Stream Flows: Daisy Lake Reservoir and the Cheakamus River

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What is happening?

Climate change predictions suggest that stream flow patterns will shift, meaning plants and animals that live alongside or in rivers will need to adapt to survive. Changing stream flow patterns will also influence the volume and timing of freshwater input to the marine environment, and consequently, the timing of plankton blooms (see Plankton, Ocean Watch Howe Sound Edition [OWHS] 2017), among other potential impacts. Therefore, it is important to monitor river flows to understand yearly differences and long-term trends.

Within the Átl'k̲a7tsem/Txwnéwu7ts/Howe Sound watershed, there are numerous river systems that are monitored for stream flows by the Water Survey of Canada (WSC), including most rivers and their major tributar-

The Squamish River, into which the Cheakamus River drains. (Credit: Aroha Miller) ies in the Squamish River watershed (the Mamquam, Squamish, Ashlu, Elaho, Cheakamus and Stawamus rivers). Daily river flow from Daisy Lake Reservoir was previously reported (see Stream Flows, OWHS 2017). The shift in flow seasonality reported for Daisy Lake Reservoir appeared similar to projected shifts due to climate change.

Daisy Lake Reservoir is located along the Cheakamus River. The upper Cheakamus River flows into the reservoir, where reservoir inflows and outflows have been monitored since the construction of the Cheakamus Generating Station in the late 1950s. The reservoir is connected to the Cheakamus Generating Station, which produces electricity.[1] The water used for power generation is discharged into the Squamish River.[1]

The amount of freshwater input into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is an important variable impacting the marine environment. The Cheakamus River drainage basin is approximately 1070 km^2, while the drainage basin for the Squamish River is approximately 3600 km^2. Thus, the Squamish River contributes around two-thirds, or 66%, and the Cheakamus contributes almost one-fifth, or 20% of freshwater input into the Sound.[2] All drainage basins in the watershed, including the Cheakamus and Squamish Rivers, are largely glacier fed.

In 2019, the Government of Canada released *Canada’s Changing Climate Report*, in which it predicted changes in the seasonal availability of freshwater and an increased risk of water supply shortages in summer.[3] The Daisy Lake Reservoir/Cheakamus River system is the most studied watercourse in the Squamish River watershed and serves as an excellent indicator system for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. We are therefore updating data presented in the OWHS 2017 report, as well as taking a higher-level look further back in the historical record along the Cheakamus River (below the dam), to see if this predicted change could also be observed in Cheakamus River stream flow data.

What is the current status?

Daisy Lake Reservoir

Stream flow into Daisy Lake Reservoir has been monitored on an ongoing basis since construction in the 1950s. This long-term data was reported in OWHS 2017. Data presented here adds stream flow since 2017, up until early June 2019, although monitoring is ongoing.

The long-term range of flows (data from 1960 to 2016 inclusive, light-blue shading, Figure 1) shows freshet[i] typically peaks in mid-June, although there is considerable variation between years (Figure 1). Data for 2017 and 2018 fall within this long-term range. However, spring freshet appears to have occurred slight-

i) Freshet – increased water flow due to snow melt, typically resulting from spring thawing of the snowpack, and generally characterized by a steady rise in stream flow, to a peak, after which stream flows begin to decrease again.

ly earlier (mid-May to early June) compared to the long-term average, and summer flows are lower than average long-term summer flows. Flow peaks due to rainfall events were observed in fall and again in winter (December to February) although again, these are within the long-term range. The addition of two years of data is not enough to draw any conclusions about long-term trends.

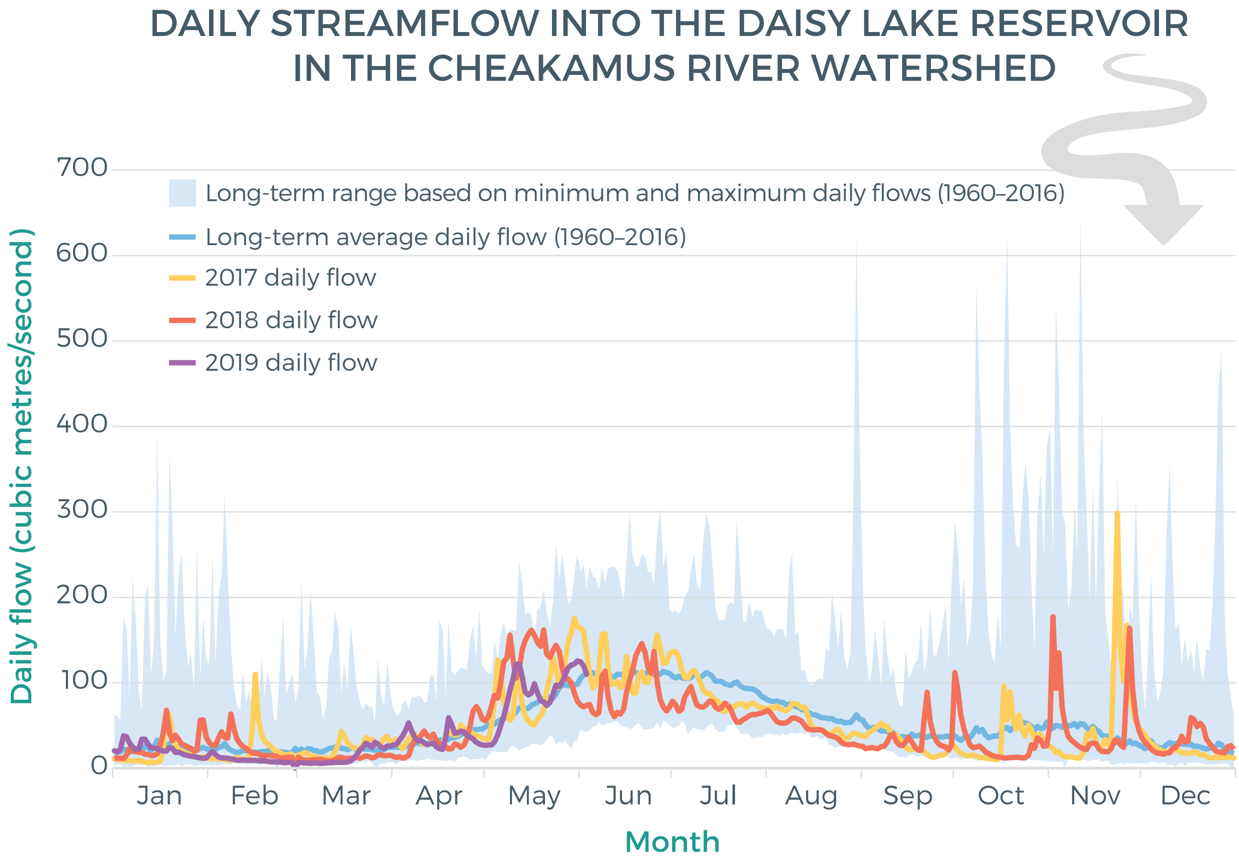

Figure 1. Daily stream flow into Daisy Lake Reservoir in the Cheakamus River watershed.[4] Light-blue shading shows the long-term range of flows (1960–2016). The light-blue line indicates the long-term average daily flow (1960–2016). The orange and red lines show the 2017 and 2018 daily stream flow, respectively, while the purple line shows daily stream flow for 2019, ending in early June 2019 due to data availability.

Cheakamus River

We looked at natural[ii] average daily discharge (flow) in the first and last 20 years of a 100-year data set. The early data set (1917–1937) was from a gauge that is no longer operational (*Cheakamus at Garibaldi*); the latter data set (1997–2017) is from the next closest gauge that is still operational (*Cheakamus at Brackendale*) (Figure 2). Data from the earlier period at the first gauge location has been normalized to the drainage area size of the second gauge location (representing the latter period). See Methods for further details.

We observed some differences between the two periods that appear to support predicted changes to the availability of freshwater (Figure 3).[3] The freshet peak is smaller, indicating less snowpack, and slightly earlier, peaking at the start of June (small blue oval), possibly because more precipitation fell as rain rather than snow in the winter, resulting in a smaller snowpack and therefore a smaller thaw. Average daily post-freshet summer flows are lower in the 1997–2017 period relative to the earlier period (large blue oval). Storm event peaks in the fall and winter are larger, again likely due to more of the annual precipitation volume falling as rain rather than snow.

Figure 2. Location of the two water gauges and the Daisy Lake Spillway, in relation to Sḵwx̱wú7mesh/Squamish town.

ii) Natural river flow – the volume of water under non-regulated flow conditions. The natural stream flow is calculated by BC Hydro as the sum of reservoir inflows plus inflows below Daisy dam.
Non-regulated – river flow is not controlled.
Actual river flow – the volume of water under regulated flow conditions.
Regulated – river flow is controlled during power-generating operations (typically this occurs year-round).

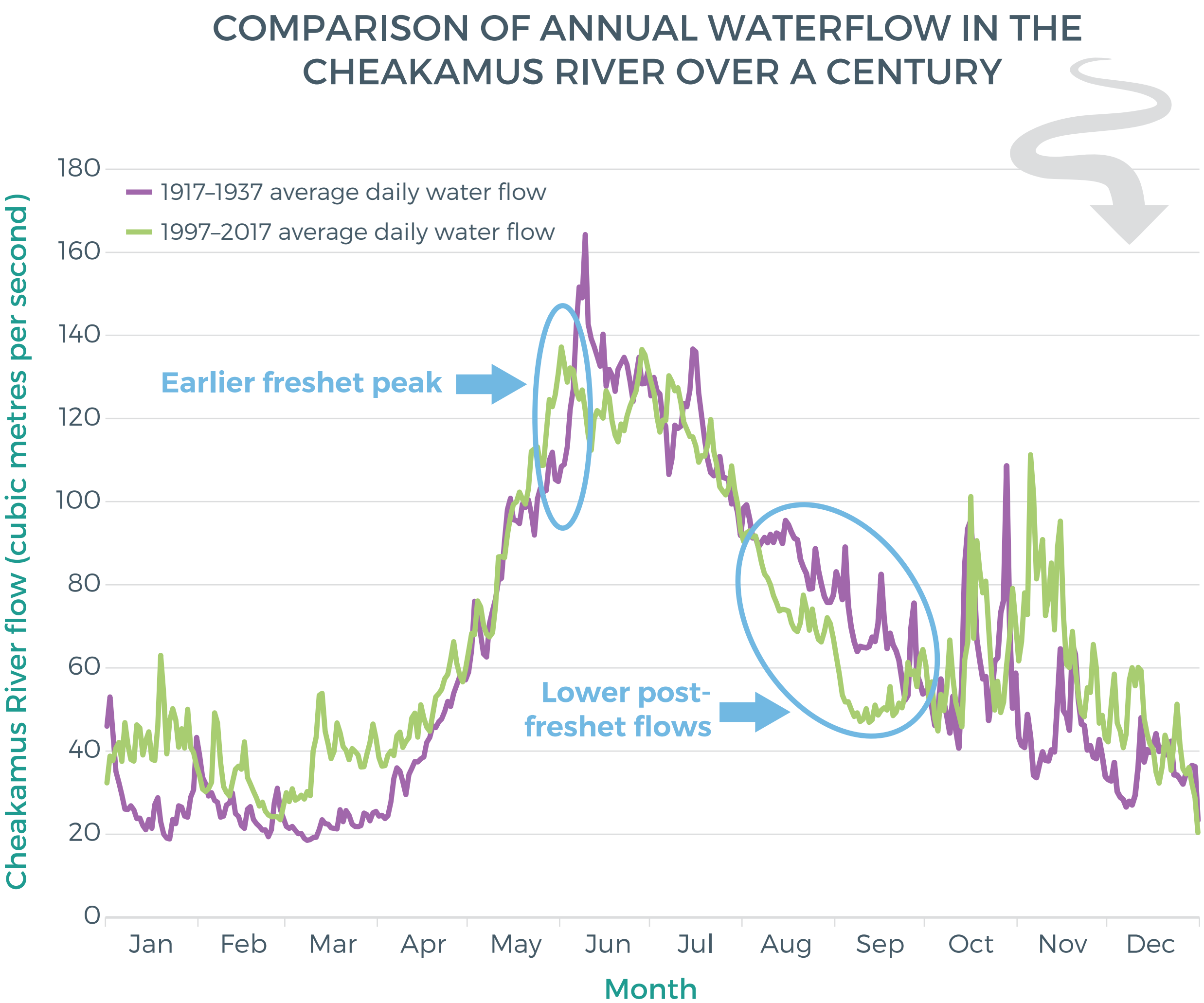

Figure 3. Natural annual water flow in the Cheakamus River. The purple line represents the average daily water flow for the period 1917–1937. The green line represents the average daily water flow for the period 1997–2017. The small blue oval indicates a smaller, earlier freshet peak; the large blue oval indicates lower post-freshet flows.

How will climate change impact stream flows in Átl’ḵa7tsem/ Txwnéwu7ts/Howe Sound?

Climate change will likely result in earlier peaks in stream flows (i.e., freshet), larger storm peak flows and lower late summer flows.[3] Such changes in stream flow may have implications for wildlife seasonal cycles both in the river and in the marine environment. For example, extreme precipitation events can lead to increased river flows, causing scouring of riverbeds and destroying spawning habitat for some fish species. Likewise, droughts can lead to low flows and increased water temperature, resulting in poor survival of eggs and early life stages.[5]

The rivers in the wider Átl’ḵa7tsem/Txwnéwu7ts/ Howe Sound watershed contribute to changes in volume and timing of freshwater input into Átl’ḵa7tsem/ Txwnéwu7ts/Howe Sound. The same changes we observed in freshwater availability for the Cheakamus may possibly be seen in other watercourses within the watershed. These changes impact ocean temperatures in the Sound (see Ocean Warming, OWHS 2017) and potentially the timing of plankton blooms, which form the basis of the food web in Átl’ḵa7tsem/Txwnéwu7ts/ Howe Sound (see Plankton, OWHS 2017).

Squamish River as it flows south towards the estuary and Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Rich Duncan)

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Become familiar with the current Integrated Flood Hazard Management Plan (IFHMP). Be aware of flood hazards in your area and be prepared for an emergency at your home and workplace.	Refer to the District of Squamish's IFHMP, adopted in 2017.
Help prevent climate change by producing fewer greenhouse gasses. Adopt policies and practices within your organization.	Incentives to decrease the costs of electric vehicles are available in B.C., link below. https://pluginbc.ca/incentives/vehicle-incentives/#izev
GOVERNMENT ACTIONS AND POLICY	
Continue to closely monitor streamflow data and trends.	BC Hydro continues to monitor river flows in areas where they have run-of-river hydroelectricity generators. This includes Daisy Lake Reservoir and Culliton Creek in the Squamish watershed.[5] Other hydroelectric projects monitor stream flows, e.g., Mamquam River. While BC Hydro is a provincial Crown corporation, other hydroelectric operators are not.
Increase capacity to respond to extreme weather events, including droughts.	Refer to the District of Squamish's IFHMP, adopted in 2017.
Continue to renew the Integrated Flood Hazard Management Plan (IFHMP) every five to 10 years.	See Resources on extreme weather events below. This is not a substitute for government-level actions. A number of the district municipalities have an emergency response program section on their websites.
Protect the coastline from storm surge and flooding using Green Shores techniques.	Greater awareness of and interest in Green Shores through Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound has been noted, although the increase in inquiries has not yet translated into enrolled projects (see Shorelines, OWHS 2020).
Withdraw, relocate or abandon public assets in high-risk areas of flooding.	Being discussed in some local Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound municipalities.
Increase public education on what to do in the event of extreme weather, flooding and drought.	A selection of resources outlining what to do in these events are provided below.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- Record stream levels when enumerating salmon spawning.
- Withdraw, relocate or abandon private assets in high-risk areas of flooding.
- Implement and practise water conservation measures in your home and within your organization.
- NEW Plant trees and vegetation along waterways.
- NEW Join a citizen science group that restores wetlands.

Government Actions and Policy:

- Take action to minimize rainfall-related flooding and associated consequences.
- Develop an education plan for the Integrated Flood Hazard Management Plan to educate locals, especially those in high-risk areas.
- Identify and develop plans for slopes at high risk of landslide.
- Develop policies for back-up power in all eventualities.
- Increase flood construction levels, add covenants to reduce liability and retrofit existing buildings.
- Identify future no-build zones or use land acquisition or restriction tools such as land trusts.
- Work with BC Hydro to ensure sufficient water flow in “managed” rivers that support salmon spawning and migration.
- NEW Increase awareness and education around the importance of headwaters.
- NEW Data collected by BC Hydro and other independent run-of-river plants should be made available to independent researchers.
- NEW Hydroelectric power generation requires a substantial quantity of water. Operators of these facilities and government authorities that regulate power plants should consider water availability changes when setting future targets for water diversion.

Methods

Daisy Lake Reservoir

The previous graph from OWHS 2017 was updated with smoothed data from BC Hydro. Smoothed data is based on calculations of reservoir storage and discharge. The challenge of calculating reservoir volume is the main source of random error and therefore quality control procedures are applied to the data. A system of automated and manual data checks is applied to calculated daily averages from hourly averages. The developed application allows for estimations for poor quality or missing data.

Cheakamus River

Historical data for the Cheakamus River exists from the Water Survey of Canada (WSC) gauge *Cheakamus at Garibaldi* (08GA017). This gauge was located 1.6 km below the location of the current Daisy dam spillway and is no longer operational. The first 20 years of data available, 1917 to 1937, presented in Figure 2, comes from this gauge. The drainage area for the *Cheakamus at Garibaldi* gauge is 813 km^2.

Data for the latter 20 years, 1997–2017, were collected at WSC gauge *Cheakamus at Brackendale* (08GA043). This time period was selected because it is the most recent 20 years of data available, and natural streamflow data do not extend back beyond 1984. This gauge is located approximately 17 km downstream of the former *Cheakamus at Garibaldi* gauge, with a drainage area of 965 km^2; it is still in operation. Its location represents the flow compliance point for BC Hydro's operations on the Cheakamus River (e.g., flows must be a minimum of ≥ 15 cubic metres per second at this location from November 1 to March 31; however, the required minimum flow varies throughout the year).

In order to compare data from the two gauge locations, the *Cheakamus at Garibaldi* data were normalized to the drainage area size of the *Cheakamus at Brackendale* drainage area (e.g., daily *Garibaldi* data were multiplied by 1.2), as per methods outlined in the Indicators of Hydrologic Alteration software package.[7] Natural flows for the 1997–2017 period were calculated with BC Hydro's reservoir inflow and inflow below Daisy Lake spillway data (natural discharge at the *Cheakamus at Brackendale* gauge = Daisy reservoir inflows + inflows below Daisy dam spillway). The data presented are the average daily flows from the respective 20-year periods.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

B.C. Centre for Disease Control:
Wildfire Smoke Response Planning
http://www.bccdc.ca/health-professionals/professional-resources/wildfire-smoke-response-planning

Wildfire Smoke:
health effects of wildfire smoke, how to prepare for wildfire smoke season, portable air cleaners, face masks for wildfire smoke
http://www.bccdc.ca/health-info/prevention-public-health/wildfire-smoke

Municipal Heat Response Planning in British Columbia, Canada (2017)
http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/BC%20Municipal%20Heat%20Response%20Planning.pdf

Government of B.C.:
Get Prepared for Severe Weather in British Columbia
https://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/preparedbc/know-your-hazards/severe-weather?keyword=know&keyword=your&keyword=hazards&keyword=severe&keyword=weather

Government of Canada:
Get Prepared: Floods
https://www.getprepared.gc.ca/cnt/hzd/flds-en.aspx

Alberta Health Services:
Cleaning the House After a Flood
https://www.albertahealthservices.ca/Advisories/ne-pha-cleaning-house.pdf

Saskatchewan Ministry of Health:
Clean Up After the Flood. A Guide for Homeowners
https://www.yorkton.ca/livinghere/springrunoff/pdf/SK_cleaning_up_after_the_flood.pdf

Integrated Flood Hazard Management Plan
https://squamish.ca/yourgovernment/projects-and-initiatives/completed-projects/2018-completed-projects/floodhazard/ifhmp-2016/

References

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2 Fisheries and Oceans Canada (DFO). BC Inlets – Water Properties Trends – Howe Sound [Internet]. [cited 2020 Feb 14]. Available from: https://www.pac.dfo-mpo.gc.ca/science/oceans/BCinlets/howe-eng.htm

3 Bush E, Lemmen D. Canada's Changing Climate Report [Internet]. Ottawa: Government of Canada; 2019. p. 444. Available from: www.ChangingClimate.ca/CCCR2019 ISBN: 978-0-660-30222-5

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5 Selong JH, McMahon TE, Zale A V., Barrows FT. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Trans Am Fish Soc. 2001;130:1026–1037.

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7 Nature Conservancy. Indicators of hydrologic alteration. Version 7.1. Software User's manual. 2009.