Local Impacts of Climate Change: Investigating the past and future of glacier ice and melt processes in the North Shuswap

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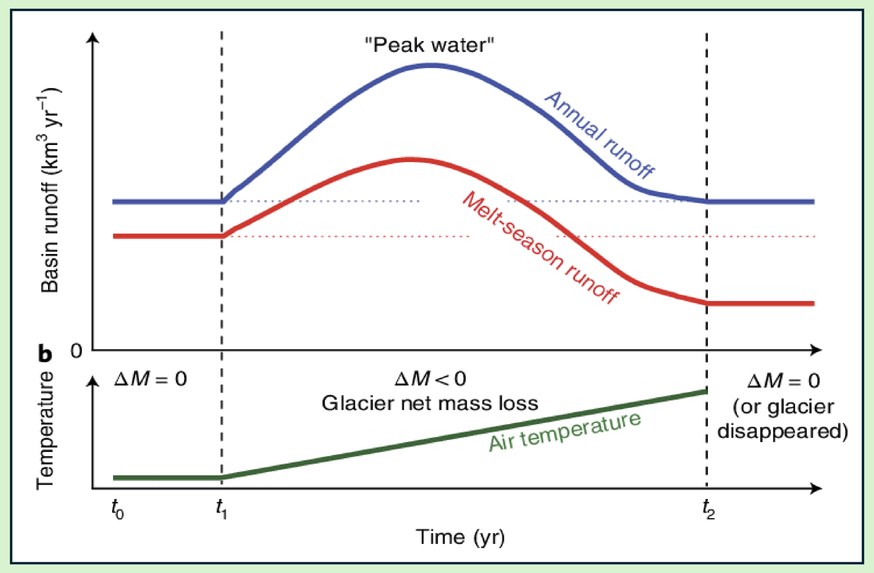
NSERC CRSNG · Adams Lake Indian Band · SHUSWAP watershed council · Mike Wiegele Helicopter Skiing

INTRODUCTION

Globally, glaciers of all sizes are receding, linearly correlated to an increase in average global temperature (Rounce et al. 2023). **Hydrological response to glacier recession may pose significant ecological and socioeconomical risks** (Spehn et al. 2002; Milner et al. 2009).

The contribution of glacier melt to the annual drainage of a catchment is generally dependent on the percent of glaciated area and the current rate of recession (Jansson et al. 2003). A glaciated area as little as 1% in a macroscale basin (100,000 km²) can account for 25% of late summer (August) river flow (Huss 2011).

Glaciers in Western North America have generally been receding since the Little Ice Age, resulting in an increasing contribution of glacier runoff in glacially influenced basins (Moore et al. 2009).



The above diagram from Huss & Hock (2018) demonstrates that annual discharge within a catchment is not influenced by glacier runoff when glaciers are in a state of equilibrium or when there is negligible glacier coverage - annual discharge is only influenced when glacier mass balance is in a state of flux.

The 'peak water' phase for glaciers located within Western Canada is expected to occur between 2020 – 2040 (Clarke at al. 2015).

It is important to assess the impact of glacier change within distinct hydrological systems.

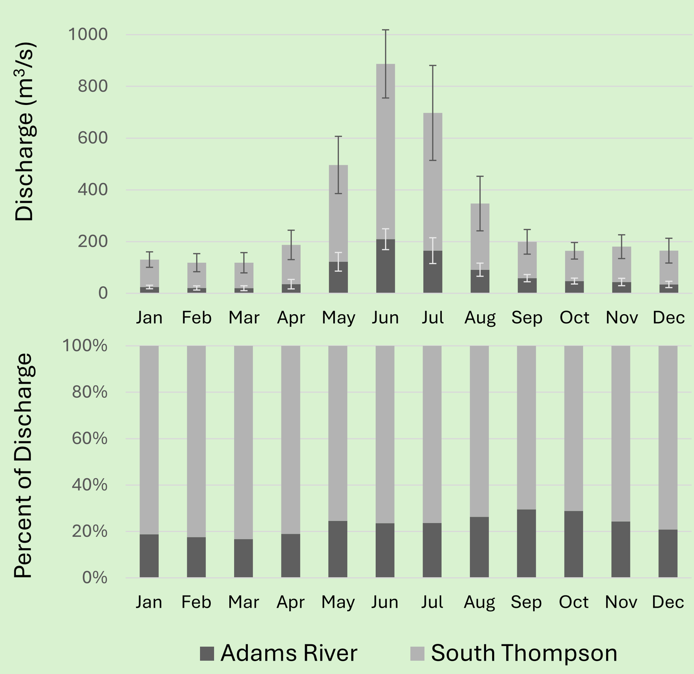
The Adams River catchment is a glaciated sub-drainage of the South Thompson River. The South Thompson is the main source of water for the community of Kamloops (*Tk̓emlúps te Secwépemc)*. Furthermore, Adams River has immense socio-economic and ecological importance, providing critical habitat for salmonids and native aquatic species (Kruger & Saayman 2017).

Is the Adams River hydrology glacially influenced?

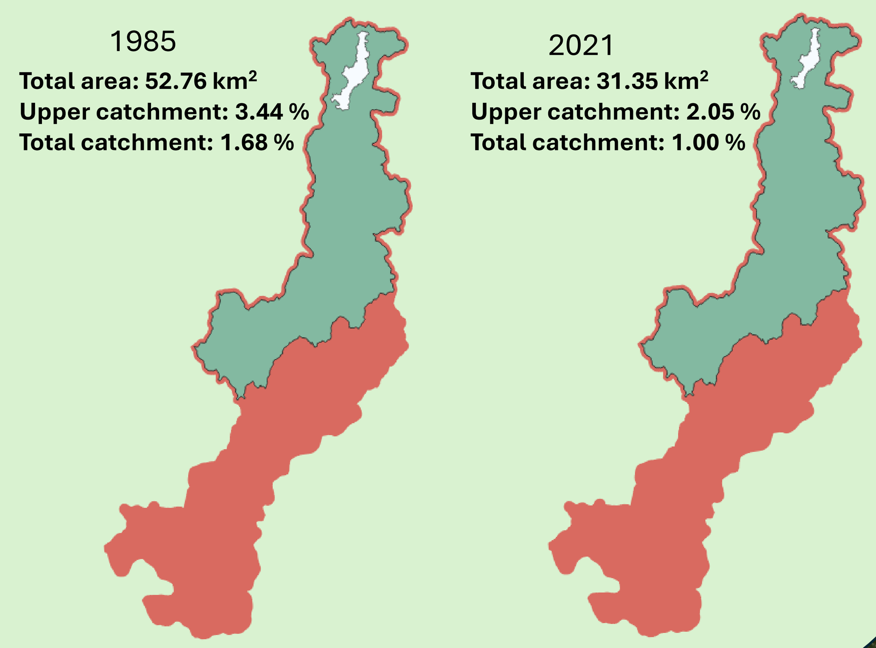
If so, how will glacier change affect the quantity of river discharge on a decadal, annual, or seasonal time scale?

INITIAL INVESTIGATION

The top figure portrays the average monthly flow, over the past 23 years, at the outflow of Adams River and at a South Thompson River hydrometric station near Chase, BC. **Adams River flow is especially important in the late summer and fall, reaching up to 29% of the South Thompson River discharge in September.**



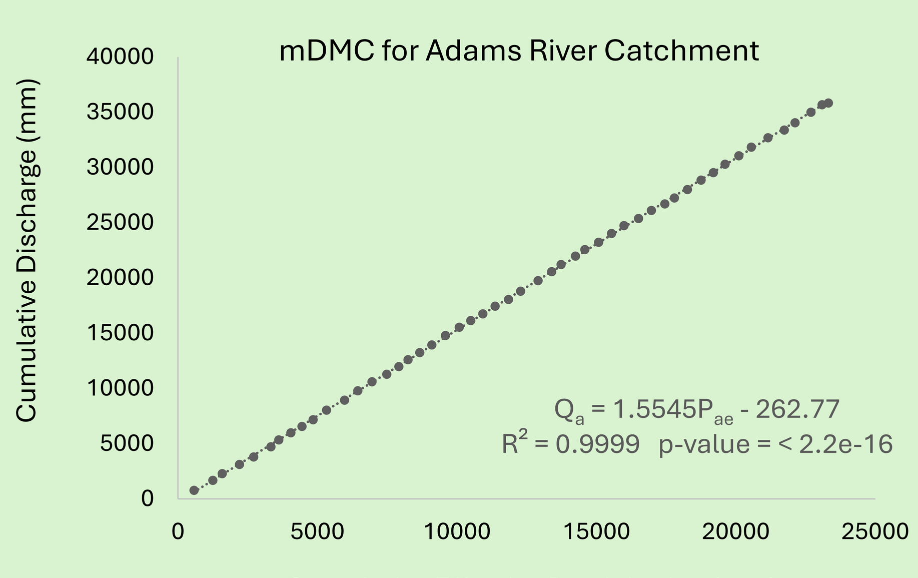
Satellite imagery was utilized to quantify the total glaciated area of the Adams watershed in 1985 and 2021 (Sever & Pypker unpublished). The upper catchment area (1532.75 km²) is shaded in green. The total catchment area (3137.13 km²) is shaded and outlined in red. Only glaciers > 0.01 km² were considered.



ANNUAL DISCHARGE TREND ANALYSIS

A modified Double Mass Curve (mDMC) detects any changes in cumulative annual discharge due to shifts in non-climatic variables when a breakpoint or change in slope occurs (Wei & Zhang 2010). In a glaciated watershed, a change in the rate of glacier recession should be depicted by a shift in the mDMC curve.

No significant break point or slope change suggests **there has not been a significant change in the quantity of annual discharge within the Adams watershed between 1971-2021; however, this does not account for any shifts in seasonal patterns or potential compensatory factors.**



Pettitt test:
Changepoint in 2009
p-value = 0.204

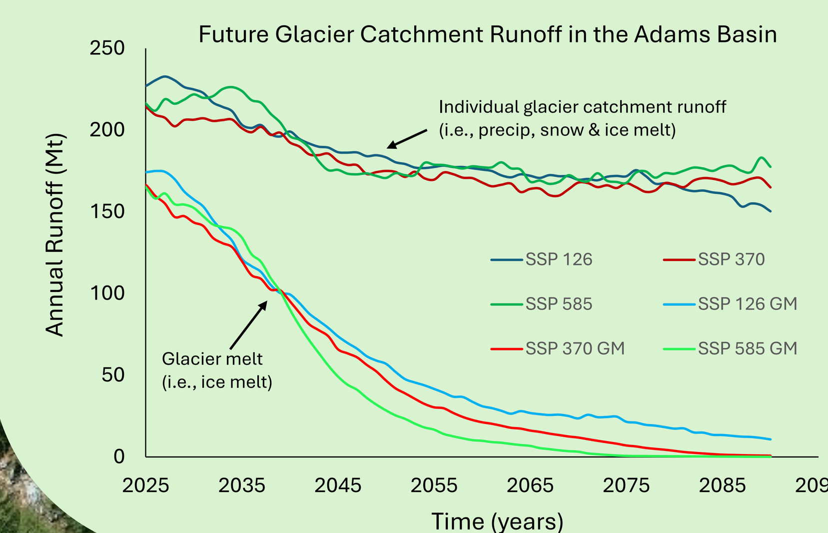
Davies' test:
Best at 13380 P_{ae}
p-value = 0.3307

ISOLATING GLACIER RUNOFF

The Open Global Glacier Model (OGGM) was utilized to project future glacier runoff and seasonal melt patterns.

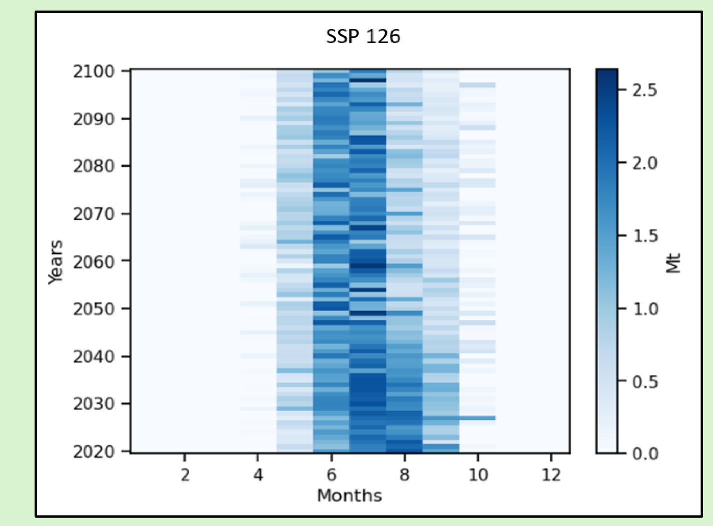
The figure below depicts projected annual runoff from all glaciers within the Adams watershed based on three climate scenarios.

- **Glacier recession in the Adams watershed is at or just past 'peak water'**
- **Glacier melt is currently equivalent to 14% of Adams River June – September flow**
- **Glaciers will recede completely or become negligible by 2100 in all climate scenarios**
- **Annual flow may be buffered by increase in precipitation**



The previous figure does not account for a change in seasonal timing. The figure below depicts the projected change in seasonal runoff from a representative glacier in the watershed for the 'best-case' climate scenario.

- **Currently, most glacier runoff occurs in July, August and September. Over time, glacier catchment runoff will occur earlier in the season due to a shift towards precipitation dominated runoff**
- **This trend is more pronounced and at a faster rate for the SSP 370 & SSP 585 climate scenarios**

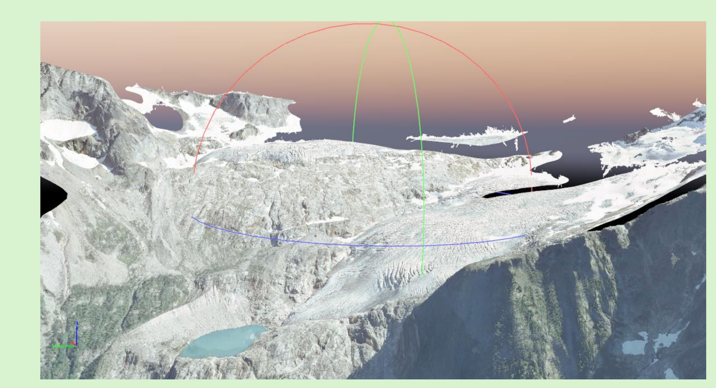


FUTURE WORK - MODEL CALIBRATION

The OGGM utilizes remote sensing data to model glacier geometry, mass balance, and volume from which water melt equivalence can be calculated (Maussion et al. 2019). ***In situ* data is important for model calibration and refining model error at a single basin scale.**

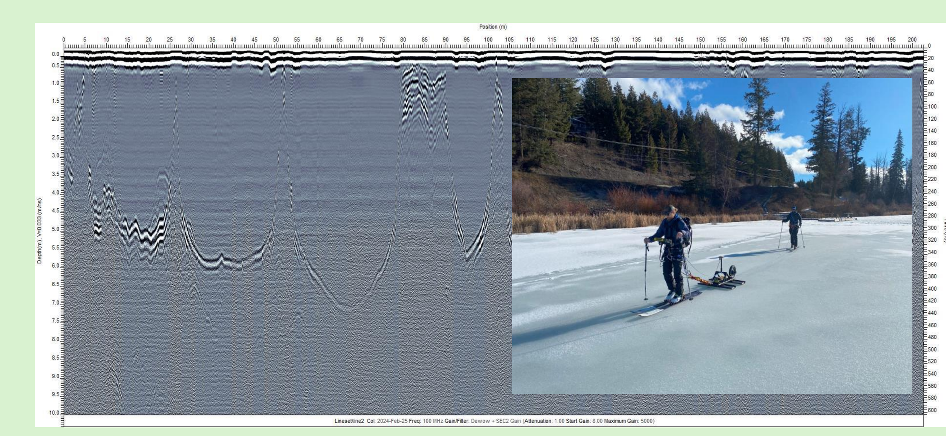
Photogrammetry

High resolution aerial images were obtained from the BC photo archives for 2011. Overlapping frames, by at least 60% form stereopairs, where the difference in photo perspective allows for 3D modelling of the surface. Photos from 1997 and 2005 will be obtained and used to fmodel the surface elevation of two representative glaciers over time within the Adams Watershed.



Ice Penetrating Radar (IPR)

Pelto et al. (2020) utilized IPR to measure thickness of glaciers that had previously been estimated with inversion models and found, on average, a 38% difference in modelled and measured ice thickness. IPR measurements from two representative glaciers within the Adams watershed will be collected in April 2024 and integrated into the OGGM model to refine ice thickness estimates.



CONCLUSIONS & FURTHER CONSIDERATIONS

- **Glaciers with the Adams Watershed have reached the 'peak water' phase and are projected to recede completely by 2100 under any climate scenario.**
- **Adams Lake has a large water holding capacity with a volume of 40.96 km³ . This may work to buffer any significant fluctuations of annual or seasonal discharge** at the outflow of the Adams watershed. This may account for no significant change in annual discharge at the Adams River hydrometric station between 1971 - 2021 despite glaciers within the catchment receding and contributing an equivalence of 14% of the Adams River late summer and early fall flow.
- **The upper Adams River does not have the same buffering system and has a higher proportional glaciated area.** The upper Adams River once provided critical spawning habitat for thousands of salmon; however, the Upper Adams sockeye run was decimated in the early 20th century due to the construction of a splash dam (Hume et al. 2003). There have been reintroduction efforts, as well as nutrient supplementation programs to re-establish a thriving Upper Adams River salmon run. **It is crucial to understand the future hydrological effects of glacier recession in the Upper Adams catchment specifically to plan for future management.**
- As glaciers have dominantly been in a state of flux since the LIA, **water allocation and management within glacially influenced basins has been developed within a period of elevated flows. As we lose this long-term water storage, it is necessary to reassess management practices within these watersheds.**

Adams watershed hydrometric station

City of Kamloops
Tk̓emlúps te Secwépemc

This study is being conducted on the traditional and unceded lands of the Adams Lake First Nations Band, within Secwepemcúl'ecw.

"Tmícw - the rough translation of this Secwepemctsín word is land, waters, and everything on Earth. Tmícw reflects layers of meaning and interrelation to the landforms, places, and beings within Secwepemcúl'ecw." – Qwelmínte Secwépemc Tmícw cumulative effects plan:

"The Adams Lake Indian Band is currently working on a draft Land Management Framework for the Adams Lake drainage system. This project will be focused on water and forestry development and will look at the cumulative effects on these resources as well as create an ALIB specific scenario for management in these areas."

References | mDMC Methods & Script | OGGM Methods | 'Cool' Glacier Photos