Joint Water Use Plan for the Capilano and Seymour Watersheds

REVISED FOR ACCEPTANCE BY THE COMPTROLLER OF WATER RIGHTS

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Acronyms

B.C.	Province of British Columbia
CC	Consultative Committee of the JWUP
cms or m^3/s	Cubic metres per second
CO_{2e}	Carbon Dioxide Equivalent
DFO	Department of Fisheries and Ocean
El.	Elevation
ft	Feet
ft^3/s	Cubic feet per second
GHG	Greenhouse Gases
GVWD	Greater Vancouver Water District
GW·h	Gigawatt hours
HB	Howell-Bunger
JWUP	Joint Water Use Plan for the Capilano and Seymour Watersheds
km	Kilometre
km^2	Square kilometre
kV	Kilovolt
LSCR	Lower Seymour Conservation Reserve
m	Metre
$M{\cdot}m^3$	Million cubic metres
MAD	Mean annual discharge
ML/d	Million litres per day
MW	Megawatt

Water Licences:

#C	Conditional Water Licence
#F	Final Water Licence

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1.0 INTRODUCTION

Metro Vancouver is a political body and corporate entity operating under provincial legislation as a ‘regional district’ and ‘greater boards’ that deliver regional services, policy and political leadership on behalf of 24 local authorities. The Greater Vancouver Water District (GVWD) is a separate corporate entity operating under the umbrella name of Metro Vancouver.

Metro Vancouver supplies drinking water on a wholesale basis to its member municipals using an extensive system including watersheds, dams, reservoirs, pumping stations and transmission pipelines. The Capilano and Seymour Watersheds provide approximately two thirds of the drinking water for the 2.5 million residents and associated businesses in the Metropolitan Vancouver area of the Lower Mainland of British Columbia.

The management of drinking water for the Region is guided by the Metro Vancouver *Drinking Water Management Plan* (DWMP). The goals of the DWMP are to:

- Provide clean, safe drinking water;
- Ensure sustainable use of water resources; and
- Ensure the efficient supply of water.

The GVWD is committed to the sustainable management of the important water resources in the Capilano and Seymour Watersheds. To support the proposal to build hydroelectric generating stations to utilize water that would otherwise spill from the reservoirs, the GVWD has developed this Joint Water Use Plan (JWUP) for the Capilano and Seymour Watersheds and the Project Development Plan (PDP) for the Capilano and Seymour Hydropower Projects. The JWUP and PDP are part of an extensive planning process to accommodate the generation of clean renewable energy from the existing reservoirs without compromising the commitments by the GVWD to:

- Supply clean, safe drinking water
- Protect fish habitat

The operating conditions proposed in this plan reflect the recommendations provided by the Consultative Committee (CC) for the Joint Water Use Plan Capilano and Seymour Watersheds. The proposed new infrastructure will provide an opportunity to address a number of issues encountered with the historic construction of the dams and reservoirs. This document explains the proposed terms and conditions to be authorized under the *Water Act* (now named the Water Sustainability Act) for the beneficial use of water at the Capilano and Seymour reservoirs. Future reference to these facilities includes all the works largely comprised of the Cleveland Dam, Seymour Falls Dam, associated reservoirs, and the proposed Capilano Powerhouse and Seymour Powerhouse.

Metro Vancouver established the process for developing the JWUP in accordance with the thirteen steps outlined in the provincial *Water Use Plan Guidelines*. The process integrates technical study and evaluation with structured decision-making and public consultation. Since January 2011, Metro Vancouver has been working with key interested parties through a Consultative Committee, to develop the key elements of a JWUP that reflect the unique characteristics of the Capilano and Seymour watersheds. The JWUP Consultative Committee has developed a consensus outcome and unanimously endorsed the final report. Refer to the *Capilano-Seymour Joint Water Use Plan: Consultative Committee Report* (October 2012) for details on the consultative process, interests, objectives, performance measures, values associated with operating alternatives, and details of the proposed monitoring program.

Through the interest-based process for the Water Use Plan, a recommendation was reached whereby domestic water, fisheries, and recreation interests were all improved over the current operations. The proposed conditions for the operation of the Metro Vancouver facilities will come into effect once an Order has been authorized under the *Water Act* of British Columbia (now named the Water Sustainability Act).

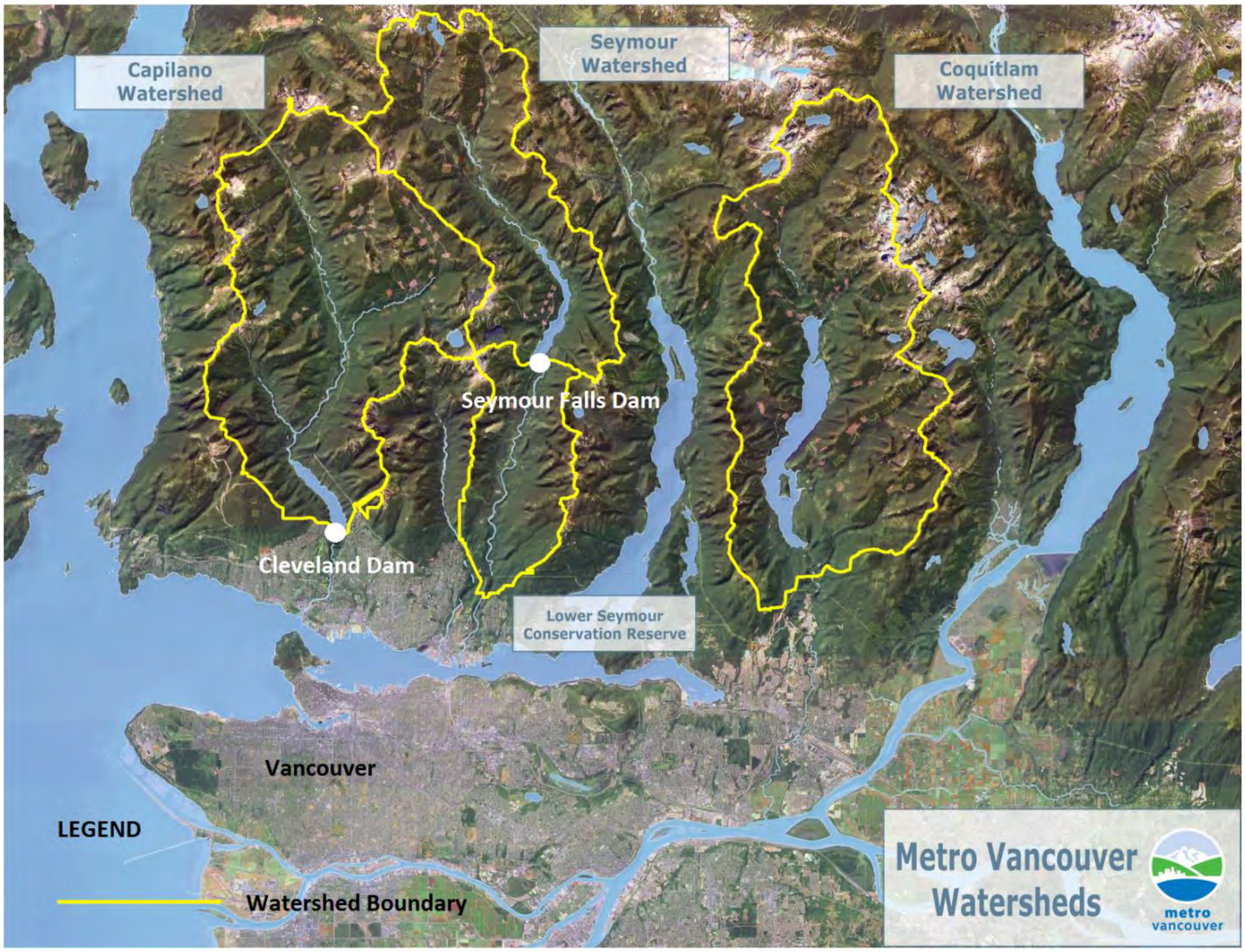

Figure 1: Metro Vancouver Watersheds & Location of Dams

2.0 DESCRIPTION OF CAPILANO WORKS

2.1 Location of Capilano Watershed

The Capilano River basin is a mountainous catchment located immediately north of the City of Vancouver, British Columbia. The watershed is 212 square kilometres in area. The Capilano River originates at Capilano Mountain and flows 33 km south to empty into the Burrard Inlet. There are eleven main tributary streams, including Eastcap Creek, Sisters Creek, and Brothers Creek.

2.2 Existing Works and Operations

Cleveland Dam

The Cleveland Dam is located 6 kilometres upstream of the mouth of the Capilano River to Burrard Inlet. Approximately 93% of the catchment area is situated above the dam. The Greater Vancouver Water District completed construction of the dam during 1954. The dam is 89.92 metres high and 195.07 metres wide.

Capilano Reservoir

The Capilano Reservoir is 312 hectares in area and behind the dam forms a lake which is 5.4 kilometres in length by 0.80 kilometres wide and 75 metres deep. The licensed storage capacity for the reservoir is 57.9 million cubic metres of water. The reservoir operates between the centre-line level of the intake at 115.58 m elevation and the full pool level of level of 145.89 m elevation. The reservoir is normally full during the fall, winter and spring months. Once the reservoir fills to its maximum storage capacity, excess water spills down the dam spillways. The reservoir is surrounded by the Greater Vancouver Water District Watershed and has restricted public access.

Palisade Reservoir

Palisade Reservoir, an alpine lake with a usable storage capacity of 8.5 $M{\cdot}m^3$, is used to augment flow in the Capilano River during the dry season. To improve overall water quality in the Capilano Reservoir, clear, cold and well-oxygenated water is released from the Palisade Reservoir.

Capilano Salmon Hatchery

The Capilano Salmon Hatchery is located 340 m downstream of the Cleveland Dam on the east bank of the Capilano River. Construction of the hatchery was completed during 1971. The hatchery is operated by Fisheries and Oceans Canada to rear coho, steelhead and chinook salmon. Salmon raised in the hatchery are released above and below the dam. The hatchery obtains water from the same intake as the domestic water supply, as well as groundwater seepage from drainage tunnels originating from the East Abutment of the dam. All of the water used by the hatchery is discharged directly back into the Capilano River.

Capilano Raw Water Pump Station, Twin Tunnels & Energy Recovery System

Raw water from the Capilano Reservoir, elevation range of 115.58 m to 145.89 m, is pumped 7.1 kilometres through a tunnel to the Seymour-Capilano Filtration Plant at an elevation of 194 m. The Capilano Raw Water Pump Station controls the flow directed from Capilano to the Seymour-Capilano Filtration Plant. Treated drinking water is stored in the filtration plant clearwell with a portion returned through a twin tunnel by gravity to an energy recovery turbine located above the break head tank at the Capilano Reservoir service area. The treated water then enters the distribution system to supply the Capilano service area, or is pumped by the Cleveland Dam Pump House, located at the base of the Cleveland Dam to the Prospect Reservoir and Glenmore Tank to service higher elevations in the Capilano area. Water from the Capilano Reservoir also provides hydraulic energy to power pumps in the Cleveland Dam Pump House and to maintain fish flows to the downstream Capilano Salmon Hatchery.

2.3 Existing Water Licences

Restrictions on the volume of water stored and drawn from the reservoir for waterworks purposes are governed by water licenses granted by the Province of British Columbia. A list of existing water licenses is provided in Appendix A.

3.0 DESCRIPTION OF SEYMOUR WORKS

3.1 Location of Seymour Watershed

The Seymour River Watershed is a mountainous catchment located north of the City of Vancouver, British Columbia. The Seymour River originates at Coastal Mountain and flows south for 39 km to the Burrard Inlet. The drainage area of the Seymour River Watershed is 186 km^2 with 68% of its area above the Seymour Falls Dam.

3.2 Existing Works and Operations

Seymour Falls Dam

The Seymour Falls Dam is located 19 kilometres upstream of the mouth of the Seymour River to Burrard Inlet. The Greater Vancouver Water District completed construction of the present dam during 1961. The dam is 236 metres in length and 30 metres in height.

Seymour Reservoir

The Seymour Reservoir forms a lake with an area of 260 hectares. The reservoir is 6.5 kilometres in length and between 0.20 and 0.75 kilometres wide. The usable storage capacity for the reservoir is 32 million cubic metres of water. The reservoir operates between the centre-line level of the intake at 189.78 m elevation and the full pool level of level of 214.77 m elevation. When stop logs are installed at the Seymour Fall Dam the reservoir level is raised by two metres to provide additional storage of 4.4 million cubic metres of water. The stop logs are typically installed during late spring to early summer. During the period of out-migration by the smolts, while the stop logs are installed, all of the spill openings in the dam are closed except one opening to allow the passage of smolts. The stop logs are removed once the rain returns during the fall. The reservoir is normally full during the fall, winter and spring months. Once the reservoir fills to its maximum storage capacity, excess water spills down the dam spillways. The Seymour Reservoir is surrounded by the GVWD Watershed and has restricted public access.

Alpine Reservoirs

Loch Lomond and Burwell Lake have a combined available storage of 19 $M \cdot m^3$. These alpine lakes can be used to augment flow in the Seymour River during the dry season. Moreover, water released from the alpine reservoirs can improve water quality by adding clear, cold and well-oxygenated water and reduce the production of ammonia in the Seymour Reservoir.

Seymour-Capilano Filtration Project

Seymour-Capilano Filtration Project will provide a wide range of benefits such as improved water quality and system reliability. The Seymour-Capilano Filtration Plant currently treats water from the Seymour reservoir at the facility in the Lower Seymour Conservation Reserve. When the underground tunnels between the Capilano and Seymour reservoirs become operational during 2014, raw water from the Capilano source will be pumped through one of the tunnels to the filtration plant for treatment. The treated water will then be returned to Capilano through a parallel tunnel so that the water can be distributed through the Capilano water supply system. See Section 2.2 for an explanation of the Capilano raw water pump station, twin tunnels and energy recovery facility.

Seymour River Fish Hatchery and Education Centre

The Seymour River Fish Hatchery and Education Centre is located 300 m downstream of the Seymour Falls Dam on the West bank of the Seymour River. The hatchery was built by the British Columbia Institute of Technology (BCIT) during 1977. Water from the Seymour Reservoir is supplied to the fish hatchery at a rate of 0.2 m^3/s and is delivered by a dedicated pipe from the domestic water intake. All water used by the hatchery is discharged directly back into the Seymour River.

The hatchery is operated by a non-profit organization, the Seymour Salmonid Society, which is funded by the Federal Department of Fisheries and Oceans, Metro Vancouver, and donations. Each year the hatchery releases back into the river 30,000 Steelhead trout, 120,000 Coho salmon, 100,000 to 600,000 Chum salmon, and 1.0 to 1.2 million Pink salmon every two years.

3.3 Existing Water Licences

Restrictions on the volume of water stored and withdrawn from the reservoir for waterworks purposes are governed by water licenses granted by the Province of British Columbia. A list of existing water licenses is provided in Appendix A.

4.0 HYDROLOGY OF THE CAPILANO AND SEYMOUR BASINS

The Capilano and Seymour Reservoirs are classified as "coastal reservoirs" where the majority of the inflow of water results from seasonal storms and melting snow.

4.1 The Capilano Watershed

The Capilano River is approximately 33 km in length and has two large tributaries. Eastcap Creek is 11.5 km upstream and Sister Creek is 6.5 km upstream from the Cleveland Dam.

The area of the watershed above the Cleveland Dam is 197 km^2. The maximum length and width of the catchment area is 22 km in the North-South direction and 14 km in East-West direction. There are many small lakes inside the catchment area, but only Palisade Lake is being used to store an important source of emergency water. The catchment area of Palisade Lake is 2.3 km^2.

The upper catchment area is characterized by rugged topography, steep rocky slopes at higher elevations, and mountain peaks 900 to 1760 m above sea level. The minimum elevation is 146 m with a mean catchment elevation of 1042 m above sea level.

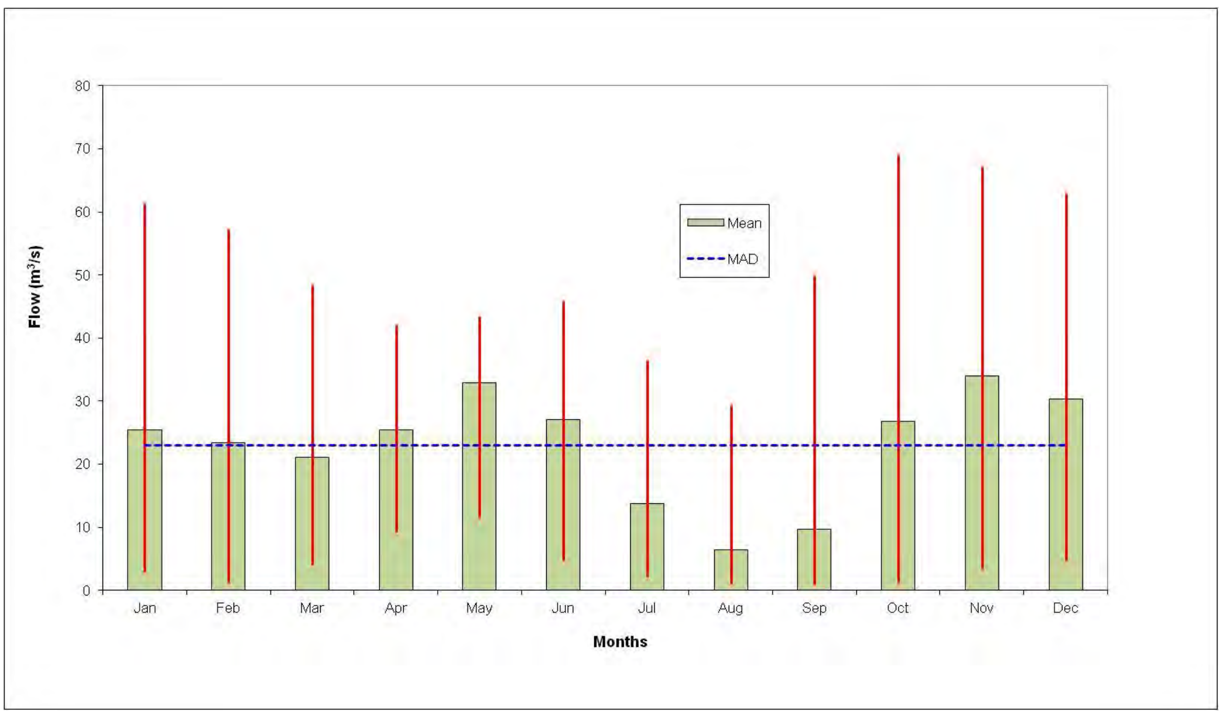

Figure 6: Hydrograph and Mean Annual Discharge at Cleveland Dam

The licensed storage capacity for the reservoir is 57.8 million cubic metres of water. The reservoir operates between the centre-line level of the intake at 115.58 m elevation and the full pool level of level of 145.89 m elevation. The maximum depth of the reservoir is 75 m. Metro Vancouver operates its reservoirs to ensure at least 98% reliability for the drinking water supply. The long–term minimum annual inflow volume of 490 Mm^3 to the Capilano Reservoir is considerably larger than the maximum reservoir capacity of 52 Mm^3 and average annual water demand 233 Mm3 from Capilano System, which is based on an average annual water demand of 1045 MLD. The ratio between reservoir storage and mean annual watershed yield is 0.07. The low ratio indicates that each year a large volume of water spills from Capilano Reservoir. As shown in Figure 4, while the Capilano Reservoir can be refilled during the fall, winter and spring, the average water withdrawals exceed the average inflows during the summer months. In addition, inflow or storage is required for continuous release of water for fish flow requirements during the summer.

Approximately 7% of the total catchment area for the Capilano River is below the Cleveland Dam. Downstream from the dam, the topography consists of gentler slopes and benches that are occupied by residential and commercial properties. For the first few kilometres immediately below the dam, the Capilano River traverses through a rock canyon that is bordered by the Metro Vancouver Capilano River Regional Park. Deep pool glide fish habitat is prevalent here. Just before reaching the bridge for the Upper Levels Highway, the river opens up and becomes a flatter, broader low gradient channel. Boulder riffle glide sections dominate the lower sections of the river. Residential and commercial properties and Capilano Indian Reserve # 5 border the river before it enters Burrard Inlet west of the Lions Gate Bridge.

Appendix C, the *Hydrology of Capilano Watershed* (2008), describes in detail the physiography, hydrometeorological network, climatology, streamflow statistics, reservoir inflow, outflow and storage relationship, and reservoir operational inflow forecast.

4.2 The Seymour River Watershed

The Seymour River receives inflow from twenty tributaries including Clipper Creek, Fannin Creek, Jamieson Creek, Orchid Creek, Sheba Creek, Balfour Creek, Gibbens Creek, Burwell Creek, Paton Creek, Cougar Creek, Needles Creek, Hayes Creek, Intake Creek, Elsay Creek, Hydraulic Creek, Suicide Creek, and Canyon Creek.

The total watershed area is 185.7 km^2 at the river mouth. The maximum length and width of the watershed is 39 km in the North-South direction and 7.5 km in the East-West direction. The width of the lower part of the catchment gradually reduces downstream of Intake Creek to Burrard Inlet. The minimum and maximum basin elevations are 5 m and 1737 m, respectively, with a mean basin elevation of 746 m above sea level. There are many small lakes inside the basin, but only Loch Lomond and Burwell Lake, with catchment areas of approximately 2.5 km^2 and 3.7 km^2, respectively, are currently being used for controlled storage of water.

Reservoir Watershed

The total watershed area at Seymour Falls Dam, the watershed area supplying the reservoir, is 125.9 square kilometres. The maximum length and width of the watershed is 20 km in the North-South direction and 7.5 km in the East-West direction. The reservoir watershed is characterized by rugged topography and steep rocky slopes at higher elevations with mountain peaks at elevations reaching 900 m to 1737 m above sea level. The minimum and maximum basin elevations are 190 m and 1737 m, respectively, with a mean basin elevation of 948 m above sea level.

The usable storage capacity for the reservoir is about 32 million cubic metres of water. The reservoir operates between the centre-line level of the intake at 189.78 m elevation and the full pool level of level of 214.77 m elevation. The maximum depth of the reservoir is 23 m without stoplogs and approximately 24.8 m with stoplogs in place. Metro Vancouver operates its reservoirs to ensure at least 98% reliability for the supply of drinking water. The long-term minimum annual inflow volume of 312 Mm^3 to the Seymour Reservoir is considerably larger than the maximum reservoir capacity of 32 Mm^3 and average annual water demand of 150 Mm^3 for the Seymour System, which is based on an average annual water demand of 1045 MLD. The ratio between reservoir storage and mean annual watershed yield is 0.06. The low ratio indicates that each year a large volume of water spills from Seymour Reservoir. While the Seymour Reservoir can be refilled during the fall, winter and spring, the average water withdrawals during the summer months exceed the average monthly inflows. In addition, inflow or storage is required for continuous release of water for fish flow requirements during the summer months.

Lower Seymour River Watershed

The drainage area of the Lower Seymour River, between Seymour Falls Dam and Burrard Inlet, is about 60 km^2. The Lower Seymour Watershed is a narrow valley, which rises in the East to an elevation of 1455 m (Mt. Seymour) and 1466 m in the West (Coliseum Mountain, Lynn Ridge and the Needles). The drainage area within the Lower Seymour Conservation Reserve is pristine land, which contains a mosaic of forests providing a variety of habitats as well as educational and recreational opportunities. Some forests are 350 years old, and they are highly significant from a regional and provincial perspective due to their ecological value, representation of rare and endangered ecosystems, and provision of habitat for many rare and endangered wildlife species. The drainage area inside the District of North Vancouver is an urban watershed where land use patterns include residential, commercial, and recreational components.

The Lower Seymour River receives runoff from several tributaries which originate on both sides of the river. The river area is characterized by a cobble-gravel-bed starting from the Seymour Falls Dam (upstream) and ending approximately at the Dollarton Highway in District of North Vancouver (downstream). Only the last 0.9 km of the river, which reaches between the Dollarton Highway and the Burrard Inlet, is a flat sand-gravel bed reach. The 2 km river section between the Swinburne Avenue of the District of North Vancouver and the Twin Bridges in the Lower Seymour Conservation Reserve area is a bedrock canyon. The channel widens and narrows along the entire length of the river with riffle pool system. The Lower Seymour Watershed aquatic habitats include the Seymour River, tributaries, several lakes, and wetlands which support salmon, trout and a diversity of other species.

Appendix D, *Hydrology of the Seymour Watershed* (2009), describes in detail the physiography, hydrometeorological network, climatology, streamflow statistics, reservoir inflow, outflow and storage relationship, and reservoir operational inflow forecast.

5.0 CONDITIONS FOR FACILITY OPERATIONS AND WATER USE

5.1 Role of Facilities in the GVWD System

The Capilano and Seymour Reservoirs are two of the three primary sources for the supply of drinking water for the Metro Vancouver region. Together, these systems supply approximately 70 percent of the region’s drinking water, while Coquitlam supplies the remainder.

5.2 Water Use at the Capilano and Seymour Facilities

The management of the drinking water for the Region is guided by Metro Vancouver’s *Drinking Water Management Plan* (DWMP). The goals of the DWMP are to:

- Provide clean, safe drinking water;
- Ensure sustainable use of water resources; and
- Ensure the efficient supply of water.

The Seymour-Capilano Filtration Plant on the North Shore will supply filtered water from both the Seymour and Capilano Reservoirs to the member municipalities.

The lower watersheds of both the Seymour and Capilano rivers are used for a range of recreational activities including hiking, picnicking, fishing, swimming, canoeing and kayaking. Metro Vancouver will continue to support and preserve the unique recreational activities offered in the lower watershed areas.

5.4 Operation of Works for Proposed Diversion and Use of Water

As a result of the consultation process for the JWUP Capilano and Seymour Watersheds, Metro Vancouver proposes to operate its facilities in accordance with the conditions described below.

5.4.1 Reservoir Levels

Capilano System

The Capilano Reservoir is normally full, or close to full, during the fall, winter and spring months. The reservoir operates between the centre-line level of the intake at 115.58 m elevation and the full pool level of level of 145.89 m elevation.

Seymour System

The Seymour Reservoir is normally full during the fall, winter and spring months at a reservoir elevation of 212.94 m; while the normal full supply level with stop logs in place is 214.77 m. The stop logs are typically installed during late spring to early summer and are removed once the rain returns during the fall.

5.4.2 Mitigation of Floods

Historic rainfall records indicate that annual maximum flood peaks occur between September and May with the potential for extreme floods being greatest during the period from October to February.

The Capilano and Seymour Reservoirs do not effectively reduce the flood peaks due to major storms because of relatively small storage capacities of the reservoirs. The intent of operating procedures during flood conditions is to allow the flood peaks to pass downstream. Where possible, flood forecasting allows operators to slowly increase discharge rates during the early stages of a flood to minimize any sudden increases or decreases in flow in the rivers downstream of the dams. However, even with well-developed procedures for operating during flood conditions, severe storms during the fall and winter, particularly when rainfall occurs over snow covered terrain, can result in the sudden rise of the river level.

5.4.3 Diversion of Water by the GVWD

Diversion of water for waterworks purposes from the Capilano and Seymour Reservoirs is governed by water licenses granted by the Province of British Columbia. For Capilano the Water Licenses are #C123813, #C016296, and #F008691, and, for Seymour the Water Licences are #C123895, #C016298, #F008689 and #F008690. Once drawn from the reservoir, the water is transmitted in a closed pipe and reservoir system until delivered to the member municipalities of the GVWD. Water is not normally discharged from the regional water distribution system directly to the environment.

5.4.4 Release for Fish Flow

Capilano System

The Consultative Committee for the JWUP proposed increasing the minimum fish flow releases from the Capilano Reservoir to the lower Capilano River under most operating conditions (JWUP Consultative Committee, Alternative 3E). The release of water for fish flow requirements depends on a number of factors, including the time of year, the level of the reservoir, the spill rate from the reservoir, inflows to the reservoir and the storage in the Alpine Lakes (see Appendix F). The proposed minimum fish flow releases are:

June 1 to November 30, release varies from 0.57 m^3/s to 2.3 m^3/s;

December 1 to May 31, release of 1.2 m^3/s, provided that the reservoir is above the elevation of 130 m;

During unusual maintenance or other unusual or emergency conditions, minimum fish flows may be reduced to 0.57 m^3/s if required.

To enable release of water for the proposed fish flows, new facilities to control the release of water will be built in conjunction with the proposed hydropower project.

Seymour System

The JWUP Consultative Committee proposed increasing the minimum fish flow releases from Seymour Reservoir to the lower Seymour River under most operating conditions (JWUP Consultative Committee, Alternative 4D). The release of water for fish flow requirements depends on a number of factors, including the time of year, the level of the reservoir and the storage in the Alpine Lakes (see Appendix F). The proposed minimum fish flow releases are:

June 1 to November 30, release varies from 0.7 m^3/s to 2.8 m^3/s;

December 1 to May 31, release of 1.36 m^3/s;

During unusual maintenance or other unusual or emergency conditions, minimum fish flows may be reduced to 0.57 m^3/s if required.

5.4.5 Ramping Rates

Ramping rates limit the speed at which the discharge flow rates will change whenever releases from the reservoir to the downstream rivers are changed or the inflows to the reservoir change quickly, for example during storm conditions. Appendix E illustrates the ramping rates for increasing and decreasing flows with respect to Cleveland Dam using the Drum Gate, Upper Outlet Slide Gates and Lower Outlet Howell-Bunger Valves and at the Seymour Falls Dam using the Howell Bunger Valves and Fish Flow Valves. The increasing discharge ramping rates limit the speed at which the flows increase and provide some time to anyone who may be on or near the river downstream to adjust their activities. The decreasing discharge ramping rates limit the speed at which the flows decrease. This will help minimize the risk of stranding fish along the banks and shallow areas of the river.

6.0 PROPOSED MONITORING PROGRAM

As recommended in the Provincial Water Use Planning Guidelines, the JWUP Consultative Committee has suggested a number of monitoring and communications activities as part of the JWUP. The following provides an overview of the activities that are common to the two watersheds:

- Monitoring and annual reporting of reservoir water levels, drinking water withdrawals, fish flow releases and hydropower withdrawals (when commissioned);
- Monitoring and annual reporting of river flows, at one location, in the lower Capilano River below Cleveland Dam and at one location in the lower Seymour River below Seymour Falls Dam along with analysis and reporting of the rate of flow changes (ramping);
- Assessments needed for the final design of a hydropower project and/or studies related to the operation of the hydropower project; and
- Operation of a JWUP monitoring committee to provide annual feedback on the monitoring results and, as appropriate, advice on unique watershed conditions.

6.1 Monitoring Activities Unique to the Capilano Watershed

Monitoring activities that are unique to the Capilano watershed include:

A flow monitoring station has been operated on the Capilano River above Capilano Reservoir since 1914. In recent years this station has been funded by Metro Vancouver. The JWUP proposes that this hydrometric station be operated on an ongoing basis.

The GVWD Board has previously committed to a "trap and truck" program on Capilano Reservoir. Out-migrating Coho and Steelhead smolts are captured and transported around the Cleveland Dam. This program reduces the mortalities associated with smolts passing over the spillway. The program also serves to monitor and enumerate the out-migrating smolts. The monitoring results will be used to optimize the design of the new facilities to capture the smolts that will be integral to intake channel for the new hydropower facility. The level of effort for the monitoring program is expected to decrease after commissioning of the new facilities to capture the smolts.

The JWUP Consultative Committee expects measurable improvements to fish habitat in the lower Capilano River once the proposed new fish flow releases are implemented, and has suggested the following monitoring for about two years prior, and up to five years after the fish flow releases are changed:

- Water temperature monitoring;
- Biological response monitoring of status and trends in key fish species.

Details and costs of the proposed monitoring program are provided in the 2012 *Capilano-Seymour Joint Water Use Plan: Consultative Committee Report*.

7.0 IMPLEMENTATION OF THE JWUP RECOMMENDATIONS

The conditions for the operation and the monitoring program proposed in the JWUP will come into effect when Metro Vancouver receives direction from the Comptroller of Water Rights for implementation under the *Water Act* of British Columbia (now named the Water Sustainability Act).

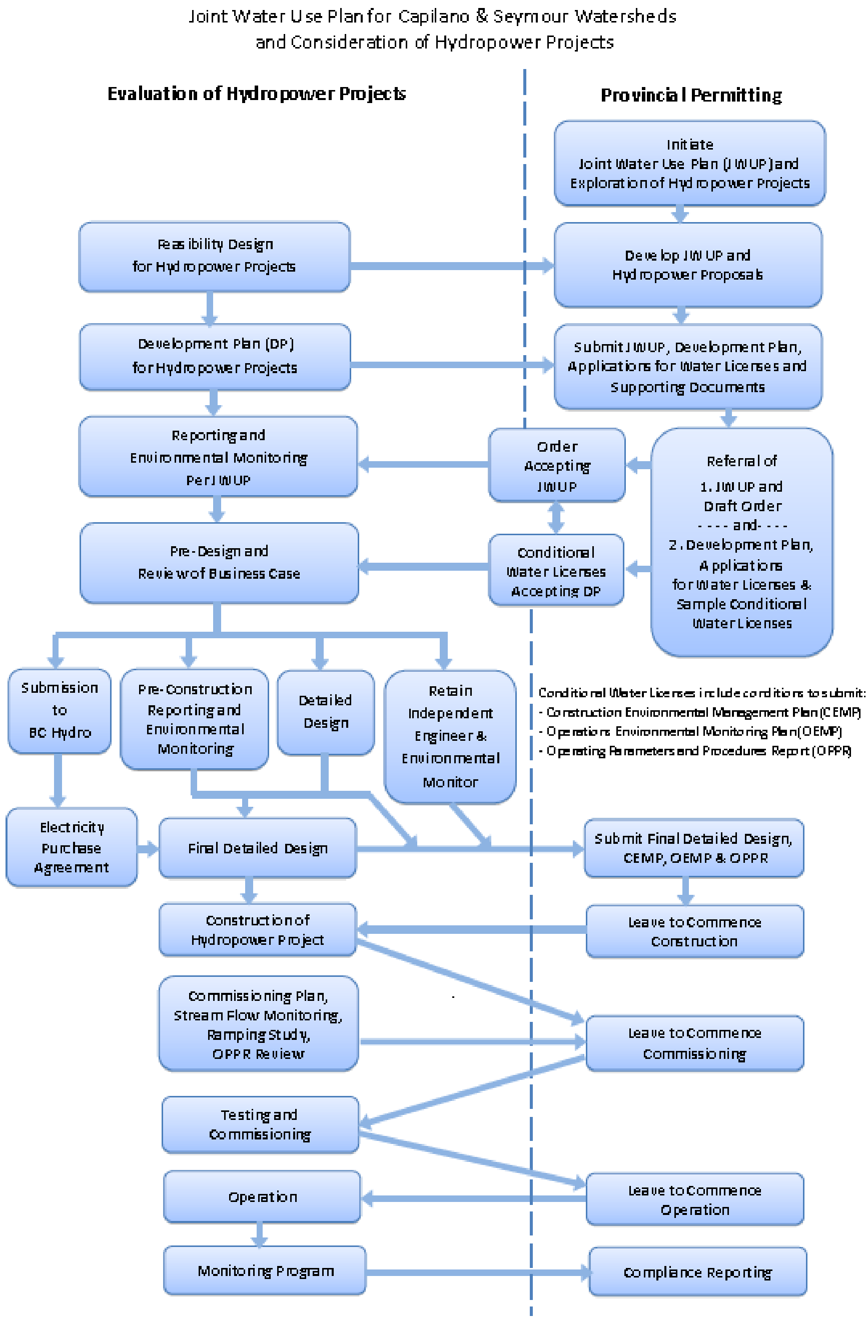

Figure 7: Overview of Technical, Commercial and Permitting Aspects

See Appendix G for larger size Figure 7: Overview of Technical, Commercial and Permitting Aspects

8.0 EXPECTED WATER MANAGEMENT IMPLICATIONS OF THE JWUP

8.1 Raw Water Quantity and Quality

Capilano System

The proposed conditions in the JWUP are not expected to affect the current raw water quality of the Capilano Reservoir or Capilano River below Cleveland Dam. However, upon operation of the new hydropower facility, the improvement in the water temperature in the Capilano River below Cleveland Dam is expected to enhance aquatic growth.

Seymour System

The proposed conditions in the JWUP are not expected to affect current raw water quality of the Seymour Reservoir or Seymour River below Seymour Falls Dam.

8.2 Drinking Water Quantity and Quality

The proposed conditions in the JWUP are not expected to affect current high quality drinking water supplied to the GVWD associated with the Capilano and Seymour Reservoirs. The capacity to reliably supply drinking water will be maintained at current levels, in the June to November period, even in dry years with low reservoir inflows.

8.3 Riparian Rights

The proposed conditions in the JWUP are not expected to affect riparian rights associated with the Capilano Reservoir or Capilano River below Cleveland Dam and the Seymour Reservoir or Seymour River below Seymour Falls Dam.

8.4 Proposed Fish Design Objectives and Criteria

Capilano System

The Consultative Committee for the JWUP has proposed increases to the minimum fish flow releases from Capilano Reservoir to the lower Capilano River. New water control facilities will be built in conjunction with the proposed hydropower project to enable the release of the increased flows for fish.

The proposed hydropower project on the Capilano River has the potential to partially restore natural Coho and Steelhead productivity in the watershed above and below the Cleveland Dam. It is proposed that the new hydropower facility will have a screened surface intake and underground powerhouse on the West bank of the Capilano River.

The surface intake for hydropower generation will generate an attraction flow for smolts during the spring freshet. This facilitates the design of a long-term smolt collection system located in the forebay of the surface intake that can efficiently capture the smolts. The surface intake will generally be discharging warmer water and this will improve the fish productivity in the lower Capilano River. In addition, the new water valves associated with the surface intake can allow for a gradual adjustment of downstream flows that will minimize the risk of stranding fish.

Seymour System

The Consultative Committee for the JWUP has proposed increases to the minimum fish flow releases from Seymour Reservoir to the lower Seymour River under most conditions.

Relative to the existing situation, the proposed JWUP will provide improved environmental and fish flows to the Seymour River below Seymour Falls Dam under most conditions.

8.5 Wildlife Habitat

The proposed conditions in the JWUP are not expected to significantly affect wildlife habitat associated with Capilano Reservoir or Capilano River below Cleveland Dam and Seymour Reservoir or Seymour River below Seymour Falls Dam.

8.6 Flood Mitigation Provisions

The proposed conditions in the JWUP are expected to maintain current levels of flood mitigation in the Capilano River below Cleveland Dam and the Seymour Reservoir or Seymour River below Seymour Falls Dam. The previously established triggers for flood management and protocols for communication have proven effective and do not warrant any changes at this time.

8.7 Recreation

Capilano System

The proposed conditions in the JWUP are expected to significantly improve recreation associated with the Capilano River below Cleveland Dam. There will be a significant improvement in flows for angling, kayaking and canoeing in the lower Capilano River below Cleveland Dam and more opportunities for paddlers to take advantage of preferred conditions through real-time flow gauges and access to forecast information on dam releases for the coming week. Preferred paddling flows were estimated to almost double over current conditions.

Seymour System

The proposed conditions in the JWUP are expected to significantly improve recreation associated with the Seymour River below Seymour Falls Dam. There will be significantly improved flows for angling and kayaking in the lower Seymour River below Seymour Falls Dam and more opportunities for paddlers to take advantage of preferred conditions through real-time flow gauges and access to forecast information on dam releases for the coming week.

8.8 Culture

The proposed conditions in the JWUP are not expected to affect the current cultural use of water associated with Capilano Reservoir or Capilano River below Cleveland Dam and Seymour Reservoir or Seymour River below Seymour Falls Dam.

8.9 Industrial Use of Water

The proposed conditions in the JWUP are not expected to significantly affect the current industrial use of water associated with the Capilano River below Cleveland Dam and the Seymour River below Seymour Falls Dam.

8.10 Other Licensed Uses of Water

The proposed conditions in the JWUP are not expected to affect other current licensed users of water associated with Capilano Reservoir or Capilano River below Cleveland Dam and Seymour Reservoir or Seymour River below Seymour Falls Dam.

8.11 Electrical Power Generation

Capilano System

The proposed conditions in the JWUP are expected to significantly increase the electrical power generation associated with Capilano Reservoir. The Capilano hydropower project is planned to be a 14 to 20 MW facility which will have an expected annual power output of 30 to 70 GW·h. The potential maximum reduction of annual greenhouse gas (GHG) is up to 1,200 tonnes CO_{2e}.

Seymour System

The proposed conditions in the JWUP are expected to significantly increase the electrical power generation associated with Seymour Reservoir.

8.12 First Nations Considerations

Metro Vancouver identified 52 potentially affected First Nations and tribal councils/associations whose traditional territory lies within, overlaps with, or who have interest in territory within the subject area of the JWUP. During April 2010, the identified groups received a letter and follow-up phone call communications. Response was received from the Tsleil-Waututh and Squamish Nations. Members of the Squamish Nation attended the October 2010 public meeting to initiate the JWUP process and have been involved in the Consultative Committee and the Fisheries Technical Working Group. The Squamish Nation hosted two of the JWUP Consultative Committee meetings at the band offices near the Seymour River on March 31, 2011 and July 14, 2011. Metro Vancouver has also met with the Squamish Nation separately and there may be other opportunities to meet directly with the Squamish Nation and other First Nations as the JWUP process is completed.

Tsleil-Waututh was invited to participate in the JWUP process and indicated they would like to participate on the JWUP Consultative Committee, but did not attend any meetings. Throughout the JWUP process, Tsleil-Waututh was sent all of the information distributed to the Consultative Committee members.

As the JWUP process is completed, Metro Vancouver will also inform, notify and seek comments from other First Nations and tribal councils and associations, whose traditional territories lie within, overlap with, or who have asserted interests within the areas covered by the JWUP.

8.13 Archaeological Considerations

The proposed conditions in the JWUP are not expected to affect First Nations archaeological interests. If future projects warrant archaeological assessment, Metro Vancouver will work with First Nations under the provincial *Heritage Management Act* to protect cultural sites located within the reservoirs from erosion, exploitation, to provide opportunities for archaeological investigation in the reservoirs, and to maintain the cultural, aesthetic and ecological context of important cultural resources and spiritual sites.

8.14 Net Cost of Water Supply

The costs for Metro Vancouver to monitor and report compliance with the JWUP will be higher than the existing situation. However, these costs are considered appropriate when compared to the monitoring costs of other water use plans adopted in other locations in British Columbia and considering the gained benefits of hydropower.

As Metro Vancouver proceeds further on the engineering design of the proposed hydropower projects there will be specific assessment needed to minimize and mitigate the potential impacts of the construction and operation of these projects.

The JWUP maintains the capacity to reliably supply drinking water under the stressed conditions that are used to design the drinking water system. However, during the December to May period when extremely low inflows can be encountered, the increased release for fish flow in the JWUP will only slightly reduce the amount of drinking water that could be reliably supplied from the Capilano and Seymour watersheds. Analysis shows that this increased release for fish flow during the December to May period still maintains the supply of drinking water at or above needed levels.

9.0 RECORDS AND REPORTS

9.1 Compliance Reporting

Metro Vancouver will submit data as required to the Comptroller of Water Rights, to demonstrate compliance with the conditions conveyed in the Water Licenses and Orders. The submission will include records of:

- Capilano Reservoir Elevations;
- Seymour Reservoir Elevations;
- Capilano Fish Flow Releases;
- Seymour Fish Flow Releases;
- Total Discharge into Capilano River;
- Total Discharge into Seymour River;
- Generation Discharge from Capilano Generation Station;
- Generation Discharge from Seymour Generation Station; and
- Diversion flows.

9.2 Non-Compliance Reporting

Non-compliance with operating conditions required by the water licenses or *Water Act* order (now named the Water Sustainability Act), or anticipation thereof, will be reported to the Comptroller of Water Rights in a timely manner.

9.3 Monitoring Program Reporting

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

10.0 PLAN REVIEW

The Consultative Committee for the JWUP has suggested that ideally the review for this joint water use plan should occur concurrently approximately 15 years after the approval of the JWUP. However, if the Capilano hydropower project is delayed, then the review period may be separated for the two watersheds and the review of the Capilano component of the JWUP initiated 10 years after the hydropower facilities at Cleveland Dam are commissioned.

11.0 NOTIFICATION PROCEDURES

Notification procedures for floods and other emergency events are outlined in the Dam Emergency Response Plan Cleveland Dam and Seymour Falls Dam. These documents are filed with the Office of the Comptroller of Water Rights.

APPENDIX A: WATER LICENCES

Water Licenses

STREAM NAME	LICENCE #	WR MAP/POINT CODE	PURPOSE	QUANTITY	LICENSEE
CAPILANO RIVER	C016296	8100 T5 (PD45592)	Storage-Non Power	57973560 m^3/year	GVWD
	C122190	8100 C (PD45591)	Power-General	17.5 m^3/s	GVWD
	C123813 (in substitution of C016295)	8100 C (PD45591)	Waterworks Local Auth	256531312.61 m^3/year	GVWD
	F008691	8100 C (PD45591)	Waterworks Local Auth	41099767.672 m^3/year	GVWD
	Proposed		Power-General	27 m3/s	GVWD
PALISADE CREEK	F008692	92G/6gh A (PD45384)	Storage-Non Power	16651980 m^3/year	GVWD
SEYMOUR RIVER	C122190	92G/7e C (PD60312)	Power-General	17.5 m^3/s	GVWD
	C016298	8100E S5 (PD63181)	Storage-Non Power	67841400 m^3/year	GVWD
	C024510	92G/7e C (PD60312)	Storage-Non Power	23621142 m^3/year	GVWD
	C118986	92G/7e C (PD60312)	Storage-Non Power	63647568 m^3/year	GVWD
	C123895 (in substitution of C016297)	92G/7e C (PD60312)	Waterworks Local Auth	290713363.32 m^3/year	GVWD
	F008689	8100 U4 (PD45615)	Waterworks Local Auth	75052831.828 m^3/year	GVWD
		92G/7e C (PD60312)	Waterworks Local Auth	75052831.828 m^3/year	GVWD
	F008690	92G/11a A (PD45388)	Storage-Non Power	22264314 m^3/year	GVWD
		92G/7e C (PD60312)	Storage-Non Power	22264314 m^3/year	GVWD
	Proposed		Power-General	16.2 m3/s	GVWD
BURWELL CREEK	F008690	92G/7e E (PD60314)	Storage-Non Power	22264314 m^3/year	GVWD

APPENDIX C: HYDROLOGY OF CAPILANO WATERSHED

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Acronyms

AES	Atmospheric and Environmental Services
B.C.	Province of British Columbia
DSS	Decision Support System
El.	Elevation
ENSO	El Niño Southern Oscillation
ft	Feet
ft^3/s	Cubic feet per second
GVWD	Greater Vancouver Water District
GVRD	Greater Vancouver Regional District
H-B	Howell-Bunger
JWUP	Joint Water Use Plan for the Capilano and Seymour Watersheds
km	Kilometre
km^2	Square Kilometres
m	Metre
m^3/s	Cubic metres per second
$M{\cdot}m^3$	Million cubic metres
MAD	Mean annual discharge
MLD	Million litres per day
MOE	Ministry of Environment, BC
PDO	Pacific Decadal Oscillation
SCADA	Supervisory Control and Data Acquisition
SOI	Southern Oscillation Index
WSC	Water Survey of Canada

1.0 INTRODUCTION

The Capilano Reservoir is one of the three main sources of drinking water for the Metropolitan Vancouver area. The Capilano Watershed encompasses over 200 square kilometres in a mountainous area on the North Shore of the Lower Mainland, British Columbia. The watershed is located near the ocean and is subject to heavy precipitation. Tributary streams are steep and the runoff is rapid. The heavy precipitation and steep mountain slopes allow the Capilano Watershed to gather billion of litres of snowmelt and rainwater each year. The Cleveland Dam stores the water collected in the watershed. The Cleveland Dam was constructed by the Greater Vancouver Water District (GVWD) during 1954 (Figure 1.1) and has been operating since 1958.

Capilano Reservoir has the following general characteristics:

- Cleveland Dam impounds Capilano River 6 km upstream of the river mouth.
- At its full pool-level (145.89 m) the reservoir is 5.4 km long and 0.8 km wide and 90 m deep (maximum depth).
- Size of the main reservoir is 2.63 km^2 at full pool level.
- There are many small alpine lakes inside the watershed. Only Palisade Lake is currently used for controlled water storage.

This report highlights the hydrology of the Capilano River basin. The physiography of the entire watershed, including the drainage area downstream of Cleveland Dam and Palisade Lake, is reviewed in Chapter 2. A detailed description of hydrometeorological stations is provided in Chapter 3. This report reviews the climatology of the watershed in Chapter 4. Inflow characteristics, basin water yield, low-flow and peak flow statistics are provided in Chapter 5. Typical inflow hydrographs and summary statistics are provided. Capilano Reservoir inflow, outflow calculations and storage relationships are discussed in Chapter 6. Capilano Reservoir operational forecast is discussed in Chapter 7.

Figure 1.1: Capilano Reservoir and Cleveland Dam, built 1954, 6.3 km N of Burrard Inlet.

2.0 PHYSIOGRAPHY

2.1 Capilano River Watershed

The Capilano River Watershed is a mountainous catchment located in the western South Coast Mountain region of British Columbia. The Capilano River originates at Capilano Mountain and flows 33 km to Burrard Inlet. Capilano River receives runoff from two large tributaries including Eastcap Creek and Sister Creek which are located 11.5 km and 6.5 km upstream of Cleveland Dam. Figure 2.1 provides an aerial view of the drainage basin of the Capilano River.

The total area of the watershed is 212.6 km^2. The maximum length and width of the watershed is 33 km in the north-south direction and 14 km in the east-west direction. The width of the lower part of the catchment gradually reduces downstream of Palisade Lake to the mouth of the river at Burrard Inlet. The minimum and maximum basin elevations are 3 m and 1760 m, with a mean basin elevation of 746 m above sea level. There are many small lakes inside the basin, but only Palisade Lake is currently being used for controlled storage of water.

The watershed is primarily covered with forests, most of which are considered old growth greater than 250 years old. The forest vegetation at the lower elevations of the watershed includes western hemlock, amabilis fir, western red cedar, Sitka spruce and Douglas fir. In the mid-elevation, yellow cedar and mountain hemlock are the dominant species. At the highest elevations, the vegetation of the alpine tundra zone includes herbs, lichens, and low alpine shrubs (GVRD, 2002).

2.2 *Capilano Reservoir Watershed*

The total watershed area at the Cleveland Dam is 197 km^2 (termed the “reservoir watershed”). The maximum length and width of the watershed is 22 km in the north-south direction and 14 km in the east-west direction. The reservoir watershed is characterized by rugged topography and steep rocky slopes at higher elevations with mountain peaks at elevations reaching 900 to 1760 m above sea level (Cleveland, 1923). The minimum basin elevation is 146 m with a mean basin elevation of 1042 m above sea level.

The elevation-storage relationship shown in Figure 2.2 indicates the storage capacity of the Capilano Reservoir at different reservoir elevations. Usable storage available between the normal operating range of 118.5 m and 145.89 m is estimated from the stage-storage curve to be 52 million cubic metres. The maximum depth of the reservoir is 90 m.

2.3 *Lower Capilano River Watershed*

The drainage area of the Lower Capilano River, between Cleveland Dam and Burrard Inlet, is 15 km^2. The Lower Capilano River receives runoff from two tributaries known as Brothers Creek and Houlgate Creek, which are 1 km and 5 km upstream of Burrard Inlet. Brothers Creek originates on the south side of Hollyburn Ridge and is the third largest watershed in the District of West Vancouver. The length and drainage area of Brothers Creek are 6.9 km and 5.7 km^2. The drainage area of Houlgate Creek is 1.2 km^2. The drainage area below the Cleveland Dam is 8 km^2 and discharges directly into the Capilano River.

Land uses include residential, commercial and recreational components. The river reach between Cleveland Dam and Ridgewood Drive in North Vancouver is a typical rocky canyon with steep slopes. The Lower Capilano River reach downstream of the Trans Canada Highway gradually reduces its gradient as the river descends to the mouth at Burrard Inlet. The lower part of the river from the Marine Drive

Bridge is a tidal reach. Most of the Lower Capilano watershed is urban, however, western hemlock, western red cedar and Douglas fir are the most common tree species.

2.4 Palisade Lake

Palisade Lake is located 9.6 km north of the Cleveland Dam near the east watershed boundary. The lake has a catchment area of 2.3 km^2 and the depth of the reservoir of 85 m. The lake was developed by the GVWD during 1926 to supplement the seasonal low flows of Capilano River. Today, the Palisade Lake storage facility is integral to the Metro Vancouver Water Supply System in the Capilano watershed. The stored water is released during the summer to augment low flows into the Capilano Reservoir. A concrete-lined tunnel through the bedrock, pipe system and control valves are normally closed, but can be opened to release water during the hot summer months when the level of Capilano Reservoir reaches a threshold level. When Palisade Lake is full or the control valves are closed then excess flow spills over the spillway.

Palisade Lake has an estimated usable storage capacity of 19.5 million cubic metres between the normal operating range of 887.5 m and 843.27 m. Palisade Lake can store more than the annual inflow volume. As a result, if the lake drains completely, a two year period is required to refill the lake. For that reason, annual storage volume released from the Palisade Lake remains below 10 Mm^3 which is approximately half of the usable storage. The long-time annual reliable refillable volume is approximately 8.5 Mm^3.

3.0 HYDROMETEOROLOGICAL NETWORK AND DATA

Hydrometeorological data is collected to plan, monitor, and operate facilities in the Capilano Watershed. Hydrometeorological stations in the vicinity of the Capilano Watershed are listed in Table 3.1 and Table 3.2.

3.1 Meteorological Stations

A total of eight Atmospheric and Environmental Services (AES) stations are located within or near the Capilano Watershed. The AES stations collect meteorological data such as precipitation, temperature, humidity, atmospheric pressure, evaporation, wind speed, and wind direction. The stations are listed in Table 3.1 in ascending order of elevation.

3.2 Stream Flow Stations

Four stream-flow gauging stations are located in the Capilano Watershed (Table 3.2). All stations are located above the Cleveland Dam outlet except the station 08GA031. The stream-flow gauge with the longest record is Station 08GA010 at the Capilano River above the intake. This station has a continuous record since 1914, so except for a few missing years, there are 90 years of complete daily flow and level records available from 1914 to 2010. This data record is sufficient to complete a reasonable hydrological analysis.

During 2007, Metro Vancouver established a permanent flow monitoring station 250 m below the dam. The continuous hydrometric measurements for this station are flow and level. During 2009, Metro Vancouver established four temporary flow monitoring stations on the Lower Capilano River. These stations are now maintained by the Watershed Division of Metro Vancouver. Water levels are monitored and recorded continuously.

3.3 Monitoring Stations for Reservoir Level

Metro Vancouver continuously monitors and records the water levels in the Capilano Reservoir at the Cleveland Dam. The water level data is important for the operation of the dam and to calculate the discharge through the various valves and over the spillway. Palisade Lake water level is recorded by an automatic sensor.

3.4 Snow Survey Stations

Metro Vancouver in cooperation with the Ministry of Environment maintains two snow survey stations at Palisade Lake and Grouse Mountain in the Capilano watershed. Average snow depth, snow water equivalent depth and climate data is gathered from these stations. Snow pack data has been collected since 1937 at Grouse Mountain and since 1946 Palisade Lake.

4.0 CLIMATOLOGY

4.1 General

The Capilano River Basin is within the western south coastal climatic region. During winter, large-scale cyclonic storms[1] produce heavy and prolonged rainfall as south-westerly winds from the Pacific Ocean push saturated, or near saturated, air masses into the windward slopes of the mountains. The abrupt rise of the Coast Mountains exerts a strong orographic influence[2] on these airflows. The Capilano River basin is open to these south-westerly flows of warm, moist air which produce the heaviest rainfall for storm durations greater than one or two hours. The largest storms occur during the fall and winter months of November to February, and fewer storms occur during the summer months of June to August.

4.2 Precipitation

Monthly precipitation is recorded at the Grouse Mountain, Hollyburn, and Cleveland Dam stations. Hollyburn Station generally receives more precipitation than the other two stations because of its proximity to the coast. Mean monthly precipitation values are lower at the Cleveland Dam station due to its lower elevation (157 m geodetic). Minimum and maximum monthly precipitation (rainfall and snow) values are also indicated on Figure 4.1 which illustrates the variability of the data. The plot shows that up to 60 percent of the annual precipitation falls between the months of October and January. Mean annual precipitation is 2477 mm at Grouse Mountain Station. The maximum historical monthly total rainfall record was 875 mm at the Grouse Mountain Station and 666 mm at the Cleveland Dam Station, both recorded during November of 2006. A probable maximum precipitation (PMP) event for the Capilano watershed over the 24-hour is 457 mm (KWL, 2012).

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[1] *Cyclonic Storm*s in the Northern Hemisphere are characterized by strong counter-clockwise winds.

[2] *Orographic influence or lift* occurs when an air mass is forced from a low elevation to a higher elevation as it moves over rising terrain such as a mountain barrier. Resulting precipitation, if occurs, is called *Orographic* or, *Relief rain*.

4.3 Snow Depths

Metro Vancouver collects snow information at Palisade Lake and Grouse Mountain to determine the amount of water stored in the snow. The snow depths are reported on a monthly basis from January to June, and more frequently during May and June. At the Palisade snow study site, the average maximum snow depth is 361 cm (April 1 survey period) or approximately 12 feet. The maximum depth recorded at the Palisade site was 765 cm or approximately 25 feet on April 1, 1946. The snow water equivalent information helps manage water supply during the summer.

4.4 Air Temperature

The Grouse Mountain and Hollyburn stations are 8.5 km apart in an east-west direction. Hollyburn Station, at a lower elevation, would be expected to have higher average monthly temperatures than the Grouse Mountain station; however, lower values might be explained by its northerly location. The higher temperatures and lower rainfall between July and August make these months the driest period of the year.

4.5 Evaporation

Capilano Reservoir loses a significant amount of water daily due to evaporation. The rate of evaporation varies throughout the year. The evaporation rate is the highest during July at 3.87 mm/day, and the lowest in January at 0.2 mm/day. During the summer months, for example in July, the Capilano Reservoir may lose up to 10,000 m^3 of water per day at full supply level.

4.6 Overview of Climate Change

There is a general consensus in the scientific community that the global atmosphere is warming and that climate patterns are correspondingly changing throughout the world, including British Columbia. Over the past century, average annual temperatures in the Lower Mainland and the Vancouver Island Region of BC have warmed by approximately 0.6 °C, and annual precipitation in southern BC has generally increased at a rate of approximately 3 percent per decade (MWLAP, 2002). Historical trends of the mean annual discharge (MAD) were examined. The Capilano River data set indicates a slight decrease in MAD over the last 86 years of the record, as shown in Figure 4.2. This amount is a 0.53% decrease of MAD, however, there are two high MAD's observed during 1914 and 1921 which may have an impact on the general trend. There is no guarantee that these trends will continue in the near future given the inherent variability and cyclic nature of weather, but it is reasonable for the purpose of hydrological assessment to conclude that inflow pattern may change with global warming. However, at this point, significant trend changes in the historical normals are not supported by the available data.

4.7 Climate Cycles

In conjunction with long-term climate changes, regional climate is also modulated by "natural" short-term and long-term climate cycles such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). El Nino events, which occur on average every 3-7 years, are part of a natural atmosphere-ocean oscillation in the Pacific region and generally only influence the local winter and spring climates in a noticeable way (KWL, 2002). Generally El Nino winters are associated with less precipitation in the region than normal, with the opposite occurring under La Nina conditions. The position and strength of the ENSO effect is measured by the Southern Oscillation Index (SOI).

The PDO represents an ENSO-like pattern, but at much longer time scales (50-70 years) [KWL, 2002]. It is divided into "cool" and "warm" phases. During the warm phase, the region generally experiences shallow snowpack due to higher temperatures and more precipitation falling as rain instead of snow. During the cool phase, the reverse is true with the snowpack increasing in depth and occasionally precipitation totals are higher than in warm phases.

Recent studies indicate that PDO and ENSO do have an impact on the hydrology of the Capilano Watershed, especially from November through to March because ENSO and PDO only influence large scale synoptic weather systems (Fleming and Whitfield, 2006). Summer rainfall primarily originates from convective systems that operate independently from ENSO and PDO. During a combined cool PDO and La Nina, there is higher precipitation and snowpack accumulation in the Capilano Watershed (Sellars, Garrett and Woods, 2008). This in turn delays the date when spilling over the dam stops and increases the flow for the June to September period. Compared with the cool PDO, the longest reservoir drawdown durations are observed with warm PDO and ENSO (i.e. El Nino) conditions.

Environment Canada has also reported that ENSO and PDO influence the magnitude of summer streamflows only to the extent that ENSO and PDO affect snowpack accumulation and moisture levels during the winter and spring (Wang, Whitfield and Cannon, 2006). Low June to September inflows are associated with warm or neutral ENSO and PDO conditions. These low inflows did not occur during cold ENSO conditions and only one occurred during a cool phase of the PDO. As the ENSO cycle is 6 to 18 months, it is useful for planning short-term reservoir operations. The longer PDO cycle of 20–30 years is of limited use for reservoir operations though it has implications for planning future reservoir storage. In general, historical data suggests that the effect of these climate cycles far exceeds the magnitude of changes attributed to long-term climate change.

5.0 STREAMFLOW STATISTICS

5.1 Reservoir Inflow Characteristics

A total of 90 years of daily flow records from 1914 to 2010 were used to assess the daily and monthly flows. Figure 5.1 shows a “spaghetti plot” of historical daily inflows to the Capilano Reservoir. The 10th, 50th, and 90th percentile inflows are also shown in Figure 5.1. and Table 5.1 which summarize the historical daily inflows by month and highlight the variability of observed daily inflows at the gauge site (08GA010). Historically, the lowest daily inflow in the record was 0.16 m^3/s on October 23, 1987. The highest daily inflow record was 479 m^3/s in October 28, 1921. Very high inflow variability by month was observed during October followed by November, December, and January. Severe coastal rain storms and elongated dry summers cause very high daily inflows and very low daily inflows also during the month of October.

Long-term mean monthly flows were presented in Figure 5.2. Long-term mean annual discharges are 20.1 m^3/s at the Gauge 08GA010 and 23 m^3/s at Cleveland Dam (by simple area proration), respectively. August is the driest month and the flows for July through to September also remain well below the mean annual discharge. Minimum and maximum monthly flow values shown in Figure 5.2, indicate a large variation between the maximum and minimum levels. However, the lowest daily flow values were observed during September and October as shown in Table 5.1.

5.2 Basin Water Yield and Water Demand

Between the years 1914-2010 the annual watershed yield varied between 490 Mm^3 and 1050 Mm^3 with a mean annual inflow volume of 728 Mm^3 at the Cleveland Dam. The Capilano Reservoir usable storage between full pool level and maximum drawdown level is 53 Mm^3. The ratio between reservoir storage and mean annual watershed yield is 0.07. The low ratio demonstrates that a large amount of water spills from Capilano Reservoir each year.

Average monthly water withdrawals (demand) from Capilano Reservoir has been compared with the averaged reservoir monthly inflows at Cleveland Dam in Figure 5.3. Summer fish flow release is not included in the demand values. Even though the Capilano Reservoir is not supplying all the drinking water to the region as a stand-alone source, it is clear that average water withdrawals in the summer months exceed the average monthly inflows. In addition, inflow or storage is required for continuous release of water for the Summer Fish Flow requirements. Average annual water demand 233 Mm^3 from Capilano System (based on 1045 MLD total average annual demand) is equivalent to 32% of the mean annual watershed yield 728 Mm^3.

5.3 Analysis of Low Flow

Low flow is defined as the "flow of water in a stream during prolonged dry weather," according to the World Meteorological Organization. The low flow is a seasonal phenomenon, usually occurring during the "dry season", and is an important characteristic of the flow regime in a river. By contrast, a drought is a natural event that results from an extended period of below average precipitation. While droughts include low flows, a continuous seasonal low-flow event is not necessarily a drought. The historical low flow occurs when the mean monthly inflow at WSC station 08GA010 was less than or equal to 0.5 m^3/s.

6.0 RESERVOIR INFLOW, OUTFLOW AND STORAGE RELATIONSHIP

6.1 Storage Relationships

Storage relationships used to determine the volume of water in Capilano Reservoir are shown in Figure 2.2.

6.2 Calculation of Daily Outflow

Daily outflow from the Capilano Reservoir occur through various outlets at Cleveland Dam as shown in Figure 6.1. Various indirect information including reservoir elevation, drum gate elevation, percent valve openings and direct flow measuring are used in the day-to-day operation of the reservoir.

The main outflows from the Capilano Reservoir are listed below:

- Flows for domestic water supply
- Flows for Fish habitat below the dam
- Flows over the spillway
- Flows through the Mid-level outlets
- Flows through the Lower Level Outlet tunnel

6.2.1 Calculation of Withdrawal for Drinking Water

The withdrawal of water for drinking water supply is metred downstream from the dam. The daily flow rate varies over the season from 6.5 m^3/s to 9 m^3/s, with an average value of 7.4 m^3/s over the year; and 8.15 m^3/s for the peak season from July to October.

6.2.2 Calculation of Fish Flow

At present, the withdrawals for fish-flows occur through the same port used for the withdrawal of drinking water. The fish-flow withdrawal port is connected as a bypass line on the main drinking water supply line. This fish-flow passes through a system of turbines and generates a small amount of power for the operation of the facility. All flows through the turbines are discharged to the river downstream of the Cleveland Dam and are measured at the penstock. The present fish-flow release was maintained at a constant flow of 0.57 m^3/s (20 cfs) throughout the year and which is approximately 2.5 % of MAD (23 m^3/s) at the Cleveland Dam.

6.2.3 Calculation of Spillway Flow

The Cleveland Dam is equipped with a chute spillway located at the center of the dam. The spillway is 21.3 m (70 ft) long with a crest elevation 138.87 m geodetic (547 ft GVWD). The spillway crest is equipped with a variable height radial gate known as “Drum Gate”. The drum gate is 21.3 m long and 7 m high (70 ft by 23 ft). The maximum discharge capacity of the spillway is 781 m^3/s at full pool level (145.9 m). The emergency discharge capacity is 1217 m^3/s at reservoir elevation 148.02 m (2 m above full pool). The reservoir water level is regulated by the drum gate. The drum gate level moves up and down with the water level fluctuation in the reservoir and the spillway head varies over time. The reservoir level and drum gate level are continuously recorded at the Cleveland Dam.

6.2.4 Calculation of Mid-level Outflow

The mid-level outlet consists of two 1.83 m (72 in) conduits, each equipped with one 1.52 m x 1.83 m (5 ft x 6 ft) slide gate known as “Waste Gates”. The centerline elevation of these conduits is 115.58 m geodetic. The maximum discharge capacity is 57 m^3/s for each conduit when the reservoir is at full pool level. The conduits can be used as emergency outlets. Usually, no flow passes through the mid-level outlet between April and September. The conduits operate during the high flow season or any other time of the year if required.

6.2.5 Calculation of Lower-level Out-flow

The Lower Outlet consists of a tunnel and two 1.37 m (54 in) control valves known as Howell Bunger Valves. This tunnel connects the reservoir to the downstream river in a bed-rock plunge pool. The opening of each Howell Bunger Valve has a 1.52 m x 1.83m (5 ft x 6 ft) slide gate. The centerline and invert elevation of the Howell Bunger Valve are 65.37m geodetic and 64.69 m geodetic, respectively. The maximum discharge capacity of each Howell Bunger Valve is 50 m3/s when reservoir is at full pool level. Operation of the lower outlet varies throughout the year.

6.3 Total Downstream Outflow Release

The total discharge downstream of the Cleveland Dam into the Capilano River is the sum of the outflows over the spillway, through the Mid-level and Lower-level outlets and reservoir release for fisheries. Total outflow release has been monitored by Metro Vancouver at Capilano Pump-house station since January 20, 2004. It is observed that the catchment downstream of the dam contributes insignificant flow to the lower part of the river. Therefore, the flow of water in the Lower Capilano River is predominantly influenced by the release over the spillway and through the lower outlet. The largest differences between inflow and outflow volumes are during the summer months (July, August and September) due to the increase in drinking water demands and relatively low inflows.

7.0 RESERVOIR OPERATIONAL INFLOW FORECAST

During the fall and winter, the operation of the Capilano Reservoir depends on the rate of inflow and the weather forecast. Once the Capilano Reservoir has been refilled during late fall, the drum gate remains fully open and excess water flows over the spillway without regulation. When heavy precipitation is forecast, the Howell Bunger valves may be opened earlier to reduce the storage to avoid sudden sharp flood peak over the spillway.

During the spring, a constant reservoir level is maintained by the automatic drum gate control. In automatic mode, the drum gate is set to maintain a specified reservoir level. Under this condition, the drum gate is lowered to release more water from the reservoir when inflow increases, and is raised to store more water to maintain the specified reservoir level when inflow reduces. If high flood approaches to the reservoir, drum gate would be fully opened to allow maximum outflow. When the spring freshet is finished, the Capilano Reservoir water level is raised to its full pool level (by July 1st) gradually in step by step depth increments.

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TABLES

Table 3.1: Summary of Regional AES Stations within or near the Capilano Watershed.

AES Station Name	Station ID.	Years of Record	Start Year	End Year	Latitude	Longitude	Elevation (m)
Cypress Bowl Upper	1102254	19	1985	2004	49°24'	123°11.4'	1210
N. Vancouver Gr. Mt. Resort[1]	1105658	38	1971	Currently Active	49°22.2'	123°4.8'	1127
Hollyburn Ridge	1103510	39	1954	1995	49°22.8'	123°10.8'	930
W. Vancouver Capilano	1108825	2	1996	1998	49°21.8'	123°7.2'	201
N. Vancouver Cleveland	110EF56	36	1968	2010	49°21.6'	123°6.6'	157
Capilano Intake	1041380	31	1924	1955	49°24'	123°9'	146
N. Vancouver Capilano	1105655	35	1955	1990	49°21'	123°7.2'	93
Lions bay	1104634	21	1983	2004	49°27'	123°14'	52

[1] Climatological station with continuous data.

Table 3.2: Summary of Stream Flow Stations within the Capilano Watershed.

Station Name	Station ID	Years of Record	Start Year	End Year	Latitude	Longitude	Catchment Area (km^2)
Capilano River[1] above Intake	08GA010	91	1914	Currently Active	49° 23.75'	123° 8.67'	172.1
Capilano River above Eastcap Creek	08GA026	5 + 7 =12	1926 1997	1930 2003	49° 27.23'	123° 6.5'	69.9
Eastcap Creek Near the Mouth	08GA027	5 + 2 =7	1926 2002	1930 2003	49° 27'	123° 6.2'	41.40
Capilano River at Canyon[2]	08GA031	38	1929	1956	49°21.5'	123°6.5'	197

[1] Hydrometric Station with continuous data.
[2] Station downstream of the Cleveland Dam.

Table 5.1: Variability in Capilano Reservoir Daily Inflows (1914 -2006).

Months	Minimum Daily Flow (m^3/s)	Mean Daily Flow (m^3/s)	Maximum Daily Flow (m^3/s)
Jan	1.33	22.24	360
Feb	0.74	20.41	354
Mar	2.15	18.40	329
Apr	2.97	22.23	272
May	5.65	28.69	247
Jun	2.61	23.65	204
Jul	1.25	**12.00**	196
Aug	0.67	**5.65**	266
Sep	0.36	**8.44**	276
Oct	**0.16**	23.33	**479**
Nov	1.29	29.66	393
Dec	1.56	26.46	331

* Minimum, maximum and driest month’s values are highlighted.

FIGURES

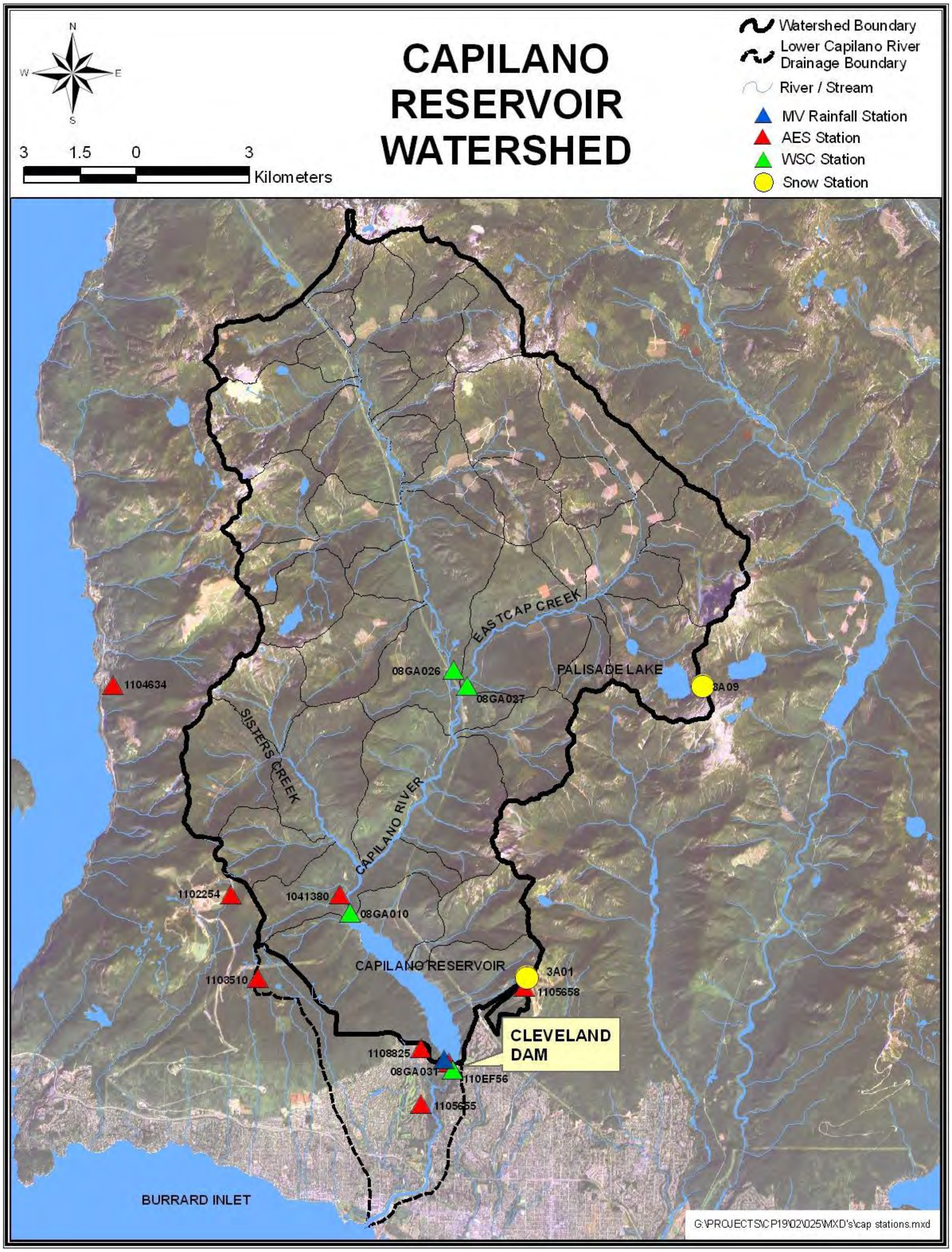

Figure 2.1: Aerial view of the Capilano River Watershed and Tributaries.

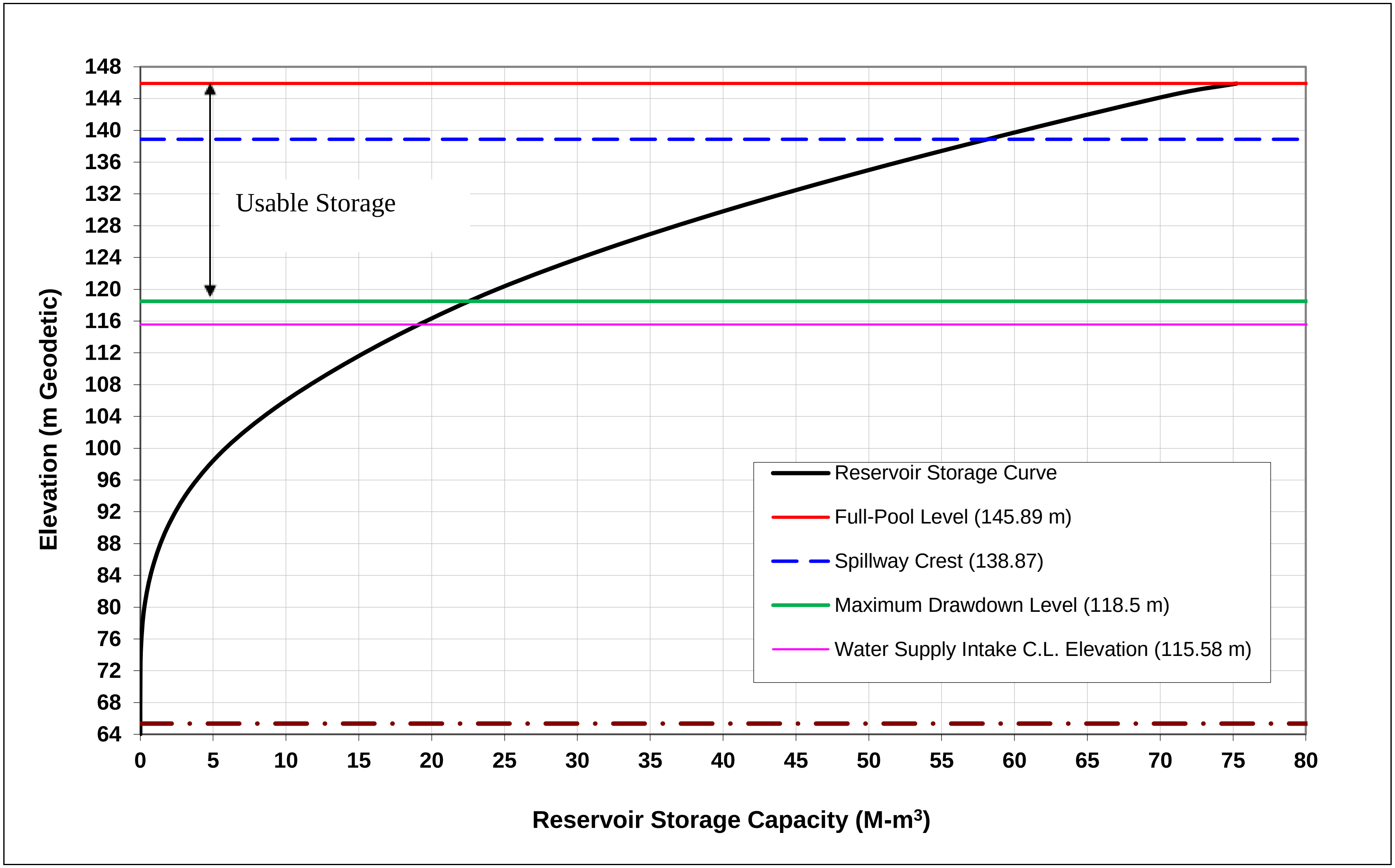

Figure 2.2: Elevation-Storage Curve for the Capilano Reservoir.

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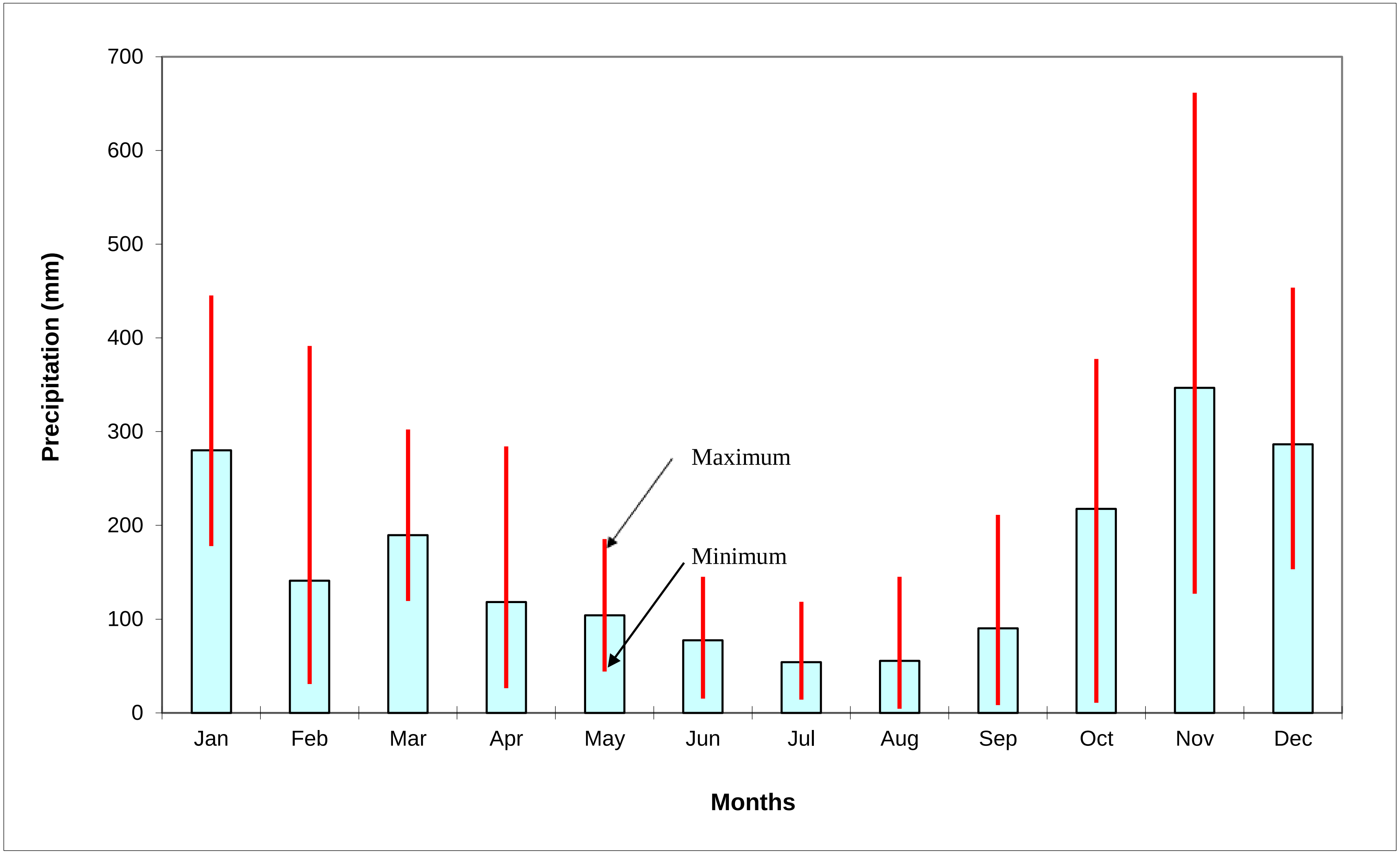

Figure 4.1: Mean Monthly Precipitation at Cleveland Dam Station (Cleveland Dam Station Operated by the Metro Vancouver).

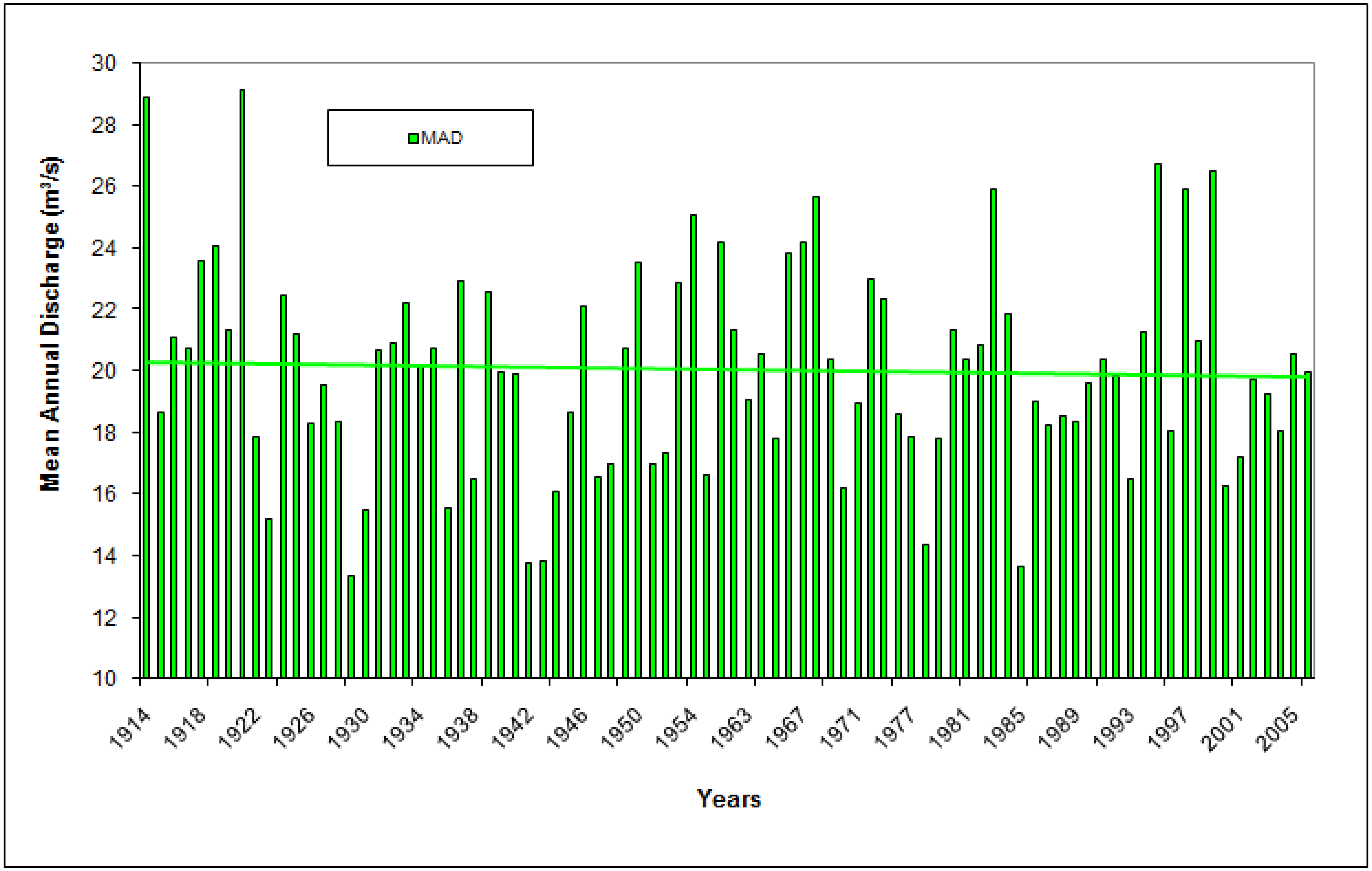

Figure 4.2: Mean Annual Discharges (MAD) of Capilano River at WSC Station 08GA010.

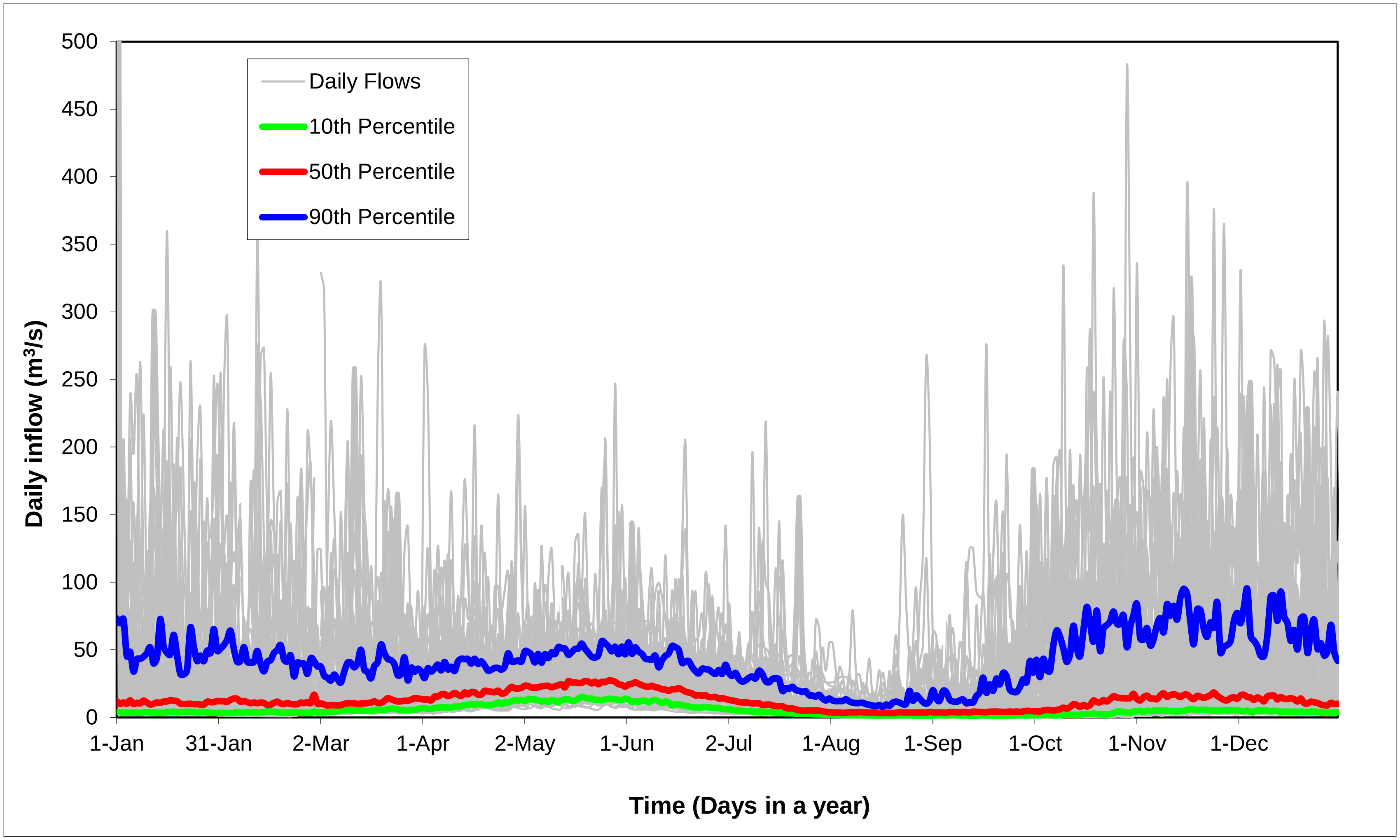

Figure 5.1: Historical Daily Inflows for Capilano Reservoir (Data from WSC Station 08GA010).

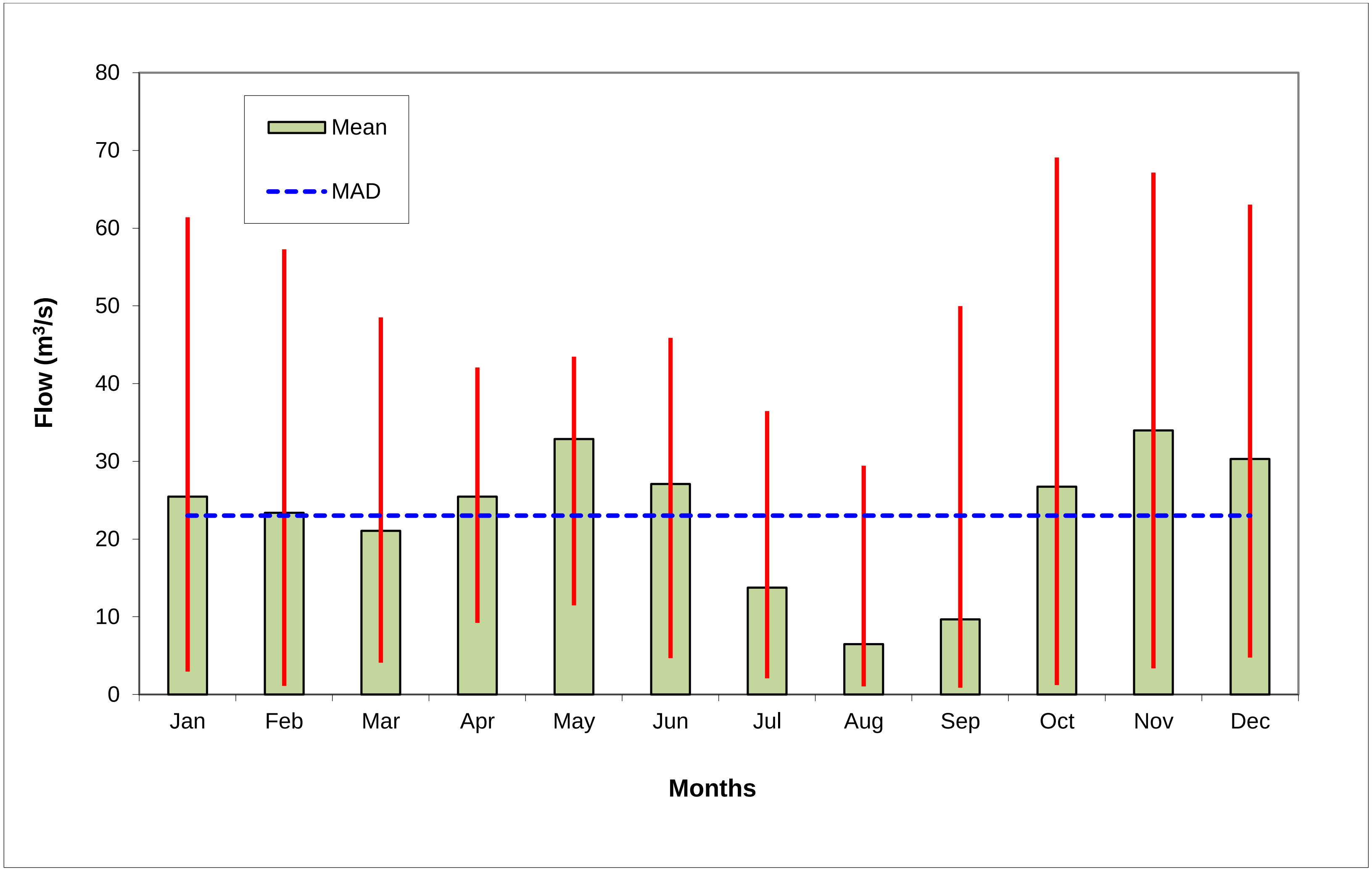

Figure 5.2: Variability in Mean Monthly Inflows of Capilano River at Cleveland Dam (Data prorated from gauge 08GA010).

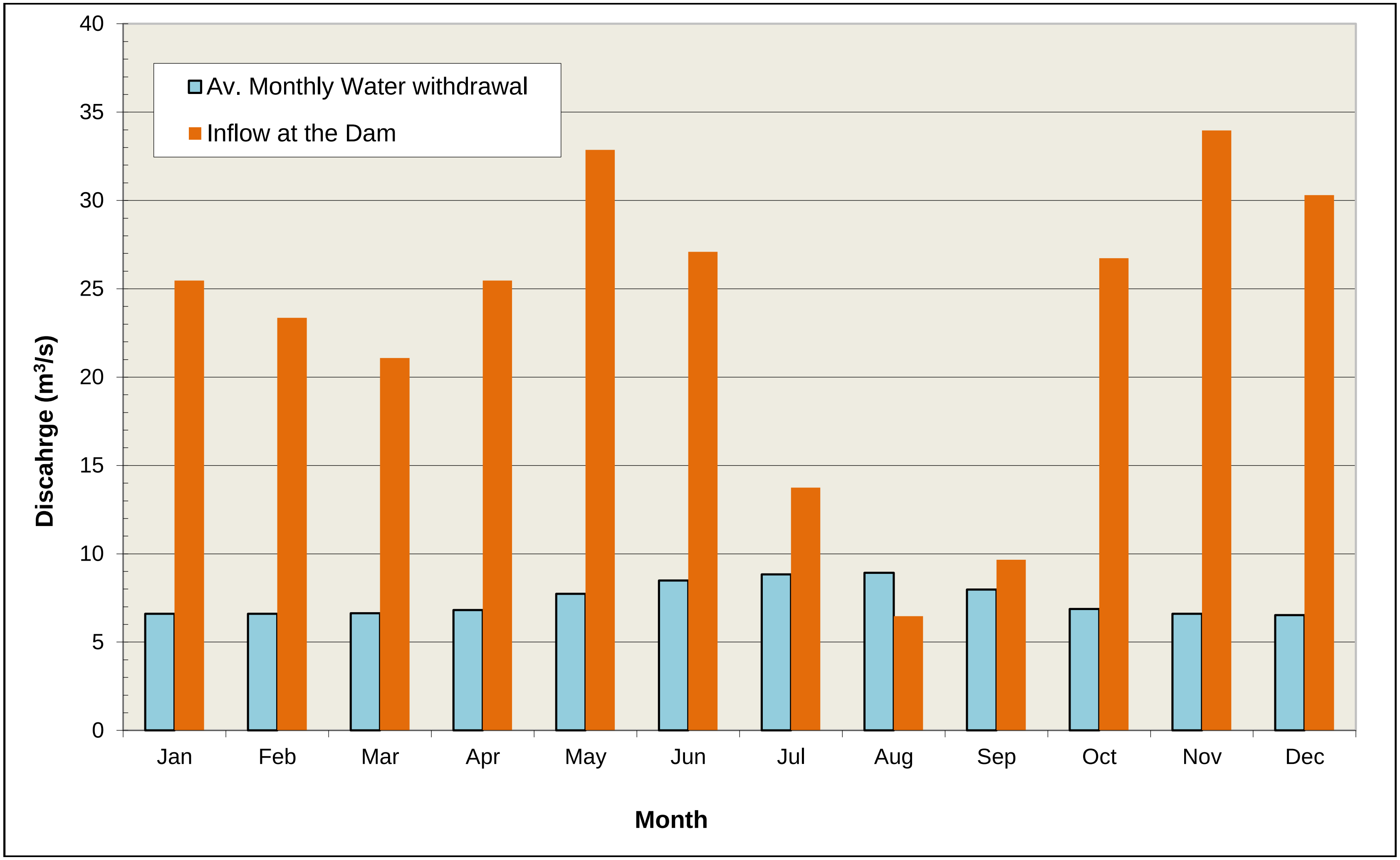

Figure 5.3: Comparison of Average Monthly Inflows to Average Monthly Water Withdrawals at Cleveland Dam.

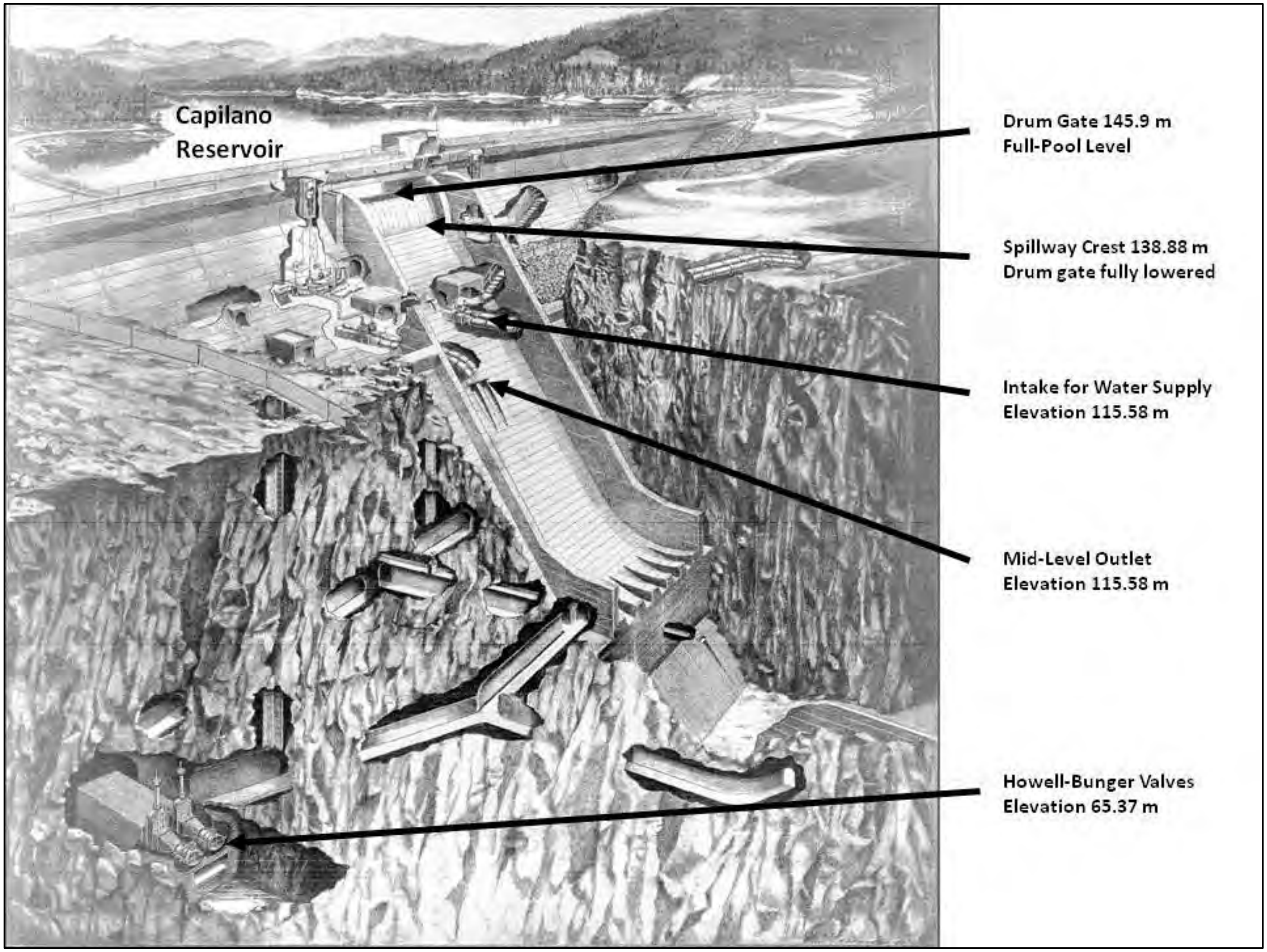

Figure 6.1: Major Capilano Reservoir Outlets at the Cleveland Dam.

APPENDIX D: HYDROLOGY OF SEYMOUR WATERSHED

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Acronyms

AES	Atmospheric and Environmental Services
B.C.	Province of British Columbia
DSS	Decision Support System
El.	Elevation
ENSO	El Niño Southern Oscillation
ft	Feet
ft^3/s	Cubic feet per second
GVWD	Greater Vancouver Water District
GVRD	Greater Vancouver Regional District
H-B	Howell-Bunger
JWUP	Joint Water Use Plan for the Capilano and Seymour Watersheds
km	Kilometre
km^2	Square Kilometres
LSCR	Lower Seymour Conservation Reserve
m	Metre
m^3/s	Cubic metres per second
$M{\cdot}m^3$	Million cubic metres
MAD	Mean annual discharge
MLD	Million litres per day
MOE	Ministry of Environment, BC
PDO	Pacific Decadal Oscillation
SCADA	Supervisory Control and Data Acquisition
SOI	Southern Oscillation Index
WSC	Water Survey of Canada

1.0 INTRODUCTION

The Seymour Reservoir on the Seymour River is one of the three main drinking water supply sources for the Metropolitan Vancouver area. The Seymour River Watershed is a mountainous watershed located in the North Shore, British Columbia. The Seymour River drains the watershed to the Burrard Inlet near the Second Narrows Bridge. The watershed is covered with heavy first growth timber and under growth trees in the lower to mid elevation and bare rocks cover the higher elevation areas. This watershed is located near the ocean and receives heavy precipitation. The heavy precipitation and steep mountain slopes allow the Seymour Watershed to gathers billion of litres of snowmelt and rainwater each year. The Seymour Falls Dam stores the water collected in the watershed. The Seymour Falls Dam constructed during 1928 had a spillway crest elevation of 197.7 m to the geodetic datum (740 ft GVWD) and is known as Low-head Seymour Falls Dam. The present Seymour Falls Dam, constructed by the Greater Vancouver Water District (GVWD) on the Seymour River during 1961, has a spillway crest elevation of 212.93 m to the geodetic datum (790 ft GVWD) [Figure 1.1].

Seymour Reservoir has the following general characteristics:

- Seymour Falls Dam impounds Seymour River 19.5 km upstream of the river mouth.
- At its full pool-level (214.76 m with stop logs in place) the reservoir is 7 km long and between 0.20 and 0.75 km in width.
- Size of the main reservoir is 2.73 km^2 and 2.99 km^2 at spill level and summer full pool level (with stop logs in place), respectively.
- There are many small alpine lakes inside the watershed. Only Loch Lomond and Burwell Lake are currently used for controlled water storage.

This report highlights the hydrology of the Seymour River basin. The physiography of the entire watershed, including upper and lower drainage area upstream and downstream of Seymour Falls Dam, is reviewed in Chapter 2. A detailed description of hydrometeorological stations is provided in Chapter 3. This report reviews the climatology of the watershed in Chapter 4. Inflow characteristics, basin water yield, low-flow and peak flow statistics are provided in Chapter 5. Typical inflow hydrographs and summary statistics are provided at the head of the Reservoir and Seymour Falls Dam. Seymour Reservoir inflow, outflow calculation and storage relationship are discussed in Chapter 6.

Figure 1.1: Seymour Reservoir at Seymour Falls Dam, built 1961, 19.5 km north of Burrard Inlet

2.0 PHYSIOGRAPHY

2.1 *Seymour River Watershed*

The Seymour River Watershed is a mountainous catchment located in the western South Coast Mountain region of British Columbia. Seymour River originates at Coastal Mountain near Loch Lomond and flows 39 km to Burrard Inlet. The Seymour River receives runoff from several tributaries, including Clipper Creek, Fannin Creek, Jamieson Creek, Orchid Creek, Sheba Creek, Balfour Creek, Gibbens Creek, Burwell Creek, Cougar Creek, Needles Creek, Hayes Creek, Intake Creek, Elsay Creek, Hydraulic Creek, Suicide Creek, and Canyon Creek. Figure 2.1 provides an aerial view of the drainage basin of the Seymour River.

The total watershed area is 185.7 km^2 at the river mouth at Burrard Inlet. The maximum length and width of the watershed is 39 km in the north-south direction and 7.5 km in the east-west direction. The width of the lower part of the catchment gradually reduces downstream of Dog Mountain to Burrard Inlet. The minimum and maximum basin elevations are 5 m and 1737 m, respectively, with a mean basin elevation of 746 m above sea level. There are many small lakes inside the basin, but only Loch Lomond and Burwell Lake are currently being used for controlled storage of water.

The watershed is covered with forests, most which are considered to be old growth greater than 250 years old. The vegetation at the lower elevations of the watershed includes western hemlock, amabilis fir, western red cedar, Sitka spruce, and Douglas fir. In the mid-elevation, yellow cedar and mountain hemlock are the dominant species. Vegetation at the highest elevation of alpine tundra zone includes herbs, lichens, and low alpine shrubs (GVRD, 2002).

2.2 Seymour Reservoir Watershed

The total watershed area upstream of Seymour Falls Dam is 125.87 km^2 (termed the “reservoir watershed”). The maximum length and width of the watershed is 20 km in the north-south direction and 7.5 km in the east-west direction. The reservoir watershed is characterized by rugged topography and steep rocky slopes at higher elevations with mountain peaks at elevations reaching 900 to 1737 m above sea level. The minimum and maximum basin elevations are 190 m and 1737 m, with a mean basin elevation of 948 m above sea level.

The stage-storage relationship shown in Figure 2.2 indicates the storage capacity of the Seymour Reservoir at different reservoir elevations. Usable storage available between the normal operating range of 196.8 m (737 ft) and summer full pool level 214.77 m (796 ft) (with stoplogs in place) is estimated from the stage-storage curve to be 32 million cubic metres (approx.). The maximum depth of the reservoir is 23 m without stoplogs and 24.77 m with stoplogs in place.

2.3 Lower Seymour River Watershed

The drainage area of the Lower Seymour River, between Seymour Falls Dam and Burrard Inlet, is 60 km^2. The Lower Seymour Watershed is a narrow valley, which rises in the east to an elevation of 1455 m on Mt. Seymour and 1466 m in the west on Coliseum Mountain near Lynn Ridge and the Needles. The drainage area within Lower Seymour River watershed has areas of forest and urban development. The drainage area which is located within the Lower Seymour Conservation Reserve (LSCR) is a pristine land and forests providing a variety of habitats as well as educational and recreational opportunities. Some forests are 350 years old, and significant from a regional and provincial perspective due to their ecological value, representation of rare and endangered ecosystems, and provision of habitat for rare and endangered wildlife species. The remainder of the drainage area, located inside the District of North

Vancouver, is an urban watershed where land use patterns include residential, commercial, and recreational components.

The Lower Seymour River receives runoff from several tributaries which originate on both sides of the river. The river area is characterized by a cobble-gravel-bed starting from the Seymour Falls Dam (upstream) and ending approximately at the Dollarton Highway in District of North Vancouver (downstream). Only the last 0.9 km of the river, which reaches between the Dollarton Highway and the Burrard Inlet, is a flat sand-gravel bed reach. The 2 km river section between the Swinburne Avenue of the District of North Vancouver and the Twin Bridge is a bedrock canyon. The channel widens and narrows along the entire length of the river with riffle pool system. The Lower Seymour Watershed aquatic habitats include the Seymour River, tributaries, several lakes, and wetlands which support salmon, trout and a diversity of other species (GVRD, 2002).

2.4 Burwell Lake and Loch Lomond

Burwell Lake is located 2.1 km north-west of the Seymour Falls Dam near the west watershed boundary. It has a catchment area of 3.7 km^2 and depth of the reservoir is 45.72 m. Loch Lomond is located 17.5 km north-west of the Seymour Falls Dam near the North watershed boundary. It has a catchment area of 2.5 km^2 and depth of the reservoir is 31.35 m.

The alpine storage reservoirs were developed by the GVWD during 1926 to supplement the seasonal low flows of Seymour River. Today, Loch Lomond and Burwell Lake are an integral part of the Metro Vancouver's Water Supply System in the Seymour watershed. This controlled water storage facility is used to augment summer low flows into the Seymour Reservoir. A concrete-lined bedrock tunnel, pipe system and valves are used to release the water from the Loch Lomond and Burwell Lake to the downstream river. The control valves are closed throughout the year and opened to release water during the hot summer months when Seymour Reservoir levels falls below a threshold level. When the alpine lakes are full or control valves are closed then excess flow spills over the spillway. Any water that comes out of the alpine lakes either over the spillway or through the tunnel goes to the Seymour Reservoir.

The usable storage available for Burwell and Loch Lomond is 15.5 and 7 million cubic metres, respectively. Burwell and Loch Lomond refill every year except few exceptional dry years. For that reason, total storage volume used from the Burwell Lake and Loch Lomond stays between 5.5 Mm^3 and 12.5 Mm^3 in a year.

3.0 HYDROMETEOROLOGICAL NETWORK AND DATA

Hydrometeorological data is collected to plan, monitor, and operate facilities in the Seymour Watershed. Hydrometeorological stations in the vicinity of the Seymour Watershed are listed in Table 3.1 and Table 3.2 and shown in Figure 2.1. In addition, Metro Vancouver operates two small fire weather stations in the Seymour Watershed.

3.1 Meteorological Stations

A total of six Atmospheric and Environmental Services (AES) stations and two Metro Vancouver Fire Weather Stations are located within or near the Seymour Watershed (Table 3.1). The AES stations collect meteorological data such as precipitation, temperature, humidity, atmospheric pressure, evaporation, wind speed and direction. The stations are listed in Table 3.1 in ascending order of elevation.

3.2 Streamflow Stations

A total of seven Water Survey Canada (WSC) stream-flow gauging stations are located in the Seymour Watershed (Table 3.2). A total of four stations 08GA077, 08GA079, 08GA021 and 08GA025 are located above the Seymour Falls Dam outlet and three stations 08GA028, 08GA013 and 08GA030 are located below the dam. During 1997 the stream flow gauging station (08GA079) was established at the head of the Seymour Reservoir. The stream-flow gauge with the longest record is Station 08GA030 at the Seymour River near North Vancouver. This station has a continuous record since 1928; however, it is significantly affected by the water intake and dam operations. Stream flow records from Gauge 08GA021 (later moved below the dam and renamed as Gauge 08GA028) at Seymour Falls is the only data set which represents the natural stream flows at Seymour Falls Dam. After September 8, 1927, all data records are affected by the dam operation.

3.3 Monitoring Stations for Reservoir Level

Metro Vancouver continuously monitors and records the water levels in the Seymour Reservoir at the Seymour Falls Dam. The water level data is important for the operation of the dam and to calculate the discharge through the various valves and over the spillway. Burwell Lake level is recorded by an automatic sensor. The lake level is measured manually for Loch Lomond. There are no flow metres available to automatically measure the outflows from the alpine lakes but the daily average discharge is calculated from the water level data and reservoir elevation-storage curves.

3.4 Snow Survey Stations

Metro Vancouver in cooperation with the Ministry of Environment maintains two snow survey stations at Orchid Lake and Dog Mountain in the Seymour watershed. Average snow depth and snow water equivalent depth data are available from these stations. Snow pack data has been collected since 1945 at Dog Mountain and since 1972 at Orchid Lake.

4.0 CLIMATOLOGY

4.1 General

The Seymour River Basin is within the western south coastal climatic region. During winter, large-scale cyclonic storms[2] produce heavy and prolonged rainfall as south-westerly winds from the Pacific Ocean push saturated, or near saturated, air masses into the windward slopes of the mountain. The abrupt rise of the Coast Mountains exerts a strong orographic influence[2] on these airflows. The Seymour River basin is open to these south-westerly flows of warm, moist air which produce the heaviest rainfall for storm durations greater than one- or two-hours. The largest storms occur during the fall and winter months of November to February, and fewer storms occur during the summer months of June to August.

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[2] *Cyclonic Storm*s in the Northern Hemisphere are characterized by strong counter-clockwise winds.

[2] *Orographic influence or lift* occurs when an air mass is forced from a low elevation to a higher elevation as it moves over rising terrain such as a mountain barrier. Resulting precipitation, if occurs, is called *Orographic* or*, Relief rain*.

4.2 Precipitation

The mean monthly precipitation as recorded at the Seymour Falls Dam station (1107200) is shown in Figure 4.1. Minimum and maximum monthly precipitation (rainfall + snow) values illustrate the variability in the data. Up to 60 percent of the annual precipitation falls between October and January. Mean annual precipitation is 3900 mm. The maximum historical monthly rainfall record was 1528 mm in November 1990. A probable maximum precipitation (PMP) event over the 24-hour range from 467 mm to 798 mm depending on the watershed location (Klohn Leonoff, 1987).

4.3 Snow Depths

Metro Vancouver collects snow information at Orchid Lake and Dog Mountain stations to determine the amount of water stored in that snow pack. The snow depths are reported on a monthly basis from January to June, and more frequently during May and June. The average snow depth was 413 cm (14 feet) and 259 cm (8.5 ft) at the Orchid Lake and Dog Mountain snow survey sites, respectively (April 1 survey period). The maximum snow depth recorded at the Orchid Lake site was 786 cm or approximately 26 feet on March 23, 1999. The snow water equivalent information helps manage water supply during the summer.

4.4 Air Temperature

The Grouse Mountain station has a continuous temperature record since 1971. Since the station is 11 km away from the dam site, and the Seymour River Watershed is at a relatively higher elevation (1127 m a.m.s.l), the data is corrected for elevation. Temperature data from 1987 to 2007 is from Seymour Fire Weather Station located about 5 km north of Seymour Falls Dam. The higher temperatures and lower rainfall between July and August make these months the driest period of the year.

4.5 Evaporation

Seymour Reservoir loses a significant amount of water daily due to evaporation. The rate of evaporation varies throughout the year. The evaporation rate is the highest during July at 3.87 mm/day, and the lowest in January at 0.2 mm/day. During the summer months, for example in July, the Seymour Reservoir may lose up to 11,500 m^3 of water per day at summer full pool level.

4.6 Overview of Climate Change

There is a general consensus in the scientific community that the global atmosphere is warming and that climate patterns are correspondingly changing throughout the world, including British Columbia. Over the past century, average annual temperatures in the Lower Mainland and the Vancouver Island region of BC have warmed up by approximately 0.6 °C, and annual precipitation in southern BC has generally increased at a rate of approximately 3 percent per decade (MWLAP, 2002). Historical trends of the mean annual discharge (MAD) were examined. The Capilano River data set indicates a slight decrease in mean annual discharge (MAD) over the last 86 years (1914 to 2005) of the record. This amount is a 0.53% decrease of the Capilano MAD, however, there are two high MAD's observed during 1914 and 1921, which may have an impact on the general trend. However, the similar trend for Seymour as shown in Figure 4.2, is supposed to be valid for the Seymour River due to the close proximity of the two watersheds. There is no guarantee that these trends will continue in the near future given the inherent variability and cyclic nature of weather, but it is reasonable for the purpose of hydrological assessment to conclude that inflow pattern may change with global warming. However, at this point, significant trend changes in the historical normals are not supported by the available data.

4.7 Climate Cycles

In conjunction with long-term climate changes, regional climate is also modulated by "natural" short-term and long-term climate cycles such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). El Nino events, which occur on average every 3-7 years, are part of a natural atmosphere-ocean oscillation in the Pacific region and generally only influence the local winter and spring climates in a noticeable way (KWL, 2002). Generally, El Niño winters are associated with less precipitation in the region than normal, with the opposite occurring under La Niña conditions. The position and strength of the ENSO effect is measured by the Southern Oscillation Index (SOI).

The PDO represents an ENSO-like pattern, but at much longer time scales (50-70 years) [KWL, 2002]. It is divided into "cool" and "warm" phases. During the warm phase, the region generally experiences shallow snowpack due to higher temperatures and more precipitation falling as rain instead of snow. During the cool phase, the reverse is true with the snowpack increasing in depth and occasionally precipitation totals are higher than in warm phases.

Recent studies indicate that PDO and ENSO do have an impact on the hydrology of the Seymour watersheds, especially from November through to March because ENSO and PDO only influence large-scale synoptic weather systems (Fleming and Whitfield, 2006). Summer rainfall primarily originates from convective systems that operate independently from ENSO and PDO. During a combined cool PDO and La Niña, there is higher precipitation and snowpack accumulation in the Capilano Watershed (Sellars, Garrett and Woods, 2008). This in turn delays the date when spilling over the dam stops and increases the flow for the June to September period. A similar effect may occur in the Seymour Watershed due to its location within the same hydroclimatic region. Compared with the cool PDO, the longest reservoir drawdown durations are observed with warm PDO conditions.

Environment Canada has also reported that ENSO and PDO influence the magnitude of summer streamflows only to the extent that ENSO and PDO affect snowpack accumulation and moisture levels during the winter and spring (Wang, Whitfield and Cannon, 2006). Low June to September inflows into the Capilano Reservoir are associated with warm or neutral ENSO and PDO conditions. There are no similar observations made yet for the Seymour reservoir due to the lack of data. These low inflows did not occur during cold ENSO conditions and only one occurred during a cool phase of the PDO. As the duration of the ENSO cycle is 6 to 18 months, it is useful for planning short-term reservoir operations. The longer PDO cycle of 20–30 years is of limited use for reservoir operations though it has implications for planning future reservoir storage. In general, historical data suggests that the effect of these climate cycles far exceeds the magnitude of changes attributed to long-term climate change.

5.0 STREAMFLOW STATISTICS

5.1 Natural Stream Flow Data at Seymour Falls Dam

To complete the hydrological analysis for the Seymour Falls Dam, long-time and high quality records are required for the natural stream flow. The definition of the natural stream flow is the total stream flow available at Seymour Falls Dam prior to any flow diversion for water supply purpose. Stream flow records from all available stations within the Seymour Watershed are partially or completely affected by the water diversions or Alpine Lakes operation which have altered the natural stream flow in the Seymour Watershed. Subsequently there is no consistent set of data available that could be applied directly in a hydrological analysis.

In order to generate a synthetic long-term natural stream flow series, using the short-term natural flow records of Seymour River, it was found that there is a high degree of co-relation between the watershed characteristics and rainfall distribution patterns in the Seymour and Capilano systems which are located in the same climatic region. Regression analysis of concurrent data and validation yielded regression equations to generate long-term synthetic daily flow data series equivalent to the natural stream flow series at the Seymour Falls Dam.

5.4 Reservoir Inflow Characteristics

A total of 90 years of synthetic daily flow series from 1914 to 2010 at the Seymour Falls Dam was used for the daily and monthly flow assessments. Figure 5.1 shows a "spaghetti plot" of historical daily inflows to the Seymour Reservoir at the Seymour Falls Dam. The 10th, 50th, and 90th percentile inflows are also shown in Figure 5.1 and Table 5.1 which summarize the historical daily inflows by month and highlight the variability of observed daily inflows at the gauge site. Historically, the lowest daily inflow in the record was 0.6 m^3/s on September 23, 1930. The highest daily inflow record was 347 m^3/s on October 28, 1921. Very high inflow variability by month was observed for the months of October, November and January. Severe coastal rain storms and elongated dry summers cause very high daily inflows and very low daily inflows during September and October, the end of summer months.

The monthly inflow statistics of the synthetic dataset at the Seymour Falls Dam are summarized in Table 5.2. The long-term mean annual discharge is 14.0 m^3/s, which equal to a unit runoff of 112 $L/s/km^2$. This unit-runoff value lies within the expected range of values for this region, and is slightly less than the unit-runoff of Capilano River Basin (116 $L/s/km^2$), which is produced from the entire 90 years of Capilano River flow data. The maximum and minimum monthly values shown in the Figure 5.2 indicate a large variation between the maximum and minimum levels. August is the driest month and the mean monthly flows during the five months of February, March, July, August, and September remain below the mean annual discharge value.

5.5 Basin Water Yield and Water Demand

Between the years 1914-2010 the annual watershed yield varied between 312 Mm^3 and 640 Mm^3 with a mean annual inflow volume of 445 Mm^3 at the Seymour Falls Dam. The Seymour Reservoir usable storage between full pool level and maximum drawdown level is 28 Mm^3. The ratio between reservoir storage and mean annual watershed yield is 0.06. The low ratio demonstrates that a large amount of water spills from the Seymour Reservoir each year.

Average monthly water withdrawals (demand) from Seymour Reservoir has been compared with the averaged reservoir monthly inflows at Seymour Falls Dam in Figure 5.3. Summer fish flow release is not included in the demand values. Even though the Seymour Reservoir is not supplying all the drinking water to the region as a stand-alone source, it is clear that average water withdrawals in the summer months exceed the average monthly inflows. In addition, inflow or storage is required for continuous Summer Fish Flow requirements. Average annual water demand 150 Mm^3 from Seymour System (based on 1045 MLD total average annual demand) is equivalent to 34% of the mean annual watershed yield 445 Mm^3.

5.6 Analysis of Low Flow

Low flow is the "flow of water in a stream during prolonged dry weather," according to the World Meteorological Organization. A low flow is a seasonal phenomenon, usually occurring during the "dry season", and is an important characteristic of the flow regime in a river. By contrast, a drought is a natural event that results from an extended period of below average precipitation. While droughts include low flows, a continuous seasonal low-flow event is not necessarily a drought. The historical low flow occurs when the mean monthly inflow at Seymour Falls Dam was less than or equal to 0.8 m^3/s.

6.0 RESERVOIR INFLOW, OUTFLOW AND STORAGE RELATIONSHIP

6.1 Storage Relationships

Storage relationships used to determine the volume of water in the Seymour Reservoir are shown in Figure 2.2.

6.2 Calculation of Daily Outflow

Daily outflow from the Seymour Reservoir occur through various outlets at the Seymour Falls Dam as shown in Figure 6.1. Various indirect information including reservoir elevation, stoplogs elevation, percent valve openings and direct flow measuring at gauge station located at the head of the reservoir are used in the day-to-day operation of the reservoir.

The main outflows from the Seymour Reservoir are listed below:

- Flows for domestic water supply
- Flows for Fish habitat below the dam
- Flows over the spillway
- Flows through the Lower Outlet

6.2.1 Calculation of Withdrawal for Drinking Water

The withdrawal for drinking water supply is metred downstream from the dam. Daily flow rate varies over the season from 4.2 m^3/s to 5.7 m^3/s, with an average value of 4.7 m^3/s over the year; and 5.2 m^3/s for the peak season from July to October.

6.2.2 Calculation of Fish Flow

At present, the withdrawals for fish-flows occur through the Fish Flow Valve. The valve is a 24" Hollow-Cone Valve. The volume of the daily fish-flow release from the Seymour Reservoir varies throughout the year with the available reservoir storage. The present minimum fish-flow release varies from 4.1 % to 9.7 % of MAD (14 m^3/s). Fish valve operation is automatic and controlled remotely from the operation control center. Only 50% valve opening is required to deliver the maximum fish flow of 1.36 m^3/s.

6.2.3 Calculation of Spillway Flow

The Seymour Falls Dam is equipped with a spillway located at the center of the dam. The spillway is 250 m long with a crest elevation 212.94 m geodetic (790 ft GVWD). The height increases 1.8 m when the stoplogs are in place. The maximum discharge capacity is 990 m^3/s at winter full pool level (212.94 m). The emergency discharge capacity is 1143 m^3/s at reservoir elevation 216.8 m (2.04 m above summer full pool) under PMF condition. There are three modes of operation for the spring, summer and winter periods.

Winter Operation: All of the stoplogs are removed and all of the bays are opened for operation during the winter period. The purpose of the winter operating condition is to handle the largest possible flood.

However, currently three stoplogs remain installed in Bay 9, 10 and 11 to protect valves below from large woody debris during winter spill events.

Spring Operation: Stoplogs are installed in 11 bays. One bay is left open for the migration of the smolt. For operation during the spring period, stoplogs are typically installed during late April or early May depending on weather conditions, particularly snow pack and rainfall.

Summer Operation: Stoplogs are installed in 12 bays for operation during the summer period. The level of the Seymour Reservoir is controlled by the stoplogs. The stoplogs increase the capacity of the reservoir and raise the spillway crest elevation from 212.94 m to 214.76 m. This elevation indicates summer full pool level. For summer operation, stoplogs are typically installed during late May or early June depending on weather conditions, particularly snow pack and rainfall. After the reservoir is drawn down to below the concrete crest elevation, the stoplogs are removed during early September for winter operation mode.

The reservoir water level is not regulated by an automatic gate. The spillway is a fixed-crest overflow spillway and therefore flow releases occur once reservoir level exceeds the spillway crest elevation of 212.76 m geodetic (Figure 6.2). It is called winter full pool level. Downstream flow transition sections of the spillway pass through 12 bays separated by concrete buttress walls (Figure 6.1 and Figure 6.2). Flow leaves the spillway over the flip bucket (ski-jump) to the downstream rocky riverbed.

6.2.4 Calculation of Lower-level Out-flow

The Lower Outlet consists of two 1.45m (57 in) control valves known as Howell-Bunger Valve. When opened these valves discharge directly to the downstream river in a bed-rock pool. The opening of each Howell Bunger Valve has a 1.52m x 1.83m (5 ft x 6 ft) slide gate. The centerline elevation of the Howell-Bunger Valve is 194.64 m geodetic (Figure 6.1). The maximum discharge capacity of each Howell-Bunger Valve is 23.6 m^3/s when reservoir at winter full pool level (212.94 m) and valves are 100% open. Operation of the lower outlet varies throughout the year.

6.3 Total Downstream Outflow Release

The total discharge downstream of the Seymour Falls Dam into the Seymour River is the sum of the outflows over the spillway, through the Lower outlets and Fish valve. Total outflow release is not monitored by Metro Vancouver. However, total downstream flow release from the dam is calculated and recorded on a daily basis. It is observed that during the summer, the catchment downstream of the dam contributes insignificant amount of flow to the lower part of the river. Therefore, the Lower Seymour River (08GA030) is predominantly influenced by the flow release from the dam during the summer months. The inflow and outflow rates are similar except during the summer months of July, August and September, due to the increase of drinking water demand and relatively low inflows. During the spring, fall and winter the drainage area downstream of the dam (32% of total drainage basin) contributes a significant amount of flow to the river.

7.0 RESERVOIR OPERATIONAL INFLOW FORECAST

During the fall, winter and spring, the operation of the Seymour Reservoir depends on the rate of inflow and weather forecast. Once the Seymour Reservoir has been refilled during late fall then all of the stop logs are removed and the excess water flows over the spillway without regulation.

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TABLES

Table 3.1: Summary of Regional Climate Stations within or near the Seymour Watershed.

AES Station Name	Station ID.	Years of Record	Start Year	End Year	Latitude	Longitude	Elevation (m)
N. Vancouver Gr. Mt. Resort[2]	1105658	38	1971	Active[1]	49°22.2'	123°4.8'	1127
Mount Seymour	1105230	11	1958	1968	49°24'48"	122°57'0"	823
N. Vancouver Seymour Falls	1107200	76	1928	2008	49°26'24"	122°58'12"	244
Seymour Fire Weather Station[3]	SYFWS	21	1988	Active[1]	49°26'24"	122°57'55"	230
N. Vancouver Seymour Hatchery	110N666	28	1981	Active[1]	49°26'24"	122°58'12'	210
Seymour Fire Weather Station 2[3]	SYFWS 2	21	1988	Active[1]	49°23'45"	122°59'48'	180
Seymour Creek	1107195	24	1924	1947	49°25'12"	122°57'00'	178
N. Vancouver Seymour Blvd.	110EFFF	15	1968	1982	49°19'12"	123°1'12"	8.5

[1] Hydrometric Station with continuous data has shown in Italics.
[2] Grouse Mountain Station is located outside of the Seymour Watershed.
[3] Seymour Fire Weather station is maintained by the Metro Vancouver.

Table 3.2: Summary of Stream Flow Stations within or near the Seymour Watershed.

Station Name	Station ID	Years of Record	Start Year	End Year	Latitude	Longitude	Catchment Area (km^2)
Seymour River below Orchid Creek	08GA077	16	1992	active	49° 31'17"	123°0'10"	62.9
Seymour River at head of reservoir	08GA079	12	1997	active	49° 29'46"	122°58'10"	82.6
Seymour River at Seymour Falls	08GA021	7	1921	1927	49° 26'25"	127°57'55"	139.85
Seymour River at Seymour Falls Dam (below the dam)	08GA028	14	1927	1940	49° 26'25"	127°57'55"	125.87
Seymour River above Intake	08GA013	21	1914	1934	49° 23' 53"	122°59'4"	152.80
Seymour River Near North Vancouver	08GA030	38	1928	active	49° 20'32"	123°0'5"	176
Burwell Creek	08GA025	4	1924	1928	49° 27'29"	122°59'27"	N/A

*Hydrometric Station with continuous data shown in Italics.

Table 5.1: Variability in Seymour Reservoir Daily Inflows (1914 -2010).

Months	**Minimum Daily Flow (m^3/s)**	**Mean Daily Flow (m^3/s)**	**Maximum Daily Flow (m^3/s)**
Jan	2.65	14.8	208
Feb	1.42	12.8	205
Mar	2.91	11.9	183
Apr	3.43	14.8	161
May	5.20	19.2	151
Jun	2.20	16.8	141
Jul	1.08	8.7	138
Aug	0.80	3.9	161
Sep	**0.60**	6.6	204
Oct	2.21	19.0	**347**
Nov	2.21	21.5	266
Dec	3.55	18.7	203

* Minimum, maximum values and driest months are highlighted.

Table 5.2: Summary of Mean Monthly Inflows (Synthetic Flow) at Seymour Falls Dam (1914 -2010).

Months	Minimum (m^3/s)	Mean (m^3/s)	Maximum (m^3/s)
Jan	3.58	14.64	37.10
Feb	1.65	12.75	34.02
Mar	3.98	11.86	28.43
Apr	7.08	14.70	26.31
May	8.70	19.09	28.00
Jun	3.64	16.73	32.09
Jul	1.66	8.64	25.86
Aug	1.03	3.83	18.21
Sep	0.97	6.57	37.24
Oct	2.98	18.88	51.78
Nov	3.60	21.31	46.56
Dec	5.47	18.63	40.76
MAD* =		***14.0***	

* Mean Annual Discharge value shown in bold letter.

FIGURES

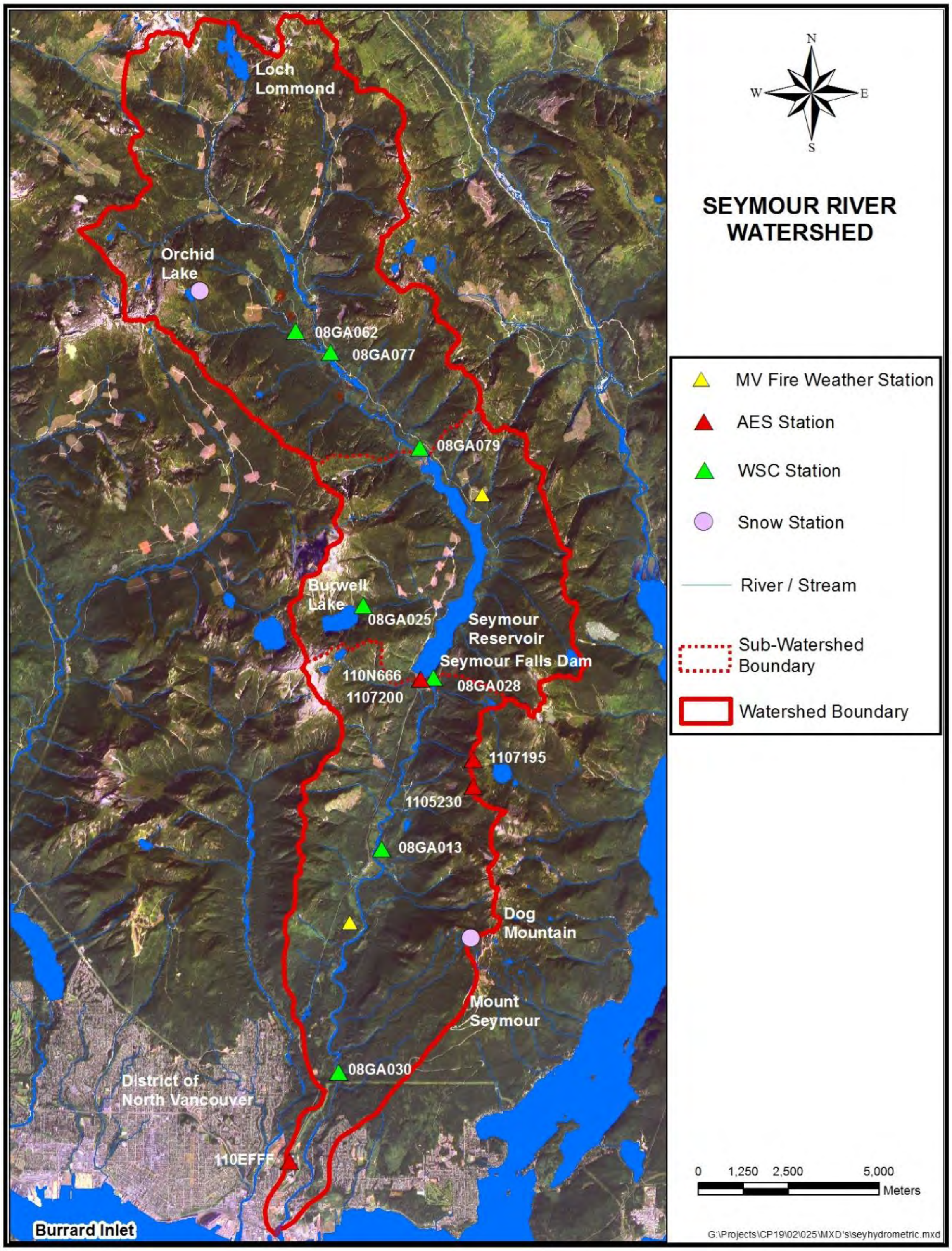


Figure 2.1: Aerial view of the Seymour River Watershed and Tributaries

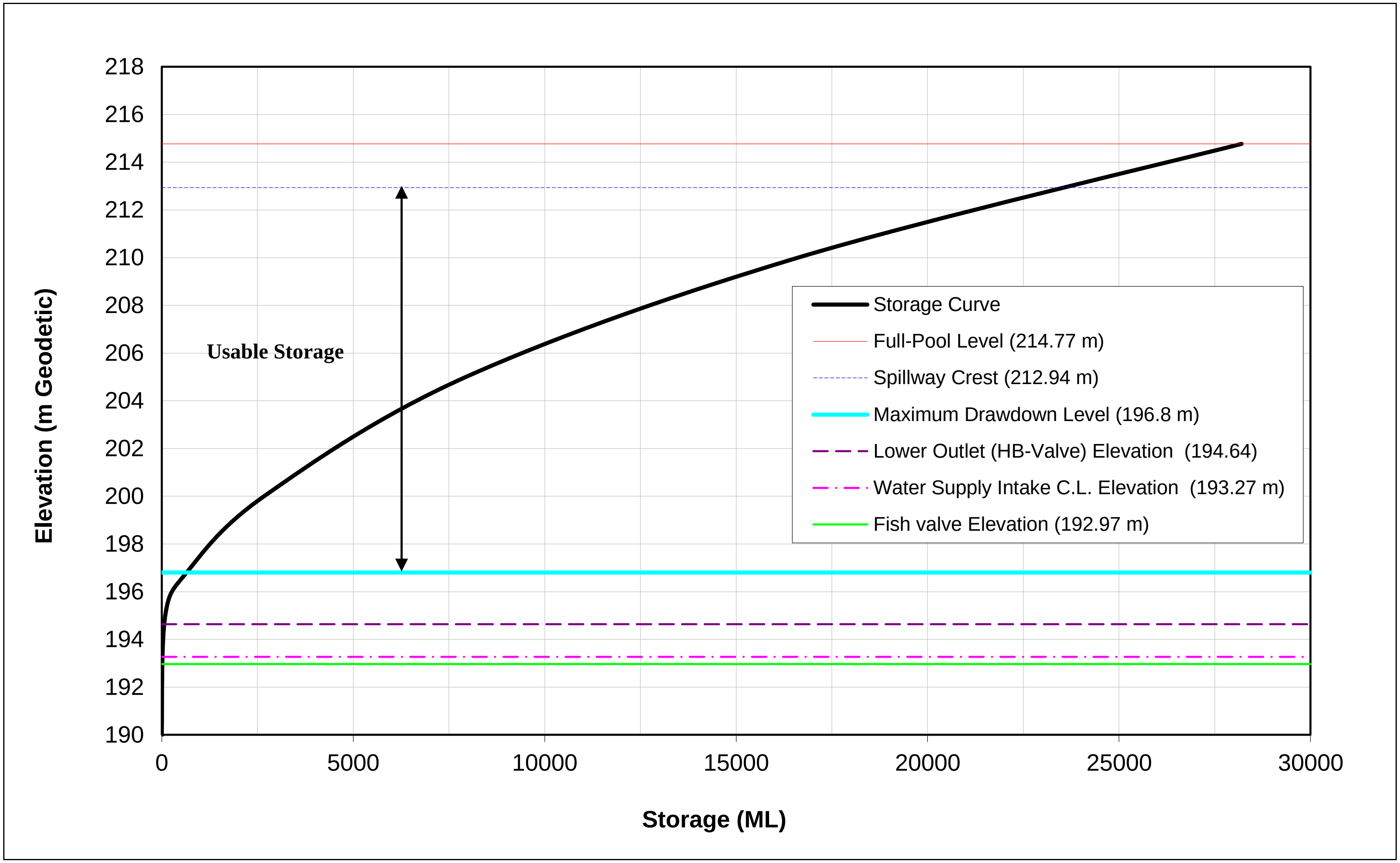


Figure 2.2: Stage-Storage Curve for Seymour Reservoir.

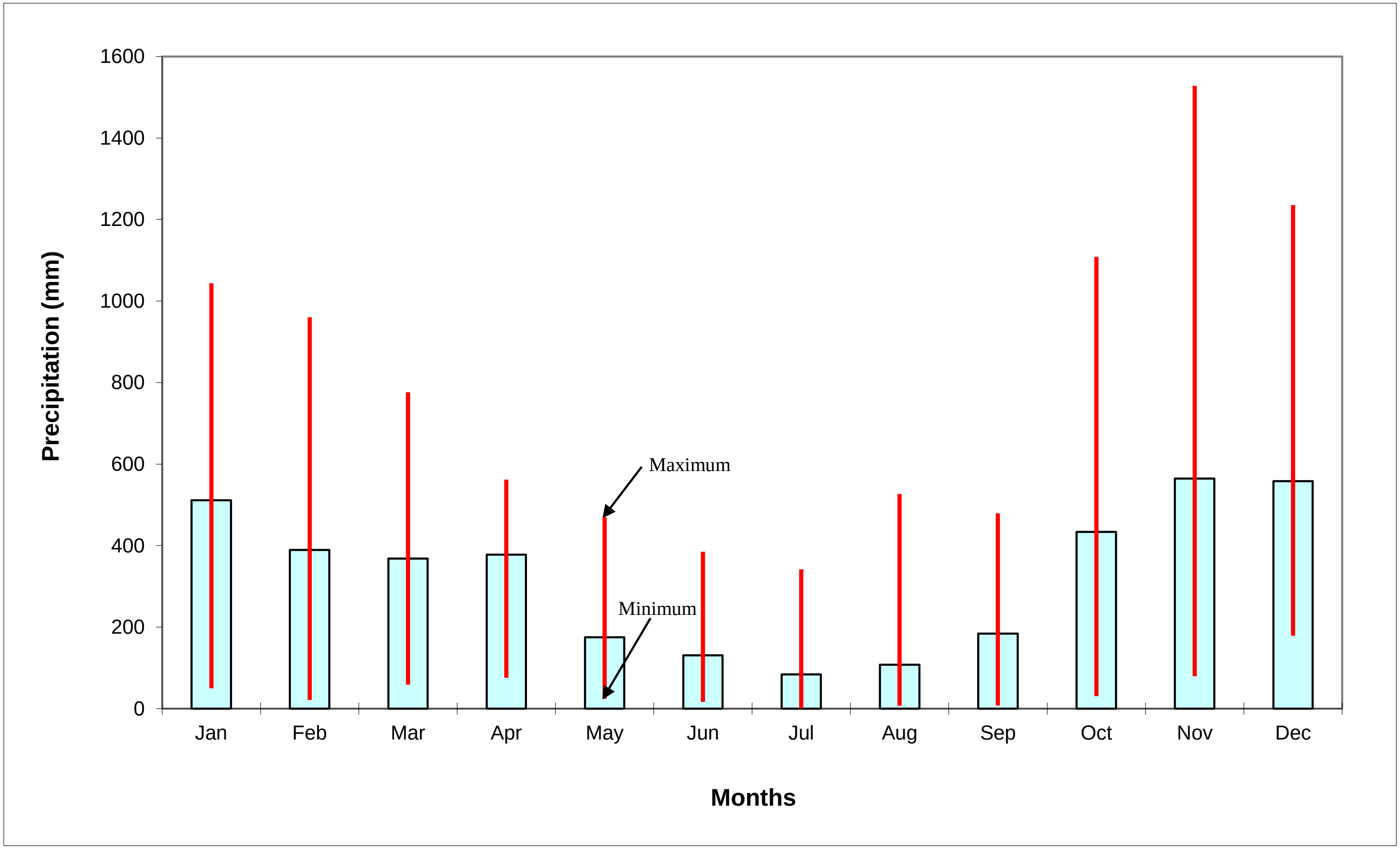


Figure 4.1: Mean Monthly Precipitation at Seymour Falls Dam Station [1928-2008] (Seymour Falls Dam Station at the dam site is operated by GVWD since 1997).

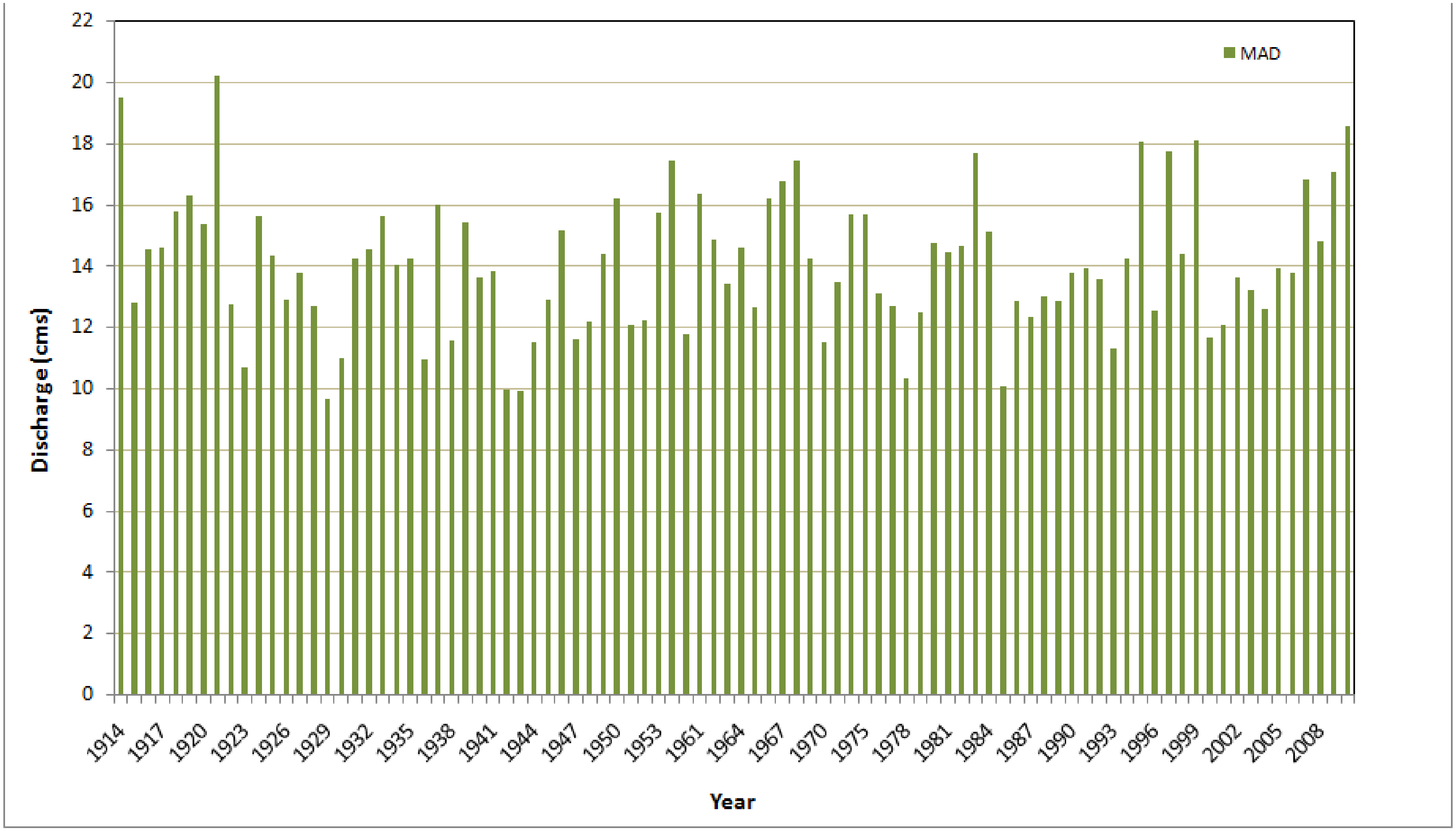


Figure 4.2: Mean Annual Discharges (MAD) of Seymour River (Data Synthesized from WSC Station 08GA010)

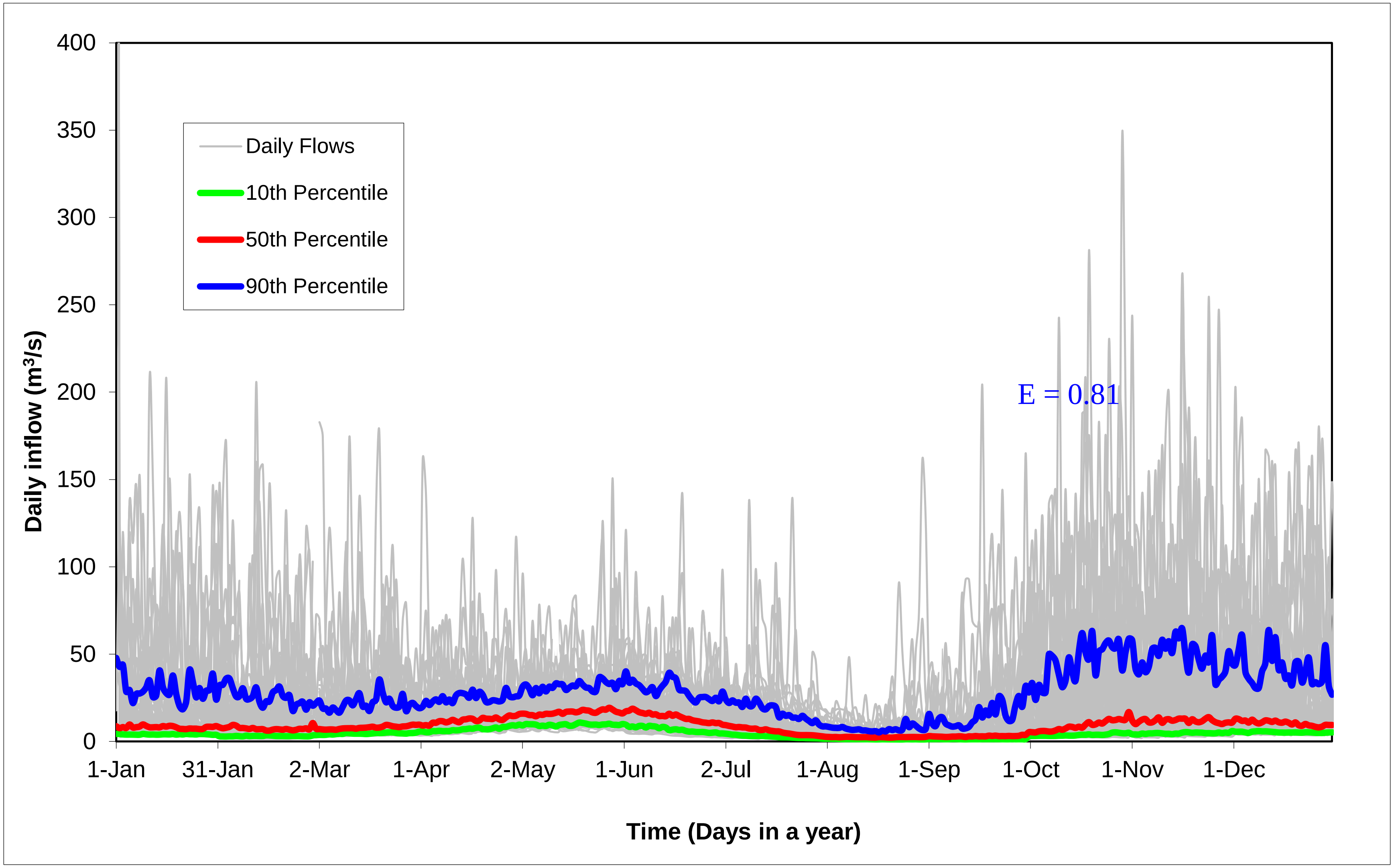


Figure 5.1: Historical Daily Inflows for Seymour Reservoir (data synthesized from WSC Capilano above Intake Station, 08GA010).

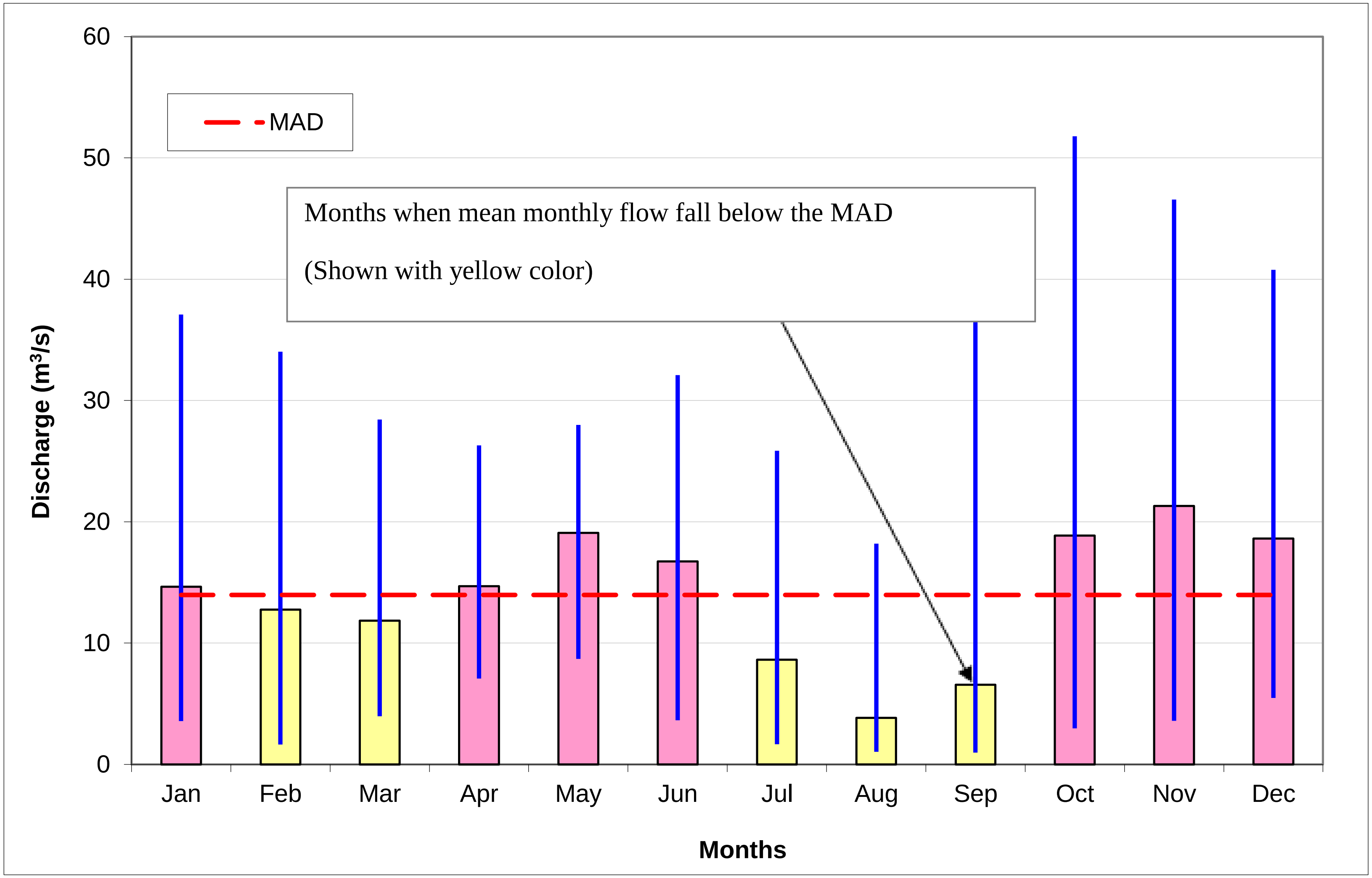
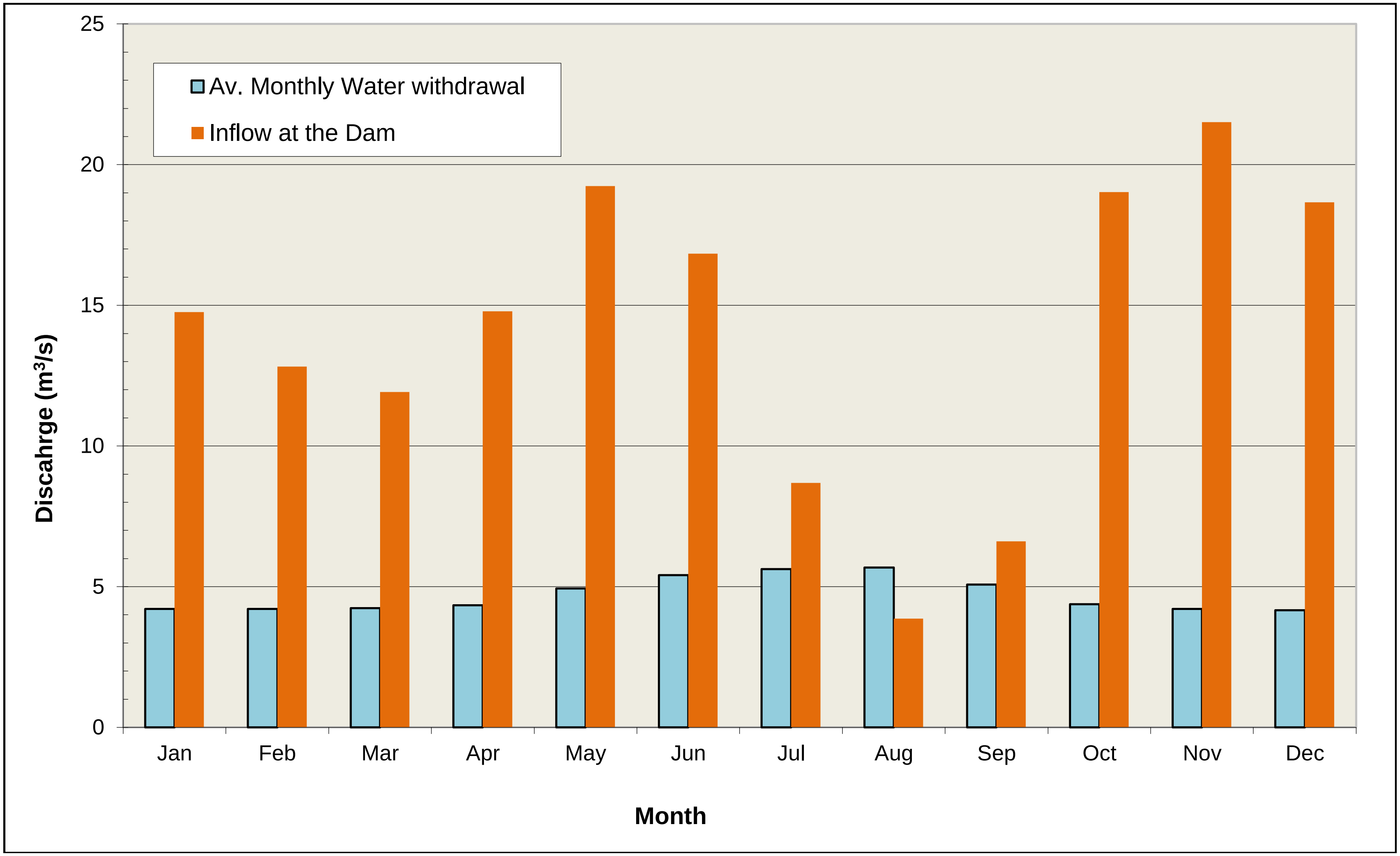


Figure 5.2: Variability of Mean Monthly Inflows of Seymour River at Seymour Falls Dam (data synthesized from WSC Capilano above Intake Station, 08GA010).



*Note: Seymour Reservoir is not supplying all MV water demand as a stand-alone source.

Figure 5.3: Comparison of Average Monthly Inflows to Average Monthly Water Withdrawals at Seymour Falls Dam.

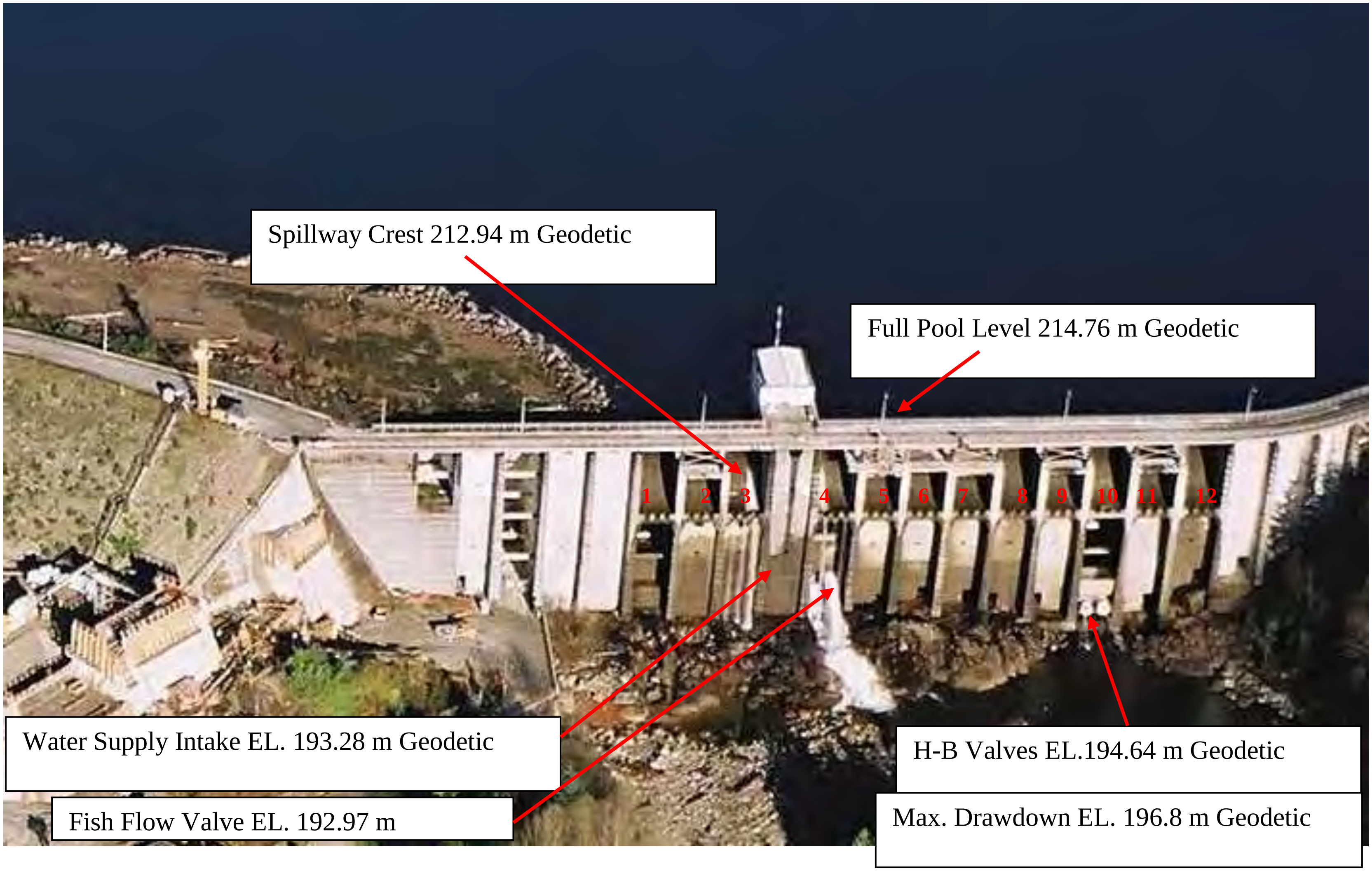


Figure 6.1: Major Seymour Reservoir Outlets at the Seymour Falls Dam. (Bays are numbered 1 to 12 from left to right).

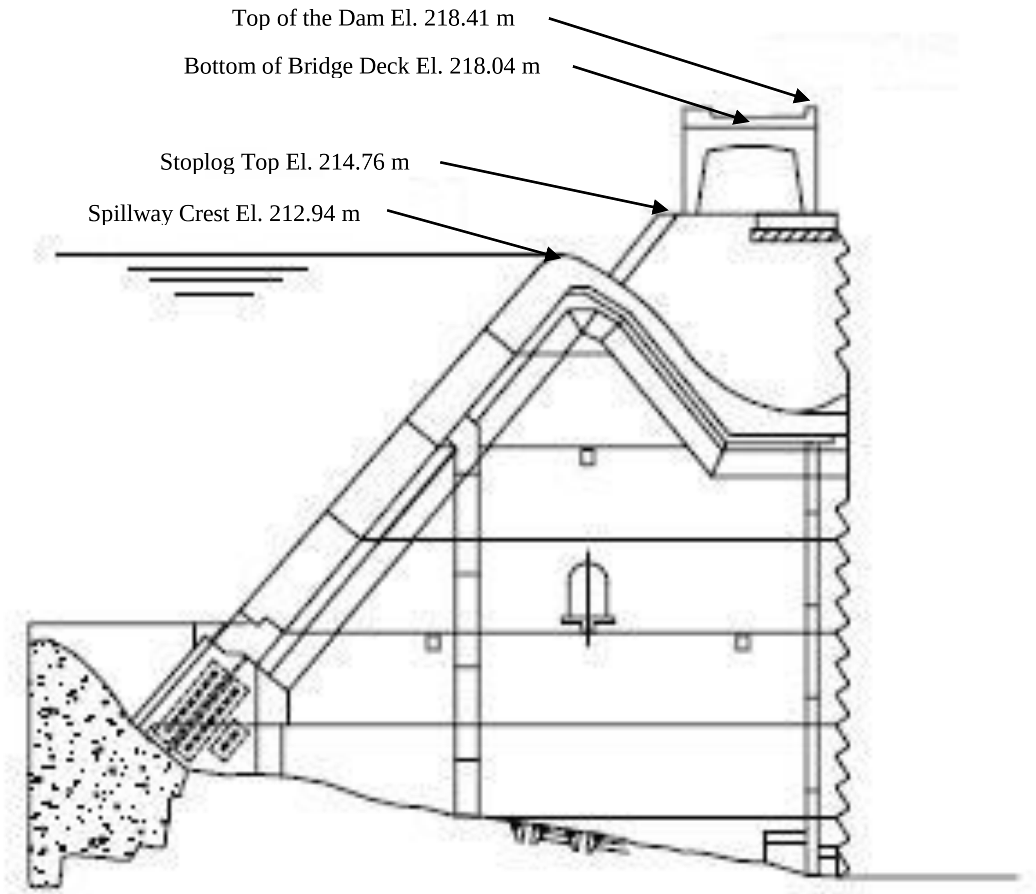


Figure 6.2: Elevation View of Spillways at Seymour Falls Dam (GVWD Drawing: WG 272 Sheet 36).

APPENDIX E: RAMPING RATES

The Howell-Bunger valves at each dam are used to control the reservoir level. In order to reduce the risk to the public downstream of the dams and slowly change river levels for fish, the ramping rate tables give the fastest allowable dam discharge flow rate change. The Utility Systems Controller sets the valve position then waits for at least the minimum time before making the change to the next valve position shown in the ramping rate tables. Typically, the wait time for the new valve setting will be greater than the minimum.

Ramping rates for the Cleveland Dam Drum Gate operation are also used to limit the rate of change of the dam discharge whenever set points are changed and/or the inflows to the reservoir change quickly (i.e. storm conditions). For the Drum Gate, these ramping rates are adjusted through local programming logic and the Utility System Controller monitors the results.

Please refer to the following pages for the guidelines for increase and decrease of flow for Cleveland and Seymour Falls Dam.

Cleveland Dam Increasing Ramping Rates					
1st Opened Howell-Bunger Valve % Open	2nd Opened Howell-Bunger Valve % Open	1st Opened Slide Gate % Open	2nd Opened Slide Gate % Open	Minimum Time Before Next Change in Valve Setting minutes	Estimated Discharge Flow at Reservoir Elevation. 145.89m m3/s
0				0	0.0
5				30	4.2
10				30	8.2
15				30	12.2
20				15	15.9
25				15	19.5
30				15	22.9
40				15	29.2
50				15	34.8
65				15	41.3
100				15	49.8
100	10			15	58.1
100	25			15	69.0
100	40			15	79.0
100	60			15	89.8
100	100			15	99.7
100	100	50		15	132
100	100	100	0	15	157
100	100	100	50	15	190
100	100	100	100	0	214

Notes:

1. The table shows the minimum times and maximum valve position steps for conditions with no spillway flow. Slower ramping rates may be used.
2. Contact the Utility Systems Control Superintendent for authorization to increase steps or decrease times if necessary for reservoir management.
3. The discharge flow shown does not include the pump house discharge of 0.57m^3/s
4. The ramping rates do not include the Drum Gate discharge

Cleveland Dam Decreasing Ramping Rates					
1st Closed Slide Gate % Open	2nd Closed Slide Gate % Open	1st Closed Howell-Bunger Valve % Open	2nd Closed Howell-Bunger Valve % Open	Minimum Time Before Next Change in Valve Setting minutes	Estimated Discharge Flow at Reservoir Elevation. 145.89m m3/sec
100	100	100	100	---	214
100	50	100	100	30	190
100	0	100	100	30	157
50	---	100	100	30	132
0	---	100	100	30	99.7
---	---	70	100	30	94.0
---	---	50	100	30	84.4
		40	100	30	79.0
		30	100	30	72.2
		20	100	30	65.7
		10	100	30	58.1
		0	100	60	49.8
			80	60	47.0
			60	60	39.9
			50	60	34.5
			40	60	29.2
			35	60	26.2
			30	60	22.4
			25	60	19.0
			20	60	15.9
			16	60	12.5
			12	60	9.6
			8	60	6.5
			5	120	4.2
			0	---	0.0

Notes:

1. The table shows the minimum times and maximum valve position steps for conditions with no spillway flow. Slower ramping rates may be used.
2. Contact the Utility Systems Control Superintendent for authorization to increase steps or decrease times if necessary for reservoir management.
3. The discharge flow shown does not include the pump house discharge of $0.57m^3/s$
4. The ramping rates do not include the Drum Gate discharge

Cleveland Dam Drum Gate			
Maximum Rate of Discharge Increase			
Drum Gate Elevation Step Change Increments m	Minimum Time between Changes in Discharge Flow minutes	Calculated Change in Discharge Flow m3/s	Estimated Discharge Flow Range m3/s
0.06864	15	1.4	0 – 6.0
0.03466	10	1.4	6.0 – 14.0
0.0268	5	1.4	14.0 – 28.0
0.0425	5	2.8	28.0 – 56.0
0.0508	5	4.2	56.0 – 112.0
0.0702	5	7.0	112.0 – 170.0
0.1205	5	14.0	170.0 – 280.0
0.1485	5	21.2	280.0 – 560.0
0.1646	5	28.3	560.0 – 850.0
0.2922	5	56.6	850.0– 1130.0
0.6006	5	141.6	>1130.0

Cleveland Dam Drum Gate			
Maximum Rate of Discharge Decrease			
Drum Gate Elevation Step Change Increments (m)	Minimum Time between Changes in Discharge Flow (minutes)	Calculated Change in Discharge Flow (m3/s)	Estimated Discharge Flow Range (m3/s)
0.6197	5	141.6	>1130.0
0.2979	5	56.6	1130.0 – 850.0
0.1669	5	28.3	850.0 – 560.0
0.1404	5	21.2	560.0 – 420.0
0.1052	5	14.0	420.0 – 280.0
0.0983	5	11.3	280.0 – 170.0
0.086	15	8.5	170.0 – 112.0
0.0869	15	7.0	112.0 – 56.0
0.0853	30	5.6	56.0 – 28.0
0.0768	60	4.2	28.0 – 16.0
0.0618	60	2.8	16.0 – 9.0
0.0555	60	2.1	7.0 – 9.0
0.0686	60	1.4	< 7.0

Seymour Falls Dam Increasing Ramping Rates				
Fish Valve % Open	1st Opened Howell-Bunger Valve %Open	2nd Opened Howell-Bunger Valve %Open	Minimum Time before Next Change in Valve Setting minutes	Estimated Discharge Flow for Reservoir at Spillway Elevation 212.94m m3/s
15/Auto	0	0	-	0.79
25	0	0	15	1.3
50	0	0	15	2.6
75	0	0	15	3.7
100	0	0	15	4.6
-	5	0	30	7.8
-	10	0	30	9.5
-	15	0	30	11.7
-	20	0	15	13.7
-	30	0	15	17.1
-	40	0	15	20.5
-	50	0	15	22.8
-	60	0	15	25.0
-	100	0	15	28.4
-	-	10	15	33.2
-	-	20	15	37.5
-	-	30	15	40.9
-	-	40	15	44.3
-	-	50	15	46.6
-	-	60	15	48.8
-	-	100	-	52.2

Notes:

1. The table shows the minimum times and maximum valve position steps for conditions with no spillway flow. Slower ramping rates may be used.
2. Contact the Utility Systems Control Superintendent for authorization to increase steps or decrease times if necessary for reservoir management.
3. The discharge flow shown does not include the turbine flow of $0.71m^3/s$
4. Except during unusual drought conditions, maintain a minimum total dam discharge of ~$1.25m^3/s$ by operating the fish valve at 25% or by operating the fish valve in STATION mode (15%) in combination with the normal turbine discharge.

Seymour Falls Dam Decreasing Ramping Rates				
1st Closed Howell-Bunger Valve % Open	2nd Closed Howell-Bunger Valve % Open	Fish Valve % Open	Minimum Time before Next Change in Valve Setting minutes	Estimated Discharge Flow for Reservoir at Spillway Elevation 212.94m m3/s
100	100	100	-	52.2
60	100	100	30	48.8
30	100	100	30	40.9
10	100	100	30	33.2
0	100	100	30	28.4
-	60	100	30	25.0
-	40	100	30	20.5
-	25	100	30	15.4
-	15	100	30	11.7
-	5	100	30	7.8
-	0	100	60	4.6
-	-	80	30	3.9
-	-	65	30	3.2
-	-	50	30	2.6
-	-	40	30	2.1
-	-	30	30	1.6
-	-	25	30	1.3
-	-	15/Auto	-	0.79

Notes:

1. The table shows the minimum times and maximum valve position steps for conditions with no spillway flow. Slower ramping rates may be used.
2. Contact the Utility Systems Control Superintendent for authorization to increase steps or decrease times if necessary for reservoir management.
3. The discharge flow shown does not include the turbine flow of $0.71m^3/s$
4. Except during unusual drought conditions, maintain a minimum total dam discharge of ~$1.25m^3/s$ by operating the fish valve at 25% or by operating the fish valve in STATION mode (15%) in combination with the normal turbine discharge.

APPENDIX F: MINIMUM DAM RELEASES

Capilano - Minimum Dam Releases During The Period

	June 1	June 15	July 1	July 15
Abundant Water Conditions *Criteria / Threshold*	Q_{min} = 2.3cms If by June 1st: • Lake level is > (145.89m) **and** • Spilling >10cms	Q_{min} = 2.3cms If by June 15th: • Lake level is > (145.89m) **and** • Spilling >10cms	Q_{min} = 2.3cms If by July 1st: • Lake level is @ full pool (145.89m) **and** • Spilling >10cms	Q_{min} = 2.3cms If by July 15th: • Lake level is @ full pool (145.89m) **and** • Spilling >2 cms
Average Water Conditions	Q_{min} = 1.2cms	Q_{min} = 1.2cms	Q_{min} = 1.2cms	Q_{min} = 1.2cms
Criteria	*Between Wet and Dry water condition thresholds*			
Drought Conditions *Criteria / Threshold*	Q_{min} = 0.57cms If by June 1st: • Lake level is less than 145.0m	Q_{min} = 0.57cms If by June 15th: • Lake level is less than 145.0m	Q_{min} = 0.57cms If by July 1st: • Lake level is less than 145.0m	Q_{min} = 0.57cms If by July 15th: • Lake level is less than 143.0m
	Aug 1	**Aug 15**	**Sept 1**	**Sept 15**
Abundant Water Conditions *Criteria / Threshold*	Q_{min} = 2.3cms If by Aug 1st: • Lake level is >143.5m **and** • Inflows to lake >12cms (excl Alpine releases)	Q_{min} = 2.3cms If by Aug 15th: • Lake level is >142.0m	Q_{min} = 2.3cms If by Sep 1st: • Lake level is >140m	Q_{min} = 2.3cms If by Sept 15th: • Lake level is >138m
Average Water Conditions	Q_{min} = 1.2cms	Q_{min} = 1.2cms	Q_{min} = 1.2cms	Q_{min} = 1.2cms
Criteria	*Between Wet and Dry water condition thresholds*			
Drought Conditions *Criteria / Threshold*	Q_{min} = 0.57cms If by Aug 1st: • Lake level is <139.0m	Q_{min} = 0.57cms If by Aug 15th: • Lake level is <135.0m	Q_{min} = 0.57cms If by Sep 1st: • Lake level is <130m	Q_{min} = 0.57cms If by Sep 15th: • Lake level is <130m and • Alpine storage has been released
	Oct 1	**Oct 15**	**Nov 1**	**Nov 15**
Abundant Water Conditions *Criteria / Threshold*	Q_{min} = 2.3cms If by Oct 1st: • Lake level is >136m	Q_{min} = 2.3cms If by Oct 15th: • Lake level is >134m	Q_{min} = 2.3cms If by Nov 1st: • Lake level is >136m	Q_{min} = 2.3cms If by Nov 15th: • Lake level is >138m
Average Water Conditions	Q_{min} = 1.2cms	Q_{min} = 1.2cms	Q_{min} = 1.2cms	Q_{min} = 1.2cms
Criteria	*Between Wet and Dry water condition thresholds*			
Drought Conditions *Criteria / Threshold*	Q_{min} = 0.57cms If by Oct 1st: • Lake level is <130m and • Alpine storage has been released	Q_{min} = 0.57cms If by Oct 15th: • Lake level is <130m and • Alpine storage has been released	Q_{min} = 0.57cms If by Nov 1st: • Lake level is <130m and • Alpine storage has been released	Q_{min} = 0.57cms If by Nov 15th: • Lake level is <130m and • Alpine storage has been released

Seymour - Minimum Dam Releases During The Period

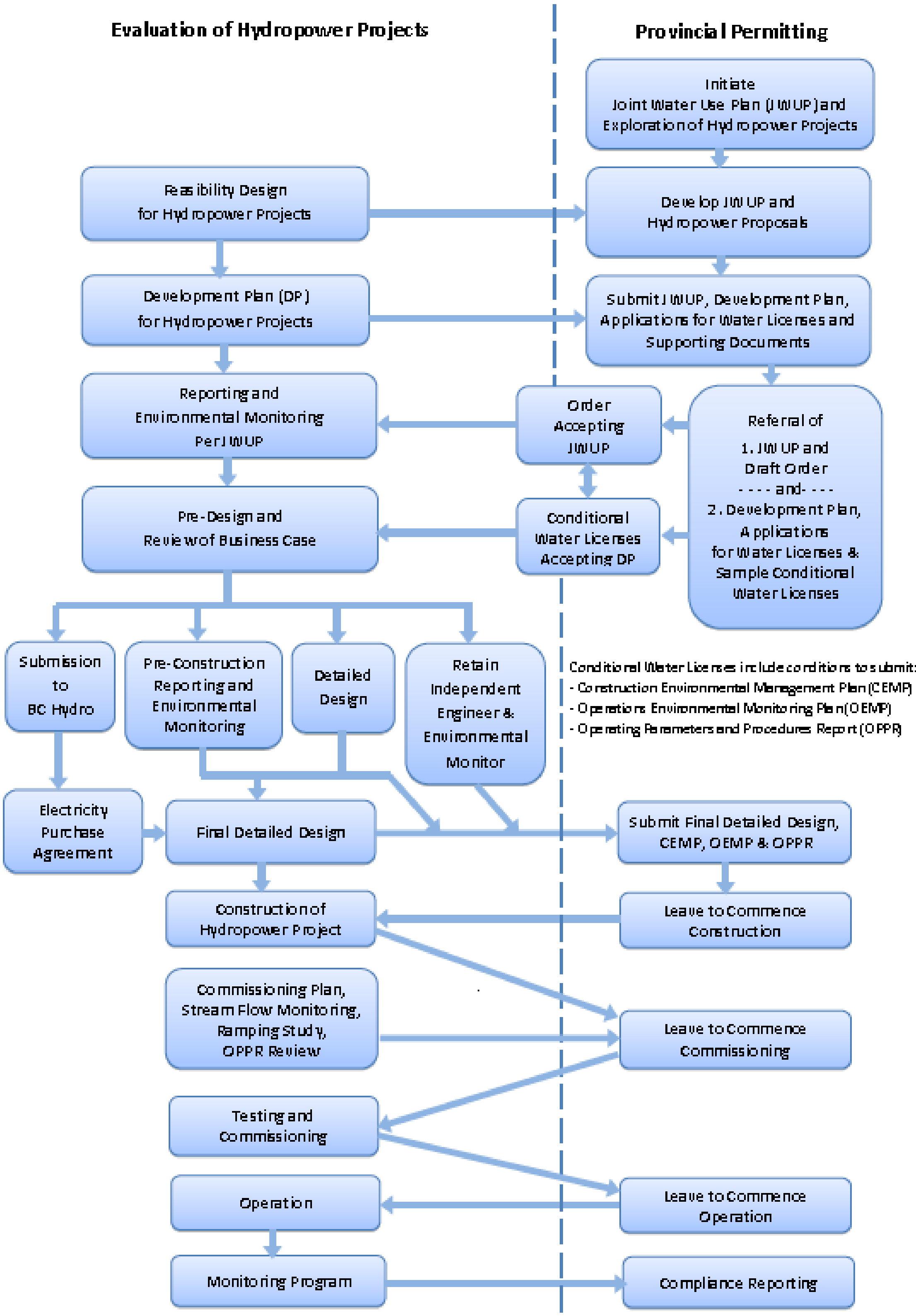
	June 1	June 15	July 1	July 15
Abundant Water Conditions *Criteria / Threshold*	Q_{min} = 1.36cms	Q_{min} = 1.36cms	Q_{min} = 1.4cms	Q_{min} = 1.4cms
Average Water Conditions	Q_{min} = 1.36cms	Q_{min} = 1.36cms	Q_{min} = 1.4cms	Q_{min} = 1.4cms
Criteria	*Between Wet and Dry water condition thresholds*			
Impending Drought Conditions *Criteria / Threshold*	Q_{min} = 1.1cms If by June 1st: Lake level <213m	Q_{min} = 1.1cms If by June 15th: Lake level is <214m	Q_{min} = 1.1cms If by July 1st: Lake level is < 213m	Q_{min} = 1.1cms If by July 15th: Lake level is <211m
Drought Conditions *Criteria / Threshold*	Q_{min} = 0.7cms If by June 1st: Lake level < 212m	Q_{min} = 0.7cms If by June 15th: Lake level is <213m	Q_{min} = 0.7cms If by July 1st: Lake level <212m	Q_{min} = 0.7cms If by July 15th: Lake level is <210m

	Aug 1	Aug 15	Sept 1	Sept 15
Abundant Water Conditions *Criteria / Threshold*	Q_{min} = 2.8cms If by Aug 1st: Lake level is >213.8m	Q_{min} = 2.8cms If by Aug 15th: Lake level is >213.4m	Q_{min} = 2.8cms If by Sep 1st: Lake level is >213m	Q_{min} = 2.8cms If by Sept 15th: Lake level is >212m
Average Water Conditions	Q_{min} = 1.4cms	Q_{min} = 1.4cms	Q_{min} = 1.4cms	Q_{min} = 1.4cms
Criteria	*Between Wet and Dry water condition thresholds*			
Impending Drought Conditions *Criteria / Threshold*	Q_{min} = 1.1cms If by Aug 1st: Lake level is <208m	Q_{min} = 1.1cms If by Aug 15th: Lake level is <206m	Q_{min} = 1.1cms If by Sep 1st: Lake level is <204 and Alpine storage released	Q_{min} = 1.1cms If by Sep 15th: Lake level is <204 and Alpine storage released
Drought Conditions *Criteria / Threshold*	Q_{min} = 0.7cms If by Aug 1st: Lake level is <207m	Q_{min} = 0.7cms If by Aug 15th: Lake level is <205m	Q_{min} = 0.7cms If by Sep 1st: Lake level is <203 and Alpine storage released	Q_{min} = 0.7cms If by Sep 15th: Lake level is <203 and Alpine storage released

	Oct 1	Oct 15	Nov 1	Nov 15
Abundant Water Conditions *Criteria / Threshold*	Q_{min} = 2.8cms If by Oct 1st: Lake level is >211m	Q_{min} = 2.8cms If by Oct 15th: Lake level is >210m	Q_{min} = 2.8cms If by Nov 1st: Lake level is >210m	Q_{min} = 2.8cms If by Nov 15th: Lake level is >212m
Average Water Conditions	Q_{min} = 1.4cms	Q_{min} = 1.4cms	Q_{min} = 1.36cms	Q_{min} = 1.36cms
Criteria	*Between Wet and Dry water condition thresholds*			
Impending Drought Conditions *Criteria / Threshold*	Q_{min} = 1.1cms If by Oct 1st: Lake level is <204 and Alpine storage released	Q_{min} = 1.1cms If by Oct 15th: Lake level is <204 and Alpine storage released	Q_{min} = 1.1cms If by Nov 1st: Lake level is <204 and Alpine storage released	Q_{min} = 1.1cms If by Nov 15th: Lake level is <206 and Alpine storage released
Drought Conditions *Criteria / Threshold*	Q_{min} = 0.7cms If by Oct 1st: Lake level is <203 and Alpine storage released	Q_{min} = 0.7cms If by Oct 15th: Lake level is <203 and Alpine storage released	Q_{min} = 0.7cms If by Nov 1st: Lake level is <203 and Alpine storage released	Q_{min} = 0.7cms If by Nov 15th: Lake level is <205 and Alpine storage released

APPENDIX G: OVERVIEW OF TECHNICAL, COMMERCIAL AND PERMITTING ASPECTS

Joint Water Use Plan for Capilano & Seymour Watersheds
and Consideration of Hydropower Projects



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