Shuswap River Water Use Plan (Shuswap Falls & Sugar Lake Project)

Revised for Acceptance by the Comptroller of Water Rights

18 August 2005

BC hydro

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C.D. Matheson
Manager, Operations

Preface

The Shuswap River water use planning process for BC Hydro's Shuswap Falls and Sugar Lake Project was initiated in March 2000 and completed in April 2002.

The operational changes proposed in this Water Use Plan reflect the recommendations of the Shuswap 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. The proposed conditions for the operation of BC Hydro's facilities will come into effect when and as Ordered by the Comptroller of Water Rights within his authority under the *Water Act*.

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1.0 INTRODUCTION

The operating conditions proposed in this Water Use Plan reflect the April 2002 recommendations of the Shuswap 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 Shuswap Falls and Sugar Lake Project are set out in this document. Future reference to the Shuswap Falls and Sugar Lake Project includes all the works including: Sugar Lake (Peers) Dam and Reservoir; Wilsey Dam and headpond; and the Shuswap Falls generating station.

The proposed operating conditions for these facilities are expected to continue to augment flows for fish from the fall through to spring as well as provide for continued recreational opportunities on Sugar Lake Reservoir and the Shuswap River. It is also expected that the operating levels in Sugar Lake Reservoir will benefit fish and aquatic productivity in the reservoir. In addition, the proposed installation of a new headpond structure at Wilsey Dam is expected to benefit fish downstream of Wilsey Dam by improving the stability of downstream flows in the river during unplanned outages.

A monitoring program and a review period are proposed in order to determine key uncertainties, to reinforce operational recommendations and to enhance future operating decisions. Refer to the *Shuswap River Water Use Plan: Consultative Committee Report* dated December 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.

The operating conditions proposed in this Water Use Plan reflect the many interests represented by members of the Consultative Committee including fisheries, dam safety, flood routing, wildlife, recreation, heritage resources, power and economic development. The Consultative Committee ultimately selected the operating alternative that met their collective interests for Sugar Lake Dam and Reservoir and flows downstream Wilsey Dam. Where agreement by consensus was not reached for Wilsey Dam, BC Hydro has provided recommendations based on the majority interest expressed during the consultative process.

2.0 DESCRIPTION OF WORKS

2.1 Location

BC Hydro's Shuswap Falls and Sugar Lake hydroelectric project is located on the Shuswap River, east of Vernon in the southern interior of British Columbia. The facilities can be reached by secondary road off Highway 6, which is the main transportation corridor between the Okanagan and Arrow Valleys.

2.2 Existing Works

The Shuswap Falls and Sugar Lake project consists of Wilsey Dam and headpond at Shuswap Falls and Sugar Lake Dam and Reservoir located 35 km and 70 km respectively east of Vernon on the Shuswap River. These hydroelectric developments include the following components.

(a) Sugar Lake Dam impounds the upper Shuswap River at its headwaters forming Sugar Lake Reservoir over the original lake. All releases from Sugar Lake Dam discharge into the Shuswap River.

(b) Downstream from Sugar Lake Reservoir, local inflows, primarily from Cherry and Ferry creeks, combine with the Sugar Lake Dam discharges to provide inflow to Wilsey Dam forebay.

(c) Wilsey Dam, spillway, headpond and powerhouse are approximately 29 km downstream of the Sugar Lake Dam on the Shuswap River. All releases from Wilsey Dam are discharged into the Shuswap River that subsequently flows into Mabel Lake.

2.2.1 Sugar Lake Dam and Reservoir

Sugar Lake Dam is a 150 m long and 13 m high concrete buttress dam that provides storage and regulation for the Shuswap Falls generating station located 29 km downstream. The discharge facilities consist of 4 low level outlets and an overflow spillway with 14 bays. Following the freshet, the crest of each bay can be raised from El. 600.00 m to El. 601.72 m with the addition of up to 6 stoplogs in each bay.

The dam was originally constructed in 1929 as a 5.2 m high overflow dam. In 1942, the dam was raised to 13 m and the existing low level outlets were added. In 1975, timber facing on the spillway bays was replaced with precast concrete sections. In 1985 and 2002, the dam and abutments were upgraded to accommodate current seismic criteria and the Probable Maximum Flood.

Normal operating levels of Sugar Lake Reservoir range between 589.64 m and 601.72 m. Water levels measured at the Sugar Lake, upstream from the dam, do not generally go lower than 594.70 m because of a natural restriction between the main body of the reservoir and the release facilities at the dam. The storage capacity of the reservoir is approximately 133.7 million m^3.

2.2.2 Wilsey Dam and Shuswap Falls Generating Station

Wilsey Dam is a 43 m long and 30 m high concrete arch dam constructed in 1929. A free overflow arch spillway is located to the right of Wilsey Dam.

The two low level outlets in Wilsey Dam were closed in 1991 by bolting stainless steel plates over passages in the arch dam. This was done because the practice of releasing water and sediment through the low level outlets was no longer accepted by the environmental regulatory agencies.

The 6 MW powerhouse is located 140 m downstream of Wilsey Dam on the left bank of the Shuswap River. Two intakes supply the generating units. The unit 2 penstock has a hollow cone bypass valve which was installed in 1993 to permit an alternate means to release water from the penstock other than via the turbine during unplanned outages (Q_{max}=19.2 m^3/s).

Inflows to Wilsey Dam forebay comprise discharge from Sugar Lake Dam plus the local inflows, primarily supplied from Cherry and Ferry creeks. Any inflows that are above the maximum turbine capacities of the generating station (Unit 1 = 16.4 m^3/s and Unit 2 = 15.2 m^3/s) are spilled.

The Wilsey Dam overflow spillway crest can be raised from El. 444.52 m to El. 445.43 m by installing flashboards. The flashboards are normally installed in the fall to raise the Wilsey Dam headpond elevation. This provides increased head for power production and reduces the risk of frazil ice buildup in the headpond and at the intake. Frazil ice is reduced by lowering the headpond water velocity and by providing an insulating cushion of water. The flashboards are removed prior to the freshet to avoid damage caused by the high water volumes and debris that spill over the crest of the spillway during the freshet.

A headpond controller, located in the powerhouse, adjusts generation to maintain the headpond level within 2 cm of the spillway crest. Two water level tranducers (primary and standby) provide water level indications to the headpond controller. The controllers prevent excessive drafting of the headpond and minimize spilling over the weir as flows change. In the event of a unit failure, the controller increases the generation of the remaining unit, if possible, to restore downstream flows.

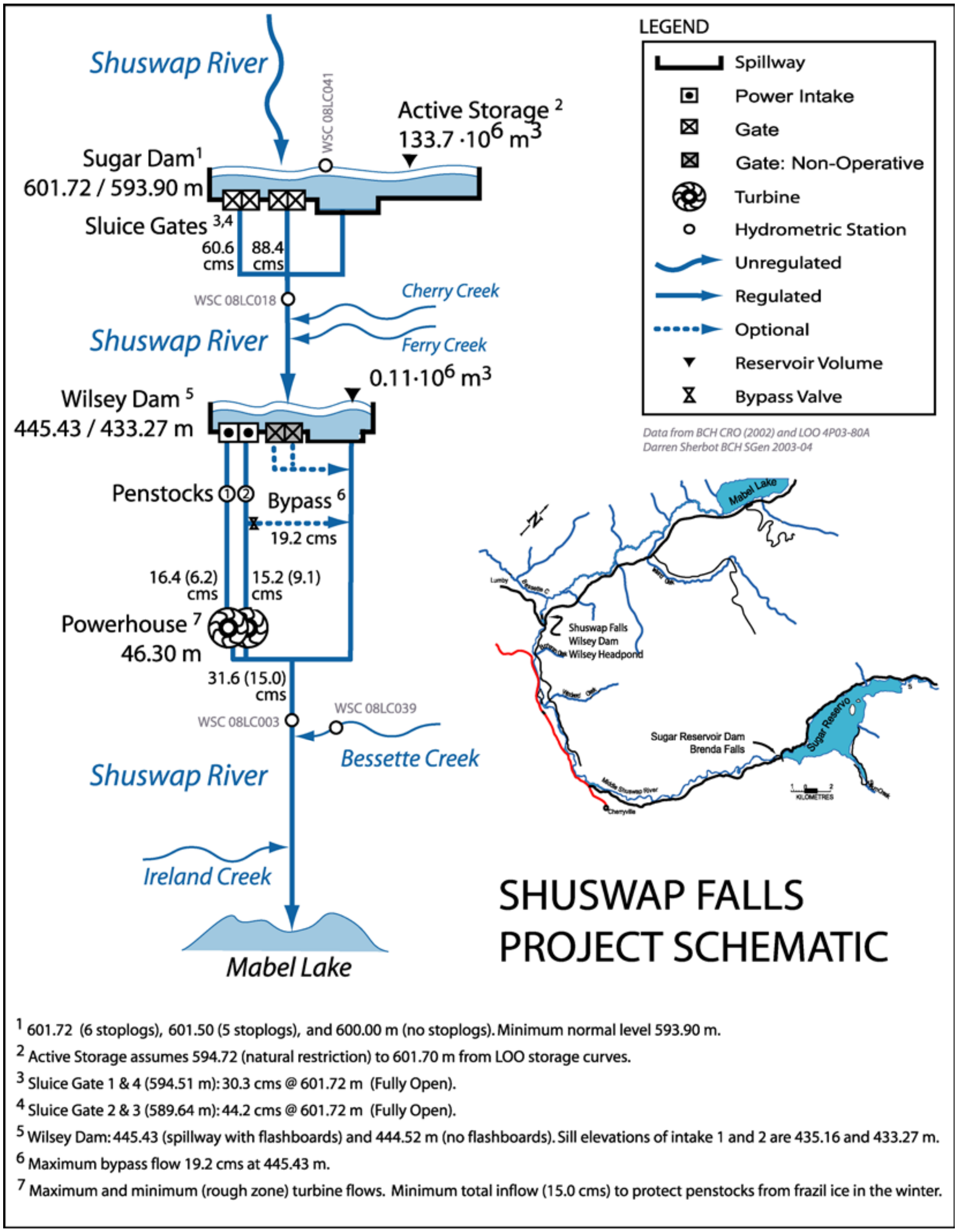

Figure 2-1: Schematic of Shuswap Falls and Sugar Lake Hydroelectric Facilities

Figure shows the existing facilities and associated structural components. It does not represent the operating recommendations.

3.0 HYDROLOGY OF THE SHUSWAP RIVER SYSTEM

The Shuswap River basin above Shuswap Falls lies within the western ranges of the Monashee Mountains. The area is bounded by the Gold Range on the east and the Sawtooth Range, Park Range and Silver Hills on the west. The drainage area behind the Sugar Lake Dam is 1113 km^2 and the tributary area between Sugar Lake Dam and Wilsey Dam is 856 km^2.

Melting snowpack and seasonal precipitation throughout the year provide inflows to the Shuswap River basin above Shuswap Falls. Spring runoff can begin as early as March and peaks in June, though there is variation from year to year. Freshet or spring floods in May–June, account for about 45 per cent of the annual inflow to the system. Inflows to the reservoir can also increase if heavy rains occur at the same time as thaw. Summer and fall rainstorms can cause other smaller peak flows. Fall rainstorms are considered important for ensuring a full reservoir for winter releases however fall inflows are not reliable.

More details on the physiography, climate and hydrology of the Shuswap River Basin are provided in Appendix 1.

4.0 OPERATING CONDITIONS FOR FACILITY

4.1 Role of Facility in BC Hydro's System

The Shuswap Falls and Sugar Lake facilities are part of BC Hydro's integrated generation system. For more information on the BC Hydro electric system and how it operates, please refer to BC Hydro's publication *'Making the Connection'*.

The Shuswap River hydroelectric system generates approximately 37,000 MWh annually, enough energy to serve approximately 4000 homes on an annual basis.

4.2 Use of Water for Power Generation at the Shuswap River Facilities

Water levels in Sugar Lake Reservoir and flows in the Shuswap River depend on snowpack, weather conditions during freshet, and rainfall, all of which vary from year to year. The storage capacity in Sugar Lake Reservoir limits BC Hydro's ability to manage the varied and volatile flow in the Shuswap River basin.

Normally, Sugar Lake Reservoir elevations are low during winter months, with increasing levels through spring and summer. During spring freshet, Sugar Lake Dam is operated with all four sluice gates fully open and stoplogs removed in order to pass the spring runoff and meet dam safety requirements. From freshet to August, stoplogs are installed when snowpack and inflows have decreased below critical levels. Water is stored in the reservoir when inflows exceed the discharge from the dam. The water stored by late fall is then released gradually through the winter until the next freshet.

Through this store and release cycle, BC Hydro uses as much of the available inflow as possible for power generation, within the storage and generation limits of the facilities. Spills occur when inflows exceed generation and 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 or 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.

- Sugar Lake Dam: Operation, Maintenance and Surveillance Manual (OMS) for Dam Safety.
- Wilsey Dam: Operation, Maintenance and Surveillance Manual (OMS) for Dam Safety.

Operational instructions for regulating the reservoirs and special undertakings, like a deep draw down, for dam safety purposes are described in the OMS Manual for Dam Safety.

4.4 Operation of Storage and Diversion Works

The following operating constraints are based on the recommendations of the Shuswap River Consultative Committee. It is recognized that BC Hydro may need to operate outside these constraints during emergencies such as extreme hydrological events, equipment failure, and public and personnel safety. When it is anticipated that the constraints might not be met, BC Hydro will review with the appropriate federal and provincial agencies and seek direction from the Comptroller of Water Rights in selecting an alternate operation, time and situation permitting.

4.4.1 Sugar Lake Reservoir

Sugar Lake Reservoir will be operated on a fill and release cycle with a normal maximum operating level of El. 601.72 m and a minimum operating level of El. 589.64 m. Unavoidable incursions above the normal maximum operating level may occur while routing freshet flows, and during summer and fall storm events. The main body of the reservoir is not expected to go below 594.70 m because of a natural channel restriction between the reservoir and the release facilities at the Sugar Dam.

It is recognized that the following storage targets set out in the desired reservoir operations described here will be met in most but not all years and that the timing of achieving the targets may change from year to year depending on climatic and hydrologic conditions. Moreover, meeting storage targets are secondary to dam safety requirements for the installation and removal of stoplogs.

April to early-August Operations

The timing of spring freshet can change from year to year and is dependent on snow pack, temperature and storm events. Peak freshet flows generally occur between May and June but the freshet may begin as early as March. Stoplogs are removed prior to the freshet to meet dam safety requirements for Sugar Lake Dam.

During the freshet, the discharge from Sugar Lake Dam is maximized by leaving the four sluice gates fully open until the peak freshet has passed. Under these operating conditions inflows greater than the storage capacity will be passed over the spillway and may result in flooding downstream.

Once the peak of the freshet has passed, stoplogs are installed and removed at Sugar Lake Dam consistent with the OMS Manual.

Summer Operation (June – August)

Between 1 June and 31 July, BC Hydro will target to bring the reservoir elevation up to and maintain an elevation of 600.61 m or greater soon after the stoplogs have been installed. This permits boat ramp access at Kokanee Resort Lodge.

Between 1–31 August, BC Hydro will target to bring the reservoir up to and maintain an elevation of 601.22 m or greater for recreation use and for the storage of spawning and incubation flows for the fall and winter months.

The aforementioned targets are secondary to maintaining the minimum discharge requirements from Wilsey Dam. Subsequently, under certain hydrologic conditions the aforementioned elevations will not be met and reservoir elevations may drop below these targeted minimums if reservoir storage is required to meet the minimum Wilsey Dam flows.

Fall (September – December) and Winter Operations (January – March)

BC Hydro will draft the reservoir gradually through the fall and winter. The rate of drawdown will depend on the natural variability in inflows during the fall and winter and on the flow release requirements from Sugar Lake Dam and Wilsey Dam.

BC Hydro will target to meet maximum available storage within Sugar Lake Reservoir to reduce the risk of flooding downstream by drawing the reservoir down to El. 596.00 m or lower prior to freshet (1 May). Over winter, flow adjustments both upwards and downwards are expected and can result in reduced releases equal to inflow if the freshet is later than forecast or retained storage if the freshet is earlier than forecast.

4.4.2 Sugar Lake Dam

BC Hydro will release at least 5 m^3/s year round from Sugar Lake Dam. If spring freshet is delayed and available storage has been used, BC Hydro can reduce the release to equal inflows. This release may be less than the prescribed 5 m^3/s minimum. BC Hydro will advise the appropriate regulatory agencies in advance of reducing the release below the prescribed minimum.

4.4.2.1 Sugar Lake Dam Ramp Rates

The desirable ramp rates for planned gate changes at Sugar Lake Dam are outlined in Table 4.1. These ramp rates will be used as targets due to the variability of inflows in the system, equipment limitations, uncertainties around the discharge relationships of the Water Survey of Canada (WSC) gauge and the gates, and flow release requirements to meet flows downstream of Wilsey Dam.

For operations, rate determination will be based on gate discharge curves, reservoir level, and planned gate position changes when elevations are less than or expected (over the next 72 hours) to be less than the free crest spill level. Night ramping will be initiated no earlier than two hours before sunset for Sugar Lake Dam. Actual downstream changes may be ± 50 per cent the planning criteria as observed at WSC 08LC018. These rates and the maximum daily change may be exceeded as necessary to route flood flows, meet dam safety release requirements, equipment and personnel safety and other emergencies and during spill events when the storage capacity in Sugar Lake Reservoir has been exceeded and BC Hydro can no longer control the rate of change in river stage.

Table 4-1: Sugar Lake Dam – Target Ramp Rates

Maximum Ramping Rates[1]		Down Ramp (cm/hr)		Up Ramp (cm/hr)	Daily Change (cm)	
Period	**Life Stage**	**Day**	**Night**	**Day/Night**	**Down**	**Up**
1 April – 31 July	Emergence	2.5	2.5	5.0	15	15
1 August – 30 September	Rearing	2.5	5.0	5.0	15	15
1 October – 31 March	Over Winter	0	5.0	5.0	15	25% $Q_{DDS(t-1)}$[2]

1 Rate determination based on gate discharge curves, reservoir level, and planned gate position changes. Actual downstream changes may be ± 50 per cent the planning criteria.

2 25% $Q_{DDS(t-1)}$ is 25 per cent of the previous day's discharge from Sugar Dam.

4.4.3 Wilsey Dam and Shuswap Generating Facility

4.4.3.1 Spillway Flow

There is no requirement to provide a minimum spillway flow at Wilsey Dam. Water in excess of the capacity of the generating units will be spilled.

4.4.3.2 Minimum Discharge

BC Hydro will provide the following minimum discharge below Wilsey Dam or the Shuswap Generating facility during the specified months:

- 15 August to 31 December 16 m^3/s
- 1 January to 14 August 13 m^3/s

In both time periods, these discharges reflect the minimum required and there will be no direction to reduce flows to these rates of discharge unless required due to low inflow conditions. BC Hydro is confident that it can maintain or exceed these flows 95 per cent of the time, based on the 27 years of recorded inflow. It is expected that flows will approach the minimum rates only during very dry years and that in other years, flows are expected to be higher.

During the 1 January to 31 March period, flow reduction will take place by natural means once the storage in Sugar Lake Reservoir has been used and discharge equals natural inflows. During the freshet period, it is anticipated that the minimum daily average discharge will almost always be exceeded due to natural inflows and storage limitations.

4.4.3.3 Wilsey Dam Flow Release Mechanism

The Shuswap River below Wilsey Dam provides important spawning and rearing habitat for salmon. While the impacts of periodic tripping events or plant outages at the Wilsey Dam are not well understood and are difficult to study, there is a strong feeling on the part of provincial and federal regulators that impacts could be detrimental at certain times of the year.

Given the value of this fisheries resource to the province, it is recommended that the Comptroller of Water Rights direct BC Hydro to investigate, design and install, if warranted, a new flow release mechanism, such as a gated spillway, at Wilsey Dam (see Section 6.0). The objective of this work would be to explore options to reduce flow disruptions below Wilsey Dam during tripping events. The details regarding this recommendation are provided in the *Shuswap River Water Use Plan: Consultative Committee Report.*

5.0 PROGRAMS FOR ADDITIONAL INFORMATION

Development of the operating recommendations for the Shuswap River hydroelectric system was complicated by uncertainties associated with inflow predictions and information gaps regarding the effects of plant outages. In particular, there are uncertainties associated with the effects of:

- reservoir operations on shoreline erosion;
- plant outages on fish production;
- river discharge on stage adjacent to specific property sites;
- reservoir operations on archaeological sites.

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:

- allow monitoring of 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 below. Estimated annual costs for these studies and associated tasks are summarized in the *Shuswap River Water Use Plan: Consultative Committee Report.*

5.1 Monitoring Recommendations

The Shuswap River Water Use Plan Consultative Committee recommended by consensus that the following monitoring studies be conducted as part of this Water Use Plan.

Local Inflow Measurement and Forecasting for Sugar Lake Reservoir: There is uncertainty regarding the accuracy of inflow data used in operations planning for Sugar Lake Reservoir. Increasing the capabilities of an existing gauging station located on Eagle Creek will improve the inflow forecasting and play a key role in managing water at the Shuswap Falls and Sugar Lake facilities in the future. This monitoring study will involve improving the capabilities of the gauging station capacity in year one and then providing ongoing data collection and analysis through to year 10 of the Water Use Plan.

Sugar Lake Reservoir Shoreline Erosion: There is uncertainty regarding the extent of reservoir erosion when the reservoir is operated at an elevation up to El. 601.72 m. This monitoring study would look at areas around Sugar Lake Reservoir affected by reservoir operations. In particular, the study would look at areas susceptible to erosion and estimate the potential amount of damage from operating up to El. 601.72 m. This is a one-time study that may lead to an operational change in the maximum reservoir elevation.

Local Flood Stage Measurements for Shuswap River below Wilsey Dam: There is uncertainty regarding the actual relationship between daily flows from Sugar Lake Dam, when flooding begins, and the magnitude of the flood downstream along the Shuswap River. This monitoring study would determine whether the performance measure for flooding accurately captures the point at which flooding starts downstream of Wilsey Dam, and what the link is between these flows and the extent of flooding over farmers' fields. This is a one-time study to occur after the Water Use Plan is approved. The results of this study may lead to improved understanding regarding the flow and stage change relationship.

The Shuswap River Water Use Plan Consultative Committee also expressed strong support for further archaeological study and BC Hydro supported the following study.

First Nation Archaeological Site Investigation: There is uncertainty regarding the effects of reservoir operations on archaeological sites in the reservoir drawdown zone. This monitoring study would identify the elevations of archaeological sites and assess the effects of the reservoir operations proposed in this Water Use Plan. This is a 5 year study that would involve site identification in year one and 4 years of site monitoring to determine the effects of operations. The results of this study may lead to new recommendations for reservoir operations.

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. It is anticipated that implementation will include the following steps:

- Initiate operating recommendations.
- Initiate monitoring program studies.
- Initiate investigation of a flow release mechanism – undertake an engineering feasibility study, environmental assessment and public safety review of options related to gate works at Wilsey Dam. After completing this investigation, the following decision process is recommended:
    - Prepare preliminary design and seek direction from the Comptroller of Water Rights to proceed with work.

- Complete design and construct.
- Assess effectiveness of flow release mechanism.

7.0 EXPECTED WATER MANAGEMENT IMPLICATIONS

The operating regime at the Shuswap Falls and Sugar Lake Project attempts to capture and release, within the operating constraints described in this Water Use Plan, the maximum amount of water available to augment flows for fish in the Shuswap River through the winter months. This operation also optimizes power, reservoir productivity and reservoir recreation. BC Hydro is responsible for meeting the operational parameters ordered in its licensing but not for achieving the expected outcomes. Implications for the interests considered during the preparation of this Water Use Plan are described below.

7.1 Other Licensed Uses of Water

There are numerous water licence holders on the Shuswap River. The recommended changes in operations are not expected to impact current water licenses on the river system.

7.2 Riparian Rights

The operational changes proposed in this Water Use Plan are not expected to affect riparian rights associated with the reservoir or along the river below the facilities.

7.3 Fisheries

The implementation of this Water Use Plan is expected to optimize the use of water for the benefit of fish. Benefits will include optimizing the availability of spawning and rearing habitat for resident and anadromous fish species as well as minimizing negative impacts associated with plant outages below Wilsey Dam.

7.4 Wildlife Habitat

The Water Use Plan is expected to have limited effect on wildlife however it is believed that benefits for fish will enhance the overall health of the ecosystem.

7.5 Flood Routing

The operational recommendation is expected to provide the same level of flood control as the current operations.

7.6 Recreation

The recommended operations for Sugar Lake Reservoir will provide recreational benefits through the summer months. Recreational benefits for the river are not expected to change.

7.7 Water Quality

The Water Use Plan is expected to have no effect on water quality in the Shuswap River system.

7.8 Industrial Use of Water

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

7.9 First Nation Considerations

The Shuswap project is in the asserted traditional use areas of the Shuswap Nation Tribal Council, Okanagon Nation Alliance, and the Spallumcheen band. The proposed conditions are not expected to affect traditional use in the area.

7.10 Archaeological Resources

The Shuswap River hydroelectric system lies within the traditional territory of three First Nations. Their interests will be accommodated through the archaeological site monitoring study proposed as part of this Water Use Plan.

7.11 Power Generation

The generation is not expected to change under the operations proposed in this Water Use Plan.

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 outlined in this Water Use Plan.

8.2 Non-compliance Reporting

Non-compliance with any operations 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 formal review of this Water Use Plan is recommended 10 years after its approval by the Comptroller of Water Rights.

An informal review of information collected during the monitoring program, which is expected to take five years after approval, will be conducted with the appropriate government agencies, First Nations, and interested parties. If scientific data or significant new risks are identified that could result in a change to operations, a formal review may be requested at that time.

10.0 NOTIFICATION PROCEDURES

BC Hydro will establish a communications protocol with the provincial and federal regulatory agencies to inform them of the past and projected operations under prevailing and forecast hydrological conditions.

Notification procedures for floods and other emergency events are outlined in the “Sugar Lake and Wilsey Dams Emergency Planning Guide” and the “Upper Columbia Generation Power Supply Emergency Plan (PSEP)”. Both these documents are filed with the Office of the Comptroller of Water Rights.

Appendix 1
Shuswap WUP – Hydrology of Shuswap River Basin

Inter-office memo

TO:	Eric Weiss	23 January 2002
FROM:	Mike Homenuke	File: PSE 151.0 C-SHU-151.0
SUBJECT:	Shuswap WUP - Hydrology of Shuswap River Basin - Revised	

1 INTRODUCTION

The Shuswap project is a two reservoir hydroelectric development with two dams and one generating station with the following general characteristics:

- Sugar Lake Dam impounds Sugar Lake Reservoir, which is the main storage reservoir for the project.
- Water released from Sugar Lake Dam discharges into the Shuswap River above Wilsey Dam.
- Wilsey Dam is located on the Shuswap River, ~29 km downstream from Sugar Lake Dam. Wilsey Dam impounds a small headpond and is essentially a run of river facility.
- Spill and all other non-power releases from Wilsey Dam discharge into the Shuswap River.
- Power releases from Wilsey Dam (turbine discharge) pass through the Shuswap Falls Generating Station (two units, max combined output ~ 5.2 MW).
- Discharge from the Shuswap Falls Generating Station enters the Shuswap River.

This report highlights the hydrology of the Shuswap River hydroelectric system. Physiography and climatology are reviewed for Shuswap watershed.

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 Shuswap River system referred to in this report were used in power studies conducted for the Shuswap Water Use Plan.

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

2.1 Physiography

The Shuswap River basin above Shuswap Falls lies within the western ranges of the Monashee Mountains. The area is bounded by the Gold Range on the east and the Sawtooth Range, Park Range and Silver Hills on the west. The drainage area behind the Sugar Lake Dam is 1113 km^2 and the tributary area between Sugar Lake Dam and Wilsey Dam (Wilsey Local) is 856 km^2.[1]

The drainage basin for the Shuswap system is shown in Figure 1.

Elevation within the Shuswap basin ranges from 450 m to 2680 m, with the Gold Range being approximately 600 m higher than the western ranges. The hypsometric curves for the basins are shown in Figure 2.

[1] BC Hydro. January 1983. "Shuswap Falls Project: Probable Maximum Flood", BC Hydro Hydroelectric Generation Projects Division, Report No. H1586

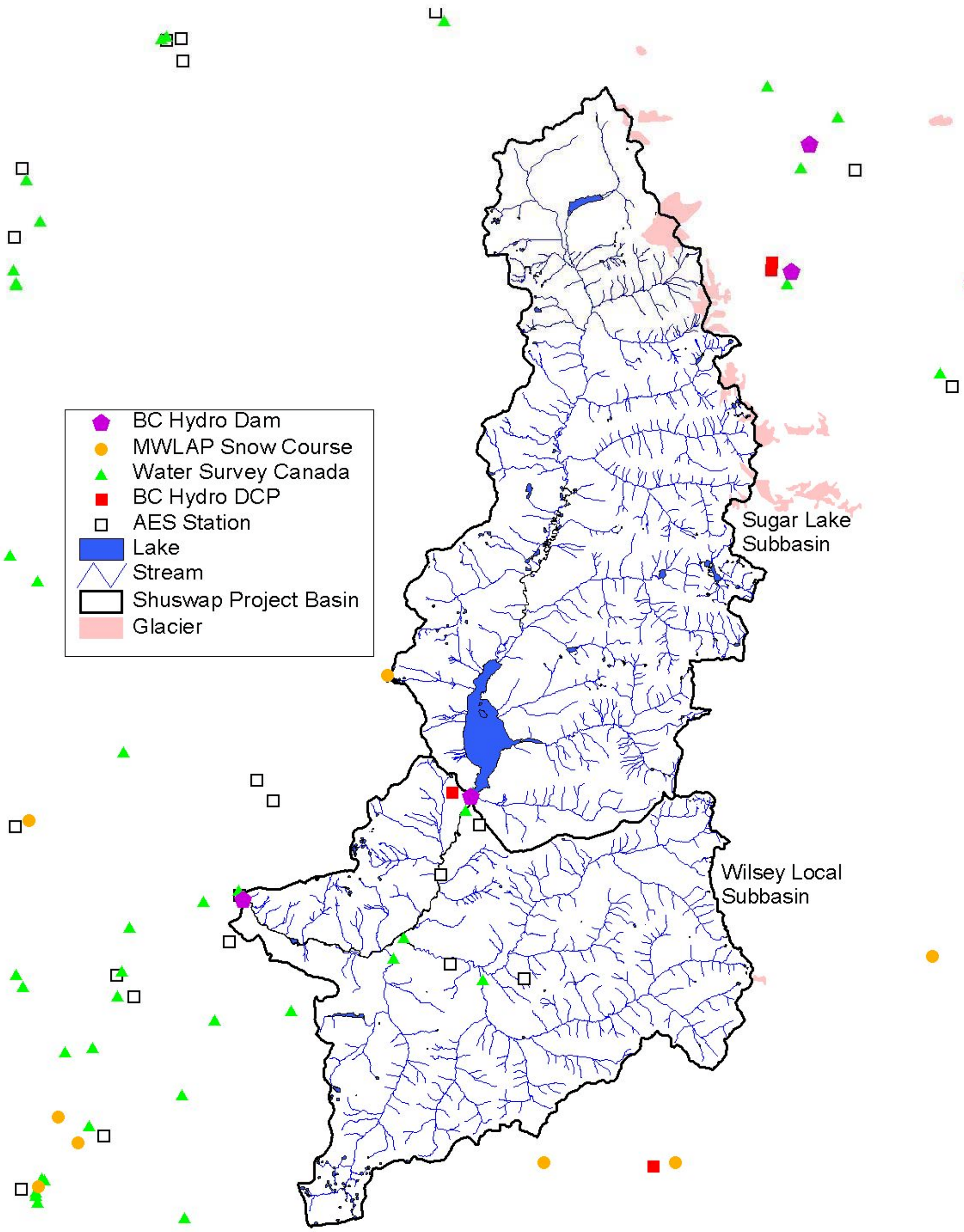

Figure 1: Watershed Map and Hydrometeorological Stations

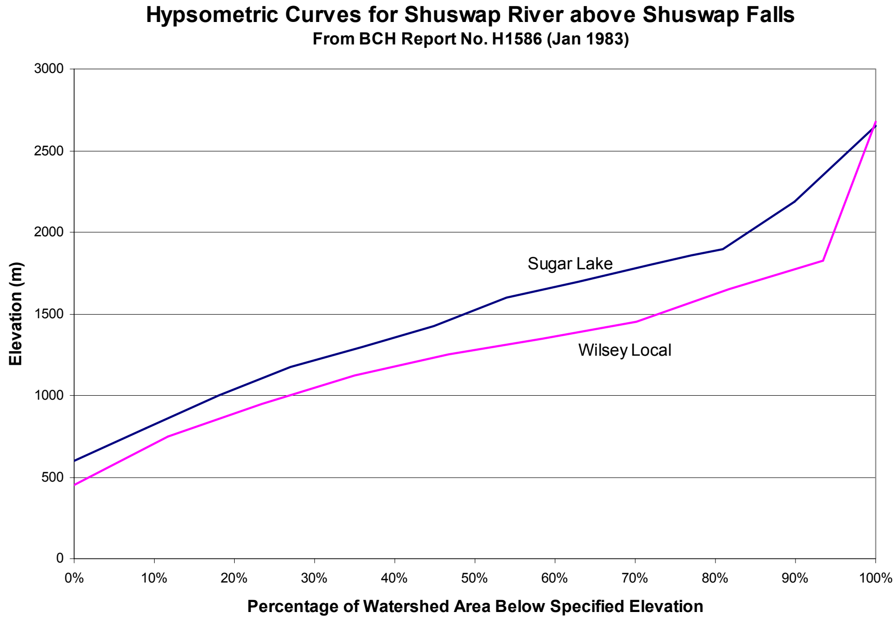

Figure 2: Hypsometric Curve for the Shuswap River Watershed

Sugar Lake Reservoir, which is impounded by Sugar Lake Dam, is approximately 10 km long. The stage-storage relationship shown in Figure 3a indicates the storage capacity of the reservoir at different reservoir elevations. Storage available within the normal operating range of El. 594.0 – 601.72 m is estimated from the stage-storage curve at about 1672 cms-days.

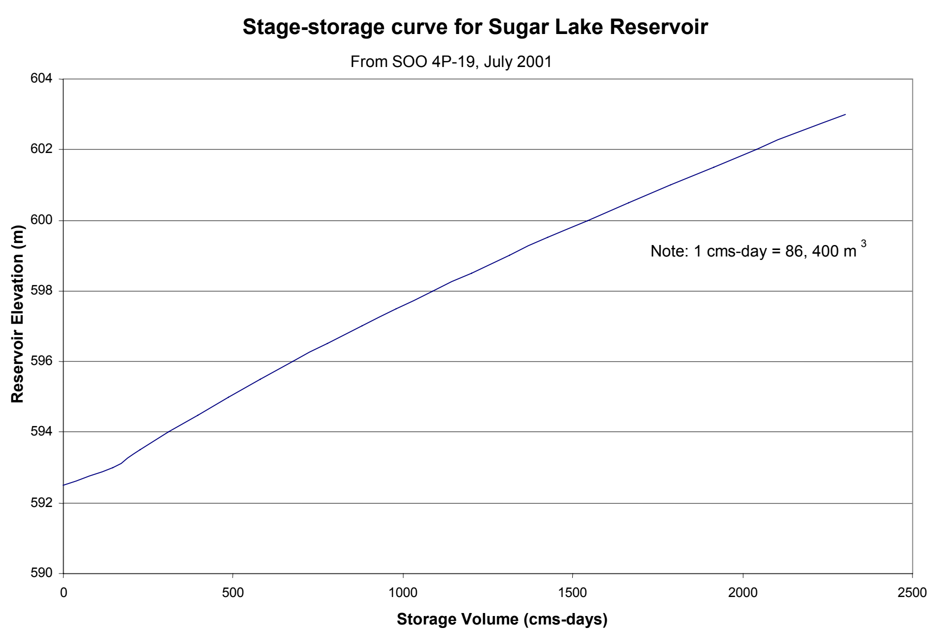

Figure 3a: Stage-storage curve for Sugar Lake Reservoir

The Wilsey Headpond uses flashboards to provide higher head for generation between September and March. Flashboards raise the normal maximum operating elevation from 444.52 m to 445.43 m. The headpond has very limited capacity as shown in the stage storage curve (Figure 3b).

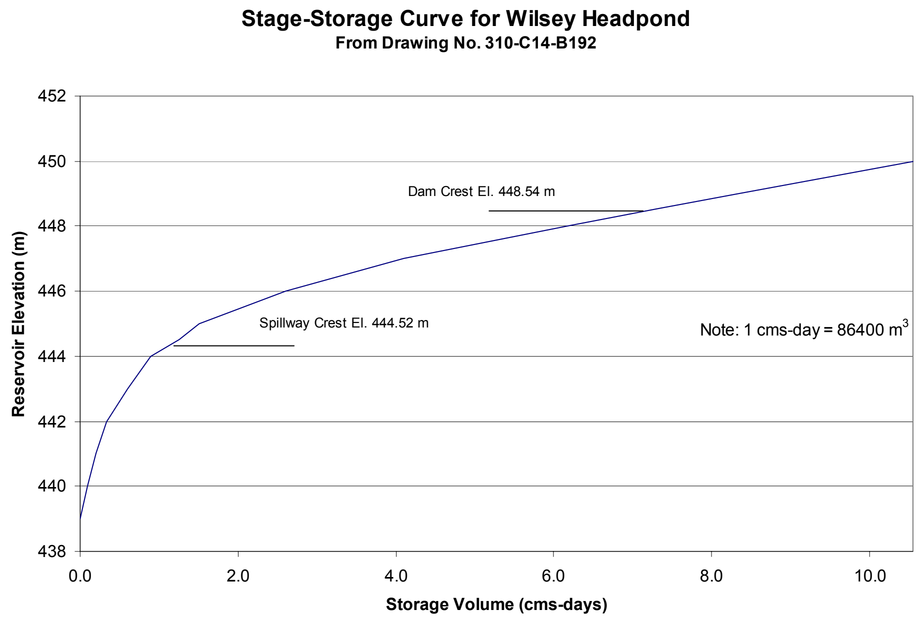

Figure 3b: Stage-storage curve for Wilsey Headpond

2.2 Climatology

The Shuswap River basin is climatically within the southeast interior region, which is affected by both continental and modified maritime conditions. The Monashee Mountains are the first range of mountains to be encountered by maritime air after losing much of its moisture over the Coast Mountains and then descending over the southern Interior Plateau. Thus, precipitation is higher than in the plateau region but considerably less than on the coastal areas. Temperatures in these basins are also affected by continental air from the south (warm) and from the north (cold). These general climatic conditions produce large snowpacks in the mountains, warming conditions in April to June and often heavy short duration rainfall in May through August. The presence of several small glaciers along the eastern ridge of the Monashees indicates heavy winter precipitation and relatively cool temperatures.

The higher land barriers in the Upper Shuswap basin combined with the flow direction of the maritime air masses produces considerably more winter/spring precipitation in the Sugar Lake basin than the Wilsey Local basin.

Substantial snowpacks develop during the winter at all elevations in the Shuswap basin. Winter maximum snowpacks for the Park Mountain snow course, located in the Sugar Lake basin (Fig. 1), average 960 mm of water equivalent. The snowpack in the Shuswap valley is usually depleted by the end of April, yet small permanent snowfields exist at the highest elevations.

The rapid snowpack depletion in the lower and middle elevation ranges is the dominant influence on the hydrology of the region. The magnitude of the river response in the early summer depends on the warming temperature pattern and the distribution of the snowpack with elevation.

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, about half of the annual precipitation normally falls between October and January. Although there is a DCP in the Sugar Lake basin, it has only been operational since 1998. For the purpose of this report a station located near Revelstoke will be used to provide historical precipitation and temperature data (Revelstoke AES, El. 443 m). The Revelstoke AES station is located just north of the Shuswap watershed boundary and experiences climatic conditions that are similar to the average conditions for the Shuswap basin.

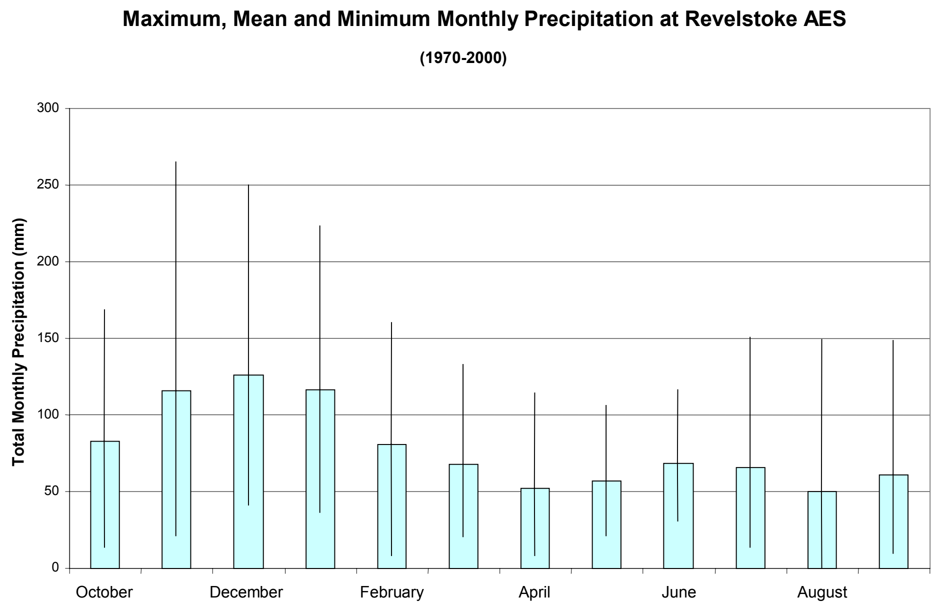

Figure 4: Total monthly precipitation at Revelstoke AES

Figure 5 shows maximum, mean and minimum daily temperatures at Revelstoke AES.

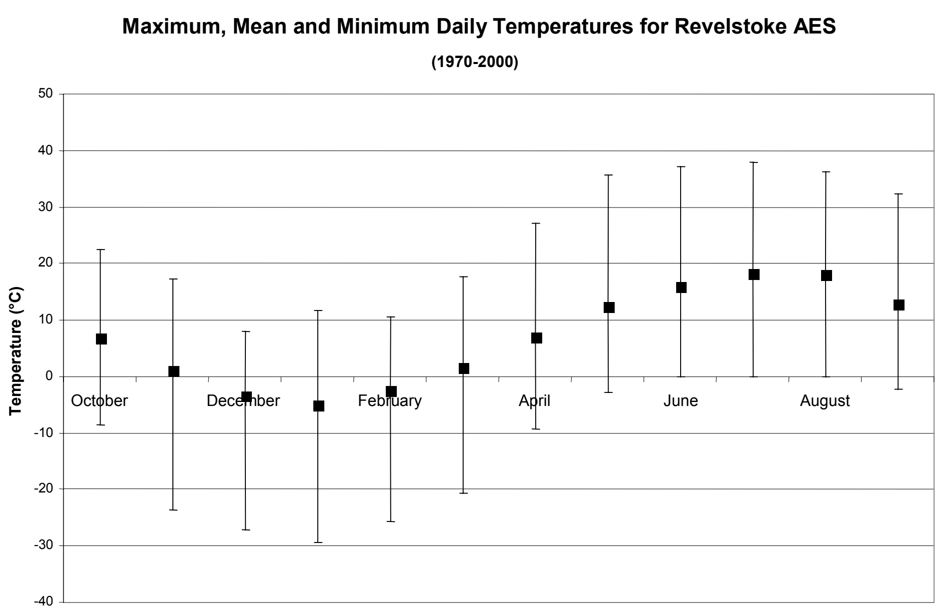

Figure 5: Maximum, mean and minimum daily temperatures at Revelstoke AES

Figure 6 shows the maximum, mean, and minimum snow water equivalent for Park Mountain snow course (1F03P) located at 1890 m elevation.

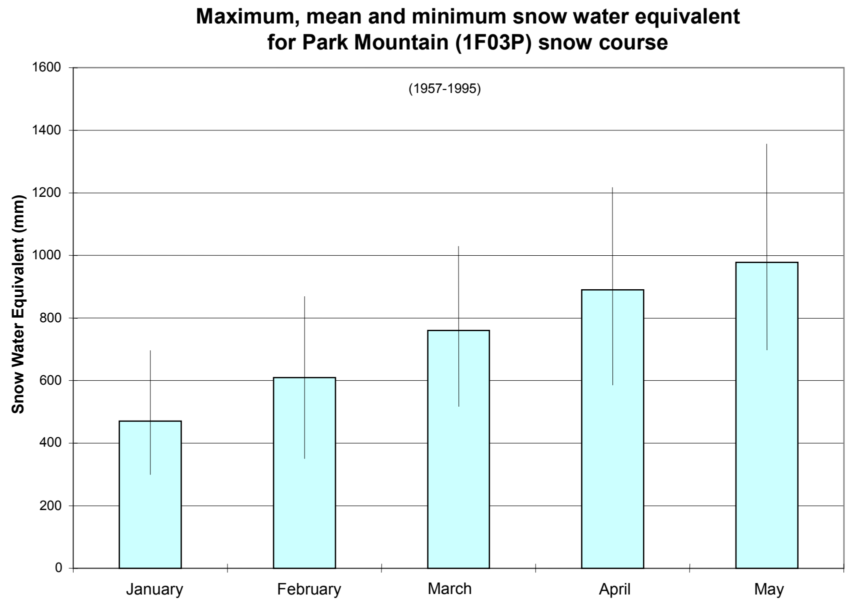

Figure 6: Maximum, mean and minimum snow water equivalent for Park Mountain (1F03P) snow course

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:

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

where INFLOW = average inflow over a one - day period

OUTFLOW = average outflow over a one - day period

Δ 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: The storage relationships used to determine the volume of water in Sugar Lake Reservoir and Wilsey Headpond are shown in Figures 3a-b.

Outflow relationships: Flow through turbines at the Shuswap Falls 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 and flow through the turbines. A generic relationship between these variables is shown in Figure 7.

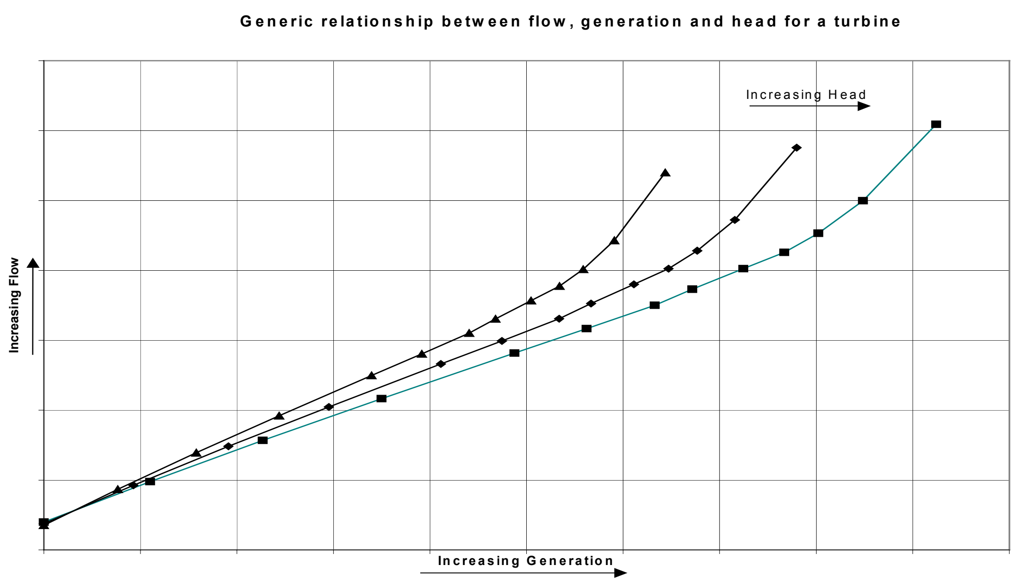

Figure 7: Generic relationship between flow, generation, and head for a turbine

“Rating curves” show the relationship between flow, opening, and elevation for a given release device. Rating curves for discharge facilities at Sugar Lake and Wilsey dams are shown in Figures 8 a-b.

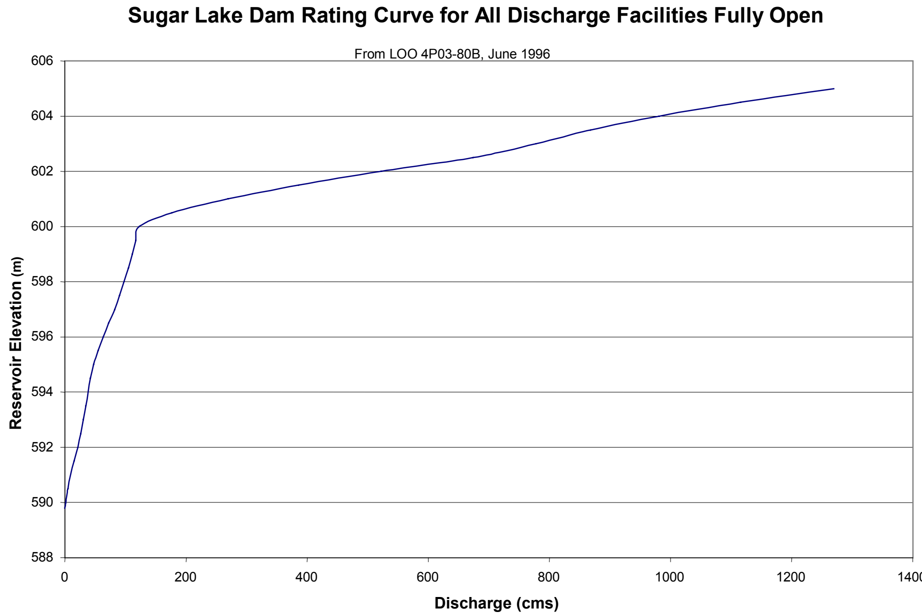

Figure 8a: Rating curve for all discharge facilities at Sugar Lake Dam

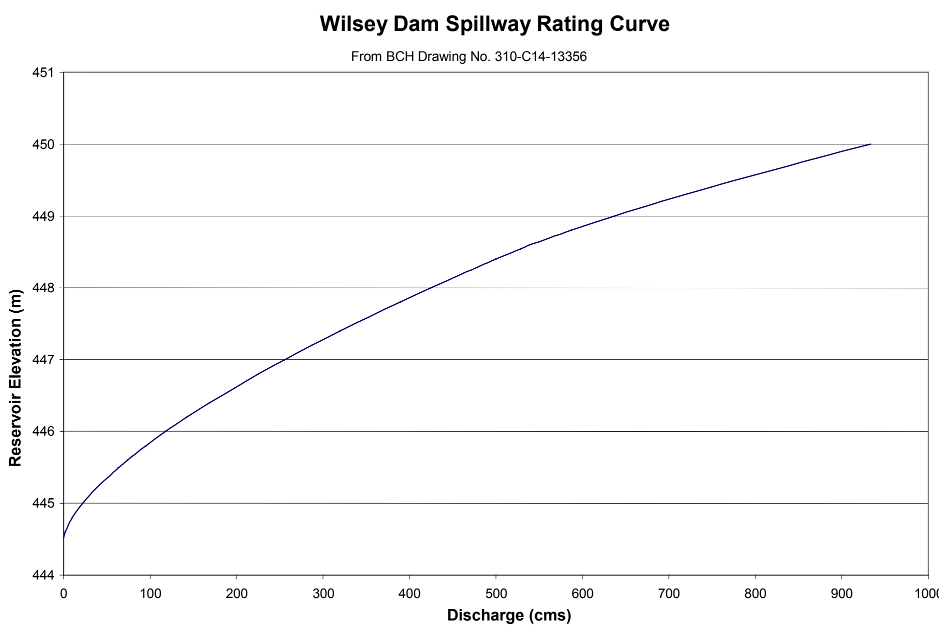

Figure 8b: Spillway Rating Curve for Wilsey Dam

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

Inflows to Sugar Lake Reservoir are computed based on equation (1).

Total inflow to the Wilsey Headpond is computed using equation (1). Local inflow to the Wilsey Headpond is equal to the total inflow to the reservoir less the regulated inflows from Sugar Lake Reservoir.

Various information, including gate openings, reservoir and tailwater elevations, energy, spill, turbine flows, and inflows are stored in FLOCAL. A FLOCAL configuration for the Shuswap system is shown in Figure 9.

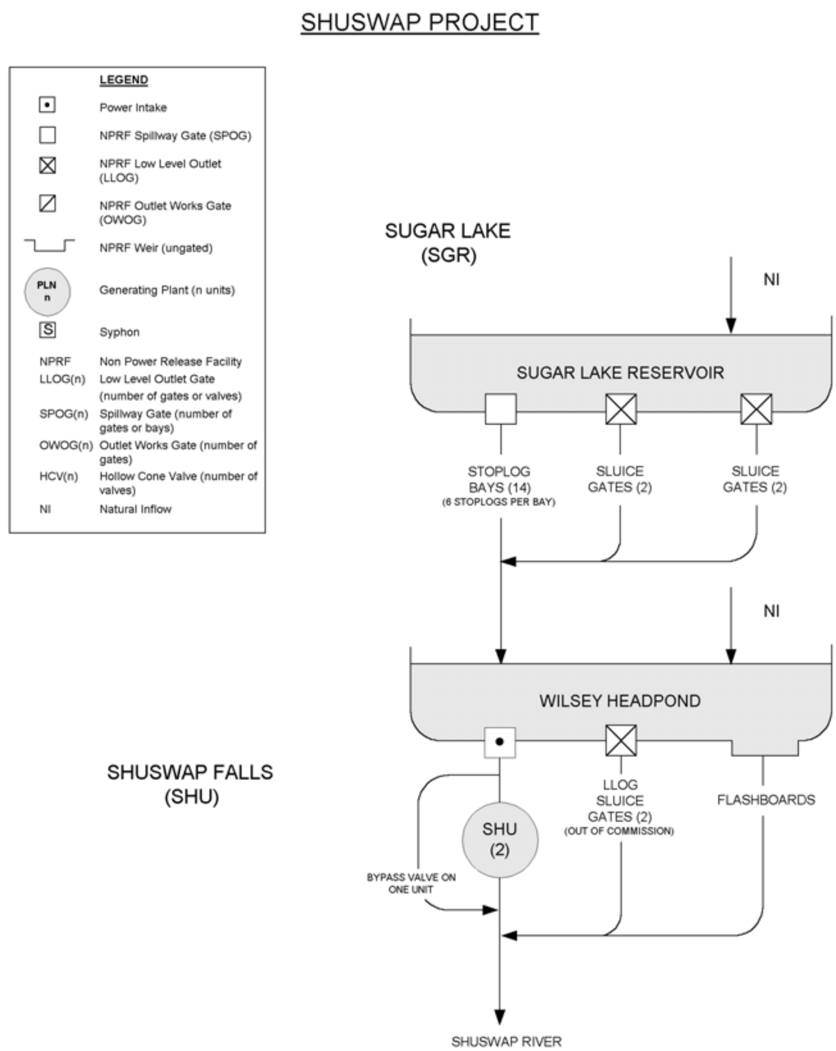

Figure 9: Schematic of the FLOCAL configuration for the Shuswap system

3.2 Reservoir inflow characteristics

Figures 10 and 11 show a "spaghetti plot" of historical natural inflows to the Sugar Lake Reservoir and Wilsey Headpond. The 10th, 50th and 90th percentile inflows are shown in bold.

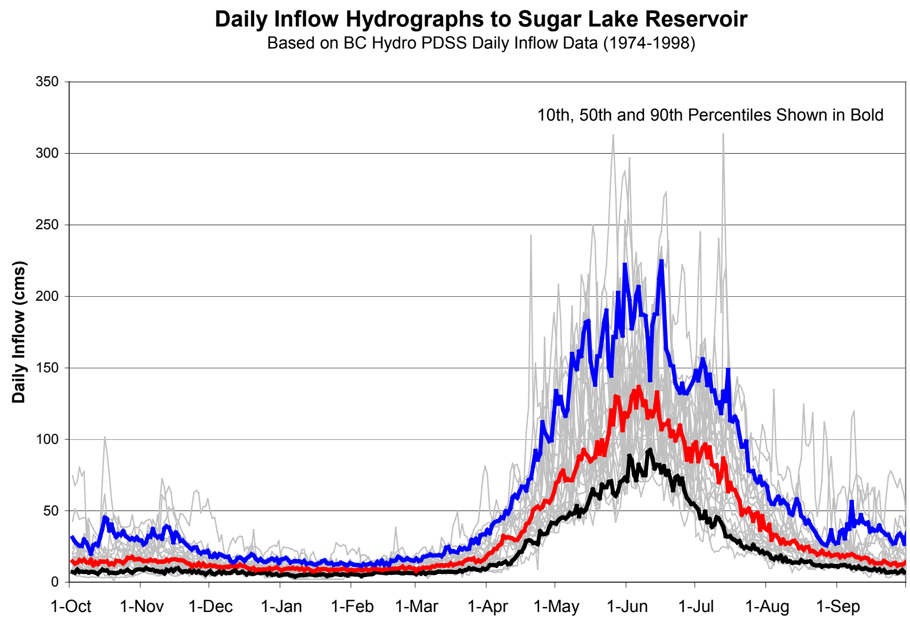

Figure 10: Daily Inflows to Sugar Lake Reservoir

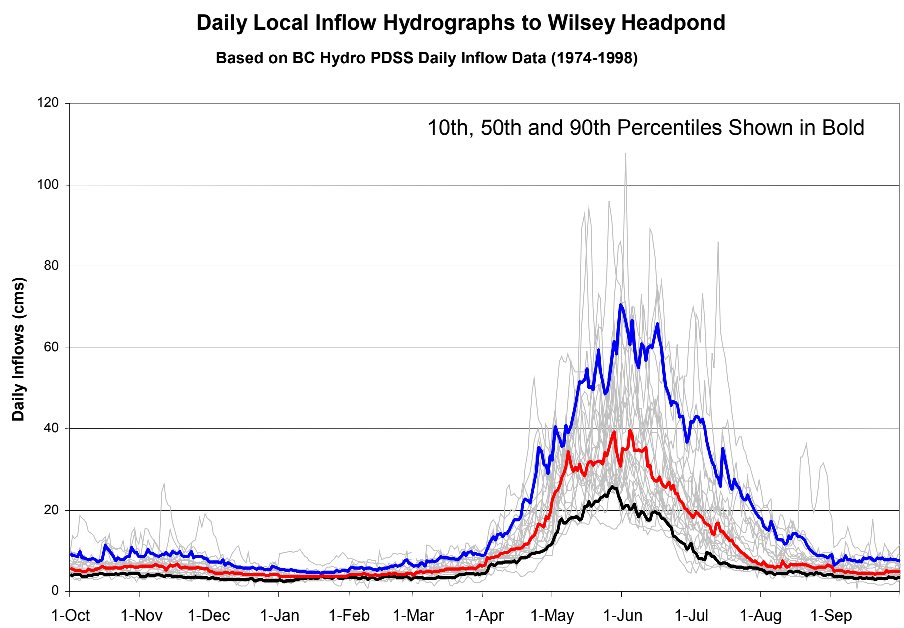

Figure 11: Daily Local Inflows to Wilsey Headpond

Mean monthly and maximum and minimum daily inflows to Sugar Lake are shown to highlight the variability of inflows to the projects. Figure 12 and Table 1 summarize the daily inflows by month.

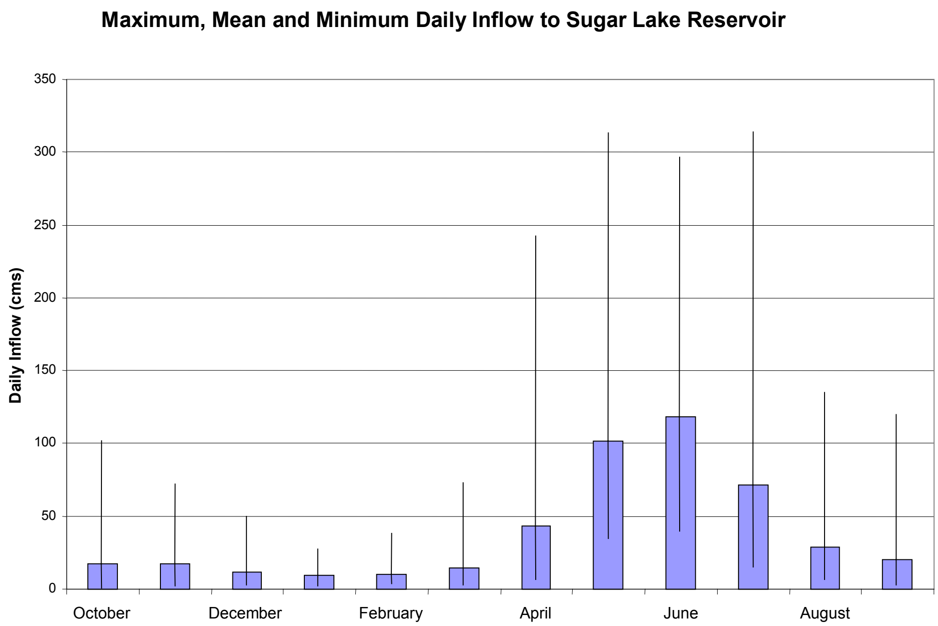

Figure 12: Variability in Shuswap Project's daily inflows

Table 1: Shuswap Project's daily inflows (1974-1998)

	Mean Daily Inflow (cms)	Maximum Daily Inflow (cms)	Minimum Daily Inflow (cms)
October	18	102	<1
November	17	72	2.4
December	11	50	3.0
January	9.0	28	2.0
February	10	38	3.8
March	14	73	2.8
April	43	243	6.8
May	102	313	35
June	118	297	39
July	71	314	16
August	29	135	6.8
September	20	120	3.1

A "flow duration curve" indicates the percent of time that a flow is greater than a given discharge. Figure 13 shows a flow duration curve of daily inflows for the years 1974-1998. The figure again illustrates the large range and variability of inflows.

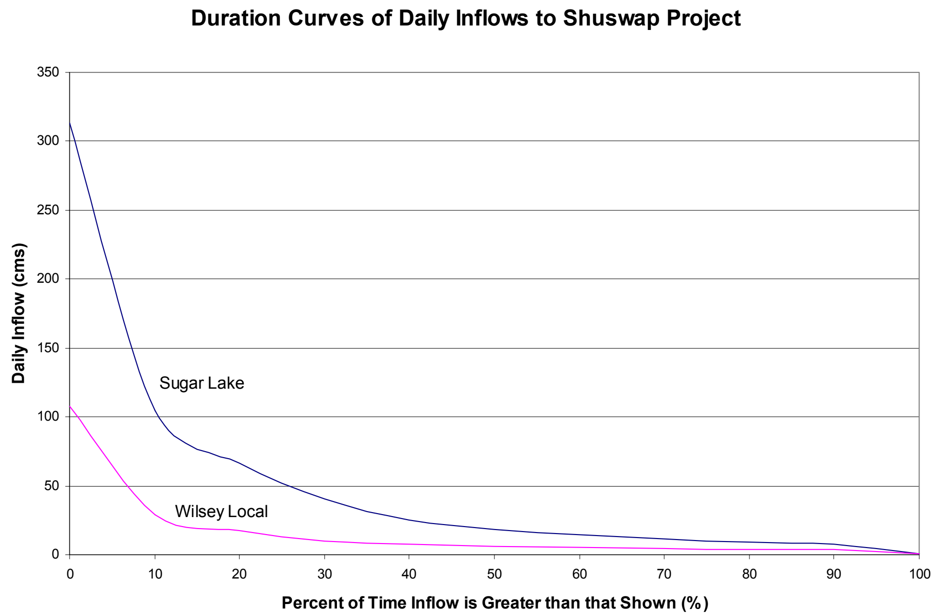

Figure 13: Duration curves of daily inflows to the Shuswap Project

Figure 14 shows a duration curve for annual flows.

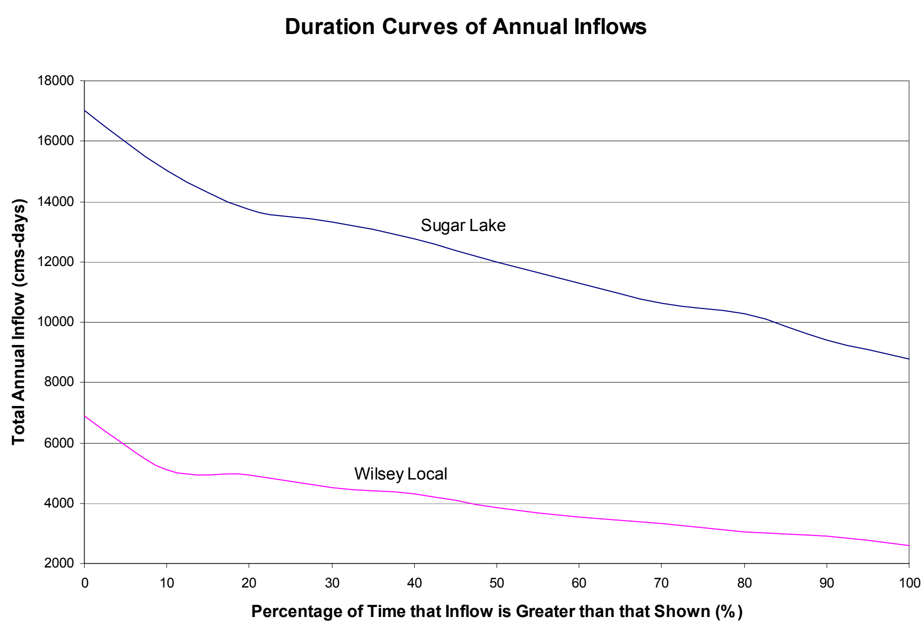

Figure 14: Duration curve of annual inflows to the Shuswap Project

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

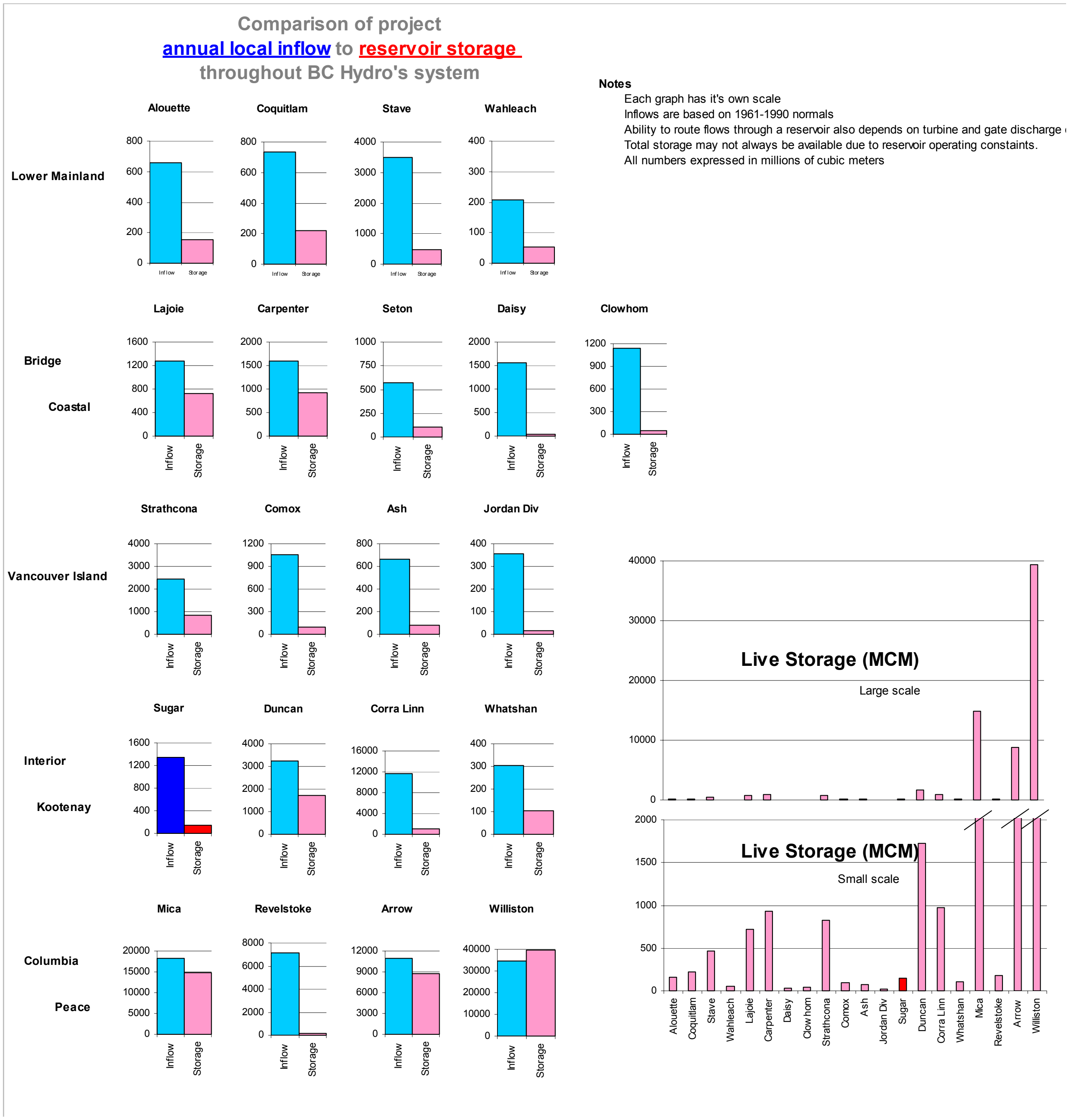

Figure 15: Comparison of project annual inflows to reservoir storage throughout BC Hydro's system

4 Operational Inflow Forecasting

BC Hydro's Resource Management produces seasonal volume inflow forecasts for the Shuswap Project. Daily inflow forecasts are not provided for this project but may be introduced in the future.

Volume inflow forecasts: Volume inflow forecasts estimate the volume of water that is expected to flow in to the project during a given period. Currently, forecasting is only carried out for the Sugar Lake basin. 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 Shuswap Project's watershed. Characteristics of the hydrometeorological data collection stations in and near the watershed are summarized in Table 2. Locations of hydrometeorological stations within the basin are shown in Figure 1.

Table 2: Hydrometeorological stations used for inflow forecasting, operations planning and general hydrologic reference

Station	**Type**	**ID**	**Elev (m)**	**Latitude**	**Longitude**	**Characteristics**
Current						
Park Mountain	MWLAP	1F03P	1890	50.45	118.62	Snow Course
Sugar Lake	DCP	SGL	675	50.36	118.53	Climate
Historical						
Revelstoke	AES	1176751	443	50.97	118.18	Climate
Nakusp CS	AES	1145297	512	50.27	117.82	Climate
Vernon Coldstream Ranch	AES	1128580	482	50.23	119.20	Climate
McCulloch (Inactive)	AES	1124980	1250	49.40	119.20	Climate
Aberdeen Lake	MWLAP	1F01A	1310	50.05	119.15	Snow Course
Whatshan (Upper)	MWLAP	2B05	1480	50.12	118.03	Snow Course
Barnes Creek	DCP	BAR	1620	50.07	118.21	Snow Course
Monashee Pass	MWLAP	2E01	1370	50.08	118.50	Snow Course
Silver Star Mountain	MWLAP	2F10	1840	50.37	119.05	Snow Course

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