# Nechako Downstream Allocation Model

## Review and Recommendations

EC 1028

Prepared for:

**Nechako Watershed Council**
Box 1078
Vanderhoof, B.C.
V0J 3A0

November 2003

Prepared by:

**Adam Lewis, M.Sc., R.P.Bio.**

ECOfish

Published by Ecofish Research Ltd., Denman Island, B.C.

Citation:

Lewis, A. F. J. 2003. Nechako Downstream Allocation Model: Review and Recommendations. Consultant's report prepared by Ecofish Research Ltd., 9086 Keith Wagner Way, Denman Island, B.C.

## EXECUTIVE SUMMARY

Ecofish Research Ltd. was retained by the Nechako Watershed Council (NWC) to review the Nechako Downstream Allocation Model (N-DAM) and to provide recommendations for its improvement. The Nechako Downstream Allocation Model (N-DAM) is a tool developed by the Nechako Watershed Council to provide an accurate representation, both past and future, of proposed flow changes at various locations along the Nechako River. N-DAM focuses on the downstream aspects of water management in the Nechako River. N-DAM operates with several universal principles and objectives that govern water allocation. These principles agree generally with those of the Nechako Watershed Council.

N-DAM adds outflows from Skins Lake Spillway, the proposed Kenney Dam Hydroelectric Facility, and the proposed Cold Water Release facility to estimate the flows that will be delivered to Cheslatta Falls. The choice of Water Release Facility (WRF) in the model determines both the amount of cooling flow required, and the resultant Freed-Up Flow (FUF) that will be remaining. Cooling water that is freed up by building the WRF can be distributed to either the river or remain in the reservoir for diversion and power generation.

N-DAM model users can manipulate four input variables: Annual Skins Lake Spillway Release (SLS) (in cms); Kenney Dam (KD) Constant Daily Release (in cms); the Temperature Target for the WRF(in °C); and quantity of FUF(in cms) to remain in the reservoir. A key driver of the SLS flows are the flows allocated for cooling under a new management regime with new release structures. N-DAM assumes that 60 cms base cooling flows are available for allocation to all uses under the new water management principles. The target temperature implies a choice of (WRF) that in turn determines both the amount of cooling flow required, and the resultant FUF that will be remaining. The model allows the option for some of the FUF to remain in the reservoir.

There are two key calculations in the model. The 'N-DAM Solution' is the sum of stakeholder interests, defined as the SLS release, the KD release, the cooling flow release and the Murray-Cheslatta (M-C) inflow. The naturalized flow redistribution is calculated as the sum of NFCP (Nechako Fisheries Conservation Program) Column 1 flows, the cooling flow release, and the M-C inflow, plus the FUF guaranteed flows, weighted by the Nechako Reservoir Inflow Hydrograph.

The model provides 13 tests of the success of a given scenario in meeting the interests/needs of stakeholders. These include tests for NFCP flows, flows for sturgeon, Murray-Cheslatta fish and economic interests, KD Power, cattle fencing, float plane, canoeing, irrigation, flooding, and flow naturalization. The tests evaluate success by comparing the N-DAM solution to the target flows for each test in each month. The model records whether a test is passed, and if not passed, it records the shortfall below the target flow. The total number of tests passed and the shortfall in flow is presented as the overall test of a particular flow alternative.

Ten issues around the model concept, design, interpretation, and the decision making process were identified and are discussed in detail in this report. These are summarized briefly here and additional details can be found in Section 3. A list of recommendations can be found in Section 4.

1. Model Platform: N-DAM is a spreadsheet model in Microsoft Excel. The model is presently independent from the Nechako Reservoir Model. Although this creates some limitations, given the existing scope and intended use of the model, this platform is adequate.

2. Model Logic: N-DAM is structured into components with information, data input, algorithms, and outputs in graphic and tabular format. The model is logical and its operations are now documented in this report. Although some issues were identified, the overall structure of the model is appropriate.

3. Appropriateness of Data Sources: The data inputs are hydrological time series. The period of record of flow data in N-DAM should be consistent: this is the case for the performance measures (PM's) calculated at Cheslatta Falls. This issue becomes important if performance measures at locations downstream of Cheslatta Falls are used (at present these are not active in the model), because these PM's use local inflow that shows substantial daily variation in flow. Releases from flow control facilities show little daily variation, so a daily time-step is unnecessary. Templates for natural flow regimes should either be consistent, or based on a specific rationale.

4. Redundant or Non-Useful Parts: The model contains five redundant components, though each of these has some useful information. N-DAM should be simplified by removing these components and reorganizing the model to facilitate data presentation and review. The user interface should be redesigned to simplify operation and to reduce operating error.

5. Performance Measure Appropriateness: Performance measures have been developed by the NWC and are structured as 13 tests of flow alternatives. These tests are appropriate in that they represent the issues of the NWC. However, because the flow targets are binary (the flow alternatives either pass or fail) they do not accurately represent environmental performance, which typically varies continuously with flow. The binary performance measures should be replaced with continuous performance measures.

6. Performance Measure Currency: The NWC has chosen to express stakeholder interests as flow targets, creating a common currency of cms (cubic meters per second). The intended benefit of this is to allow performance measures to be

compared in equal units. Standardization can lead to logical errors that could impair flow management decisions. Specifically, the standardized PM's assume that a 1 cms shortfall has the same effect on all PM's, when this is not the case: flow affects each PM differently. Furthermore, the standardized PM's assume that a 1 cms shortfall has the same effect each month, when in fact a 1 cms shortfall in December represents a substantially higher percentage of the flow than during the summer months. The performance measures should be reviewed to identify where changes in units would provide useful information for the NWC. Not all measures should be altered, but where warranted, new performance measures can be created using existing information.

7. Performance Measures for Sturgeon: NWC stakeholders are uncertain how flow affects white sturgeon. This uncertainty reduces the value of the sturgeon PM. The pattern and timing of flow aspects of the sturgeon PM are already incorporated into SLS flows and the naturalized flow alternative. Given this, it is recommended that the sturgeon PM not be incorporated into N-DAM at this time. Adaptive management has been identified as a promising approach for dealing with sturgeon issues.

8. How to Use the Performance Measures: Not all performance measures are useful in discriminating between alternatives. Those PM's that differ significantly between alternatives and can be used to make decisions should be identified. This will require the development of MSIC criteria (minimum significant increment of change criteria).

9. Role of N-DAM and the NWC in setting flows: The NWC is an advisory body without legislated authority, whose recommendations must fit within the existing legal and regulatory mix. Despite this advisory role, the NWC is well positioned to lead Nechako River flow management because it represents a broad spectrum of interests. N-DAM has a critical purpose: to inform the selection of a best flow alternative, one that meets NWC principles and is most acceptable to NWC stakeholders.

10. Other recommendations for model improvement: A number of features could be added to N-DAM. These should be characterized as the continued development of the model, rather than improvements, as the key components of the model (the logical framework, assumptions, and key algorithms) will not change. An important improvement is to expand N-DAM to consider all years. N-DAM can be expanded to consider daily flows if PM's downstream of Cheslatta Falls are added.

# TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# 1. INTRODUCTION

Ecofish Research Ltd. was retained by the Nechako Watershed Council (NWC) to review the Nechako Downstream Allocation Model (N-DAM) and provide recommendations for its improvement. The NWC wishes to evaluate the model to ensure that the next steps of the flow management process can rely on accurate information, much of which is provided by N-DAM. Accordingly, the objectives of the review are to:

1. review the logic on which the model is based;
2. confirm the appropriateness of data sources;
3. identify additional performance measures helpful in choosing among alternatives; and
4. provide other recommendations to improve the model.

N-DAM is a tool developed by the Nechako Watershed Council to provide an accurate representation, both past and future, of proposed flow changes at various locations along the Nechako River. The model must be credible and be perceived as credible, to provide stakeholders with the confidence to use it to evaluate choices about competing water management alternatives for the Nechako River.

A priority of the Council is to develop new flow regimes to meet the interests of members. Anticipating that a Cold Water Release Facility (CWRF) will be constructed at Kenney Dam, the Council has investigated new and creative alternatives of managing Nechako River flows. This work began in 1998 with the assistance of Glen Davidson, BC Water Management Branch, and Dan Bouillon and Louise Remillard of Alcan. In September 2002 a river flow model (N-DAM) was prepared by Dan Bouillon to better understand the implications of various options. This model is a counterpart to Alcan's reservoir management model which defines the relationship between annual inflows, reservoir levels and releases through the Tahtsa Intake and the Skins Lake Spillway (SLS). N-DAM and the reservoir models are not linked and operate independently.

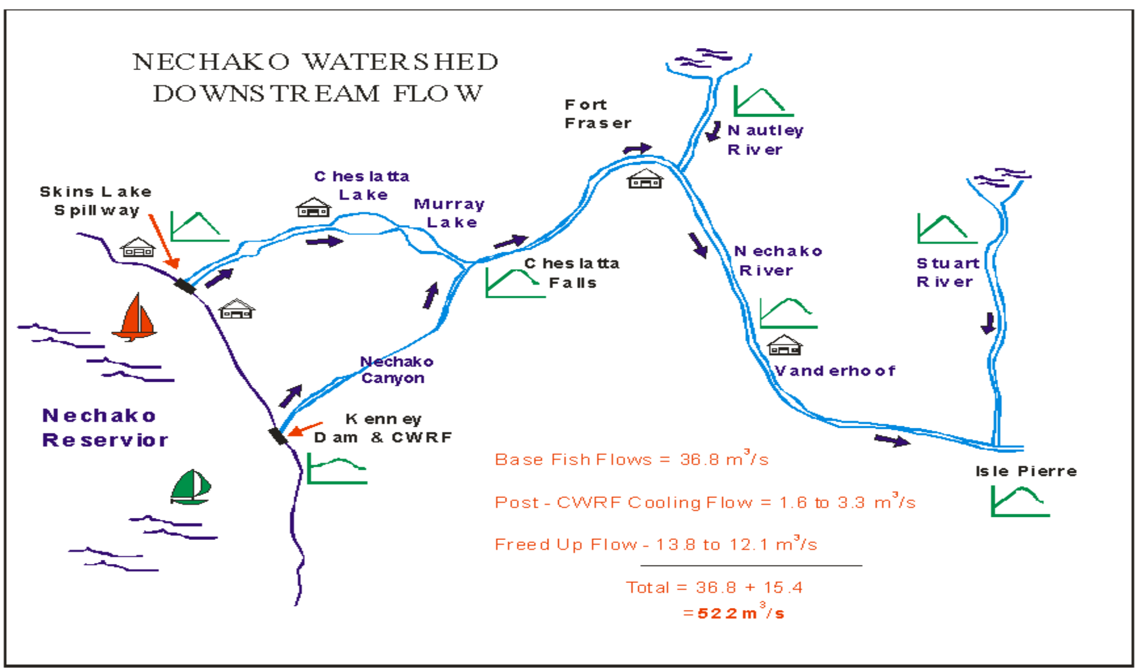
Since 1998, the NWC has identified and characterized issues throughout the watershed, focussing on flow related issues (1998-2000). From 2000 to 2002, these issues were translated to flow volumes at Cheslatta Falls (2000-2002), allowing stakeholder interests/needs to be expressed as flow requirements. These flow volumes are defined as single value thresholds that, if met, indicate success in managing water for an interest/need. These thresholds can be thought of as performance measures that allow stakeholders to identify if a particular water management alternative performs well. The thresholds are binary in nature: they are either met or not. Accordingly, the success of a particular alternative is assessed as either passing or failing. Success is the tally of passes, as well as a measure of how close flows are to the desired levels.

## 2. MODEL STRUCTURE

N-DAM focuses on the downstream aspects of water management in the Nechako River. The Nechako River is a major tributary of the Fraser River that is regulated by the Skins Lake Spillway structure located west of Fort Fraser (Figure 1). Alcan operates the structure within water license F102324 to provide for downstream flows, to maintain water surface elevations in the Nechako Reservoir, and to divert flow to the Kemano powerhouse for generation. Although reservoir operations are critical to the management of Nechako River flows, at this time the two areas are being modelled independently.

Water flows have been measured for varying periods of record at a number of locations throughout the Nechako Watershed. Gauging sites used for modelling by N-DAM are located at Skins Lake Spillway, Cheslatta Falls, Nautley River, Nechako River at Vanderhoof, Stuart River, and the Nechako River at Isle Pierre (Figure 1). N-DAM anticipates flows at Kenney Dam from the cold water release facility, although no gauge is presently located at that site.

**Figure 1. Schematic of the Nechako River downstream of the Skins Lake Spillway and Kenney Dam showing the location of tributaries and flow gauging stations. Figure provided by Dan Bouillon (Alcan).**



## 2.1. Principles and Objectives

N-DAM operates with several universal principles and objectives that govern water allocation.

The principles/objectives of the model are stated as follows:

- Naturalize hydrograph of the Nechako River.
- Naturalize hydrograph of the Cheslatta River.
- Re-water Nechako Canyon year-round, and naturalize hydrograph where possible.
- At a minimum, achieve NFCP (Nechako Fisheries Conservation Program) releases for fish.
- Supply base Skins Lake Spillway (SLS) release using NFCP fish flows (i.e. guarantee SLS release schedule).
- Redistribute Freed-Up Flow (FUF) to maximize resolution of issues identified by NWC.
- Maximize beneficial timing and volume of releases for Nechako River White Sturgeon.
- Provide year-round stable water supply for power generation at Kenney Dam.
- Maximize economic benefits for all concerned.

These principles agree generally with those of the Nechako Watershed Council.

## 2.2. Approach

N-DAM adds outflows from Skins Lake Spillway, the proposed Kenney Dam Hydroelectric Facility, and the proposed Cold Water Release facility to estimate the flows that will be delivered to Cheslatta Falls. The model also is structured to add in local inflows from tributaries to calculate the flow in the Nechako River at Vanderhoof and Isle Pierre, however, these inputs are not yet active in the model. The user can select the annual Skins Lake Spillway Release (SLS), the Kenney Dam (KD) Constant Daily Release, and the Temperature Target for Water Release Facility (WRF) (in °C). These selections determine the quantity of freed-up-flow (FUF), i.e. the flow available beyond current commitments for release to the Nechako River. The choice of WRF determines both the amount of cooling flow required, and the resultant FUF that will be remaining. Cooling water that is freed up by building the WRF can be distributed to either the river or remain in the reservoir for diversion and power generation.

Mean monthly flow for each calendar month is compared to specific water interests expressed as flow targets. These flow targets are equivalent to the performance measures (PM's) used in BC Hydro's Water Use Planning. A total of 13 tests have been defined by the NWC, each mean monthly flow series representing a long term average. The success of an alternative in meeting each target is identified for each calendar month. Success is scored as pass-or-fail for each month, for each flow target. Failures are further quantified by summing the number of months where failures occur and summing the quantity of flow needed for the alternative to meet the target. Alternatives can be compared by examining the percentage of tests passed and the cms shortfall below target (if any).

## 2.3. Model Organization

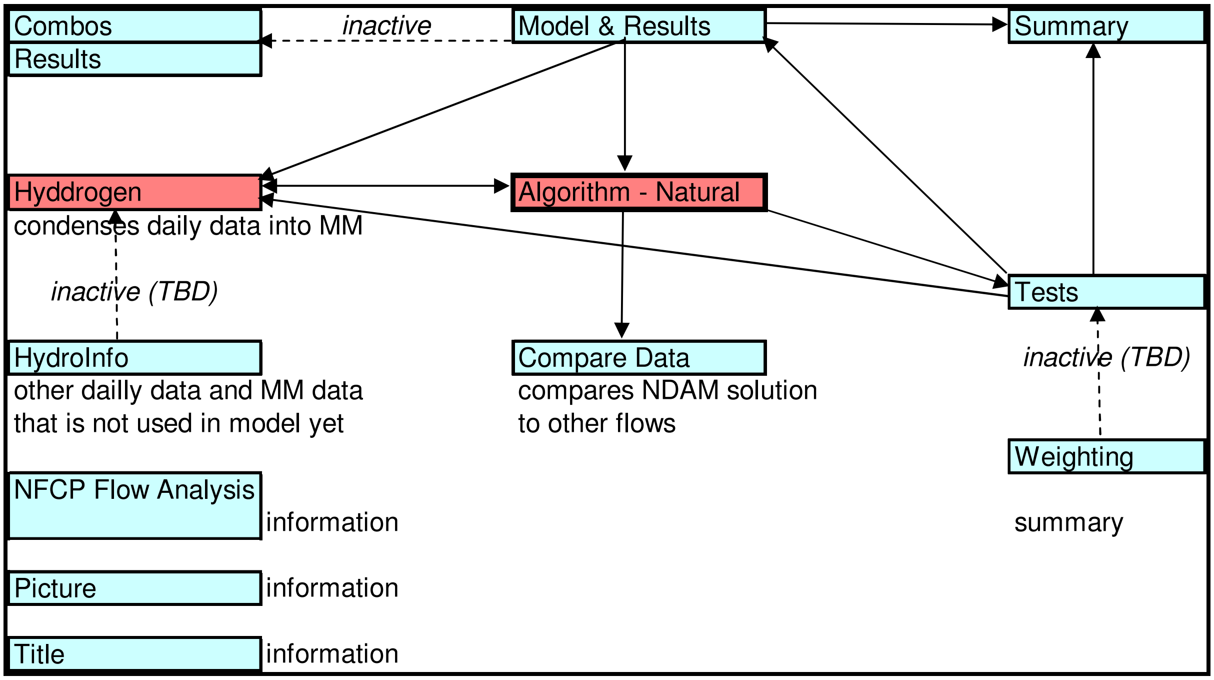
N-DAM is a spreadsheet model built in Excel®, part of the Microsoft Office package. The model is organized into components, each of which occupies a single sheet within a spreadsheet file (Table 1). In total there are seventeen components, however, five of these provide only information that could be incorporated into other components. Calculations are made on five separate sheets, but the essential components are limited to just two: 'HydroGen', which synthesizes daily flow data into mean monthly data, and 'Algorithm-Natural' which tracks, sums, and redistributes Freed-Up Flows.

The key calculations are spread among these components such that data flows back and forth (Figure 2). Data inputs also come from the 'Model and Results' component where users can enter parameter values for three key variables: Skins Lake Flows, Kenney Dam Release, and Temperature Targets for the Water Release Facility. Additional calculations are performed in the 'Tests', 'Compare Data', and 'Weighting' components. The results of the model are presented in tables and graphs. Graphics are spread among several components including 'Summary', 'Model & Results', 'Compare', 'Tests', and 'Compare Data'. Summary information is tabulated in 'Tab', 'Summary', 'Model & Results', and 'Results'.

**Table 1. N-DAM Model components by function.**

| | Model Function | | | | | |
|---|---|---|---|---|---|---|
| Model Component | INFORMATION | DATA | INPUT | CALCULATIONS | CHARTS | SUMMARY |
| Introduction | X | | | | | |
| TOC | X | | | | | |
| Tab | | | | | | X |
| Summary | | | | | X | X |
| Model & Results | X | | X | | X | X |
| Compare | | | | | X | |
| Tests | | | | X | X | |
| Compare Data | | X | | X | X | |
| Weighting | | | X | X | | |
| Algorithm - Natural | X | | | X | | |
| Hyddrogen | | X | X | X | | |
| HydroInfo | | X | | | | |
| Combos | X | | | | | |
| Results | | | | | | X |
| NFCP Flow Analysis | X | | | | | |
| Picture | X | | | | | |
| Title | X | | | | | |

**Figure 2. Schematic illustrating relationship of key model components (highlighted in red). The arrows show the direction of information flow.**




## 2.4. Data Inputs

There are two types of data inputs into N-DAM: mean monthly flow data and parameter choices. The input variables are:

- Annual Skins Lake Spillway Release (SLS) (in cms);
- Kenney Dam (KD) Constant Daily Release (in cms)
- the Temperature Target for Water Release Facility (in °C) ; and
- quantity of freed-up-flow (FUF) to remain in the reservoir.

Each of the input variables gives the user a choice of parameter level choices, and these may be either discrete or continuous choices.

For the SLS flow, model users set the mean annual flow at the SLS only and the monthly distribution of flow is calculated based on the Stellako River hydrograph. The appropriateness of the Stellako as a template is dependent on the objective related to the re-distribution of monthly flows. If the goal is mimicking natural flow, the Nechako Reservoir inflow hydrograph would be the most appropriate. If the goal is matching the timing of local inflow downstream of the reservoir, then the Stellako hydrograph is more appropriate. Regarding the quantity of annualized flow that would be delivered by the SLS to the Cheslatta River, this has been discussed by the Cheslatta First Nation and the Nechako Watershed Council. Flows of 5 cms to 30 cms have been considered, with 15 cms identified as a reasonable target. This flow will be delivered as a minimum mean annual, i.e. the annual release would not be less than the target but could be exceeded when the Kenney Dam Release could not handle unusually high flows.

At the present time, a minimum of 60 cms base flow must be delivered to the Nechako River at Cheslatta Falls during the sockeye migration and annual Summer Temperature Management Period (STMP) (July 10 - August 20), with a 60:40 split of cooling water between July and August. (Modelling for the Nechako Environmental Enhancement Fund Management Committee [NEEF MC] by Triton Environmental Consultants Ltd. showed that cooling flows are usually delivered 60% in the July period and 40% in the August period.)

The N-DAM model assumes a SLS release of 15 cms annualized, with flows released at Kenney Dam to meet the remaining base flow needs. Ignoring any lag in the delivery of water through Skins Lake, a function was developed to calculate the additional water required over and above that which has already been allotted to the SLS and KD during the STMP months. During the STMP months, the delivery of water from the SLS and KD water was assumed to be constant each day. In practice this will be true for the KD, but not for the SLS. The additional water required at the SLS during STMP months must be calculated on a mean monthly basis. Based on a release for 21 days in July (0.6774 of the month), and 20 days in August (0.6452 of the month), constants of 1.4762 (July) and 1.5500 (August) were calculated. This calculation is needed because the model works on a monthly time step, whereas the STMP operates on a daily basis. An artifact of this calculation is that model graphs show cooling flows spread out over the whole month of a lesser magnitude than the daily releases.

The temperature target for Water Release Facility is limited to 5 values: 10, 12, 14, 16 and 18 °C. These temperatures correspond to a particular model of the WRF derived from studies carried out for the NEEF MC by Triton. The WRF type, temperature target, cooling release required, and the resultant FUF available are shown in Table 2.

FUF calculations for the 10 °C and 12 °C temperature targets are built with a 15 cms Murray-Cheslatta mean annual release and a 60 cms minimum flow in Nechako River during the STMP. FUF calculations for the 14 °C , 16 °C, and 18 °C temperature targets are built on a 15 cms release from the SLS during the summer (this is similar to the average flow (Q) for the 10 °C and 12 °C scenarios).

**Table 2. Water Release Facility Type with water temperature target, cooling flow required, and resultant freed-up flow.**

| Water Release Facility | Cost ($M)* | Temperature Target (°C) | Cooling Release (cms) | Freed-Up Flow (cms) |
|---|---|---|---|---|
| #10 LLI,SIC,RS,FBS, LLO | 96 | 10 | 1.6 | 13.8 |
| #12 LLI,SIC,RS,FBS, LLO | 96 | 12 | 2.5 | 12.9 |
| #13 LLI,SIC,RS,FBS, LLO | 96 | 14 | 3.3 | 12.1 |
| #16 SIC,RS,FBS, LLO | 83 | 16 | 4.7 | 10.7 |
| #18 SIC,RS,FBS, LLO | 83 | 18 | 8.1 | 7.3 |

LLI = Low Level Intake; FBS = Flip Bucket Spillway; SIC = Surface Intake Channel; LLO = Low Level Outlet; RS = Regulating Structure;

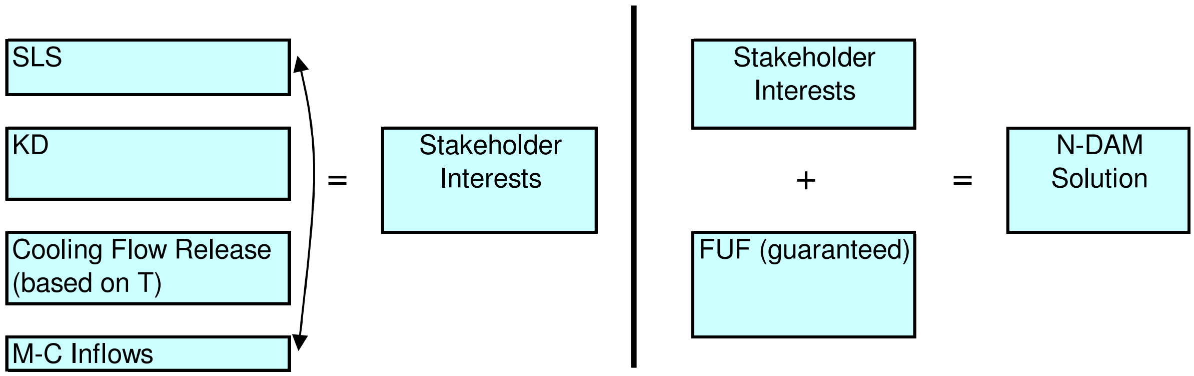
*Cost Estimates from NEEF Report

Kenney Dam Release inputs are not limited by the model. However, users should constrain the input to the three primary options identified by the NWC: 25.0 cms, 26.4 cms, and 29.33 cms. Studies of these power operations indicate that mean monthly releases of less than 26.4 cms may not provide an economically viable power generation option.

## 2.5. Model Operation

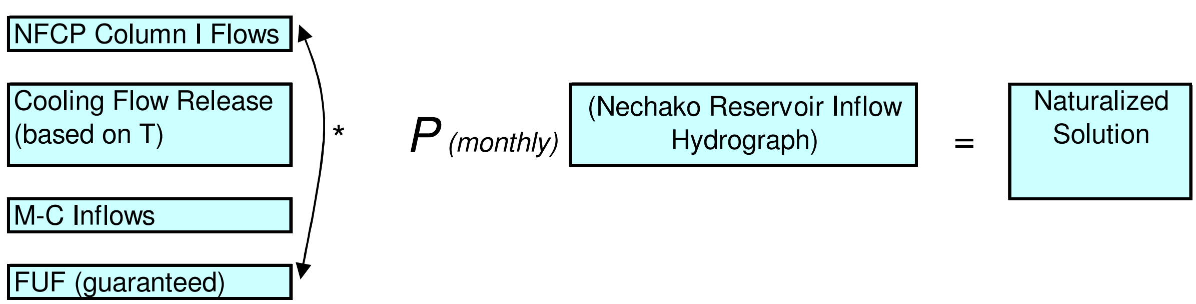
The model is 'run' by changing parameter combinations in the yellow highlighted boxes of the 'Model and Results' sheet box entitled "Choose Parameters Here" in the 'Analysis' Work Sheet. Excel® re-calculates flow distribution automatically and updates the output so that the results are obtained instantly. There are two key calculations in the model. The 'N-DAM Solution' is the sum of stakeholder interests, defined as the SLS release, the KD release, the cooling flow release and the Murray-Cheslatta (M-C) inflow. These stakeholder interests are added to the FUF distribution to create the N-DAM solution, which is composed of one mean monthly flow for each month of the year. The FUF can be divided into two components, the guaranteed flow and that which remains in the reservoir and is subsequently diverted to Kemano for power generation. Users can select the quantity of FUF that is ‘guaranteed’ (i.e. released to the river) and that which is retained in the reservoir.

**Figure 3. Calculation of N-DAM solution.**




The naturalized flow redistribution is calculated as the sum of NFCP Column 1 flows, the cooling flow release, and the M-C inflow, plus the FUF guaranteed flows, weighted by the Nechako Reservoir Inflow Hydrograph. The weighting results in the same mean annual flow as for the N-DAM release, however, mean monthly flows are altered so that their pattern matches the natural flow regime.

**Figure 4. Calculation of the naturalized solution.**



The target temperature implies a choice of Water Release Facility (WRF) that in turn determines both the amount of cooling flow required, and the resultant Freed-Up Flow (FUF) that will be remaining. The model allows the option for some of the FUF to remain in the reservoir. After choosing the desired temperature target, WRF design, and flow inputs, the model redistributes the flow into the Nechako River system, generates hydrograph figures, and assesses the fit to stakeholder interests.

Mean monthly flow data is pre-determined, but is affected by the choice of parameter levels. For example, the annual SLSR can be input to the model, however, the mean monthly distribution of flow is determined automatically by the model. Similarly, the temperature target for the KDWRF can be set by the user, however, the quantity of FUF available for release is determined automatically by the model, based on calculations made by Triton Environmental Consultants Ltd. that are embedded in the model.

## 2.6. Tests

The model provides 13 tests of the success of a given scenario in meeting the interests/needs of stakeholders. The tests are specified as flow targets or thresholds, as follows:

1. NFCP Column I Flows
2. NFCP Historical Monthly Flows
3. Sturgeon Conservation Flows - at Cheslatta
4. Sturgeon Conservation Flows - at Vanderhoof
5. Sturgeon Conservation Flows - at and Isle Pierre
6. NWC Murray-Cheslatta Fish & Economic Interests
7. NWC KD Power and Econ. Dev. Flows
8. NWC Fencing Flows for Cattle
9. NWC Float Plane flows
10. NWC Canoe Flows
11. NWC Irrigation Flows
12. NWC Required Flow before Flooding
13. N-DAM Solution vs. Naturalized Solution

The tests are of two general types. The primary type of test is a threshold mean monthly flow that must be met in each month of the year for a test to succeed. For example, NFCP Column 1 flows, specified in the settlement agreement, must be met or exceeded for a particular alternative to pass this test. Also of the primary type are those tests that specify mean monthly slows for only part of the year. For example, flows for fencing cattle and canoeing flows are required from May through September, and float plane flows are required from May through October.

The second type of test is that used to compare the fit of the N-DAM solution and the naturalized solution. The naturalized solution has the same mean annual flow as the N-DAM solution, but has a different distribution of flow between months. The model creates a naturalized hydrograph by summing the total flow of water delivered to the Nechako River just below Cheslatta Falls based on user inputs, then distributes this flow between months using the hydrograph from the Nechako Reservoir Inflow as a template. (This template differs from that used to distribute the SLS hydrograph, though it is not specified why in the model. A point of interest here: the SLS has been naturalized with a different template hydrograph than the naturalized alternative, implying that the two regimes will not match unless the two templates are identical.) The difference between the N-DAM solution and the naturalized hydrograph is calculated by summing differences in flow each month. Both N-DAM monthly flow under and over the naturalized solution contribute to the difference between the two regimes.

The tests determine success by comparing the N-DAM solution to the test flows of interest on each calendar month. When the N-DAM solution is less than the flow target, the model notes a failure has occurred and sums this, along with each successful test, to calculate the percentage of tests passed. With 13 tests scored each month, a total of 156 tests can be scored annually. The model also records the magnitude of test failure. The difference between the N-DAM solution and the test of interest is calculated each month for each test. The total shortfall is summed for all tests and presented in units of cms.

The tests can be visualized in plots of the annual hydrograph. An example of a flow test is shown in **Figure 5** with a comparison of the N-DAM solution and canoeing flows at Cheslatta. The test fails in 10 out of 12 months (passes in August and September) and has a shortfall of 28.3 cms.

**Figure 6** shows the most extreme case of failure to meet flow targets. Again, the N-DAM solution is in cms by month, denoted by blue line and solid green area. The Cheslatta sturgeon flows are shown as the red line with pink solid area. For comparison, the existing flows at Cheslatta Falls are also shown (black line). The Cheslatta Sturgeon flow targets are provided in the model: no assessment of the adequacy of these flows was done as part of this study. The N-DAM solution fails to meet this target in all twelve months, and the sum of the shortfall is 340 cms.

Figure 5. Example of flow test: comparison of the N-DAM solution (blue line) with canoeing flows at Cheslatta (red line). The red area shows the difference between the two flow regimes.

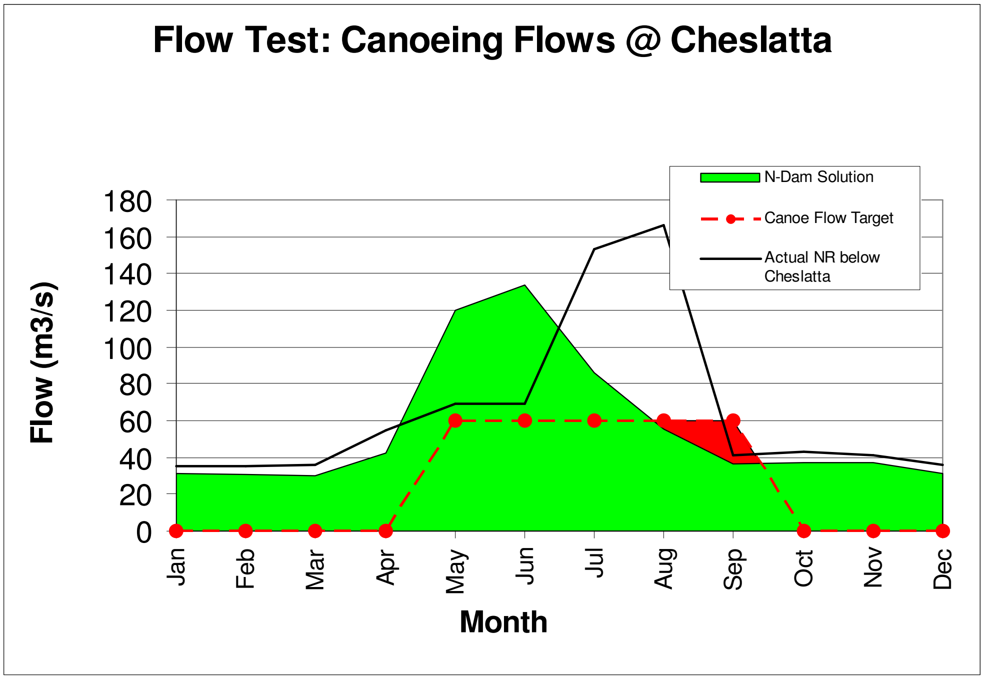
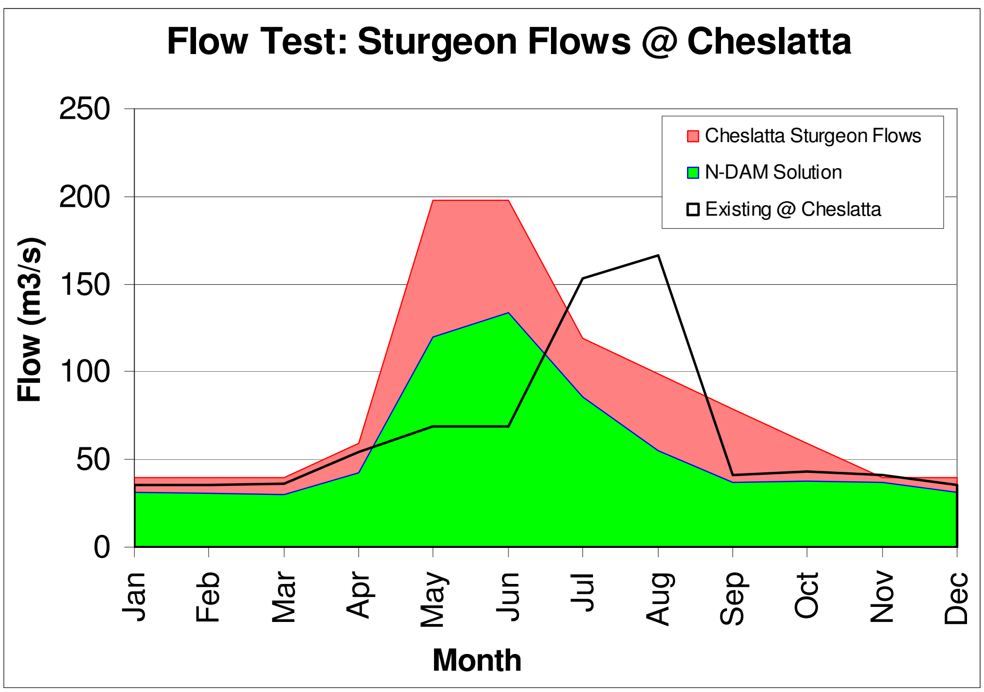
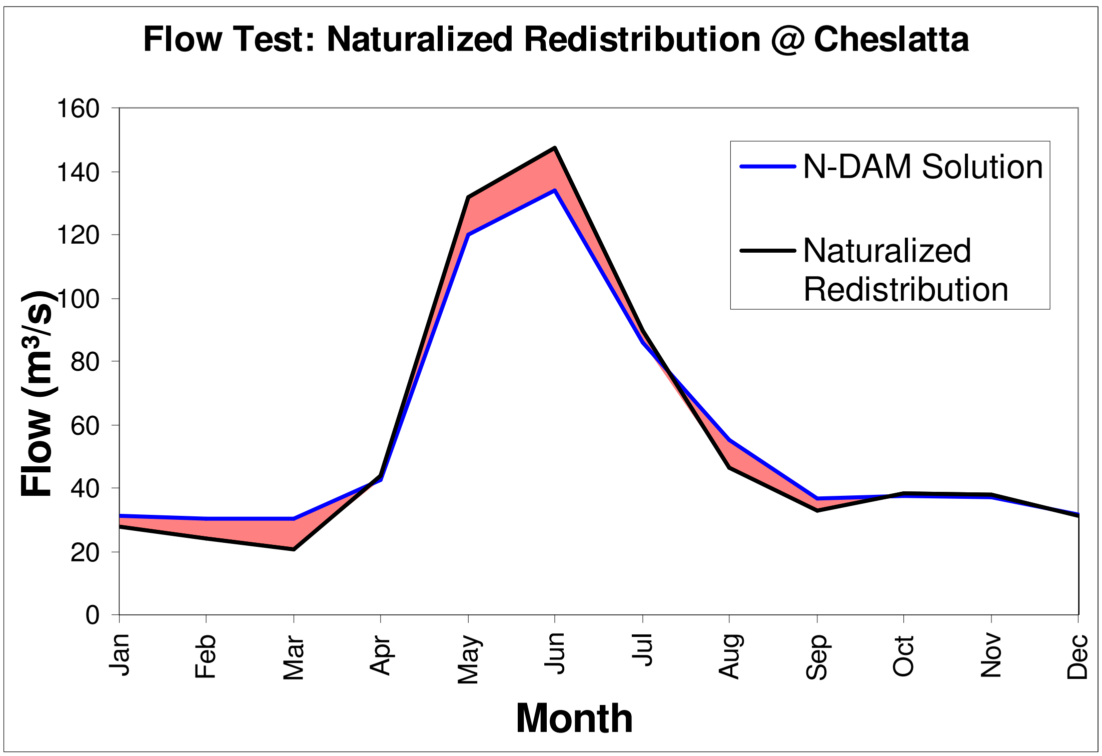



Figure 6. Example of flow test: comparison of the N-DAM solution (blue line) with Cheslatta sturgeon flows (black line). The pink area shows the difference between the two flow regimes.



The test of the naturalized flow regime is shown in **Figure 7**. In this comparison the two regimes are similar, with differences shown in the pink area between the blue and black lines. The regimes differ in each month, and the total difference is 64.7 cms.

**Figure 7. Example of flow test: comparison of the N-DAM solution (blue line) with naturalized redistribution at Cheslatta (black line). The pink area shows the difference between the two flow regimes.**



# 3. ISSUES AND RECOMMENDATIONS

## 3.1. Model Platform

The simulation model has been created in Microsoft Excel® to allow easy use and modification by Alcan. The calculations are made instantly as the input cells are entered. The advantage of this platform is that programming is simple and the platform is universal – potential model users will have Excel®. Although the model as presently designed lacks the ability to process daily data or search for optimal solutions, Excel® has Visual Basic® programming language capability that would allow these functions. The model could be automated by incorporating Visual Basic® code to simulate a time series of flow data in routines activated by the user. Alternative model platforms include pure Visual Basic® or C® languages. However, unless the model is intended to answer substantially more complex questions, the present platform appears adequate.

**Recommendation 1: Maintain the existing model platform, Microsoft Excel®. If the model is integrated with the reservoir model, the platform should be re-examined.**

## 3.2. Model Logic

In general, the model is logical, well-documented, and useful in gaming scenarios of flow release, although a few weaknesses have been identified. The model approaches water allocation in a framework consistent with Water Use Planning. The logic stems from the adherence to principles identified in the model, which are similar to principles identified more broadly by the NWC.

The NWC has defined flow principles, which are general rules governing how flows will be allocated to meet different interests/needs. The agreement between the draft flow principles and the principles or objectives used in the Nechako Downstream Allocation Model is of concern to NWC members. A key concern is whether the draft flow principles apply only to the freed-up flows or to all flows. This issue is important because the model structure and operations reflect the underlying principles. Use of the model and consideration of model results implies that the underlying principles are accepted.

**Recommendation 2: Review N-DAM principles and ensure that they are consistent with the broader principles of the NWC.**

## 3.3. Appropriateness of Data Sources

The input data sources for the model are mean monthly flows at four locations. Two of these locations are presently used in the model (SLS flows, M-C flows); the other two (Nautley River and Stuart River flows) would only be used if tests at locations downstream of Cheslatta Falls are used. The SLS flows are input by the user, but the mean annual quantity available is driven by the historical record and have been calculated from daily data based on a defined period of record. The Murray-Cheslatta flows were calculated based on the 1981-1998 period of record. Other flow solutions that have been or could be calculated manually (without N-DAM) will differ from the N-DAM solution if a different period of record is used.

The mean annual SLS release is input by the user, however the mean monthly distribution is determined based on the Stellako River hydrograph. The appropriateness of the Stellako as a template depends on the objective of the re-distribution of monthly flows. If the goal is mimicking natural flow, the Nechako Reservoir inflow hydrograph would be the most appropriate. If the goal is matching the timing of local inflow downstream of the reservoir (this would meet goals of the Nechako River White Sturgeon Recovery Initiative), then the Stellako River hydrograph would be an appropriate choice. The naturalized regime test is based on the Nechako Reservoir inflow hydrograph.

Inflows downstream of Cheslatta Falls are not presently used in the model, however, two of the proposed tests (sturgeon flows at Vanderhoof and at Isle Pierre) will require incorporation of these inflows. If these tests are to be used, the period of record (POR) of the flows being used may be important. If the POR from one basin includes a dry period and another does not, the proportion of inflow contributed by a tributary may be inaccurately estimated. This in turn may lead to the conclusion that the simulated flow does not match the reference hydrograph well, when in fact the observed differences result from using different POR's. Using all available data does maximize the capture of time trends in run-off, an advantage that could be lost by standardizing the POR. Fortunately this advantage can be realized by using the longest POR and looking for time trends within to identify whether the common POR is dry, wet, or average.

**Recommendation 3: Standardize period of record of inflows used in N-DAM. Select natural hydrograph surrogates that are appropriate for NWC objectives. Clarify why the SLS and naturalized regimes use different flow templates (Nechako Inflow vs. Stellako).**

## 3.4. Redundant or non-useful parts

The model contains a number of redundant parts. These do not impair model accuracy or speed as they are presently not arithmetically linked to the operating model. These parts can be easily removed. The components that should be removed are: TOC, Tab, Combos, Results, and NFCP Flow Analysis. Portions of these components can be retained by copying them into other components. N-DAM should be simplified by removing these components and reorganizing the model to facilitate data presentation and review. The specific areas of redundancy have been marked in each sheet of the model (see the CD enclosed on the back cover of this report).

The user interface as presently structured is confusing and could be improved to simplify model operation. The potential for user errors, particularly when inputting data, could be greatly reduced with a few modifications to the input boxes. The model can be further automated to reduce risk of errors and streamline operations.

**Recommendation 4: Remove redundant components (TOC, Tab, Combos, Results, and NFCP Flow Analysis).**

## 3.5. Performance Measure Appropriateness

Much of the important work in Water Use Planning is the development of performance measures. Performance measures in N-DAM are represented by a series of tests that have been developed with and are accepted by NWC stakeholders. The NWC has identified thirteen tests with which to evaluate flow management alternatives: 1987 Settlement Agreement NFCP Flows, Actual Historical Monthly NFCP Flow, Sturgeon Flows Based on Pre-Dam Cheslatta Falls Hydrograph, Sturgeon Flows Based on Pre-Dam Vanderhoof Hydrograph, Sturgeon Flows Based on Pre-Dam Isle Pierre Hydrograph, Murray-Cheslatta Fish & Economic Interests, KD Power Generation, Fencing Flows for Cattle, Float Planes, Canoeing Interests, Irrigation, and Flooding. All thirteen performance measures are based on flow targets that address specific stakeholder interests/issues. The subject of the performance measures is therefore appropriate.

The flow targets are binary performance measures in that success is achieved only when the target is met or exceeded. Binary measures are unrealistic because they do not accurately represent environmental performance, which typically varies continuously with flow. For example, the wetted width of a river increases continuously with flow. Furthermore, fish habitat typically shows a dome-shaped relationship with flow. The model attempts to overcome the weakness of a binary test by summing the monthly differences between the N-DAM solution and the flow target, providing an annual shortfall for each test and a sum of shortfalls for all tests. This quantifies the shortfall and allows performance to be assessed in a more continuous fashion. Unfortunately, this approach is logically flawed – it accepts that there are different degrees of failure (measured as shortfall), but ignores the fact that when flows exceed target levels there may be greater success. As an example, benefits to fish habitat may arise when the NFCP target flows are exceeded. The model does not account for these improved flow conditions, it only accounts for failures. As presently structured, N-DAM does not reflect natural ecological processes and prevents potentially successful flow management alternatives from being recognized.

**Recommendation 5: Replace binary performance measures with continuous performance measures.**

## 3.6. Performance Measure Currency

The NWC has chosen to express stakeholder interests as flow targets, creating a common currency of cms. The intended benefit of this standardization was to allow the flow targets to be compared and to allow the summation of differences between the flow targets and the N-DAM solution. Although the model does standardize the performance measure unit, the benefits of this are few, and in fact it leads to significant logical errors that will impair the process of flow management decision making. This weakness is demonstrated by the inclusion of a weighting for each flow test that varies from 0 to 1. If the standardization of measure truly equalized the unit of measure, this weighting would be unnecessary. By expressing differences in the same units in each month for each test, the PM tests rely on three critical assumptions that are unlikely to be true:

1. all interests are of equal value;
2. all interests are affected equally by a shortfall in flow – a cms shortfall in achieving one target is the same as a cms shortfall in achieving another (e.g., a 10 cms in meeting the sturgeon flow requirement is the same as a 10 cms shortfall in meeting the NFCP flows);
3. all months are equally important – a cms shortfall in one month is equivalent to the same in another month (e.g., a shortfall of 5 cms in NFCP flows in January [17% shortfall] is equal to a 5 cms shortfall in August [10% shortfall]).

A problem with this approach is that it provides misleading information to stakeholders when comparing flow alternatives that do not meet all targets. For example, if there is a 28.3 cms shortfall in canoeing flows, should this be interpreted as being 1/10 as significant as a 340 cms shortfall in sturgeon flows at Cheslatta? Does increasing flows by 28.3 cms to meet canoeing needs address less than 10% of the habitat requirement of sturgeon, as suggested by a linear interpretation of the shortfall in flow? Applying these results to a water management solution, we would assume that if flows were increased during May to 200 cms both sturgeon and canoeing PM's would be met. However, canoeing suitability may decrease at 200 cms.

An alternative approach to the common currency now used in the model is to calculate performance measures that reliably score flow management alternatives with relative accuracy (i.e., differences in scores between PM's are accurate) using a currency directly relevant to the interest. For example, canoeing flows could be scored by levels of satisfaction as determined from interviews with canoeists. Again as an example, flows of <20 cms may be unacceptable to canoeists and score 0, flows of 20 to 30 may score 0.5, flows of 30 to 40 may score 1, flows of 40 to 80 may score 2, flows of 80 to 120 may score 3, and so on. The number of days within the period of interest at a particular level of satisfaction would be recorded and multiplied by the satisfaction weighting. This would result in a score of canoeing days, weighted by satisfaction.

A canoeing PM in units of satisfaction-weighted user days would not be directly comparable to other PM's because a different currency would be used. However, it would clearly indicate the difference between water management alternatives to stakeholders. For example, the PM could be compared to the maximum possible score of ~300 (maximum satisfaction from May through September). An alternative with 270 weighted canoeing days would be near-perfect, not substantially different from an alternative with 240 weighted canoeing days, but far better than an alternative with 120 canoeing days. All stakeholders can understand that a doubling of canoeing days is substantial. This example highlights the importance of information that allows stakeholders to make meaningful choices.

Looking ahead to the selection of preferred flow management scenarios, one can imagine that with the existing PM's, stakeholders will have little information with which to assess how much better or worse an alternative performs. For example, with the existing canoeing PM, how does a shortfall of 28 cms affect canoeing? Does this shortfall justify an alternative that affects other PM's? What is the impact on those PM's? What is the economic cost or benefit of releasing flow to avoid this shortfall? If there is a cost to avoiding this shortfall, does the benefit to canoeing justify this?

Trade-offs between interests can be made successfully by stakeholders if adequate information is provided. For example, at BC Hydro's Puntledge Hydroelectric Project on Vancouver Island, stakeholders identified a trade-off between economic benefits, flows for kayaking, and fish habitat. Flows released for kayaking reduced power generation. Kayakers desired high flows during May and June to recreate and develop an official kayaking event that would have some economic benefits. However, steelhead trout habitat was negatively impacted by high flows in June. A study was undertaken to rate the quality of the kayaking at different flows and a PM was developed to rate the benefits of different flow alternatives. Considering effects on steelhead fry, benefits to kayaking, and economic costs, stakeholders identified a flow release during November as the lowest impact to fish and economics, while a June release had the highest benefits for kayaking. The stakeholders agreed to a 2-day long trial release during May 2003 and monitored the event to assess the benefits to kayakers.

**Recommendation 6: Review performance measures and identify where changes in units would provide useful information for the NWC. Not all measures should be altered, but where warranted, new performance measures can be created using existing information. The historical knowledge base from Nechako River developed over past several decades (e.g., Agency studies, NEEF studies, NFCP studies, KCP studies) can provide adequate information to create PM's in units relevant to the interest.**

## 3.7. Performance Measures for Sturgeon

NWC stakeholders are uncertain how flow affects white sturgeon. In November 2002, the Recovery Team of the Nechako River White Sturgeon Recovery Initiative (NRWSRI) provided suggestions to the NWC as to how to incorporate sturgeon needs in developing flow regimes. Two flow management principles were to 1) produce a 'naturalized' hydrograph at Isle Pierre with discrete ascending and descending limbs, and 2) time the maximum possible peak flow to coincide with peak flow in the Stuart or Nautley rivers. Implicit within this advice is the hypothesis that higher flows timed to meet the historic peaks will increase sturgeon reproduction or juvenile recruitment or both.

N-DAM currently uses a target flow regime for sturgeon at Cheslatta Falls with a MAD of 84.3 cms, 2.3 times higher than the NFCP Column 1 flows MAD of 36.7 cms. However, the natural MAD at Cheslatta falls was 176 cms, double the current N-DAM target for sturgeon. The efficacy of the N-DAM target flow in restoring sturgeon reproduction and recruitment is unknown. Although the existing PM may provide a role in discriminating between alternatives with substantially different flows and flow timing, there is high uncertainty regarding the benefits of this PM, considerably greater than for other interests. Most importantly, the uncertainty with this PM is much higher than the other PM's.

The uncertainty in how flows affect sturgeon is demonstrated on the Kootenay River, which is regulated and where sturgeon are red-listed and have low recruitment. Based on the acceptance of the hypothesis that increases in spring flows would increase sturgeon recruitment, large scale flow tests have been implemented at Libby Dam for the Kootenay River. Reproduction occurs annually in that system, but increased spring flows do not appear to have stimulated recruitment.

Other factors influence sturgeon survival. For example, water temperature (affected by regulation but also by longer-term changes in climate), may also be a key factor limiting recruitment. Laboratory tests indicate that predation rate of juvenile sturgeon decreases as turbidity increases. On the Columbia River, BC Hydro is seriously considering the hypothesis that turbidity may be a key factor and has investigated the feasibility of artificially increasing turbidity as a test of this hypothesis. If turbidity is the key factor affecting sturgeon recruitment, increasing flow alone will not increase sturgeon recruitment.

The uncertainty in our understanding of how sturgeon are affected by flow is critical to keep in mind when formulating a PM. The existing N-DAM PM with a mean annual flow of 84.3 cms may or may not benefit sturgeon. The PM goes beyond meeting the recommendations of the NRWSRI, which recommended natural annual flow pattern and timing, to recommend a specific flow target. If we have low confidence in a performance measure, we cannot make science-based decisions on which flow alternative is best.

**Recommendation 7: Exclude a specific sturgeon PM from further consideration at this time. Two key aspects of a sturgeon PM - timing and pattern of flow - are expressed in the naturalized flow test. Adaptive management is recognized as an approach to deal with sturgeon issues. For now, develop a flow regime based on non-sturgeon PM's, including naturalized flow patterns, but leave flexibility to respond to potential management actions such as flow releases to test the sturgeon recruitment limitation hypotheses.**

### 3.8. How to Use the Performance Measures

Once the PM's have been selected, criteria are needed to evaluate the significance of differences in PM scores between alternatives. Typically, some PM's show large differences among alternatives, while others show small differences. In Water Use Planning (WUP), BC Hydro used the concept of minimum significant increment of change (MSIC) – this is similar to the statistical concept of effects size which is the size of the difference that represents real change. By identifying which PM's differ significantly between alternatives, the MSIC allows stakeholders to select the most informative PM's and avoid wasting time on those less informative. Some work is required to come up with MSIC values and rationale for them, but this effort is rewarded by a simplified and more focused evaluation of alternatives.

N-DAM allows each test flow requirement, or PM, to be weighted from 0 to 1. Presumably this weighting will allow stakeholders to emphasize important PM's. Although in WUP stakeholders participate in a swing weighting analysis of the performance measure results, that activity differs in a critical way from how N-DAM has been structured. Swing-weighting is done in WUP only after stakeholders have reviewed the PM scores and developed their own weightings. Swing weighting is an investigative tool that helps stakeholders understand how and why the rank of alternatives differs. In contrast, N-DAM assigns a single weight to PM's prior to the evaluation of PM scores, potentially biasing N-DAM results against those stakeholders whose interests are lightly weighted.

Another key concern with the weights as presently structured is that they will be assigned arbitrarily. The weights are unitless, but an assignment of a 0.5 weight implies half the importance of a 1.0 weight. Are canoeing flows twice as important as sturgeon flows, or some other factor? How will stakeholders separate their own narrow interests from the broader interest of reaching a consensus on how flows on the Nechako River can be best managed? Participants are more likely to appreciate the interests of others if given the opportunity to work through the PM scoring and subsequent swing weighting process.

**Recommendation 8: Develop minimum significant increments of change to identify real differences in flow alternatives. Avoid weighting the PM's, except as a learning exercise after flow alternatives have been scored for each PM and analyzed by the stakeholders.**

### 3.9. Role of N-DAM and the NWC in setting flows

N-DAM will calculate PM scores for different flow alternatives, information that will be used to help identify a preferred flow alternative. Although no single flow regime can perfectly meet the needs of all stakeholders, there may be an optimum compromise – a flow regime that all stakeholders can accept. Stakeholders will compare alternatives by examining how well they score on each PM. Stakeholder confidence in each PM will have to be considered as the comparison is made, so that those alternatives that are not significantly different from each other can be identified. Stakeholders will learn how flow alternatives affect their own interests and the interests of others around the table. In the WUP process, this learning creates a genuine appreciation for the interest of others, which in turn creates the atmosphere for compromise.

Biophysical conditions and human values change over time, suggesting that the best flow regime may change. In addition, we will learn more about the Nechako River system and should be able to make more informed decisions in the future. By managing water adaptively we should be able to respond to new information and changing values. However, the need for certainty limits how adaptively Nechako flows can be managed: for example, KD power flows, once set, may have to be maintained for that facility to operate economically.

The NWC is an advisory body without legislated authority, whose recommendations must fit within the existing legal and regulatory mix. Despite this advisory role, the NWC is best positioned to lead the Nechako flow management issue. Regulations deal with single issues only and cannot arbitrate competing interests. The scope of technical experts is limited by their professional body to a single discipline, formally limiting their ability to comment on the impacts of a given flow alternative on most issues, and impairing their capacity to view the larger picture. The experience of BC Hydro in Water Use Planning has been the successful resolution of competing interests through dialog, learning, and compromise, all within Consultative Committees that have no legislated authority. A characteristic of WUP's has been the evolution of stakeholders with an egocentric focus to appreciate the legitimacy of competing interests, with an attendant willingness to consider new alternatives and to compromise. The fact that the NWC has no legislated authority does not diminish its usefulness as a forum for dialog, learning, compromise, and achievement. Indeed, it may be the only effective forum for advancing flow management on the Nechako River.

**Recommendation 9: Embrace the important role of the NWC in leading flow management on the Nechako River. Use N-DAM to inform the selection of a best flow alternative, one that meets NWC principles and is most acceptable to NWC stakeholders.**

### 3.10. Other recommendations for model improvement

A number of features could be added to N-DAM. These should be characterized as the continued development of the model, rather than improvements, as the key components of the model (the logical framework, assumptions, and key algorithms) will not change.

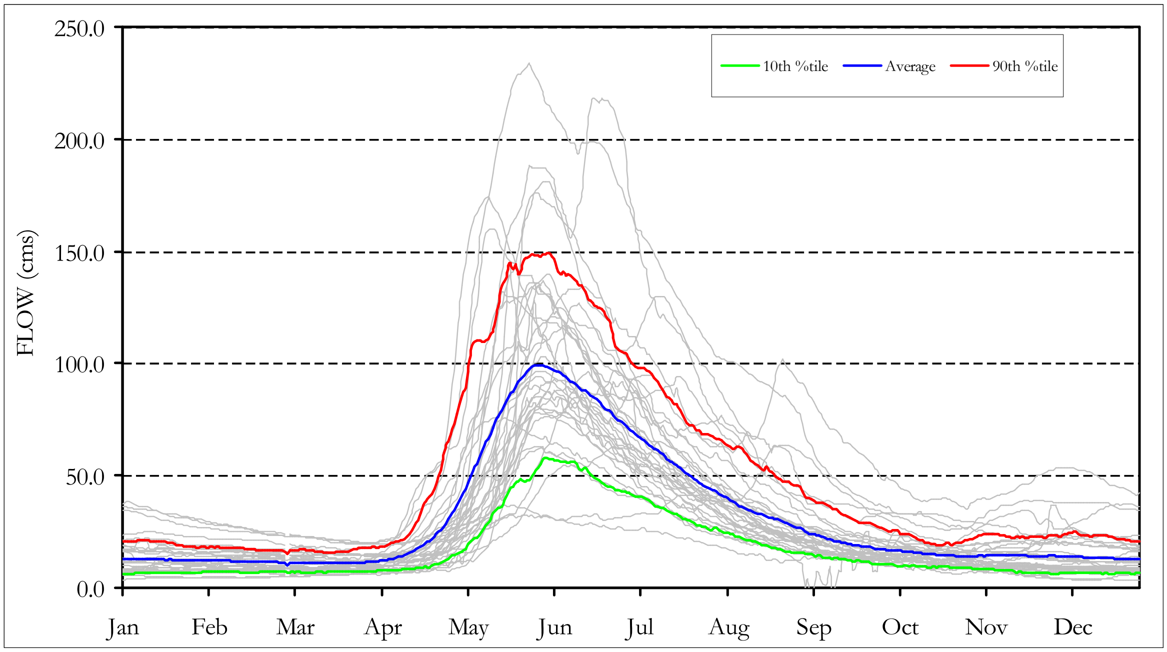
One key difference between N-DAM and models used in Water Use Planning is time step. In WUP's, daily flow data are used, which allows the examination of PM's that apply to time periods of less than one month in duration. The WUP time step is driven partly by the need to calculate the value of energy on a daily basis to capture short-term fluctuations in energy prices. However, some environmental PM's also need daily time series, such as windows for fish migration which are calculated over sub-monthly time frames or have end points partway through the month. For the NWC, the decision of whether to use daily data or not depends primarily on whether all PM's will apply at Cheslatta Falls only, or whether some PM's will include flows further downstream as well (at present only the Sturgeon PM's include locations downstream of Cheslatta Falls, but these PM's are incomplete and not active in the model). For Cheslatta Falls PM's, the Nechako Reservoir provides sufficient storage to guarantee average flow levels each year and minimize daily fluctuations, so accounting for daily flow changes is unnecessary. Although M-C inflows are variable, variation in these may not be worth considering explicitly because of their small contribution to the mean annual flow. For locations downstream of Cheslatta Falls, local inflow can be a substantial portion of the flow. Tributaries such as the Nautley and Stuart rivers display strong variation in flow between months and between days within months (**Figure 8**). Given this, it may be worthwhile modeling Nechako flows on a daily basis.

The model can be expanded to include the wet and dry years, or even all years. When all years are analyzed we can calculate the probability of a particular outcome (i.e. what is the chance of meeting a particular test in any one year?). The use of dry, average, and wet years will give a good indication of extreme events, but there may be long-term trends in flow that simple statistics do not capture. For example, the Nautley River tributaries may show different run-off time trends such that a 75 percentile year has the best outcome because of a particular combination of inflows. The Nautley River shows a long term trend of decreasing mean annual flow, with a noticeable decrease in the late 1970's.

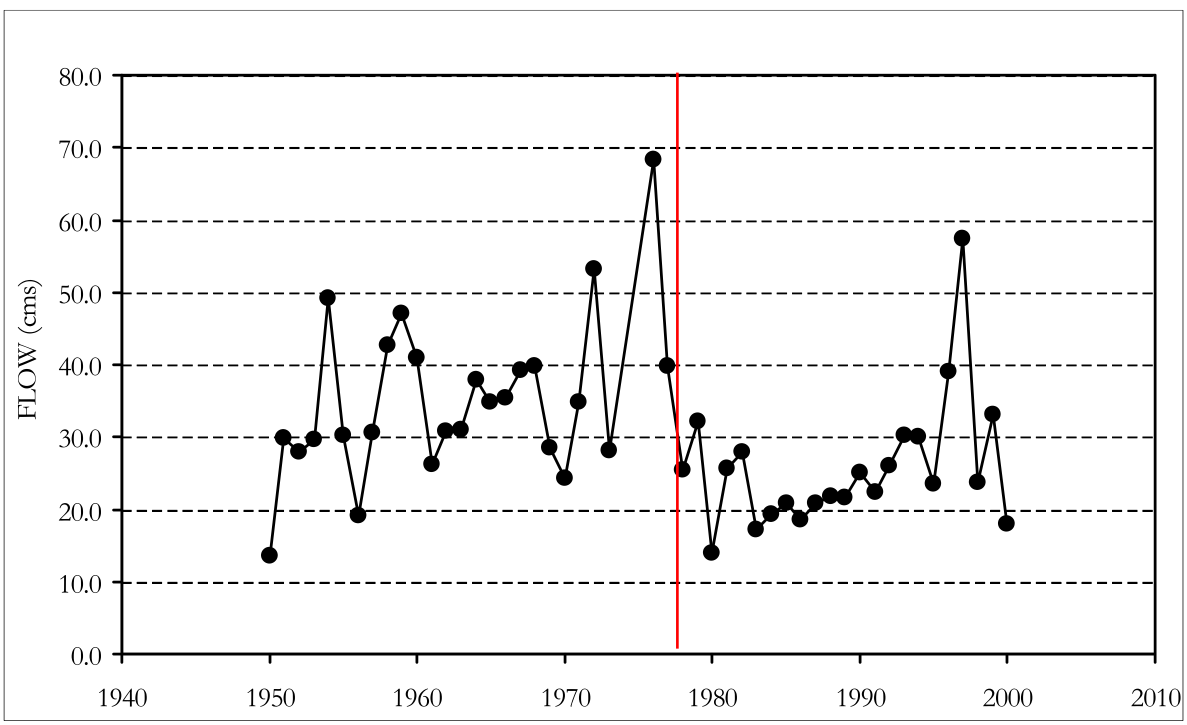
**Recommendation 10: Expand N-DAM to consider all years. Consider expanding N-DAM to include daily flows if PM's downstream of Cheslatta Falls are added to the model.**

**Figure 8. Example of variation in the natural flow regime: the Nautley River near Fort Fraser from 1950 to 2000.**

**A) Mean daily flows showing the 90th percentile, average, and 10th percentile flows. The grey lines show individual years, including 1976 when flows were highest, and 1980 when flows were lowest.**




**B) Mean annual flows: Time series illustrates the shift to lower mean annual flows in this Nechako River tributary since 1976.**



# 4. LIST OF RECOMMENDATIONS

The following recommendations are compiled from the preceding section.

**Recommendation** **Page**