# Jordan River Water Use Plan

***Revised for Acceptance by the Comptroller of Water Rights***

**30 April 2003**

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# Jordan River Project
# Water Use Plan

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BC hydro **Generation** **30 April 2003**

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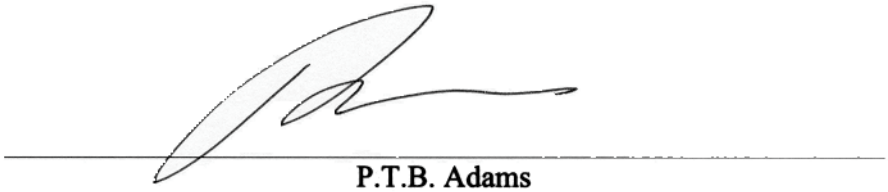

P.T.B. Adams
Manager, Operations

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# Preface

The water use planning process for BC Hydro's Jordan River facilities was initiated in April 2000 and completed in November 2001.

The operational changes proposed in this Water Use Plan reflect the recommendations of the Jordan River Water Use Plan Consultative Committee. BC Hydro thanks all those who participated in the process that led to the production of this Water Use Plan, for their effort and dedication.

# 1.0 INTRODUCTION

The operating conditions proposed in this Water Use Plan reflect the November 2001 recommendations of the Jordan River Water Use Plan Consultative Committee. The basis for the proposed terms and conditions to be authorized under the *Water Act* for the beneficial use of water at the Jordan River hydroelectric facility are set out in this document. Future reference to the Jordan River facility includes all the works including: Bear Creek Dam and Reservoir; Jordan Dam and Diversion Reservoir; Elliott Dam and Headpond; and the Jordan River generating station.

The proposed conditions would change current operations and are expected to increase habitat for resident fish (rainbow and cutthroat trout) and improve aquatic ecosystem conditions in Diversion Reservoir and the Jordan River downstream of Elliott Dam. It is also expected that higher minimum operating levels in Diversion Reservoir will benefit fish as a result of improved littoral productivity and water quality, and that this operation will also benefit recreational use. In addition, reduced turbine discharges at the Jordan powerhouse during key weekend days in March is expected to benefit recreational surfing.

A monitoring program and a review period is proposed in order to study key uncertainties to reinforce operational recommendations and to enhance future operating decisions. Refer to the Jordan River Water Use Plan: Consultative Committee Report dated February 2002 for details on the consultative process, interests, objectives, performance measures, key trade-offs, values associated with operating alternatives, expected benefits and the proposed monitoring program.

# 2.0 DESCRIPTION OF WORKS

## 2.1 Location

The Jordan River is located within the Capital Regional District, along the southwest coast of Vancouver Island, approximately 72 km by road from Victoria, B.C. The 25 km long river flows southwesterly between the Sooke Hills and the Seymour Mountain range into the Juan De Fuca Strait at the community of Jordan River. The Jordan River Generating Station is located on the west bank of the Jordan River, approximately 1 km off of Highway 14. Associated facilities can be reached on logging roads that provide access to the upper watershed. A map of the Jordan River facility is provided in Figure 2-1.

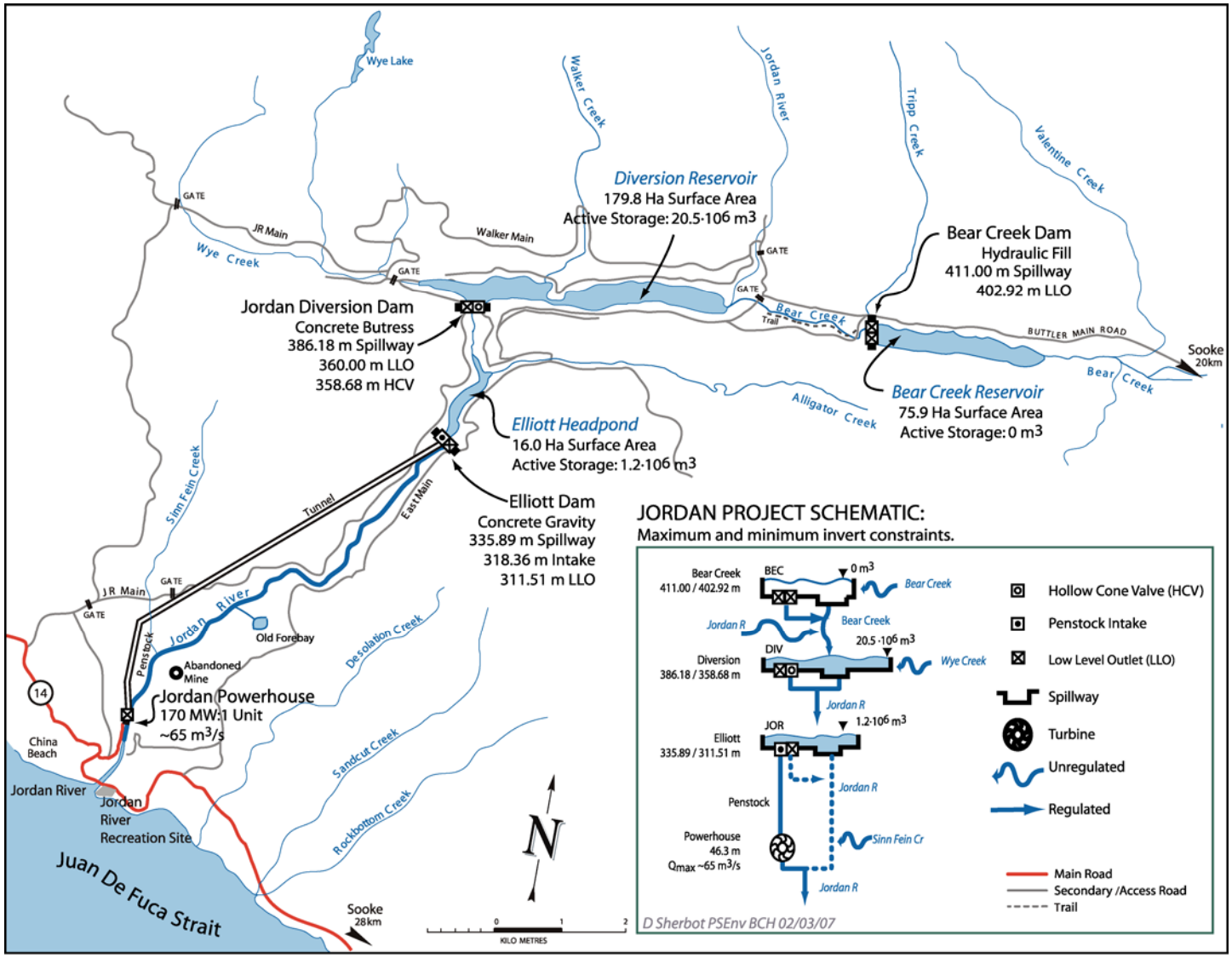


**Figure 2-1: Map of Jordan River**

## 2.2 Existing Works

The Jordan River hydroelectric system is part of the Bridge River/Coastal Generation Division of BC Hydro. It was originally completed in 1911 and redeveloped in 1971. The current facility consists of three dams, two reservoirs, one headpond, and a tunnel and penstock system that supplies water to the 170 MW powerhouse on the lower Jordan River.

The physical structures and current operating features at Jordan River include the following:

- **Bear Creek Dam**: The Bear Creek Dam is located on Bear Creek at the upstream end of the reservoir chain. The earthfill dam is 337 m (meters) long and 17.4 m high. Water release facilities consist of a freeflow overflow weir and spillway (411 m) and two low level outlet valves (402.92 m).[1]

- **Bear Creek Reservoir:** Bear Creek Reservoir is not actively managed and is operated as run-of-river with all inflow discharged via the spillway at 411 m (the elevation of the Bear Creek Dam overflow weir). As a result, Bear Creek essentially functions as a natural lake. The reservoir is approximately 7.5 $km^2$.

- **Jordan Diversion Dam**: The Jordan Diversion Dam is located on the Jordan River approximately 2.8 km downstream from the Bear Creek Dam, and impounds Diversion Reservoir. The concrete buttress dam is 232 m long and 40 m high, has an uncontrolled freeflow overflow weir and spillway (386.18 m), a controlled low level (hollow cone valve) outlet (358.68 m), and an emergency low level outlet (360.0 m).

- **Diversion Reservoir:** Diversion Reservoir has the largest storage capacity of the three reservoirs in the system. The storage capacity of the reservoir provides for approximately 3.5 days operation. Generally, the amount of inflow received in the basin limits the generating ability of the Jordan River project. The normal operating level range is between 367.9 m and 386.2 m. At elevations above 386.2 m water is released from the reservoir overflow weir at Jordan Diversion Dam. The reservoir is approximately 18 $km^2$.

- **Elliott Dam**: The Elliott Dam is located on the Jordan River approximately 1.6 km downstream of the Jordan Diversion Dam. The concrete dam is 114.6 m long and 27.4 m high, and has an uncontrolled freeflow overflow weir and spillway (335.89 m) and a low level outlet gate (311.51 m). The power intake sill is located at 318.36 m.

[1] All datum relative to Geological Survey of Canada (GSC).

- **Elliott Headpond:** The Elliott Headpond is the intake for the Jordan River powerhouse. It has the smallest storage capacity and has a normal operating level range between 325.2 m and 335.9 m. At elevations above 335.9 m water is released via the overflow weir at Elliott Dam. The surface area at full pool is approximately 1.6 $km^2$.

  Water is not normally released past the Elliott Dam into the Jordan River. Occasional uncontrolled spills (1-2 times/yr.) can occur during high inflows after the reservoirs in the system are filled to capacity.

- **Jordan River Powerhouse**: The Jordan River powerhouse is located on the west side of the lower end of Jordan River and contains a single 170 MW capacity turbine generator unit. Water is delivered to the powerhouse from Elliott Headpond through a 7.2 km tunnel and penstock. This replaced the old powerhouse and associated tailrace on the east side of the river in 1972.

# 3.0 HYDROLOGY OF THE JORDAN RIVER BASIN

The Jordan River basin is situated in the southern portion of Vancouver Island along the southwest coast. The tributary drainage areas above Bear Creek, Jordan Diversion, and Elliott dams are 23, 97 and 24 $km^2$ respectively. The Jordan River is primarily a rainfall driven basin although snow can occur within the watershed. Precipitation along the coast is high, however, inflows vary considerably throughout the year. Compared to the volume of inflow, the combined storage capacity of the reservoirs and the headpond is small. The Jordan River reservoirs can hold enough water to run the powerplant at full load for approximately 3.5 days (assuming no inflow). A detailed summary of the Jordan River basin hydrology is provided in Appendix 1.

# 4.0 OPERATING CONDITIONS FOR FACILITY

## 4.1 Role of Facility in BC Hydro's System

The Jordan River generating facilities are part of BC Hydro's integrated generation system which is described in BC Hydro's publication *'Making the Connection'* published by BC Hydro in April 2000.

The Jordan River facility is the only major hydroelectric development on the southwest coast of Vancouver Island. The facility has a generating capacity of 170 MW and can contribute up to approximately 35% of total island generation. The Lower Mainland to Vancouver Island submarine cable transmission system supplies approximately 80% of Vancouver Island's electrical demand. Jordan River is operated as a "peaking plant" to meet electrical demands during peak periods. It also plays a very important role in providing voltage control for

the transmission network, and helps to offset the effects of transmission losses that may occur as a result of transmission failures (outages/losses) on the provincial transmission grid system.

## 4.2 Water Use at Jordan River Facility

The Jordan River facility is classified as a "coastal" system with the majority of its water resulting from seasonal rainstorms and to some degree spring snowmelt. As a peaking plant, the Jordan River powerhouse is brought online to meet electricity demands at peak times of the day. As a result, the average daily turbine discharge from the Jordan River generating station varies seasonally and daily with the demand for electricity and the availability of water.

BC Hydro uses all of the available inflow, within the storage and generation limits of the facilities. Spills occur when inflows exceed generation or storage capacity.

## 4.3 Emergencies and Dam Safety

Emergencies and dam safety requirements shall take precedence over the operational constraints outlined in this Water Use Plan. Emergencies include actual and potential loss of power to customers. Dam safety requirements for operations are outlined in the following documents, which are issued by BC Hydro's Director of Dam Safety:

- Jordan River: Operation, Maintenance and Surveillance Requirements (OMS) for Dam Safety.
- Jordan River Dams Emergency Planning Guide.

Operational instructions for surcharging the reservoirs and undertaking a special drawdown for dam safety purposes are described in the OMS Manual for Dam Safety. Community notification procedures are documented in the Emergency Planning Guide.

## 4.4 Operation of Works for Diversion and Use of Water.

The conditions outlined in Table 4-1 are proposed for the operations of the Jordan River hydroelectric system. These conditions will constrain the operation of the works and will require a capital investment to undertake structural change to Elliot Dam. It is recognized that BC Hydro may not be able to operate within these constraints during extreme hydrological events.

**Table 4-1: Recommended Operating Constraints for the Jordan River Hydroelectric System**

| System Component | Constraint | Time of Year | Purpose |
|---|---|---|---|
| Bear Creek Reservoir | BC Hydro shall not operate the low level outlet in a manner which drafts the elevation below 411 m. | All year | Reservoir productivity; recreation |
| Diversion Reservoir | Minimum normal elevation of 376 m.<br>Minimum normal elevation of 372 m.<br>BC Hydro shall not operate the reservoir below the stated minimum elevations. In low water situations, when the reservoir elevation is expected to drop below the normal minimum operating level, BC Hydro shall notify the appropriate federal and provincial agencies and proceed with providing a 0.25 $m^3/s$ flow below Elliott Dam.[2] | 1 Jul-30 Sep<br>1 Oct-30 Jun | Reservoir productivity and reduced fish stress |
| Elliott Headpond Elevations | No operating constraints. | All year | Reservoir productivity |
| Elliott Dam Outlet (new release facility needed) | Base target flow of at least 0.25 $m^3/s$ with an accepted deviation to 0.225 $m^3/s$.[2] | All year | River ecosystem health |
| Turbine Discharge | BC Hydro shall plan to operate the generation with a discharge of not greater than 30 $m^3/s$ from 6:00 am to 6:00 pm on a minimum of 4 weekend days during the month of March. Higher releases are permissible when required to manage basin inflow, or emergency situations. | March | Recreational surfing |

# 5.0 PROGRAMS FOR ADDITIONAL INFORMATION

Development of the operating recommendations for the Jordan River hydroelectric system was complicated by some uncertainties and information gaps. There is uncertainty of the benefits associated with:

- changes in flows downstream of Elliott Dam;
- modifying the minimum level of Diversion Reservoir; and
- altering turbine discharges for recreational surfing on weekend days in March.

[2] During the 4-year monitoring program (post valve installation) the provision of the .25 $m^3/s$ will take priority over the minimum reservoir elevation in low water situations. A flow decision rule has been proposed for future decision-making regarding reservoir elevations at Diversion and the provision of flows below Elliott Dam. This decision rule is outlined in the Jordan River Water Use Plan: Consultative Committee Report, Appendix N.

The operating recommendations are contingent on the implementation of a monitoring program to reduce these uncertainties over time. Accordingly, it is recommended that the Comptroller of Water Rights direct BC Hydro to undertake a monitoring program that will:

- assess expected outcomes of the operational change being recommended;
- provide improved information on which to base future operating decisions.

The main elements of the monitoring program are described in Table 5-1. Estimated annual costs for these studies and associated tasks are summarized in the Jordan River Water Use Plan: Consultative Committee Report.

**Table 5-1: Recommended Monitoring Program for the Jordan River Water Use Plan**

| Study | Description | Uncertainty/ Data Gap | Operational Implications | Time (yrs)[1] Certainty |
|---|---|---|---|---|
| **FISH-River** | | | | |
| Lower Jordan River Discharge and Local Inflow Measurements | Install gauging stations below Sinn Fein Creek and below Elliott Dam. Establish stage discharge relations curves for each station. Monitoring local inflows and accurately estimate the impact of a 0.25 $m^3/s$ base flow on summer and winter minimum flows. | Accuracy of local inflow data used to rationalise a 0.25 $m^3/s$ base flow.<br>Efficacy of a 0.25 $m^3/s$ base flow release into a dry channel to increase downstream habitat. | Local inflows fail or exceed the needs to generate the habitat associated with a 0.25 $m^3/s$ base flow. Revisit necessity of a base flow to generate expected habitat gains. | 2 (4) High |
| Fish Index: Lower Jordan River | Determine direction of rainbow trout standing stock dynamics (fish size and abundance) (±) following 'treatment' with a base flow release. | Relation of habitat increases to actual changes in rainbow trout condition and population. | The base flow release may need to be increased or the efficacy of any base flow not justified for limited or negligible ecological benefits. | 2 (4) Baseline |
| Qualitative Habitat Survey for Salmonids in the Lower Jordan River | Monitor for successful spawning and rearing of salmonids in the Lower Jordan River below the first passage barrier. | Metal toxicity and/or critical low flows impact success of incubation and rearing. Base flow may mitigate against any or none of these impacts. | Increased salmonid success associated with a base flow release will influence future water allocation decisions. | 6 Baseline |

| Study | Description | Uncertainty/ Data Gap | Operational Implications | Time (yrs)[1] Certainty |
|---|---|---|---|---|
| **FISH-Reservoir** | | | | |
| Fish Index: Diversion Reservoir | Gill netting and minnow trapping at end of each growth season to assess indicators of stress. Includes associated water chemistry (dissolved oxygen and temperature). Includes a planned drawdown to elicit response. | Response and level of stress in rainbow trout (if any) associated with drawdowns below 376 m on Diversion Reservoir. | Absence of measurable changes in fish condition would not justify the recommended decrease in reservoir flexibility. | 1 (5) Medium |
| **RECREATION** | | | | |
| Surf Quality | Reduce discharge from power for four weekend days. Communicate with surfing interest to determine if quality of surf enhanced on those days. | Assess whether or not discharge reduction enhances surf quality on those days. | Revisit constraint with potential to change. | 6 Low |

1. Time as pre and (post) data collection and valve installation. Certainty measures: (High) Monitoring study will definitely lead to fine, quantitative discrimination among all of the competing hypotheses including measure of effect size. (Medium) Monitoring study will likely lead to the ability to discriminate quantitatively among some of the competing hypotheses and may quantify effect size. (Baseline) Likely to allow only qualitative comparisons among a few competing hypotheses with little or no sensitivity to effect size.

# 6.0 IMPLEMENTATION OF RECOMMENDATIONS

The operational changes and the monitoring program proposed in this Water Use Plan will be implemented after BC Hydro receives direction from the Comptroller of Water Rights. The proposed monitoring program will take approximately 6 years to complete and will allow for the collection of critical flow information that will help to confirm expected benefits and improve future decision-making. It will also provide time for the design and installation of an appropriate flow release mechanism for Elliott Dam. The following outlines how these proposed changes to operations and the monitoring program would be undertaken.

**Initiate Baseline Monitoring Program (~ 2 years)**

- Develop detailed terms of reference for the monitoring program studies.
- Initiate detailed engineering design work for the flow release mechanism.
- Commence the collection of 2 years of baseline flow information in the Jordan River below Elliott Dam.
- Constrain turbine discharge (power generation) to 30 $m^3/s$ for a total of 4 weekend days in March to address surfing interest.

- Begin monitoring surf quality and the effects of a change in turbine discharge.
- Implement changes to reservoir operations on Diversion Reservoir.
- Begin monitoring the effects of a change in Diversion Reservoir levels.

**Install Flow Release Mechanism and Assess Response (~ 4 years)**

After collecting 2 years of baseline flow information it is recommended the following be undertaken:

- Install flow release mechanism at Elliott Dam.
- Monitor the effects of the flow release for a 4-year period.

**Review Monitoring Results (at ~ year 6)**

After the installation of the flow mechanism at Elliott Dam and the subsequent collection of 4 years of information, it is recommended that BC Hydro, in consultation with the appropriate federal and provincial agencies, review the results of the monitoring program. The results of the monitoring program may trigger a Water Use Plan review.

## 7.0 EXPECTED WATER MANAGEMENT IMPLICATIONS

The provincial interests considered during the preparation of this Water use Plan were:

- value of power;
- recreational opportunities in the reservoirs;
- quality of surfing;
- habitat conditions in the reservoirs for resident fish populations, invertebrates and aquatic life;
- habitat conditions for resident fish populations in the Jordan River below Elliott Dam.

It is expected that the proposed operational changes in this Water Use Plan will have the following consequences for non-power interests. These are expected outcomes based on the best available information. After BC Hydro has been directed to implement the operational changes, BC Hydro will be responsible for meeting the operational parameters but not for achieving the expected outcomes.

## 7.1 Other Licensed Uses of Water

There are no other licensees that draw water from the Jordan River. Western Forest Products has a log sort operation at the mouth of the river. Water is currently drawn from the penstock to supply domestic water to a small group of homes in Jordan River, however this is under review. The recommended changes in operations will not impact domestic water supply. There are water licensees on either side of the Jordan River although they draw water from wells. These water uses will not be affected by the recommended change in operations.

## 7.2 Riparian Rights

The operational changes proposed in this Water Use Plan will not affect riparian rights associated with the reservoirs or along the stream below the facilities.

## 7.3 Fisheries

The implementation of this Water Use Plan is expected to result in improved ecosystem condition and an increase in habitat for resident rainbow and cutthroat trout in the Jordan River from the mouth of the river, up to and including the river 300 m below Elliott Dam. It is also expected that the higher minimum operating elevation at Diversion Reservoir during the summer months will improve aquatic ecosystem conditions - water temperature and water quality - for resident fish in the reservoir.

## 7.4 Wildlife Habitat

The Water Use Plan is expected to have limited effect on wildlife however it is believed that improved habitat for fish on the Jordan River will benefit the overall health of the ecosystem.

## 7.5 Flood Control

The operational changes will not have a significant effect on flood flows in the Jordan River.

## 7.6 Recreation

Primary recreation interests on the Jordan River system are at Bear Creek Reservoir and Diversion Reservoir and includes family-oriented recreation, camping, boating and fishing. Hiking, birdwatching and other activities also occur. Downstream of Elliott Dam, the topography of the valley is very steep and therefore difficult to access. As a result, recreational use is limited but has been known to include, occasional swimming and fishing.

The new operations will have some consequences for recreation on Diversion Reservoir. Specifically, the change in the normal minimum operating level on Diversion Reservoir from May to September will improve accessibility and aesthetics. Reduced turbine discharges for four weekend days in March are expected to enhance surfing conditions.

### 7.7 Water Quality

The Water Use Plan is expected to have a positive effect on water quality in Diversion Reservoir during the summer months.

### 7.8 Industrial Use of Water

There are no industrial uses of water on the Jordan River system that are affected by the recommended changes in operations.

### 7.9 First Nations Considerations

The Jordan River system lies within the traditional territory of three First Nations, including the T'Sou-ke Nation, Pacheedaht First Nation and Ditidaht First Nation. The T'Sou-ke Nation have an interest in re-establishing salmonid populations in the Jordan River in order to be allowed to exercise their fish and wildlife dependent rights under the Douglas Treaty.

The fish species of interest to the T'Sou-ke Nation no longer inhabit the Jordan River system due to the complex interaction between industrial activities and changes to the environment. This interaction and the factors leading to the decline of salmonid populations is not well understood. It is believed however that the provision of a base flow in the Jordan River will improve fish habitat. It is not known if the habitat will be conducive to the re-establishment of salmonid populations.

## 8.0 RECORDS AND REPORTS

### 8.1 Compliance Reporting

BC Hydro will submit data as required by the Comptroller of Water Rights to demonstrate compliance with the conditions conveyed in the Water Licenses. The submission will include records of:

- Bear Creek Reservoir elevation.
- Diversion Reservoir elevation.
- Elliott Dam flow release.
- Powerhouse discharge on weekend days during March.

### 8.2 Non-compliance Reporting

Non-compliance with any operating ordered by the Comptroller of Water Rights will be reported to the Comptroller in a timely manner.

### 8.3 Monitoring Program Reporting

Reporting procedures will be determined as part of the terms of reference for each study or undertaking.

## 9.0 PLAN REVIEW

A review of this Water Use Plan is recommended after 6 years of its implementation. A review may be triggered sooner if scientific data or significant new risks are identified that could result in a change to operations.

## 10.0 NOTIFICATION PROCEDURES

Notification procedures for floods and other emergency events are outlined in the "Jordan River Dam Emergency Planning Guide" and the "Power Supply Emergency Plan (PSEP)": South Vancouver Island Generation (Comox/Puntledge, Elsie Lake, and Jordan River Generating Facilities). Both these documents are filed with the Office of the Comptroller of Water Rights.

# Appendix 1
# Jordan River Basin Hydrology

# Inter-office memo

| | | |
|---|---|---|
| TO: | Eric Weiss | 6 December 2001 |
| FROM: | Lara Taylor | File: |
| SUBJECT: | Jordan River Projects - Basin Hydrology | |

## INTRODUCTION

As requested, the following sections summarize the hydrology of the Jordan River hydroelectric system. Physiography and climatology are reviewed for the combined areas of the Bear Creek, Jordan River diversion and Elliott watersheds.

Methods used to calculate reservoir inflows, such as BC Hydro's FLOCAL program, are discussed. Typical inflow hydrographs and summaries are provided. Flow records for the Jordan River system referred to in this report were used in power studies conducted for the Jordan River Water Use Plan.

Procedures used to provide daily inflow, such as FLOCAST, and seasonal volume inflow forecasts are also described.

### 2.1 Physiography[1]

The drainage basin for the Jordan system is shown in Figure 1. The Jordan River basin is situated in the southern portion of Vancouver Island along the western coast. The mouth of the river is approximately 50 km northwest of Victoria and discharges into the Pacific Ocean. The tributary drainage areas above Bear Creek, Jordan River Diversion, and Elliott dams are 23, 97 and 24 $km^2$ respectively.

The Jordan River originates in the north-east portion of the basin and meanders in a south-westerly direction for approximately 12 km to its junction with Bear Creek (Bear Creek dam is on Bear Creek two km upstream of the junction). The river

[1] BC Hydro. March 1985. "Jordan River Project: Probable Maximum Precipitation", BC Hydro Hydroelectric Generation Projects Division, Report No. H1588.

continues for another kilometer prior to entering Jordan River Diversion Reservoir. Releases from the diversion dam flow southward 2 km to Elliot Reservoir. The majority of the flow released from Elliott Dam is carried through a power tunnel and surface penstock a distance of 7 km to the Jordan River Generating Station on the coast. Spill flows are released into the Jordan River from Elliott dam and flow southward along the natural river channel into the Pacific Ocean.

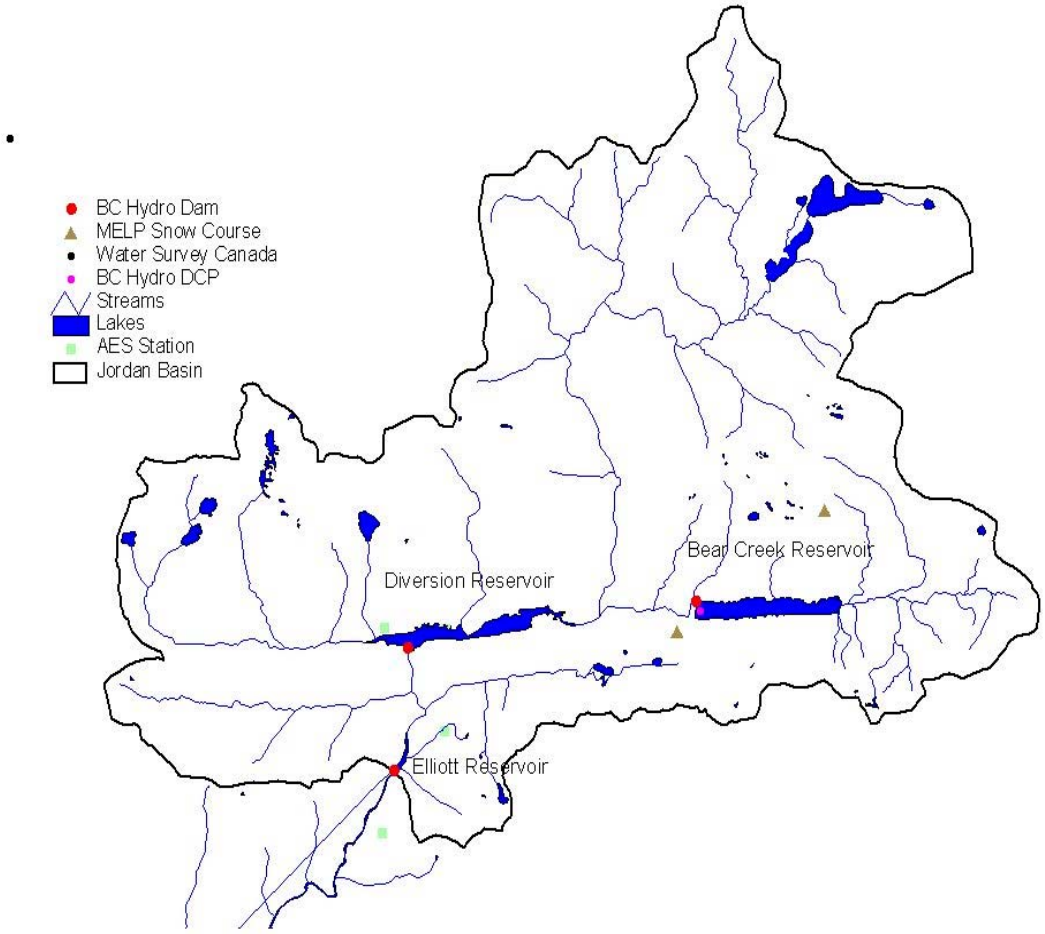


***Figure 1: Jordan River Projects Drainage Basin***

Elevations within the Jordan River basin range from 300 m to approximately 1000 m. The median basin elevation is 640 m as indicated in the hypsometric curve shown in Figure 2. The curve defines the percentage of the watershed above or below a given elevation. The terrain varies from forest in the valleys to exposed rock at upper elevations. The basin limits are defined by a combination of steep mountain ranges, gently sloping ridges, and relatively flat meadows. There are no glaciers within the watershed.

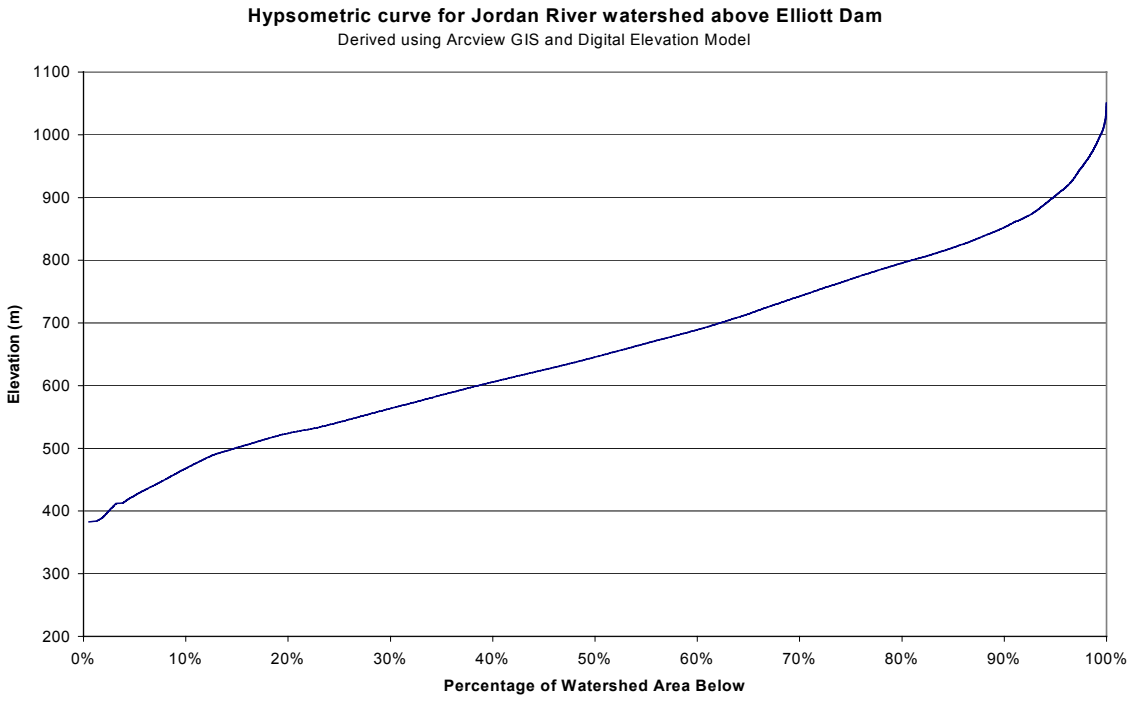


***Figure 2: Hypsometric Curve for the Jordan River Watershed***

The Bear Creek Reservoir, which is impounded by the Bear Creek Dam, is approximately 2.7 km long. The stage-storage relationship shown in Figure 3a indicates the storage capacity of the reservoir at different reservoir elevations. Since 1994, the reservoir has been operated such that inflow passes through the reservoir with little storage or regulation. The normal operating elevation is El. 411.0 m which corresponds to the crest of the spillway. The low level outlets typically remain closed and inflows are spilled over the crest of the spillway.

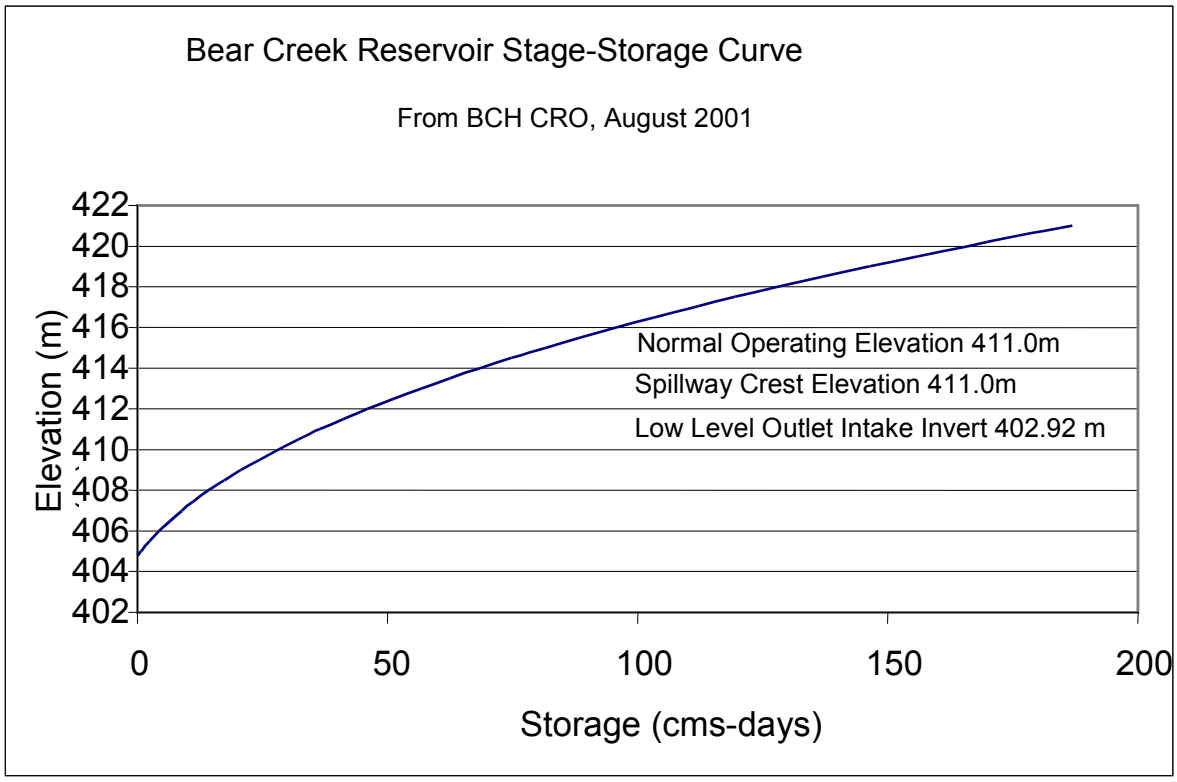


***Figure 3a: Stage-Storage Curve for Bear Creek Reservoir***

The Jordan Diversion Reservoir, which is impounded by the Jordan Diversion Dam, is approximately 5 km long. The stage-storage relationship shown in Figure 3b indicates the storage capacity of the reservoir at different reservoir elevations. Storage available within the normal operating range of El. 367.9 - 386.2 m is estimated from the stage-storage curve at about 196 cms-days (17 $Mm^3$).[2]

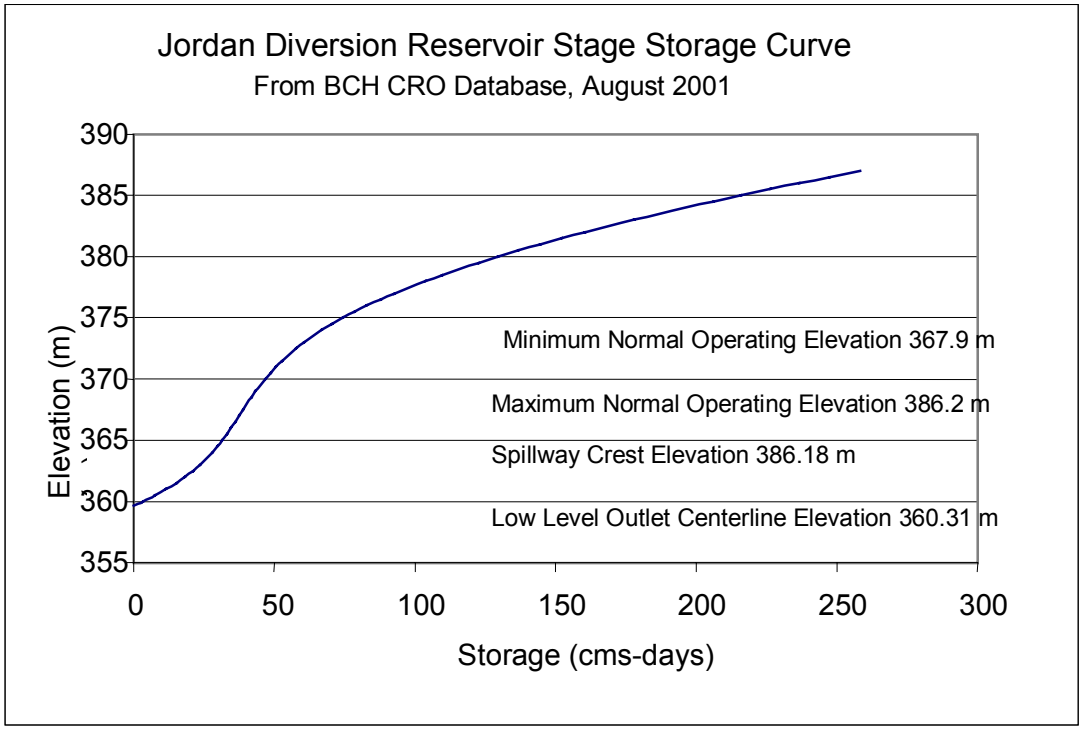


***Figure 3b: Stage-Storage Curve for Jordan Diversion Reservoir***

[2] BC Hydro. October 2000. System Operating Order 4P-34 – Jordan River Projects

The Elliott Reservoir, which is impounded by the Elliott Dam, is approximately 1.7 km long. The stage storage relationship shown in Figure 3c indicates the storage capacity of the reservoir at different reservoir elevations. Storage available within the normal operating range of El. 325.2 - 335.9 m is estimated from the stage-storage curve at about 14 cms-days (1.2 $Mm^3$). [2]

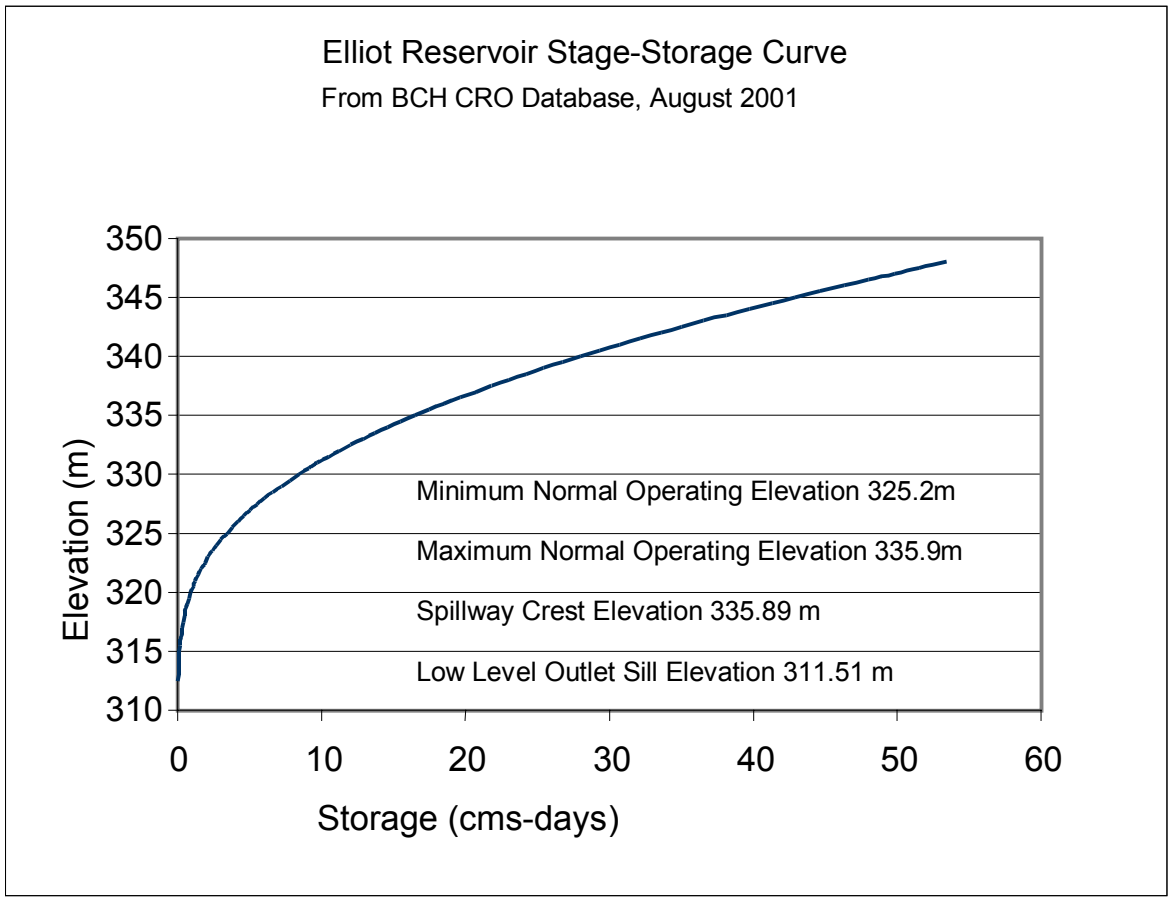


***Figure 3c: Stage-Storage Curve for Elliott Reservoir***

## 2.2 **Climatology**[1]

The dominant type of precipitation in the region occurs as a result of the confrontation of the pacific air masses with the west-facing mountain slopes all along the coast. This results in extremely prolonged and sometimes heavy rainfalls on the slopes due to the upward drift of moist air whenever a pacific cyclone approaches.

There are effectively two climatic seasons. The first, from late September or early October onwards until late February or March, is marked by the continual procession of Pacific westerlies which are occasionally broken up by the development of high pressure areas. These frontal storms and their associated strong, south-westerly flows of warm, moist air aloft are responsible for the region's heaviest rainfalls for durations greater than one or two hours. During the second climatic season, April to September, a high-pressure ridge tends to dominate off the coast. This situation persists throughout the season, occasionally being interrupted by frontal activity.

Figure 4 shows a bar chart of normal monthly precipitation. Minimum and maximum monthly precipitation is indicated to illustrate the variability in the data. As can be seen from the plot, over three-quarters of the annual precipitation normally falls between October and March. A probable maximum precipitation event of 1208 mm over 4 days has been estimated for the basin[1].

Figure 5 shows maximum, mean, and minimum daily temperatures at Bear Creek DCP.

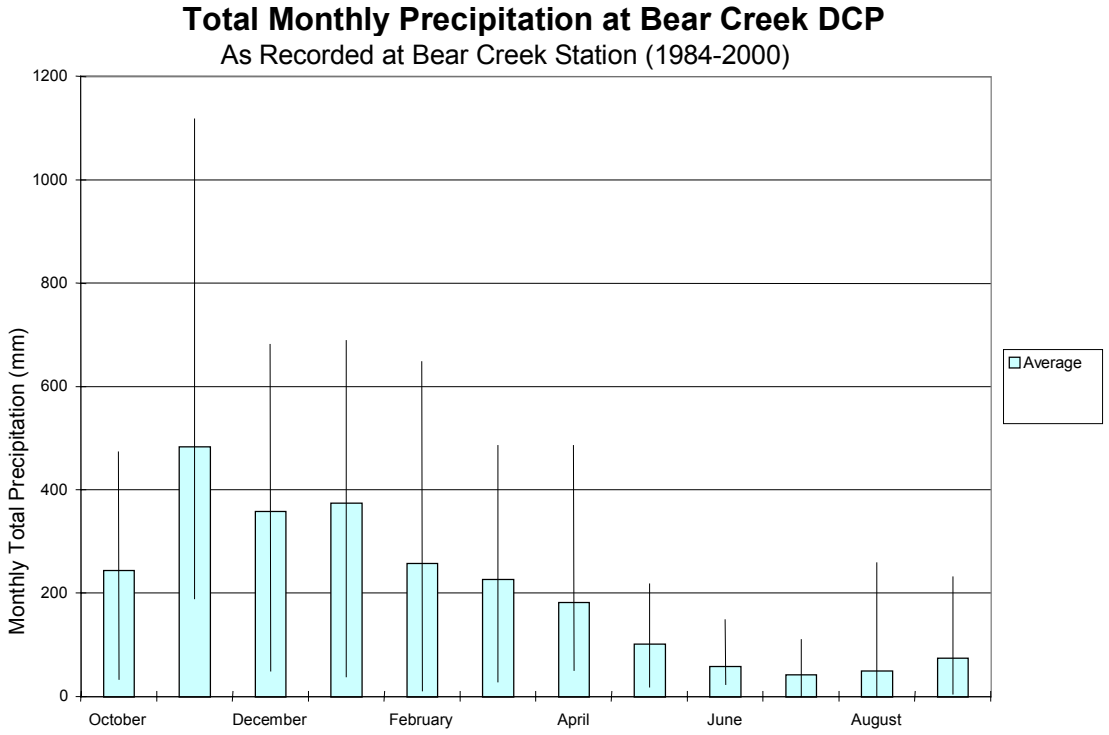


*Figure 4: Total monthly precipitation at Bear Creek DCP*

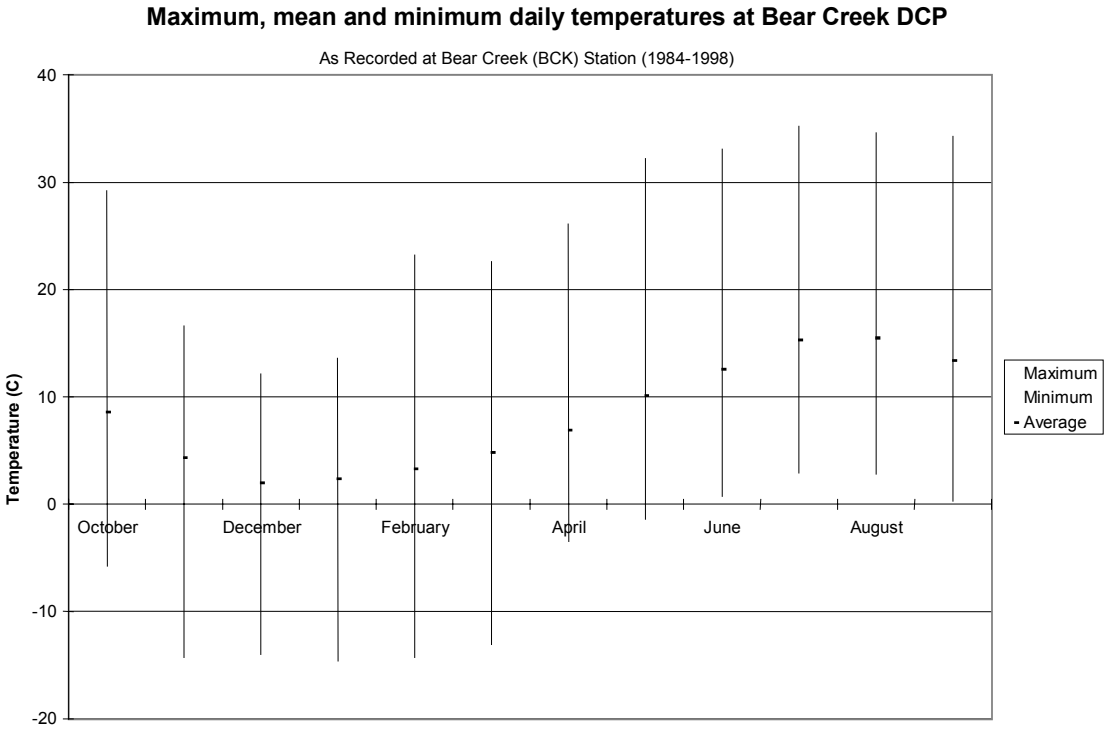


*Figure 5: Maximum, mean and minimum daily temperatures at Bear Creek DCP*

Figure 6 shows the maximum, mean, and minimum snow water equivalent for Sno-Bird snow course (3B16) located at 1400 m elevation.

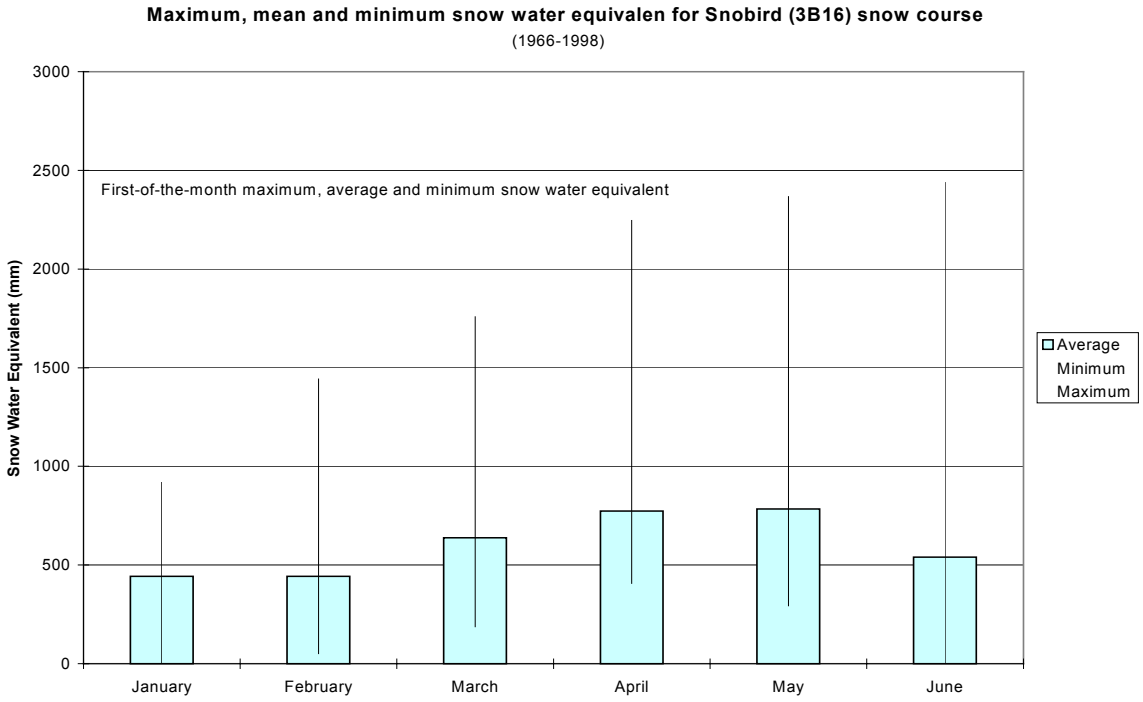


***Figure 6: Maximum, mean and minimum snow water equivalent for Snobird (3B16) snow course***

## 3.1 Inflow calculations

*Reservoir inflow calculations*: Inflow is the volume of water entering a reservoir within a given period of time. Reservoir inflows are calculated rather measured directly. Daily inflows may be derived from mean daily discharge from the reservoir and change in reservoir storage over a period of 24 hours.

The generic formula is:

$$\text{INFLOW} = \text{OUTFLOW} + \Delta\ \text{STORAGE} \quad \text{..... (1)}$$

where INFLOW = average inflow over a one - day period

OUTFLOW = average outflow over a one - day period

$\Delta$ STORAGE = S2 - S1, where

S2 = reservoir storage at the end of the day

S1 = reservoir storage at the end of the previous day

Reservoir storage for a specific reservoir elevation is derived from a stage – storage curve unique to each reservoir.

The nature of the calculation of inflows can result in "noisier" hydrographs than observed at unregulated, natural river channels. Noisy inflows can arise due to various sources of error, such as wind set up on the reservoir, resolution of elevation measurements, errors in reservoir elevation readings, errors in outflow measurements through turbines, spillways or valves, errors in stage-storage curves and errors in the rating curves for various outlet facilities. The impact of noise tends to reduce as the time interval over which inflow is computed increases.

*Storage relationships:* Storage relationships used to determine the volume of water in Jordan Diversion, Bear Creek and Elliott Reservoirs are shown in figures 3a, 3b and 3c.

*Outflow relationships:* Flow through turbines at the Jordan River power house is computed based on megawatt output and hydraulic head. "Hydraulic head" is a measure of the vertical distance between the water level in the reservoir and the water level immediately below the turbine outlet. Power output is proportional to head. A generic relationship between these variables is shown in figure 7.

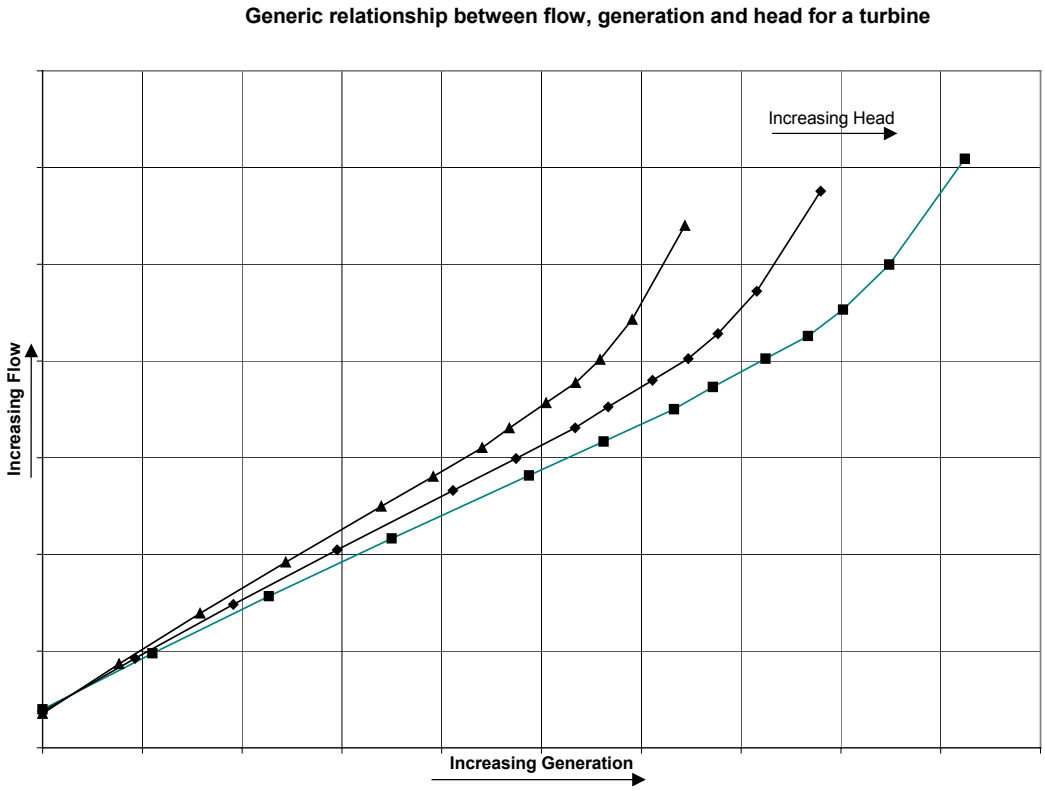


*Figure 7: Generic relationship between flow, generation, and head for a turbine*

Spillway rating curves are used to compute flow passed over a spillway. "Rating curves" show the relationship between flow, opening, and elevation for a given release device. Spillway rating curves for Bear Creek, Jordan Diversion and Elliott are shown in figures 8 a-c.

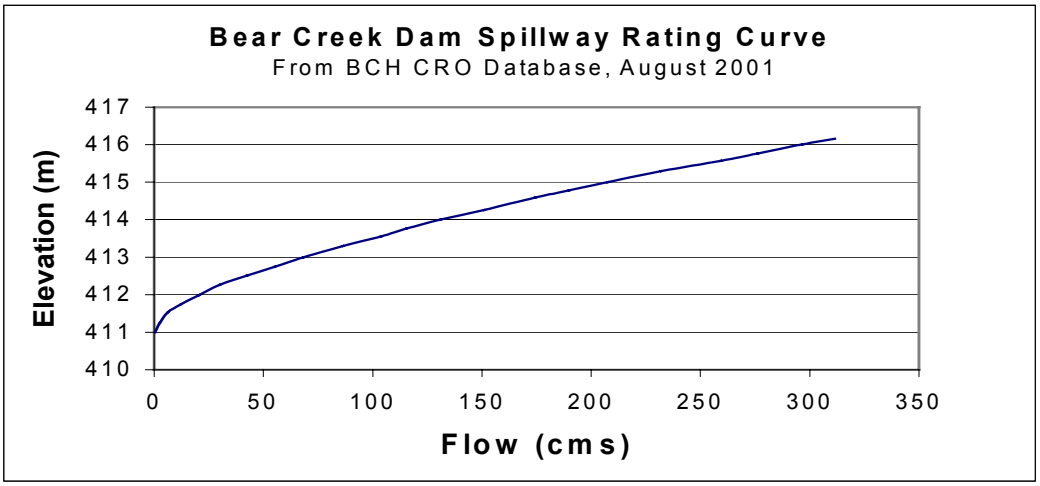


*Figure 8a: Spillway Rating Curve for Bear Creek Dam*

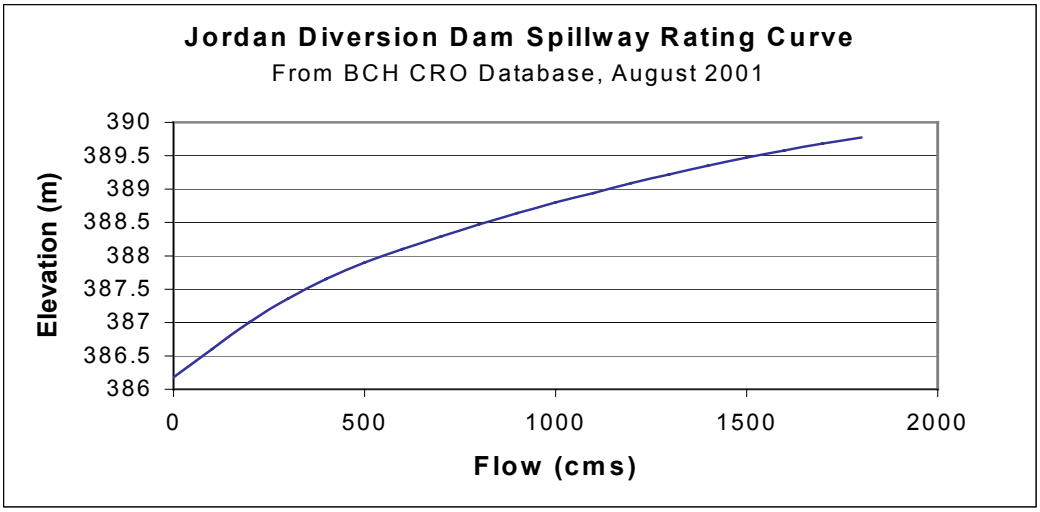


*Figure 8b: Spillway Rating Curve for Jordan Dam*

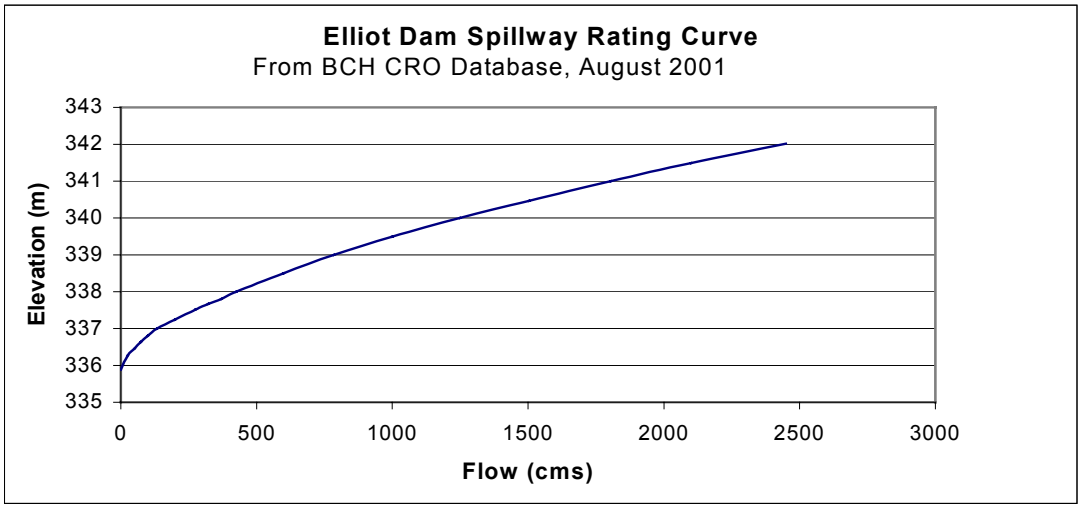


*Figure 8c: Spillway Rating Curve for Elliott Dam*

Rating tables for low-level outlet works are used to compute flow through those works. All three dams have low-level outlet works; their rating curves are shown in Figures 9a-c.

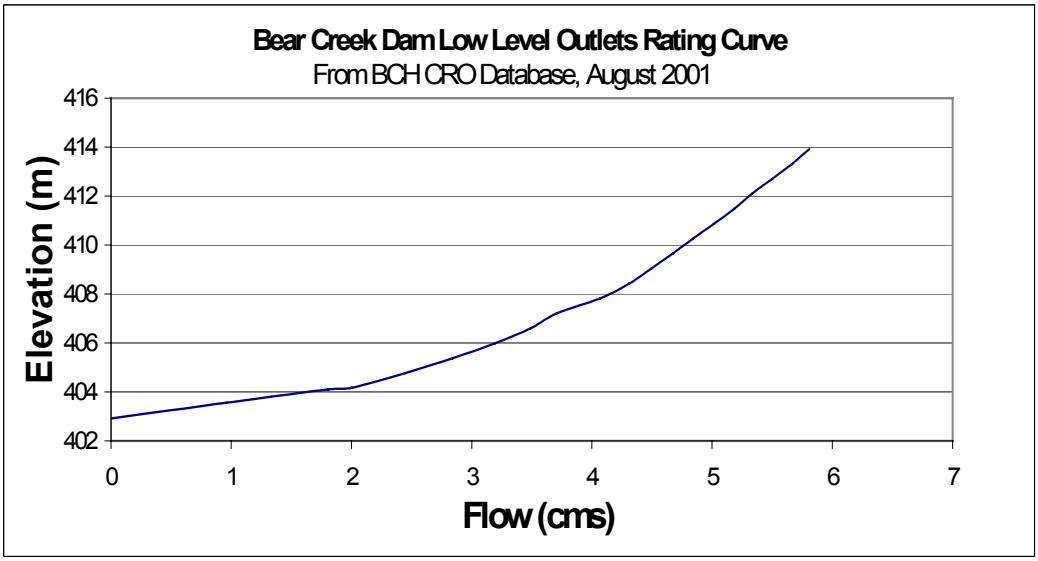


*Figure 9a: Low Level Rating Curve for Bear Creek Dam*

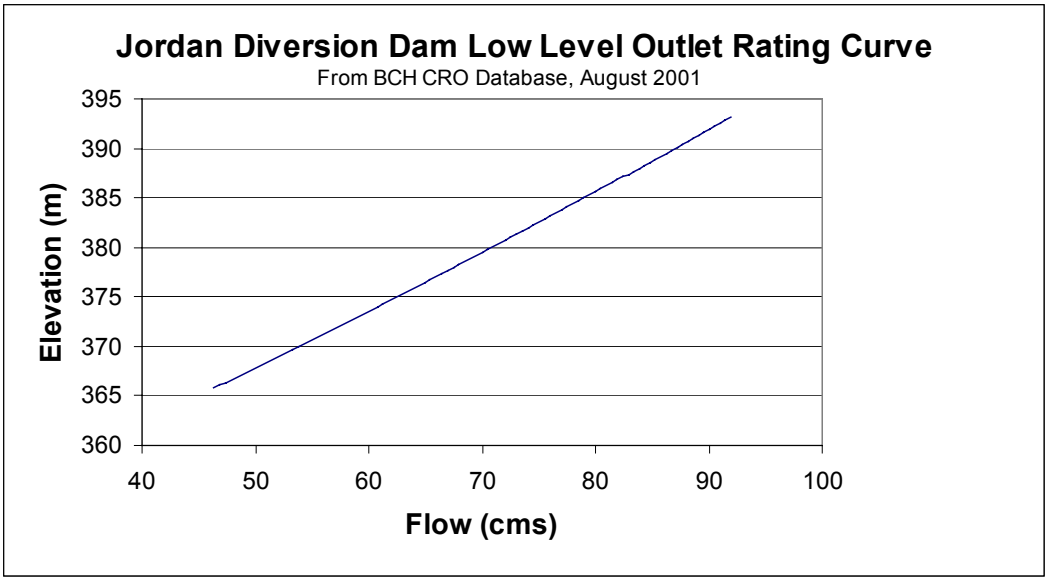


*Figure 9b: Low Level Rating Curves for Jordan Dam*

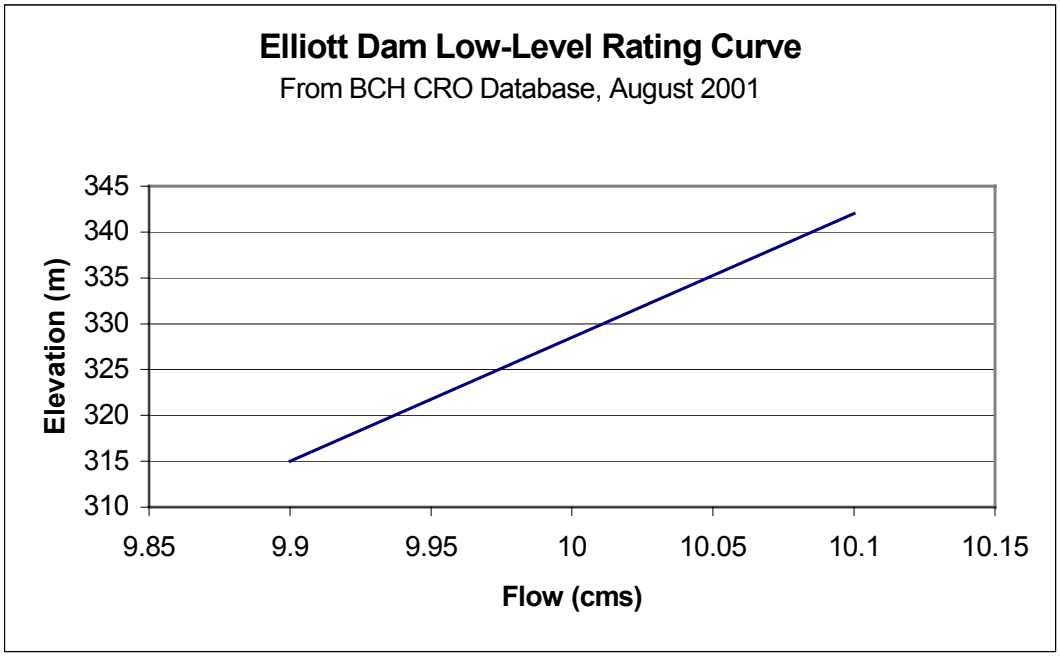


***Figure 9c: Low Level Rating Curve for Elliott Dam***

*Data records*: BC Hydro computes inflow using a computer program called FLOCAL. Specifically;

Inflows to Bear Creek Reservoir are computed based on equation (1).

Total inflow to the Jordan Diversion Reservoir is computed using equation (1).

Local inflow to the Jordan Diversion Reservoir is equal to the total inflow to the reservoir less the regulated inflows from Bear Creek Reservoir.

Total inflow to Elliott Reservoir is computed using equation (1).

Local inflow to Elliott Reservoir is equal to the total inflow to the reservoir less the regulated inflows from Jordan Diversion Reservoir.

Various information, including gate openings, reservoir and tailwater elevations, energy, spill, turbine flows, and inflows are stored in FLOCAL. A FLOCAL configuration for Bear Creek, Jordan Diversion and Elliott is shown in Figure 10.

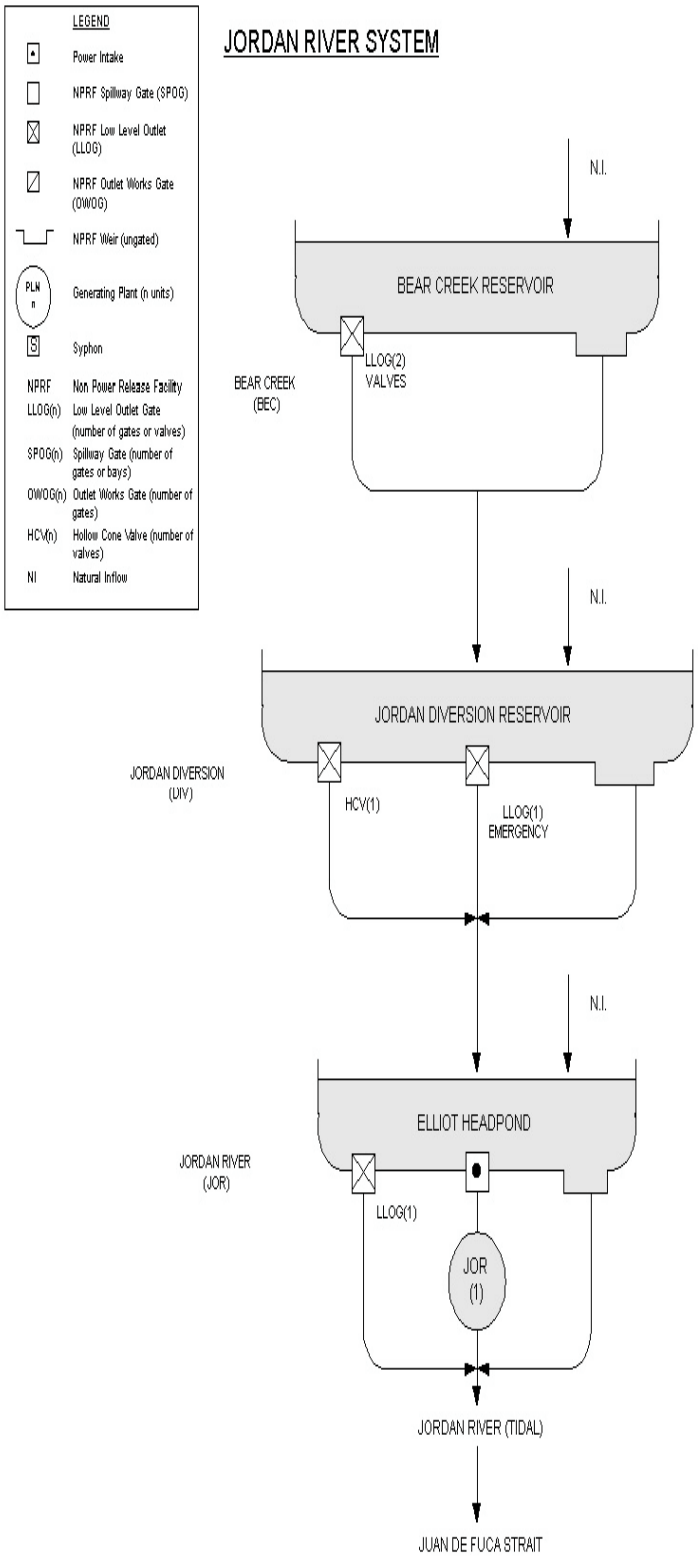


***Figure 10: Schematic of the FLOCAL configuration for the Jordan River system***

## 3.2 Reservoir inflow characteristics

Figure 11 shows a plot of historical inflows to the Jordan River Projects (daily hydrograph for all years plotted on same graph). The 10th, 50th and 90th percentile inflows are shown in bold.

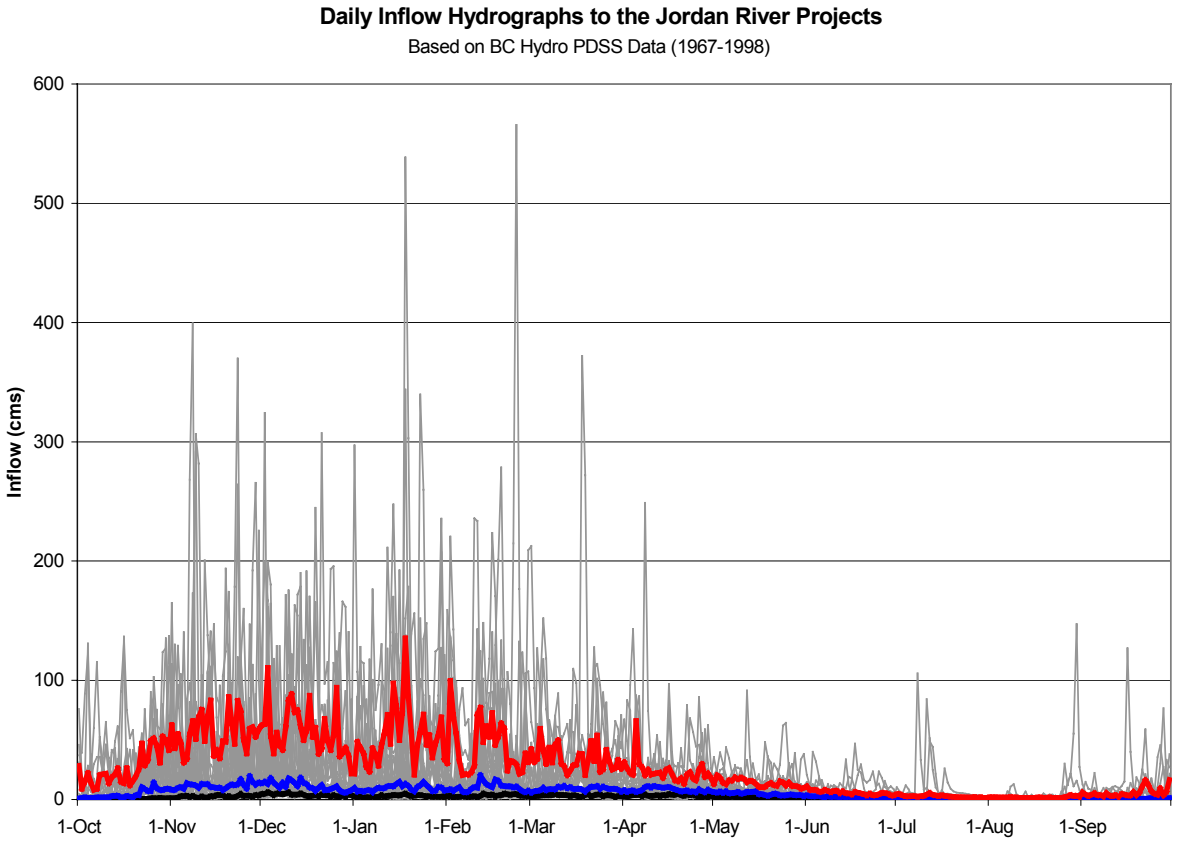


***Figure 11: Historical Daily Inflows for the Jordan River Projects***

Figure 12 and Table 1 summarize the daily inflows by month. Average monthly and maximum and minimum daily inflows are shown to highlight the variability of inflows to the projects. A "duration curve" indicates the percent of time that a parameter is greater than a specified level. Figures 13 and 14 show duration curves of daily inflow and annual inflow for the years 1966-1998. These figures again illustrate the large range and variability of inflows to the projects.

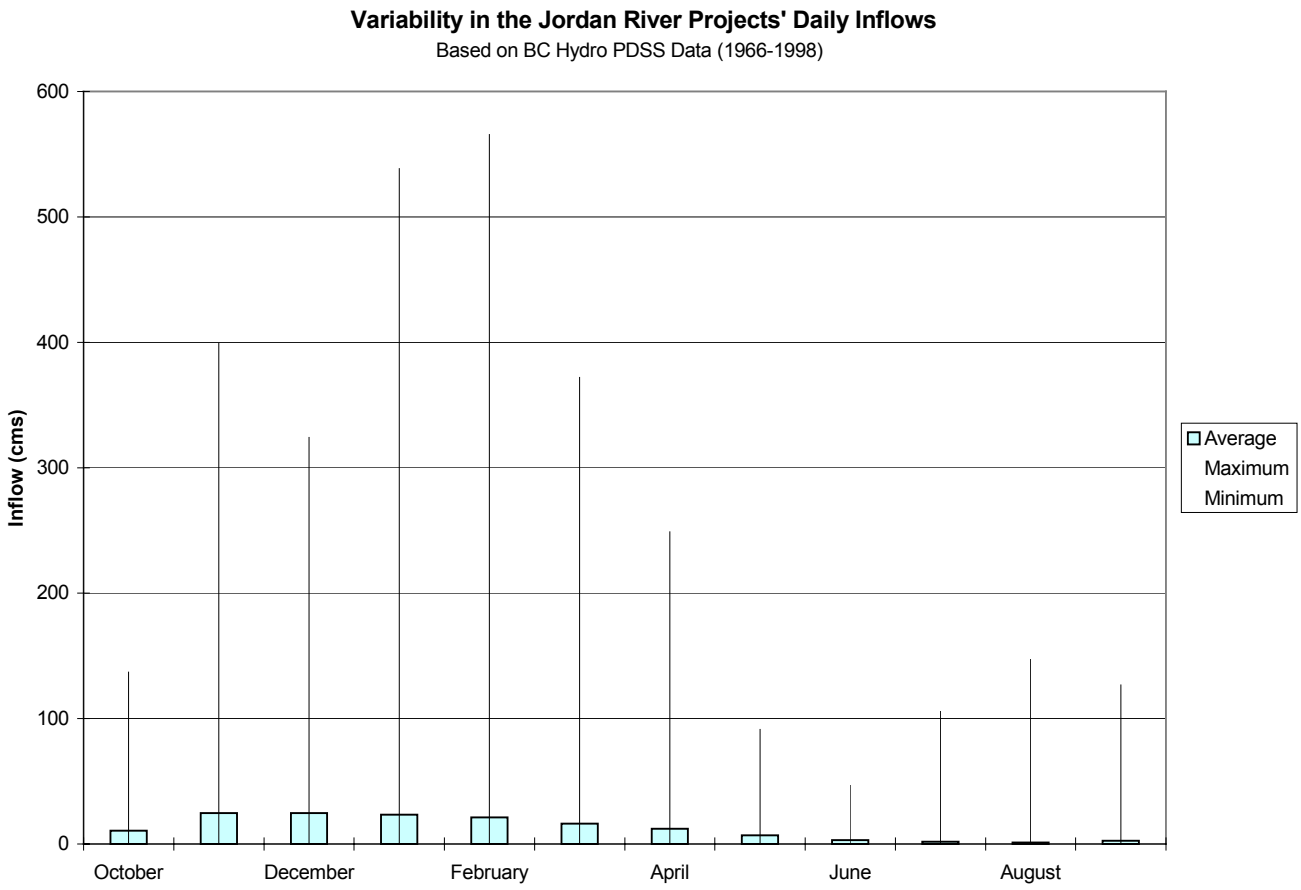


*Figure 12: Variability in Jordan River Projects' daily inflows*

*Table 1: Jordan River Project's daily inflow (1966-1998)*

| | Minimum Daily Inflow (cms) | Maximum Daily Inflow (cms) | Average Daily Inflow (cms) |
|---|---|---|---|
| **October** | <1 | 137 | 11 |
| **November** | <1 | 399 | 25 |
| **December** | <1 | 324 | 25 |
| **January** | <1 | 539 | 23 |
| **February** | <1 | 566 | 21 |
| **March** | <1 | 372 | 16 |
| **April** | <1 | 249 | 12 |
| **May** | <1 | 91 | 7 |
| **June** | <1 | 47 | 3 |
| **July** | <1 | 106 | 2 |
| **August** | <1 | 147 | 1 |
| **September** | <1 | 127 | 3 |

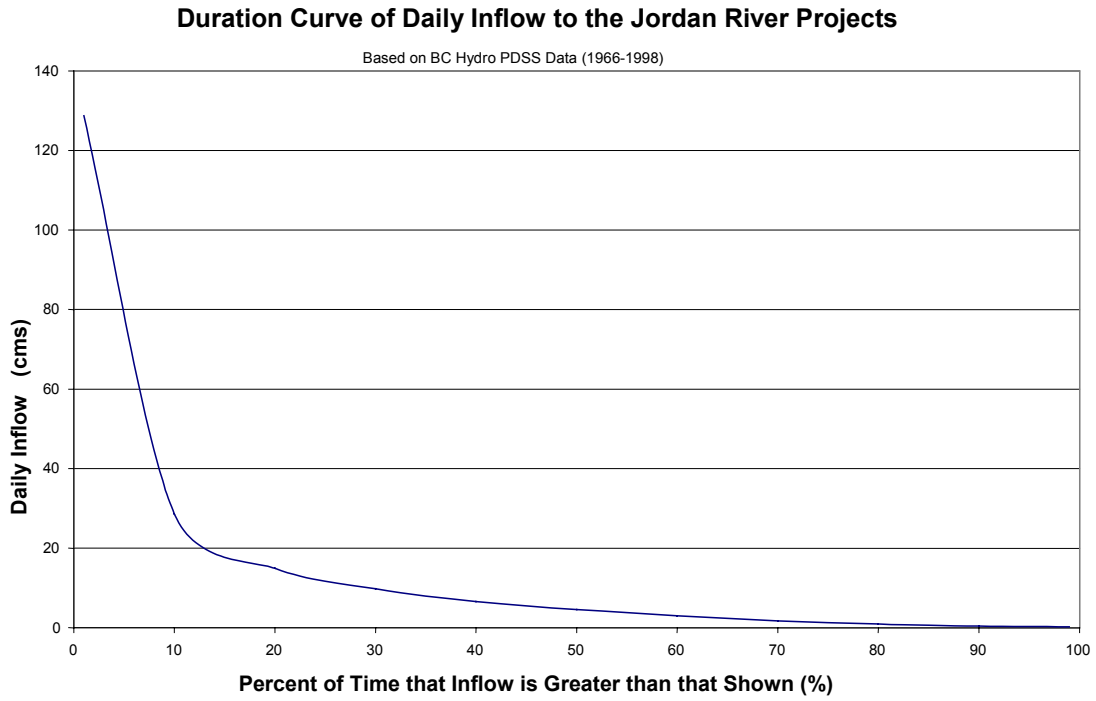


*Figure 13: Duration curve of daily inflows to the Jordan River Projects*

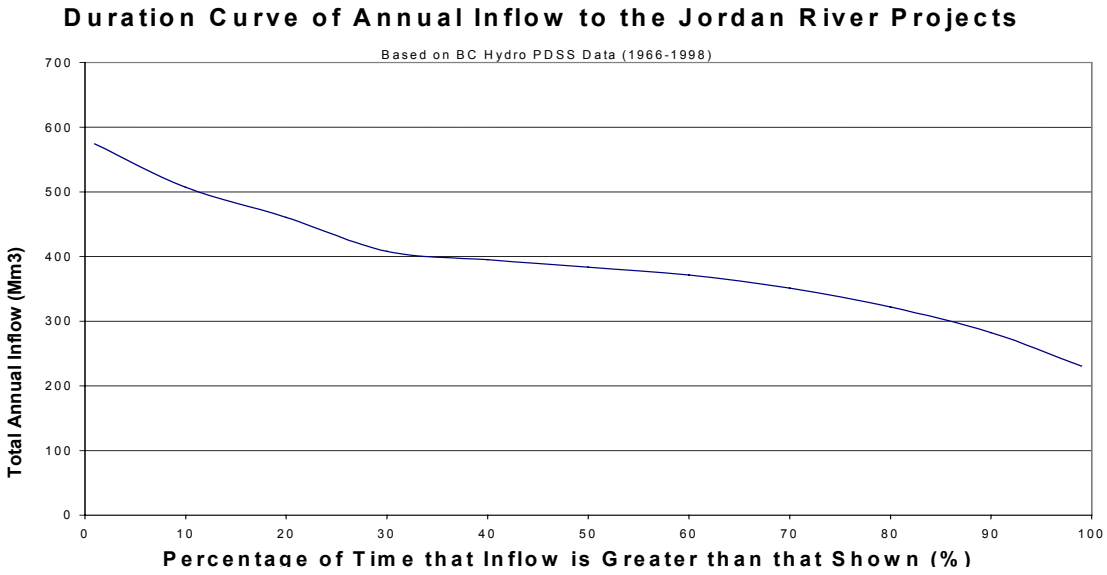


*Figure 14: Duration curve of annual inflows to the Jordan River Projects*

Figure 15 shows a comparison between the mean annual local inflow and total live storage available at a number of project reservoirs.

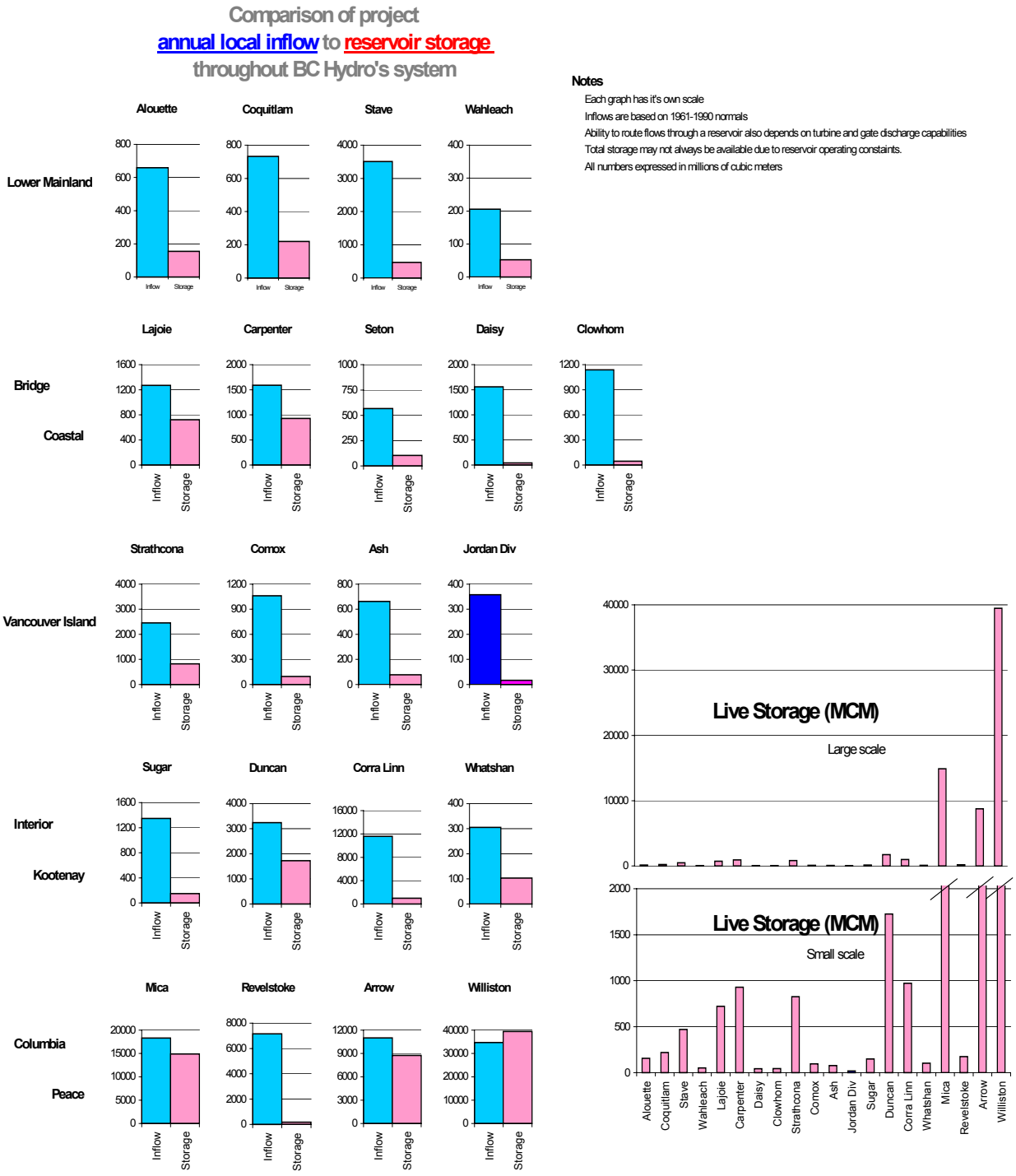


***Figure 15: Comparison of project annual inflows to reservoir storage throughout BC Hydro's system***

## 4 Operational inflow forecasting

BC Hydro's Resource Management produces two main types of hydrologic forecasts: daily inflow and seasonal volume inflow forecasts for the Jordan River Projects.

*Daily inflow forecasts:* Daily inflow forecasts are short-term forecasts that indicate the inflow expected over the next few days. An in-house conceptual watershed model, FLOCAST, is currently used to produce these forecasts. Each morning of each working day, Resource Management enters observed and forecast precipitation, temperature, and freezing level data into the model to forecast inflow over each of the next five days.

*Volume inflow forecasts:* Volume inflow forecasts estimate the volume of water that is expected to flow in to the Jordan River Projects during a given period. BC Hydro typically produces forecasts for the period February through September. Volume inflow forecasts are issued beginning January 1 of each year. The forecasts are updated on the first of each month until August 1.The ability to forecast seasonal runoff for this period lies in the fact that much of the runoff during the forecast period is the product of snowmelt runoff. By measuring snow water equivalent in the mountain snowpack, as well as other parameters such as precipitation and streamflow up to the forecast date, a more accurate estimate of future runoff can be made than one based on historical inflow data alone.

## 5 Hydrometeorologic network

Hydrometeorological data is required to plan, monitor, and operate facilities in the Jordan River Projects' watersheds. The characteristics of the hydrometeorological data collection stations used for inflow forecasting are summarized in table 2. Locations of hydrometeorological stations are shown in Figure 1.

***Table 2: Hydrometeorological stations used for inflow forecasting for the Jordan River Projects***

| Station | Type | ID | Elev (m) | Lattitude | Longitude | Characteristics |
|---|---|---|---|---|---|---|
| Bear Creek | DCP | BCK | 419 | 48.50 | 123.91 | Climate |
| Cowichan Lake Forestry | EC | | 177 | 48.83 | 124.13 | Climate |
| Elsie Lake | DCP | ASH | 340 | 49.43 | 125.14 | Climate |
| Eric Creek | DCP | ERC | 280 | 49.60 | 125.30 | Climate |
| Heather Mountain | MELP | 3B13 | 1170 | 48.95 | 124.45 | Snow Course |
| Port Alberni | EC | | 2 | 49.25 | 124.83 | Climate |
| Shawnigan Lake | EC | | 138 | 48.65 | 123.63 | Climate |
| Snow Bird | MELP | 3B16 | 1400 | 49.05 | 124.33 | Snow Course |
| Sooke Lake North | EC | | 231 | 48.57 | 123.65 | Climate |
| Victoria (Sooke) | DCP | WIR | 27 | 48.37 | 123.73 | Climate |

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