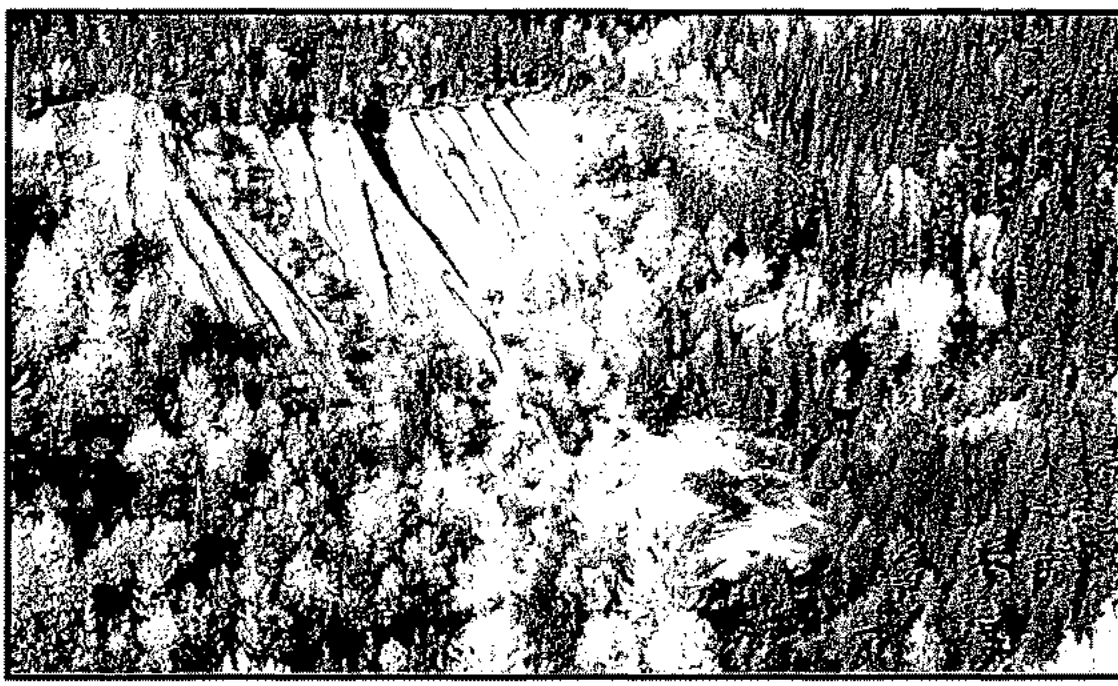
Our initial field studies indicate that the quantity of sediment stored on the canyon floor is of modest size. The principal concentrations consist of:

1. Material derived from the spoil pile located on the left bank at 0.4 km downstream of the dam (see Addendum 1, Figure 1). This site is illustrated on Plate 3.3.2-1.
2. Sediment accumulations that were in the channel following construction of Kenney Dam. These include both natural sediment deposits and material possibly winnowed from the fill placed during the early phases of dam construction. The largest example of this type of deposit occurs at Km 1.2 (Plate 3.3.2-2). The surface of these fifty-year-old materials typically consists of a cobble armour layer. Weathering is locally breaking down some of the volcanic constituents (Plate 3.3.2-3).
3. Fine textured organic rich sediments that have been deposited in small ponds (Plate 3.3.2-4). Plate 3.3.2-5 shows that little sediment deposition has occurred along the edges of these water bodies and the pre-existing river bed surface is readily apparent.
4. Small fans which have developed at the mouths of Streams 1 and 2. These materials are illustrated on Plates 3.3.2-6 and 3.3.2-7; and
5. Organic and sediment accumulations incorporated within beaver dams (Plate 3.3.2-8).

The landslide located on the right bank between Km 2.0 and 2.8 appears to be inactive and has not resulted in any recent sediment production (Plate 3.3.2-9). The right bank road failure identified by Triton (1991) at Km 0.9 also appears to have stabilized but may still be responsible for the unusual sediment deposition on the most downstream lake shown on Plate 3.3.2-4. [Further upslope investigations would be needed to determine if road deactivation or other remedial actions are warranted.]

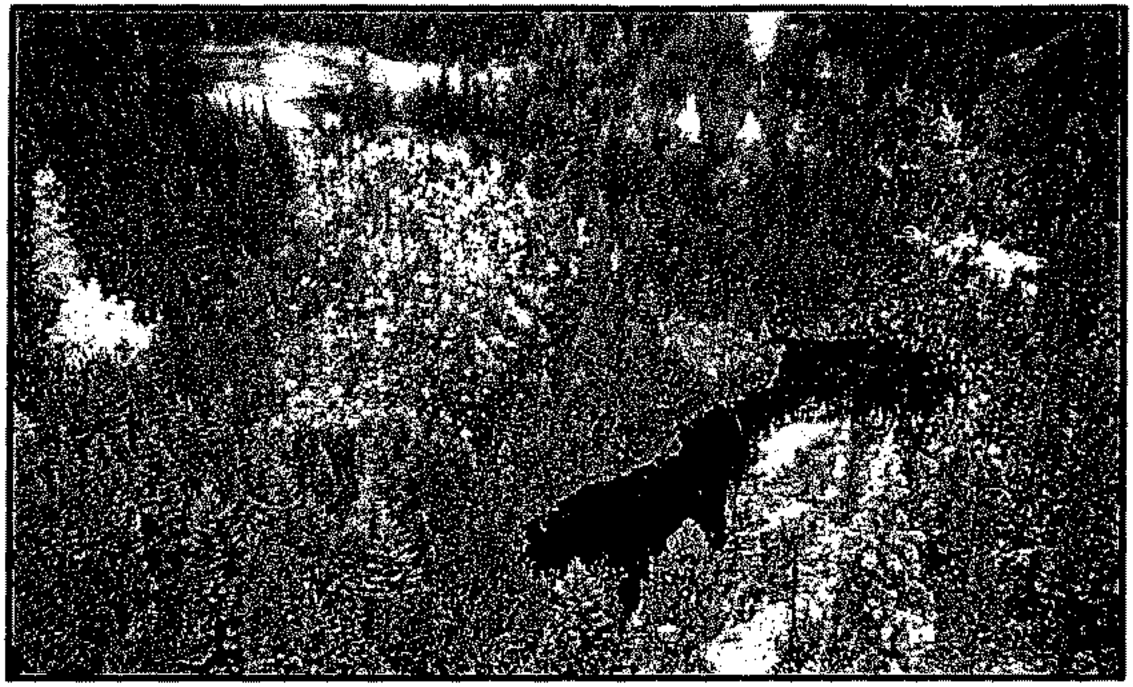
Despite the occurrence of the deposits mentioned above, a substantial portion of the upper 4 kilometres of the Nechako Canyon floor consist of rock on which very little sediment is stored (Plate 3.3.2-10). There is also very little sediment stored in the stream channel downstream of Km 4. The channel is generally flowing in bedrock (Plate 3.3.2-11) and sediment sources are, in very large measure, limited to in situ local rock weathering and colluvial sediment production from the adjacent valley walls (Plate 3.3.2-12). The total volume of potentially mobile material appears to be quite small.

MM 02 - 90 - 01A



MM 02 - 86 - 05

Plate 3.3.2-1 Looking downstream to the left bank spoil pile at Km 0.4. Slope erosion has resulted in sediment deposition in the adjacent section of channel



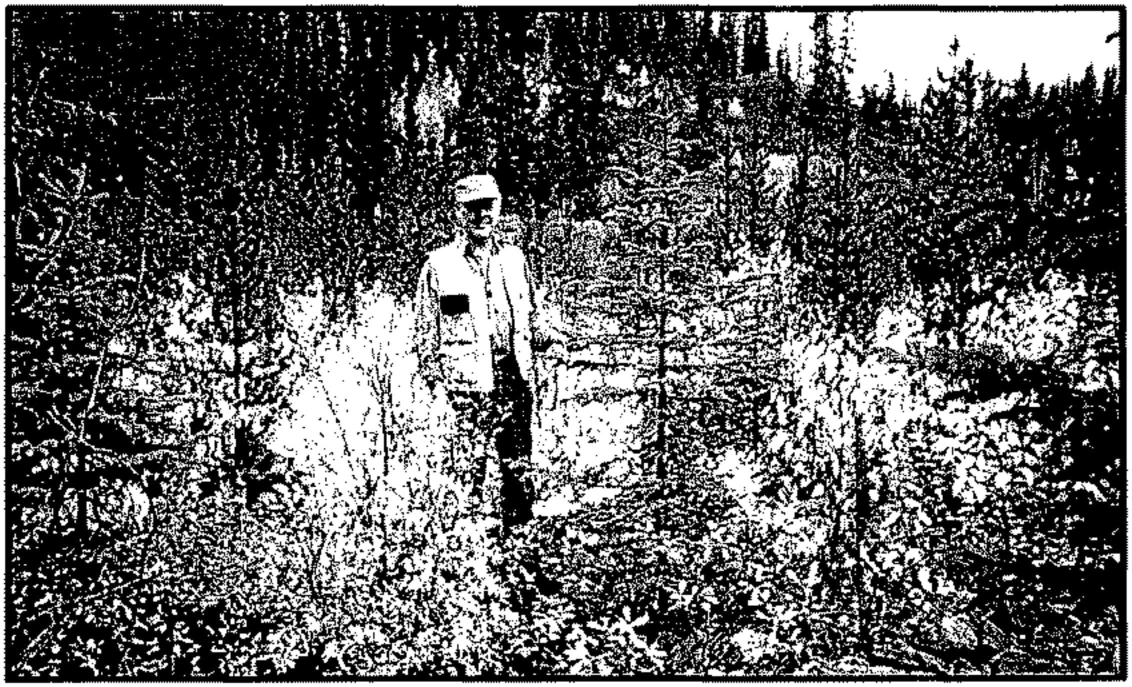
MM 02 - 89 - 15A

A) Looking upstream to the remnant point bar at Km 1.2

MM 02 - 82 - 24A

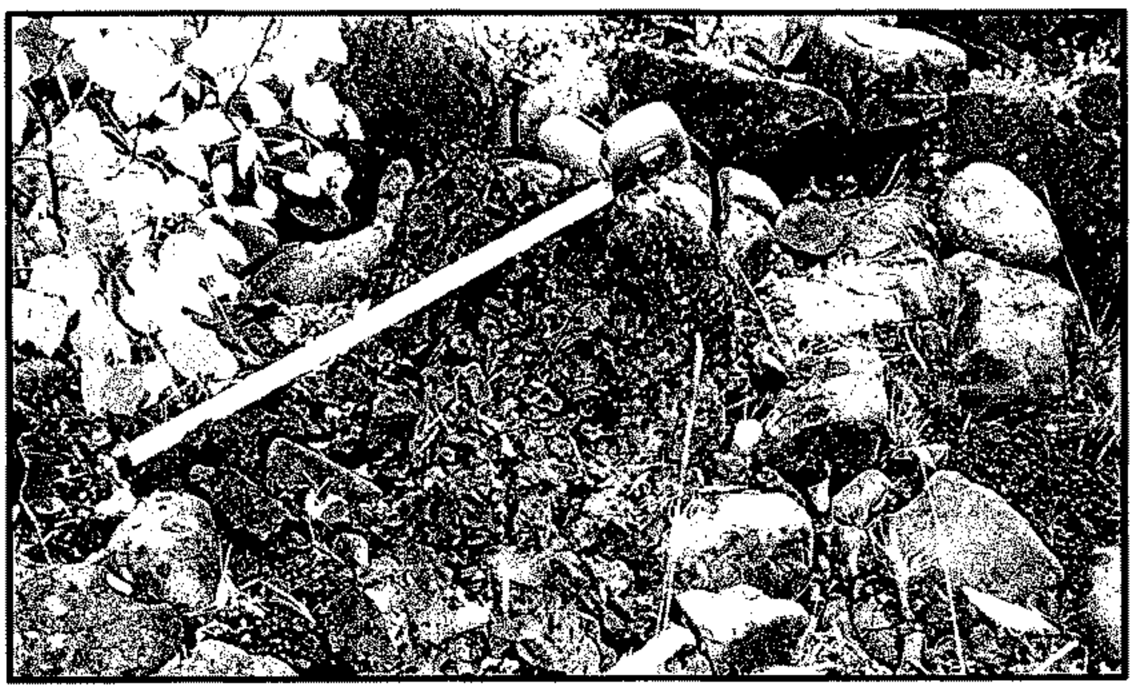
B) The surface of the bar consists principally of cobble (Km 1.2).

Plate 3.3.2-2 Fluvial deposits occur locally within the Nechako Canyon upstream of Km 4



MM 02 - 82 - 22A

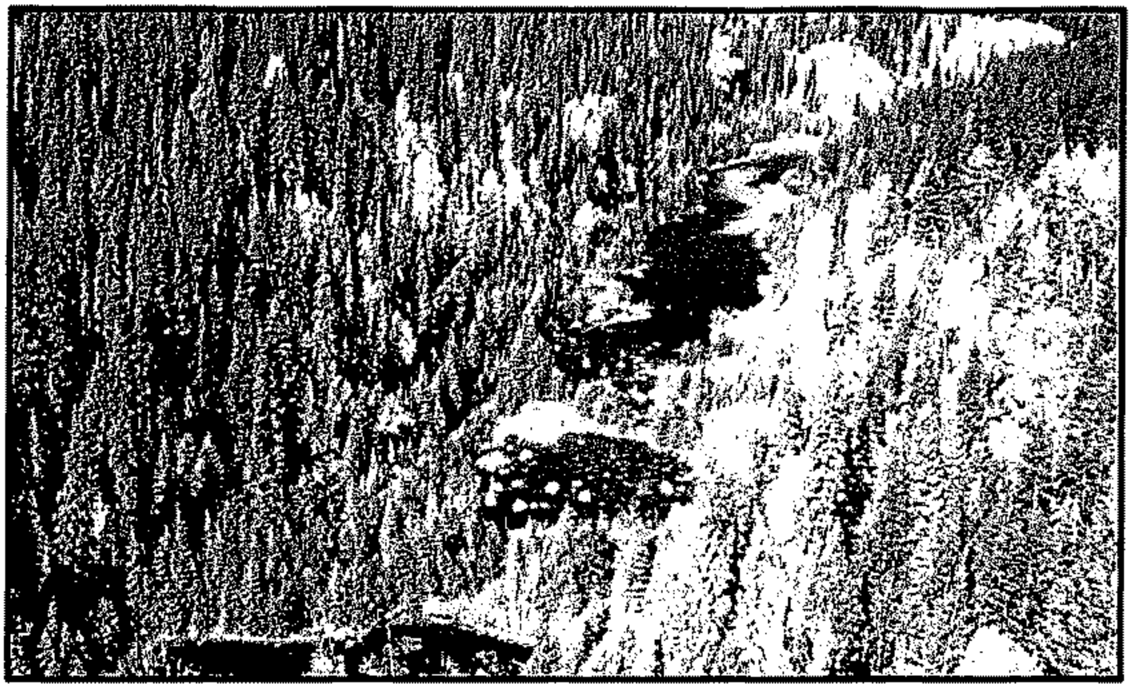
A) Looking downstream on the fluvial deposits at Km 2.1, showing the surface armour layer.



MM 02 - 82 - 28A

B) Post-regulation weathering is locally breaking down some volcanic rocks (Km 1.2).

Plate 3.3.2-3 Fluvial sediments are typically protected with an erosion resistant armour layer



MM 02 - 86 - 07

A) Looking downstream from Km 0.6

MM 02 - 85 - 27

B) Bed material in the pond at Km 0.90 (the center of the upper pond in photo A)

Plate 3.3.2-4 Fine textured organic rich sediments have accumulated in the small ponds which have formed in the upper 4 kilometres of the Nechako Canyon

MM 02 - 85 - 25

A) Looking downstream at Km 1.0

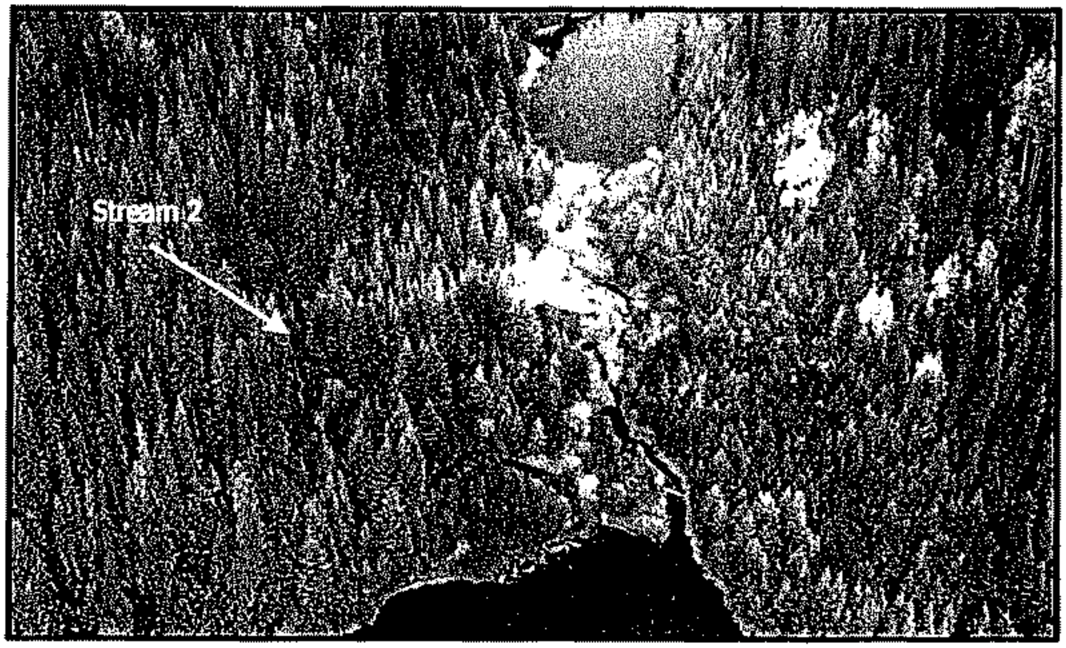
MM 02 - 85 - 26

B)

Plate 3.3.2-5 Relatively little sediment deposition has occurred along the edges of most ponds

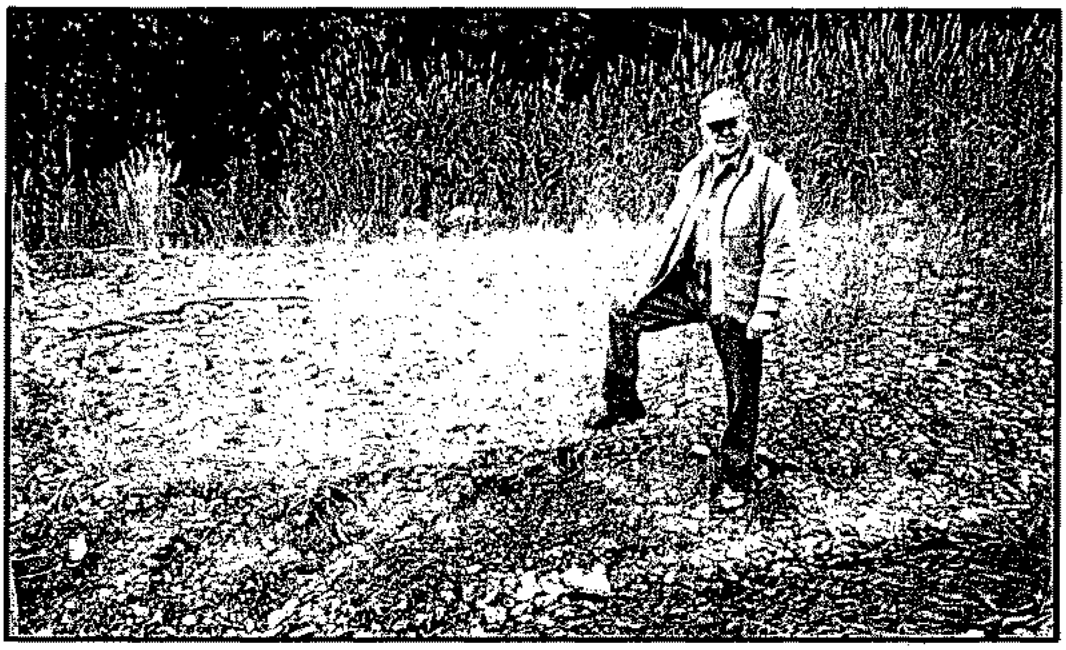
MM 02 - 90 - 4A

Plate 3.3.2-6 Looking downstream showing the vegetated left bank sediment deposits located in Nechako Canyon at the confluence with Stream 1



MM 02 - 90 - 13

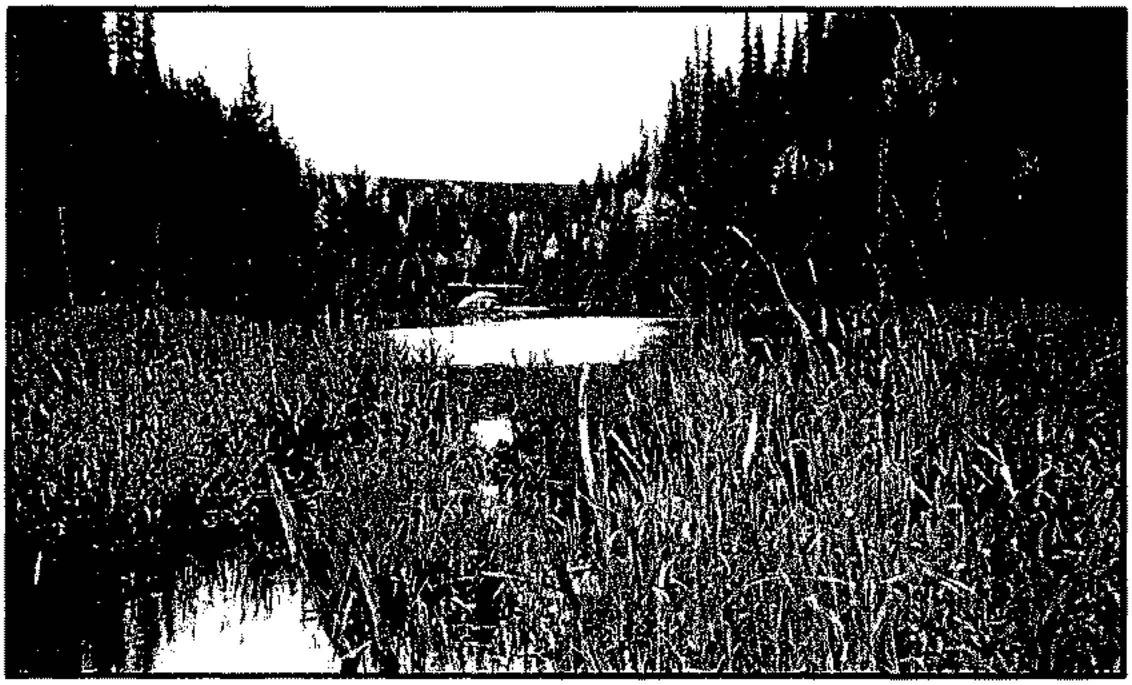
A) Looking downstream to the fan between the lakes at Km 2.4 and 2.7



MM 02 - 82 - 30A

B) Looking upstream to the fan at the upstream end of the lake at Km 2.7

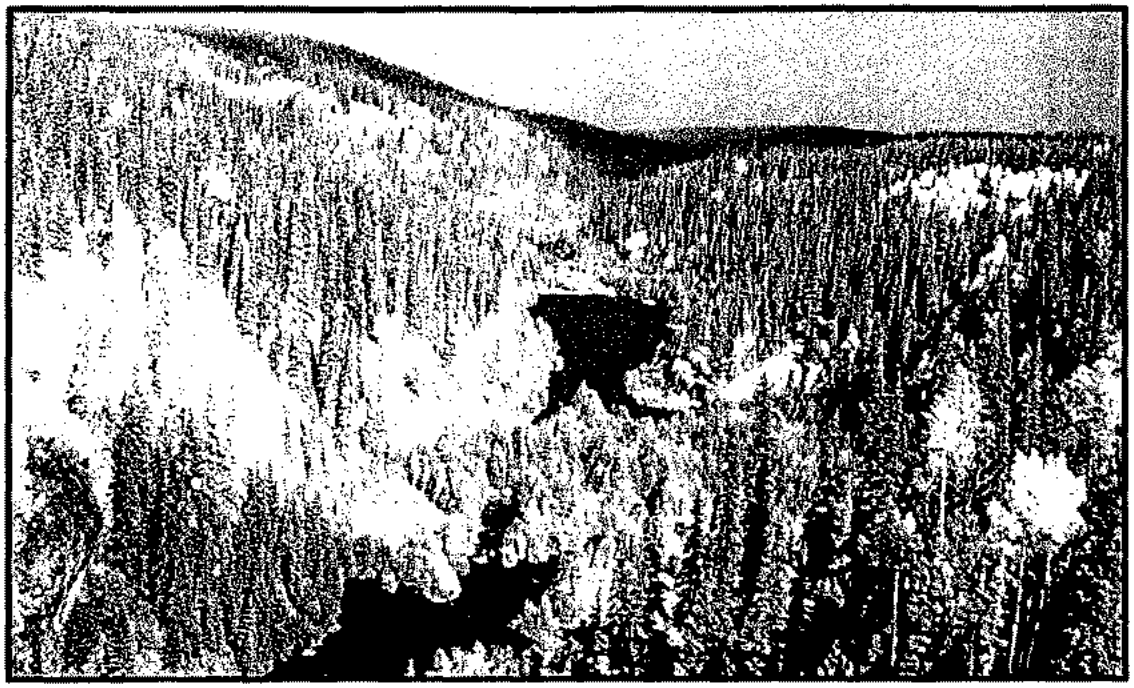
Plate 3.3.2-7 Sand and gravel sized sediments have accumulated in the Nechako Canyon at the confluence with Stream 2



MM 02 - 82 - 19A

Looking upstream to the beaver dams located at Km 1.2

Plate 3.3.2-8 Quantities of sediment and organic debris have been locally stored in beaver dams located within the Nechako Canyon

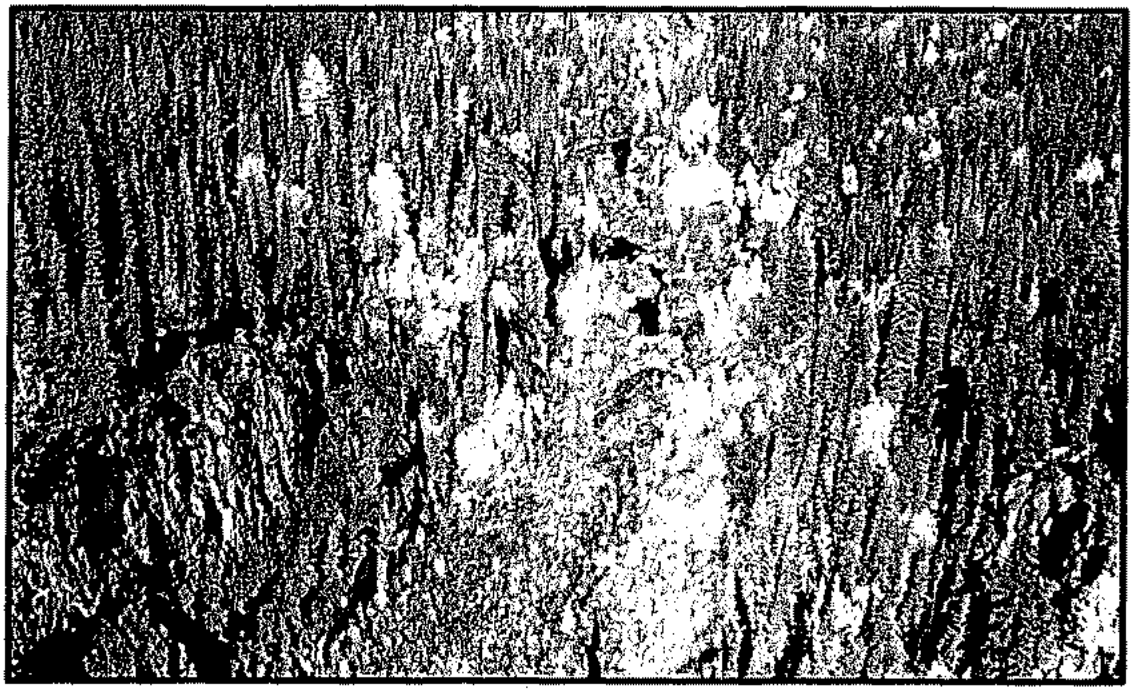


MM 02 - 86 - 15

Plate 3.3.2-9 Looking downstream towards the historic right bank landslide located between Km 2 and 2.8, showing the lack of recent sediment production

MM 02 - 90 - 08

Plate 3.3.2-10 Looking downstream from Km 1.7, showing that portions of the upper 4 km of Nechako Canyon consist of bare rock with little or no sediment deposits



MM 02 - 90 - 28

A) Looking downstream at Km 5.2

MM 02 - 88 - 23

B) Looking upstream at Km 6.5

Plate 3.3.2-11 Representative photographs of the Nechako Canyon, showing the lack of sediment accumulations which occur downstream of Km 4

MM 02 - 83 - 14A

A) Example of in situ rock weathering.

MM 02 - 82 - 28A

B) Example of locally derived colluvial deposits.

Plate 3.3.2-12 Sediment production in the lower canyon is limited to in situ rock weathering and locally derived colluvium (Km 4.4)

Triton (1991) "visually" estimated the quantity of material that could be mobilized from the Nechako Canyon. Their analyses, which are summarized on Tables 3.3.2-1 and 3.3.2-2, indicate that there is approximately 28,000 m^3 of clay, silt, pond material and sand in the canyon. It appears that this volume is the total in-situ volume of the space occupied by the sediments and consists of the solid particles and voids among them. Triton (1991) estimated that 84% of these sediments could be mobilized by a flow of 12 m^3/s, 88% at a flow of 30 m^3/s and 94% at a flow of 200 m^3/s. Ninety-eight percent of these materials are located upstream of Km 4. Triton (1991) cautions "it is very important to recognize that these estimates are based on a visual examination of the existing deposits. Neither core nor laboratory sediment analyses were undertaken during the initial canyon reconnaissance. Thus the estimates contain a potentially large, but unqualified variance" (Triton 1991, page 16). For the purposes of the present report we have adopted Triton's (1991) sediment volume estimates. It is our impression that the quantity of mobile material could be less than that estimated by Triton (1991). However, more detailed site inspections would have to be undertaken in Phase 2 of this project if the material quantities needed to be confirmed. This is probably only justified if sediment removal from specific sites (such as the alluvial deposits at the mouths of Streams 1 and 2) were to be evaluated as a mitigating measure.

3.3.3 Fisheries

Detailed fisheries surveys were not carried out as part of the work undertaken in 2002. Qualitative assessments of fisheries values were made. Within the canyon, the beaver ponds and rock controlled pools would provide year-round fish habitat for fish in the canyon. Fish (presumed to be rainbow trout) were observed to be "rising" in several of the ponds in the upper part of the canyon. With the flows currently present in the canyon, it is conceivable that fish could migrate upstream to the ponds below the dam.

Young-of-the-year rainbow trout where observed to be in very high densities in the lower end of the Stream 2 (Watershed Code 180-557700), which is the outlet stream of Cicuta Lake. Rainbow trout were stocked in Cicuta Lake (FISS 2002) and now appear to have established a reproducing population. It is unknown at this time if the fish observed originated from the Nechako River or Cicuta Lake. Given the very high densities observed it seems probably that the juvenile trout observed in September 2002 would have originated from the lake.

Further downstream, large numbers of fish were observed feeding at the surface of Scour Hole Lake.

Re-establishment of flows may result in a displacement of fish from the mainstem portion of the Nechako River, within the canyon. As the discharge regime and frequency of high flows is not yet known, it is difficult to assess the exact nature of impacts that re-watering the canyon may have on local fish resources. Local water velocities at lower discharge rates may be slow enough that fish will still be able to inhabit the canyon. The water velocities that are anticipated to occur within the canyon (Figure 3.4.1-2) at high discharge levels (i.e., 450 m^3/s) would likely result in conditions that would make it difficult for fish to hold and swim. In some portions of the canyon (e.g., Km 3 to Km 4), it may be possible for fish to maintain a presence, provided there is enough habitat complexity (e.g., large boulders) to create slower velocity areas for fish to hold in and avoid the higher water velocities of the main channel.

Table 3.3.2-1 Estimated volume of mobile sediment deposited in Nechako Canyon (*after Triton 1991*)

TRITON REACH #	RIVER KM		TOTAL VOLUME (m^3) OF MATERIAL AVAILABLE AT A FLOW OF 12 m^3/s					
	FROM	TO	CLAY	SILT	POND MATERIAL	TOTAL FINES	SAND	ALL MATERIALS
1	0	0.7	10	40	1000	1100	80	1180
2	0.7	1.73	80	250	5100	5400	560	5960
3	1.73	2.84	40	110	5200	5300	730	6030
4	2.84	3.78	10	40	7700	7800	90	7890
5	3.78	4.55	0	0	550	550	0	550
6	4.55	5.87	0	0	0	0	0	0
7	5.87	6.89	0	0	0	0	0	0
ALL REACHES			140	440	19550	20150	1460	21610

TRITON REACH #	RIVER KM		TOTAL VOLUME (m^3) OF MATERIAL AVAILABLE AT A FLOW OF 30 m^3/s					
	FROM	TO	CLAY	SILT	POND MATERIAL	TOTAL FINES	SAND	ALL MATERIALS
1	0	0.7	30	110	1000	1100	210	1310
2	0.7	1.73	100	280	5100	5500	670	6170
3	1.73	2.84	80	210	5200	5500	1300	6800
4	2.84	3.78	40	130	7700	7900	260	8160
5	3.78	4.55	0	0	550	550	0	550
6	4.55	5.87	0	0	0	0	0	0
7	5.87	6.89	0	0	0	0	0	0
ALL REACHES			250	730	19550	20550	2440	22990

TRITON REACH #	RIVER KM		TOTAL VOLUME (m^3) OF MATERIAL AVAILABLE AT A FLOW OF 200 m^3/s					
	FROM	TO	CLAY	SILT	POND MATERIAL	TOTAL FINES	SAND	ALL MATERIALS
1	0	0.7	60	190	1000	1300	370	1670
2	0.7	1.73	110	340	5100	5600	930	6530
3	1.73	2.84	180	420	5200	5800	2900	8700
4	2.84	3.78	70	200	7700	8000	390	8390
5	3.78	4.55	0	0	550	550	0	550
6	4.55	5.87	0	0	0	0	0	0
7	5.87	6.89	0	0	0	0	0	0
ALL REACHES			420	1150	19550	21250	4590	25840

TRITON REACH #	RIVER KM		TOTAL VOLUME (m^3) OF AVAILABLE MATERIAL					
	FROM	TO	CLAY	SILT	POND MATERIAL	TOTAL FINES	SAND	ALL MATERIALS
1	0	0.7	60	190	1000	1300	370	1670
2	0.7	1.73	120	350	5100	5600	1000	6600
3	1.73	2.84	300	670	5200	6100	4900	11000
4	2.84	3.78	70	200	7700	8000	390	8390
5	3.78	4.55	0	0	550	550	0	550
6	4.55	5.87	0	0	0	0	0	0
7	5.87	6.89	0	0	0	0	0	0
ALL REACHES			550	1410	19550	21550	6660	28210

Table 3.3.2-2 Estimated volume of mobile sediment in Nechako Canyon (after Triton 1991)

MATERIAL TYPE	VOLUME OF POTENTIALLY MOBILE MATERIAL (m^3/s) AT A DISCHARGE OF:			
	12 m^3/s	30 m^3/s	200 m^3/s	TOTAL AVAILABLE
CLAY	140	250	420	550
SILT	440	730	1,200	1,400
POND MATERIALS	19,600	19,600	19,600	19,600
TOTAL FINES	20,200	20,600	21,200	21,500
SAND	1,500	2,400	4,600	6,600
ALL MATERIALS	21,700	23,000	25,800	28,100

The increased flows will also re-establish gradient barriers that existed prior to the dam construction. For example, it would appear that a significant fall or cascade occurred (and will occur) at approximately Km 4.9 (Figure 3.4.1-1). This would result in blockage of fish movements upstream from Scour Hole Lake.

While there is likely to be a change in fish habitat and fish use of the Nechako Canyon, this change is not likely to result in a significant negative impact. These changes would not affect the three endangered fish species that occur in the Nechako River. Furthermore, the flow conditions that would exist following the commissioning of the CWRF would approximate the conditions that existed naturally prior to the construction of the dam.

3.3.4 Wildlife Habitat

While detailed habitat surveys were not part of the scope of this year's project, anecdotal wildlife observations were made. Moose signs (grazing, prints, droppings) were observed throughout the canyon. Even in areas with limited browse, moose signs were evident. It is possible that once moose enter the canyon, they get funneled through the canyon.

Beavers were evident in the upper part of the canyon. Beaver activity appears to be reduced, compared to the early 1990's. Triton (1991) reported 19 beaver dams in the canyon, whereas there were approximately 6 dams noted during the September 2002 overflight of the canyon. The dams were generally low, less than 1 m high. Most of the dams appeared to be old, as shrub vegetation was established along the dams. The dams were in good condition, although there was little evidence of recent repairs.

The only other wildlife observed in the canyon was a family group of otters in one of the ponds at the upper end of the canyon and some waterfowl.

Much of the wildlife found within the former bankfull channel of the river will be displaced by the re-introduction of flows to the Nechako River. Beavers will be most affected as the existing dams will be broken up and deciduous vegetation, which has developed since the dam was constructed, will be scoured out of the channel. The water velocities and depths would preclude the construction of new dams. Depending upon the discharge rates, the water velocities may also prevent ungulates from using the canyon as a movement corridor.

The impacts on wildlife are not considered to be significant as there is available habitat downstream of the canyon and alternate movement routes on either side of the canyon. In addition, the renewed flows would result in conditions similar to those that existed prior to the construction of the dam, particularly when discharges from the cold water release facility are high.

3.4 Hydraulic Analysis and Sediment Transport

3.4.1 Hydraulic Analysis

In order to assess the ability of the proposed flows through the canyon to mobilize sediment and debris, it was necessary to estimate the depth and velocity of the flows that would be expected to occur over the range of future Canyon discharges. This was accomplished by applying the HEC-RAS computer model (US Army Corps of Engineers 1998) to simulate the hydraulic conditions in the canyon. This software simulates steady-state water surface profiles in open channels for a range of discharges.

The physical dimensions of the Nechako Canyon were described in the model by a total of 40 cross sections spaced throughout the 7 km long Canyon reach. Triton and Klohn Leonoff (1991) originally developed these cross sections using topographic maps prepared by McElhanney Engineering Services Ltd. The reach covered by the model extended from the toe of Kenney Dam to Scour Hole Lake at the upstream end of the Cheslatta Fan. For the purpose of the overall project, the canyon model was coupled to another HEC-RAS model that extended across the fan and downstream for an additional 5 km. The results of the modeling for the lower reaches are described in Section 4.4.5 of this report.

Results from these model simulations are presented graphically in Figure 3.4.1-1 for discharges of 20 m^3/s, 200 m^3/s and 490 m^3/s. Simulated water surface profiles and the minimum bed elevation profile are shown in Figure 3.4.1-1. These profiles indicate that the water surface drops approximately 47 m through the 6.6 km long canyon (an average slope of 0.007 m/m). The model results indicate water surface slopes over shorter distances ranging from 0.002 to 0.090 m/m, although more extreme local slopes undoubtedly exist.

Flow velocities averaged across each cross section in the model are presented in Figure 3.4.1-1b. More extreme values of velocity would occur at certain specific locations, such as waterfalls. The overall mean velocity for the entire canyon reach was simulated for each discharge as follows:

Discharge	Velocity
20 m^3/s	1.0 m/s
200 m^3/s	2.0 m/s
490 m^3/s	2.6 m/s

Simulated average depths at each cross section in the model are presented in Figure 3.4.1-1c. These depths averaged over the entire length of the canyon reach are summarized for each discharge as follows:

Discharge	Depth
20 m^3/s	1.4 m
200 m^3/s	2.8 m
490 m^3/s	4.0 m

Figure 3.4.1-1d presents the variation of simulated average shear stress in the channel along the length of the canyon for the three discharges. These shear stress values are an indication of the force that the flowing water exerts on the materials that form the bed and sides of the channel.

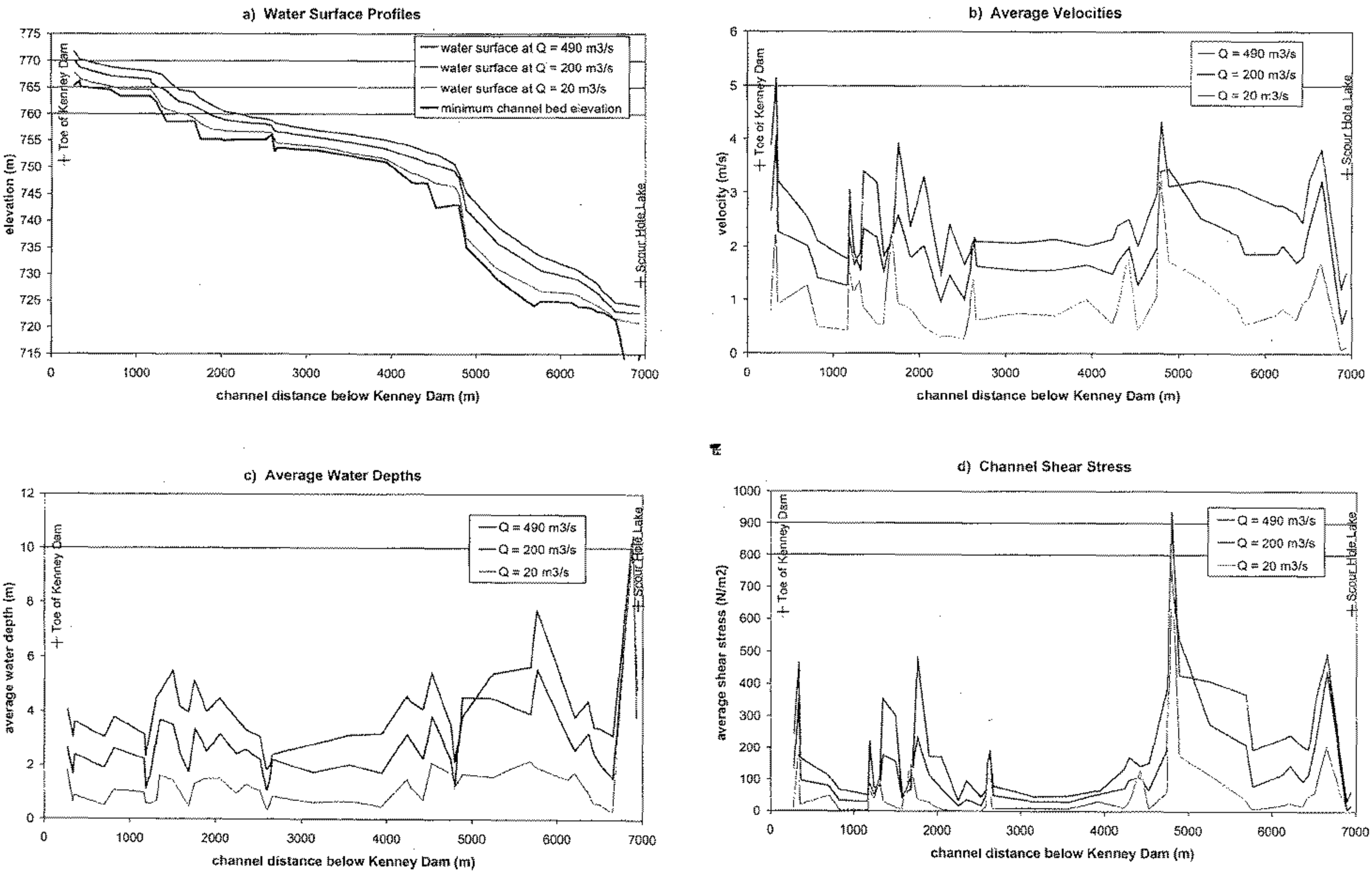


Figure 3.4.1-1 Simulated hydraulic parameters through Nechako Canyon

3.4.2 Sediment Transport

An initial assessment of the potential for sediment mobilization in Nechako Canyon can be undertaken on the basis of an equation developed by Julien (1995). The critical shear stress τ_{cr} (in N/m^2) necessary for entraining cohesionless sediment (with an average size d_{50} in mm) can be calculated as follows:

$$\tau_{cr}=0.785\ d_{50}$$

This equation is approximately valid for d_{50} >0.3 mm and was developed for conditions of uniform two-dimensional flow. In the present circumstance we are dealing with an irregular channel containing beaver dams, vegetation or other obstructions. As a consequence, our results are approximations.

Shear stresses required to entrain various sized sediments are calculated on Table 3.4.2-1. These results are plotted on Figure 3.4.2-1 that also shows the previously calculated shear values along Nechako Canyon for flows of 20, 200 and 490 m^3/s. These results indicate that even the smallest flow of 20 m^3/s will consistently entrain sand-sized materials. Fine to medium gravel is also commonly mobilized, particularly downstream of Km 4. Cobbles will be locally entrained at flows of 200 m^3/s as will small to medium boulders at flows of 490 m^3/s.

The water velocities required to move sediment are smaller than those required for entrainment. The above analyses therefore indicate that exposed fine textured sediment (consisting of sand or smaller sized materials which can be readily entrained at flows as small as 20 m^3/s) will, once mobilized, be largely excavated from the canyon. Gravel and small cobbles will be subject to entrainment and local deposition during flows of 20 m^3/s. Similar processes may also occur at higher flows in the upper canyon; however, once this material reaches Km 4, it will be largely evacuated if the discharge remains high for a sufficient period of time.

3.5 Alternatives for Nechako Canyon Flushing

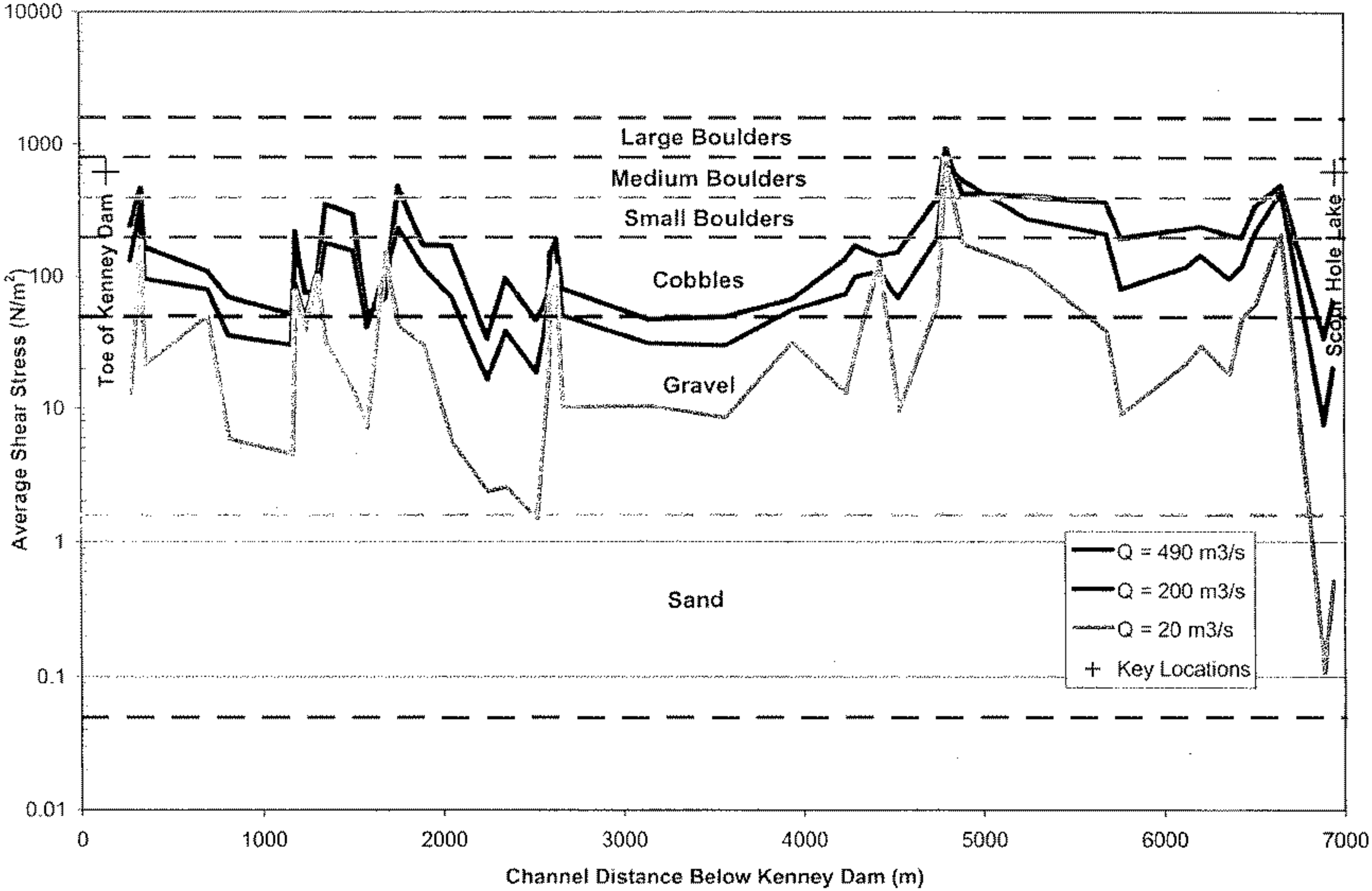
Re-activation of the Nechako Canyon requires the flushing out of a major river canyon. This channel has been kept artificially dry for approximately 50 years, after flowing continuously since the area emerged from under the Pleistocene ice cover. There are two possible approaches to estimating the effects of such a flushing event:

- Apply theoretical concepts of erosion and sediment transport to develop numerical estimates of sediment concentration and sediment transport rates at the canyon mouth as a function of the flows released at Kenny Dam; or
- Find closely related, documented case histories that might be transferable, in part or fully, to the situation at the Nechako Canyon.

Table 3.4.2-1 Approximate shear stress required to entrain cohesionless sediment

GRAIN SIZE CLASSS		GRAIN DIAMETER (mm)		ENTRAINMENT SHEAR STRESS (N/m^2)	
		MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
Boulders	Very Large	2048	4096	1608	3215
	Large	1024	2048	804	1608
	Medium	512	1024	402	804
	Small	256	512	201	402
Cobbles	Large	128	256	100	201
	Small	64	128	50	100
Gravel	Very coarse	32	64	25	50
	Coarse	16	32	13	25
	Medium	8	16	6	13
	Fine	4	8	3	6
	Very Fine	2	4	1.6	3
Sand	Very coarse	1	2	0.8	1.6
	Coarse	0.5	1	0.39	0.8
	Medium	0.25	0.5	0.20	0.39
	Fine	0.125	0.25	0.10	0.20
	Very Fine	0.062	0.125	0.05	0.10

Figure 3.4.2-1 Calculation of mobile bed material size through Nechako Canyon



The detailed hydraulics of river flow in a rough bedrock canyon are so variable and the distribution of the accumulated sediments is so irregular that a purely theoretical approach to calculating sediment flushing requirements is impossible. No amount of field data collection and computer modeling will provide reliable, quantitative results. Some qualitative observations are, however, possible. Fine sediment deposits (fine sand, silt, and clay) that are potentially damaging to the downstream fisheries resources tend to be located at relatively low levels in the canyon, in beaver dams and beaver ponds and in two small fans. These deposits are also relatively easily erodible, even though most deposits are also vegetated, which tends to increase erosion resistance. These observations indicate that relatively low flows in the order of 20 to 50 m^3/s would probably flush a major portion of the accumulated fines out of the canyon. Triton (1991) estimates that flows of 12 and 30 m^3/s would flush 94 and 96 percent, respectively, of the fines out of the canyon. While this may be somewhat optimistic, we concur with the general conclusion that relatively low flows will remove most fines from the canyon. Significantly more reliable estimates than those made by Triton are simply not possible.

The alternative approach to estimating effects of sediment flushing, the adaptation of experience elsewhere, faces the problem that we have not been successful in locating any similar, documented case histories; the proposed action may well have no closely related engineering precedent. There are, however, some documented natural and man-made events that have certain similarities with what is proposed here and can therefore provide indications on what to expect:

- floods in normally dry desert channels (wadis), where a flood of a few hours duration after 50 years of no flow might not be unusual;
- river diversions, such as the Skins Lake spillway, where large flows are suddenly released into valleys that were previously dry or contained much smaller rivers, such as the Cheslatta River;
- dam break events; and
- artificial channel flushing events, such as the well documented flushing of the Grand Canyon of the Colorado River by an artificial flood generated at Glen Canyon Dam (Webb et al. 1999).

Some relevant observations from these rather diverse types of events are:

- the erosion of limited deposits of fines takes place rapidly, on the rising limb of the flood hydrograph, and drops off quickly once flows stabilize or decrease;
- the transport of floating debris tends to come to an abrupt end once river levels stabilize or start falling;
- any reasonable flushing flows, including low ones in the 10 m^3/s range, are likely to result in episodes of very high sediment concentrations (in the order of 10 g/L) at the canyon mouth; and
- fluctuating river stage tends to encourage the deposition of fines high in the cross section, a fact well demonstrated by the artificial Colorado River flood.

The total volume of fines in Nechako Canyon is approximately 20,000 m^3, which is small in comparison to the volumes of water available for flushing. At a very low water release rate of 10 m^3/s, and assuming a canyon mouth sediment concentration of 10 g/L, the entire accumulation of fines would be removed in 3 to 4 days. Note that these numbers are simply meant to illustrate sediment volumes and flushing rates, as a flow of 10 m^3/s is almost certainly too low to achieve the objective of flushing the canyon of most fines.

The flushing of the Nechako Canyon clearly involves several major uncertainties, which are not readily resolvable with further study effort:

- the flow release rate at which flushing erosion starts is indeterminate. We suspect that it could be well below 10 m^3/s;
- the release rate at which the canyon can be cleared of the bulk of the fines (which are the main problem for downstream fish habitat) is unknown. We estimate it as being in the order of 50 m^3/s (Triton had it as low as 12 m^3/s); and
- the maximum sediment concentrations which will occur at the canyon mouth are unknown. Our working estimate is 10 g/L, but this could be off by an order of magnitude.

The uncertainty about the sediment concentration is somewhat mitigated by the fact that the total volume of sediment is reasonably well defined. Our field inspection indicates that the pre-diversion channel remains erosion resistant and, once the recently stored sediments are entrained, sediment concentrations or turbidity should quickly return to relatively low values. High sediment concentrations are therefore only expected to persist for short durations. It is probable that the canyon can be cleared of the most problematic fines over a period of likely no more than two weeks, and possibly as low as three to four days.

The above uncertainties dictate a cautious, flexible approach to canyon flushing. The opportunity for diluting the Nechako Canyon flushing flows with flow from the Skins Lake Spillway is a unique and fortunate aspect of the present situation. Dilution can clearly play a major role in minimizing downstream effects and should be kept as high as possible. The sediment dissipating aspect of rapidly fluctuating flows in the downstream channel would be limited here because the Cheslatta system responds slowly to flow changes at the Skins Lake spillway.

Our suggestion is to ramp up the flushing flows from Kenney Dam in 10 m^3/s intervals, starting at 10 m^3/s , and going higher no sooner than every 48 hours or whenever the downstream concentration has fallen to 2 g/L. The upper limit to be reached will most likely be dependent on the channel-forming flows needed on the Cheslatta fan and not on canyon flushing. Canyon flushing per se might be considered complete, once all the beaver dams and channel bed fines are removed. The removal of the trees and accumulated colluvium higher up in the channel cross section could possibly be left to take place whenever significant water releases from the reservoir become necessary.

There may be some opportunities for reducing the volumes of sediment and vegetation to be flushed out of the canyon by various pre-flushing measures. "Cleaning out" the canyon prior to releasing flushing flows is neither technically nor economically feasible. We have, however, identified four more limited mitigating opportunities that deserve additional investigation.

- at Km 0.4, immediately downstream of Kenny Dam, there is a large spoil pile dating back to the time of dam construction. The toe of this pile is potentially exposed to erosion and could be protected. This needs to be addressed as part of the release facility design and construction;
- two small streams join the canyon at Km 1.3 and 2.5, and both have deposited small alluvial fans on the canyon floor. Access into the canyon might be gained from the Holy Cross Forest Service Road, down the small stream valleys. If warranted, the bulk of the fan deposits could be

excavated and hauled out of the canyon. Local beaver dams might also be removed at the same time. As the fan deposits are expected to consist of sand and gravel, the benefits of removing these deposits could be limited;

- a significant portion of the woody debris load flushed out of the canyon could be intercepted at Scour Hole Lake with a shear boom, and burnt locally or hauled away. The question to be resolved before this option is pursued further, is whether this woody debris is, in fact, detrimental to the downstream channel environment; and
- Piling and burning woody debris in the canyon is another option that might be considered if the downstream movement of debris was felt to be a significant impact.

3.6 Engineering and Environmental Issues

The movement of fine sediments (fine sand, silt and clay) into the downstream section of Nechako River is likely the most significant environmental issue associated with re-establishing flows in Nechako Canyon. While not yet finalized, it is likely that the initial flushing flows in Nechako Canyon will also be used to commission the proposed channel through Cheslatta Fan (discussed in Section 4). This will result in more than one source of sediment to the downstream river. As a consequence, the timing and magnitude of sediment production associated with a progressively larger series of flushing flows will be variable and impossible to predict in a reliable manner.

Recent experience in the US on Colorado River (see papers in Webb et al. 1999) indicate that suitable flushing flows should be able to transport much of the fine textured material out of the lower Nechako River. Their results also demonstrated that sand size sediments which have deposited on or in the river bed can be entrained by controlled flooding and redistributed to the channel margin or flood plain areas (Hazel et al. 1999, page 181). The feasibility of providing suitable flows will depend on both water availability and the ability of the downstream channel to safely convey flows of the required magnitude.

Studies by Rood and Neill (1987) indicate that silt and fine sand deposits in the lower Nechako River can be mobilized by flows of 150 to 200 m^3/s, while coarser sand and "granules" (aka small pebbles or fine gravel) are mobilized by flows of 300 to 350 m^3/s. Bed material was estimated to be mobilized by flows of 500 to 700 m^3/s. The likelihood of depositing mobilized sediment on flood plain surfaces would be maximized by releasing flows equivalent to the pre-project two-year return period flood. This value varies between approximately 500 m^3/s at Nechako Canyon, 540 m^3/s at Fort Fraser, 690 m^3/s at Vanderhoof and 1000 m^3/s at Isle Pierre. However, the potential for flooding is likely to constrain the feasible flow options as, for example, property begins to flood when flows reach 400 to 450 m^3/s at Vanderhoof (see Section 2.1.4.3).

As discussed in Section 3.5, it is not possible to predict the suspended sediment concentrations associated with the initial flows through Nechako Canyon. Given these unavoidable uncertainties, a monitoring program would need to be developed such that flows from Kenney Dam and releases from the Skins Lake Spillway could be adjusted based on observed downstream sediment concentrations and durations. The recent studies by Newcombe (Newcombe and Jensen 1996; Newcombe 2003) provide a basis for determining the permissible duration of varying suspended sediment concentrations or turbidity values. The project's ability to "chase" dirty water downstream using clean water from the Skins Lake Spillway could be used to vary flows in a manner which met these criteria. For example, Table 3.6-1 shows Newcombe and Jensen's (1996) summary of the severity of ill effects [SEV] of suspended sediment on juvenile and adult salmonids. SEV scores can be seen to increase with both increasing concentration and duration. Newcombe and Jensen (1996) have correlated SEV scores with behavioural or physiological impacts as indicated on Table 3.6-2. Further discussions are needed with regulatory agencies to determine allowable SEV levels for this project. However, there is considerable opportunity for effective flushing flows with SEV values of 9.

Table 3.6-1 Severity table for juvenile and adult salmonids (Newcombe and Jensen 1996)

Juvenile and Adult Salmonids

Duration of exposure to SS ($\log_e$ hours)

(B) Average severity-of-ill-effect scores (calculated)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	($\log_e$ mg SS/L)
162755	10	11	11	12	12	13	14	14	-	-	-	12
59874	9	10	10	11	12	12	13	13	14	-	-	11
22026	8	9	10	10	11	11	12	13	13	14	-	10
8103	8	8	9	10	10	11	11	12	13	13	14	9
2981	7	8	8	9	9	10	11	11	12	12	13	8
1097	6	7	7	8	9	9	10	10	11	12	12	7
403	5	6	7	7	8	9	9	10	10	11	12	6
148	5	5	6	7	7	8	8	9	10	10	11	5
55	4	5	5	6	6	7	8	8	9	9	10	4
20	3	4	4	5	6	6	7	8	8	9	9	3
7	3	3	4	4	5	6	6	7	7	8	9	2
3	2	2	3	4	4	5	6	6	7	7	8	1
1	1	2	2	3	3	4	5	6	6	7	7	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Table 3.6-2. Scale of ill effects associated with increased concentration and duration to suspended sediment (Newcombe and Jensen 1996).

Severity of Ill Effects	Description of Effect
	Nil Effect
0	No behavioral effect
	Behavioral effects
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
	Sub lethal effects
4	Short-term reduction in feeding rates; short-term reduction in feeding success
5	Minor physiological stress; increased rate of coughing; increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation; impaired homing
8	Indicators of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition
	Lethal and paralethal effects
9	Reduced growth rate; delayed hatching; reduced fish density
10	0-20% mortality; increased predation; moderate to severe habitat degradation
11	>20-40% mortality
12	>40-60% mortality
13	>60-80% mortality
14	>80-100% mortality

Determining the downstream pattern of sediment deposition resulting from re-establishing flows in the Upper Nechako is also a difficult task. The post 1961 formation of Cheslatta Fan is in some ways fortuitous as it resulted in the downstream passage of approximately 0.4 to 0.5 x 10^6 m^3 of principally fine-textured sediment. Some of the previous river morphology analyses (Rood and Neill, 1987; Rood, 1998a, b and c; Rood, 1999; nhc, 2002a and b) provide an initial assessment of how instream sediment accumulations have changed following this event. If more detail is required, it would be possible to undertake additional air photo studies similar to that undertaken for the Cheslatta Fan (see Appendix 2). These analyses would allow localized areas of post-1961 sediment deposition to be identified and to better determine the time required for these materials to be moved downstream. Field investigations at identified depositional areas might also be able to provide information on the persistence of any of these sediments. It would also be possible to undertake more detailed sediment transport calculations to better quantify potential sediment transport rates in lower Nechako River under various flow and sediment load scenarios. It is, however, important to realize the limitations of this type of numerical analysis as the results will depend principally on the entrained sediment load, and as discussed in Section 3.5, this cannot be reliably estimated for the Nechako Canyon.

4.0 THE CHESLATTA FAN

4.1 Background

4.1.1 Objectives of Year 1 Study

Activity 6 of NWC's Work Plan for the Cold Water Release Facility calls for a review of the Cheslatta Fan pilot channel concept proposed by NEEFMC and described in the report entitled Options for Passing Flows through the Cheslatta Fan (Hayco 2000). The objectives of that review were to determine the following:

- the feasibility of constructing the Cheslatta Fan pilot channel concept;
- the likelihood of the channel developing as proposed when geotechnical information is considered;
- the expected time frame for the channel to develop under operating and commissioning constraints;
- likely duration and magnitude of downstream sediment concentrations;
- cost competitiveness of the concept compared with other options; and
- likelihood for approval of the concept by regulatory agencies.

In addition to the objectives listed above, the Work Plan listed the following tasks to be included in the Year 1 activities:

- review the Hayco (2000) report;
- review the design criteria for the KCP Cheslatta Fan Channel design;
- determine the constructability, commissioning and likely development of the channel concept;
- if that concept is not feasible, determine whether other options for construction and commissioning exist; and
- determine the likely method, constraints and duration of channel commissioning, including the quantity of water to be released from the reservoir to commission the channel, and time frame.

During the initial meetings with the NES, we were asked to consider any new concepts that appear to be feasible and that might meet the criteria more effectively than the pilot channel concept proposed by Hayco (2000). The principal objectives of the channel across the fan were understood by the team to be as follows:

- Provide a conduit for the future range of CWRF discharges across Cheslatta Fan that will not harm downstream fisheries, yet will be economically viable.
- If possible, allow the development of a natural channel that would provide opportunities for expanding and enhancing fish habitat, and eliminate the need for maintenance.
- To the extent possible, preserve the aesthetics of the area consistent with the principles of the Nechako River Resource Management Zone, which are:
    - to manage it as a protected area;
    - to maintain current recreational values; and
    - to enhance future opportunities for interpretation of the values of this unique area.

4.1.2 Previous Studies

A number of studies have been done on the Cheslatta Fan since the Kemano Completion Project was first proposed. The design of the water release facility at Kenney Dam has changed as the concept has evolved; consequently the volume of water that must be transported past the Cheslatta Fan has also changed. Initially, the Kenney Dam water release facility was designed to accommodate flows up to 170 m^3/s in order to provide summer cooling flows. With the cancellation of the Kemano Completion Project, the water release facility has undergone several iterations. The cold water release facility concept identified by the NEEFMC has a release capacity of up to 450 m^3/s in order to provide flood relief to the Cheslatta River. This facility would be able to accommodate all discharges up to a 200-year return period flood. When flows greater than a 200-year return period occur, excess water would be released from the reservoir via the Skins Lake Spillway (NEEF 2001).

The design requirements agreed to under the 1987 Settlement Agreement between Alcan and the Federal Government required (Klohn Leonoff 1989, 1991):

- preservation of rearing habitat for chinook salmon and rainbow trout in the remnant channel of the Nechako River;
- development of a new channel;
- non-erosion of the fan;
- that flows from the release facility were not to transport debris (particularly organic debris) accumulated in the canyon onto downstream spawning beds; and
- that total suspended sediment concentrations not increase above background by more than 10 mg/L.

Klohn Leonoff (1989) examined several options before recommending a single, non-erodible (i.e., riprap lined) channel as the preferred option for meeting the criteria noted above. Detailed design of this channel was undertaken in 1991 (Klohn Leonoff 1991). The preliminary construction cost was estimated to be approximately $38 million.

Given the benefits that could be potentially achieved by construction of a CWRF, the NEEFMC contracted Hay and Company (Hayco) and Aquatic Resources to evaluate alternative concepts for passing flows through the Cheslatta Fan (NEEF 2002). Hayco (2000) examined 14 options ranging from a concrete flume to a channel cut by simply releasing water from the CWRF. Their recommendation was to develop a meandering pilot channel prior to re-establishing flows in the Nechako Canyon. This option was estimated to cost $600,000, whereas options requiring more mechanical intervention (e.g., removal of large volumes of sediment) were considerably more expensive (approximately $9 million). It is important to note that the options evaluated by Hayco (2000) would not have met all of the criteria identified in the 1987 Settlement Agreement.

4.2 Methodology

4.2.1 Site Investigation

The study team inspected the Cheslatta Fan from the air and on foot on 28 and 29 September 2002. Visual inspections of the topography, surficial soils, vegetation, fish habitat and wildlife habitat were conducted. Photographs and video recordings were taken, tree coring was performed and shallow test holes were dug by hand. The Scour Canyon, from which the material forming the fan originated, was also inspected.

Alternate routes for a pilot channel were discussed and inspected. Study team members proposed and debated ideas, identified advantages and disadvantages of the different concepts, and attempted to visualize the future consequences of commissioning the alternative options.

4.2.2 Concept Development and Evaluation

Initially, the 14 options presented in the Hayco (2000) report were studied and reviewed. The evaluation matrix presented by Hayco was assessed and deemed reasonable. We concluded that there was little merit in repeating the evaluation using a new matrix, although the ranking of one concept in particular was challenged.

Our study team held a "brainstorming" session to search for other concepts that were not presented in the Hayco (2000) report. Two new options were identified, although each was similar in many respects to a concept already proposed in the Hayco (2000) report. To evaluate these, each new option was compared to the most similar Hayco concept, and this comparison allowed them to be sufficiently ranked in the overall rating developed earlier, such that a clear decision regarding the best concept could be made.

On the basis of the evaluation and the objectives outlined in Section 4.1.1 above, the best concept was selected. A variation of this concept was developed, and both the original concept and its variation were advanced to a more detailed stage of evaluation.

A reassessment of the cost of the Meandering Pilot Channel concept recommended by Hayco (2000) was conducted. The cost of this option was estimated and compared with the best two concepts evolving from this study.

A steady-state hydraulic model was developed for the Cheslatta Fan, using the modeling software known as HEC-RAS (USACE 1998), to simulate depths, velocities and shear stresses for a range of discharges over the existing and future channels over the fan. The dimensions of the future channels were estimated on the basis of relationships found in a study of channels incised into alluvial fan deposits below lake outlets (Kellerhals 1967).

4.3 Site Conditions

4.3.1 Historical Channel Morphology

As discussed in Section 2.1.6, formation of the Cheslatta Fan has resulted in substantial sediment accumulations on the Nechako River valley flat. The principal deposit is located upstream of the "Neck" at Km 8.25 (Plate 4.3.1-1); however, sediments have also been transported downstream and a sizeable quantity of material is located in the area between the "Neck" and the Cheslatta River confluence (Plate 4.3.1-2). The principal source area for these sediments is the left or north bank gully[7]

[7] This has been referred to as the Scour Canyon in other reports.

that developed after Cheslatta River shifted its course (Plate 4.3.1-3). The Cheslatta Fan appears to have formed over an extended time period. The historical air photo analyses in Appendix 2 confirm that the initial stages of channel shifting were occurring in 1961. The associated Skins Lake Spillway Flow was greater than 500 m^3/s, which was the highest value, at that time, to occur since reservoir construction[8]. The air photo analyses also indicate that the erosion gully and fan show further incremental enlargements on both the 1971 and 1974 air photos. This suggests that upslope erosion continued periodically over the period until the mid 1970's when the inlet to the gully was blocked off. This hypothesis is supported by the Skins Lake discharge data in Appendix 1, which indicates that discharges $\geq$400 m^3/s occurred in 1962, 1964, 1971 and 1972.

Formation of the Cheslatta Fan, in conjunction with the presence of a bedrock sill at Km 7.4, has partially impounded the pre-existing scour hole and resulted in the enlargement of Scour Hole Lake (Plate 4.3.1-4).

The Cheslatta Fan slopes towards the right bank or south side of the valley bottom (Plate 4.3.1-5). This directs the residual flows from Nechako Canyon into a channel that is at the base of the right bank valley wall. This channel flows between an island and the valley wall at the upper end of the fan and both channel banks in this area are well defined (Plates 4.3.1-6 and 7). Further downstream, the left hank consists of gently sloping fan deposits and, in conjunction with local beaver dams, results in a more poorly defined channel (Plate 4.3.1-8). Channel definition again improves near the lower end of the fan, as the left bank is formed by a steep erosional contact with the Cheslatta Fan sediments (Plate 4.3.1-9).

Bedrock is exposed on both banks at the constriction at Km 8.25 (Plate 4.3.1-10). Two bedrock outcrops occur upstream of the "Neck." The presence of a number of beaver dams in the vicinity of the "Neck" has resulted in the formation of an extensive wetland (Plate 4.3.1-11).

The valley bottom downstream of the "Neck" is extensively infilled with sands and gravels as far as the Cheslatta confluence. The residual Nechako River has formed a sinuous channel within this area (Plate 4.3.1-12). The Cheslatta River has locally eroded these sediments (Plate 4.3.1-13) and the size of the residual pavement was measured (using the tape grid technique described in Kellerhals and Bray 1971). The results are summarized on Table 4.3.1-1. These measurements provide an initial indication of the bed material texture that may develop in any constructed diversion channel. The average diameter ranges between 60 mm on the bar surface and 88 mm along the waters edge.

Cheslatta River forms a steep channel containing rapids and waterfalls in the area where it drops down into the Nechako Valley (Plate 4.3.1-14). The small saddle dam that has been constructed to prevent Cheslatta River from flowing into the erosion gully to the fan is illustrated on Plate 4.3.1-15.

[8] The maximum value of record (538 m^3/s) occurred in 1981.