

Bessette Creek Streamflow Monitoring

FWCP Project No.:

COA-F24-F-3937



Prepared by:

Zhaozhi (George) Wang

Okanagan Nation Alliance Fisheries Department

Prepared for:

Fish & Wildlife Compensation Program

26-June-2024

Prepared with financial support of the Fish & Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and Public Stakeholders.



Okanagan Nation Alliance

**101-3535 Old Okanagan Highway,
Westbank, BC V4T 3L7**

Phone: (250) 707-0095 Fax: (250) 707-0166

Acknowledgements

Funding for this project was generously provided by the Fish & Wildlife Compensation Program. We wish to thank Okanagan Indian Band staff who coordinated this project.

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Citation: Wang, Z. 2024. Bessette Creek Streamflow Monitoring, 2024 Final Report. Prepared for Fish & Wildlife Compensation Program by the Okanagan Nation Alliance Fisheries Department, Westbank, BC.

EXECUTIVE SUMMARY

This project falls into two priority actions, including research and information acquisition, and monitoring and evaluation. Specifically, this project closely aligns with the priority action #10 “SHU.RLR.RI.10.01 Improve fish production & survival during low flow Middle SHU-P2” in FWCP’s Shuswap River Watershed Action Plan.

Bessette Creek, a vital tributary of the Shuswap River, covers 795 km², sustaining diverse fish populations including Chinook and Coho salmon, salmon, and rainbow trout. However, challenges such as water scarcity and declining fish populations necessitate conservation efforts, especially given the creek’s role in supporting endangered Coho salmon and Chinook salmon and rainbow trout spawning in the Shuswap Lake area.

This project aims to address these challenges and support conservation efforts through two primary objectives. Firstly, it seeks to enhance available streamflow data within the Bessette watershed for effective drought response and water management. This involves operating and maintaining hydrometric stations and analyzing data to provide continuous streamflow records in real-time. Secondly, the project aims to improve water quality and quantity to support Chinook and Coho salmon spawning and rearing in the Bessette watershed. This includes utilizing hydrometric data to respond effectively to drought conditions and monitoring water temperature to assess its impact on salmonids and aquatic habitat.

The methodology employed in this study comprehensively assessed surface water dynamics in Bessette Creek, focusing on streamflow and temperature monitoring at strategically positioned hydrometric stations. Rigorous field visits ensured accurate data collection, and the AQUARIUS Time-Series platform facilitated efficient data management and timely publication of results.

These stations offer vital information for informed decision-making, especially considering Ministerial Order No. M239 under section 88 of the Water Sustainability Act. The analysis revealed persistent challenges for salmonid migration and spawning in Bessette Creek, particularly at certain stations where streamflows consistently fall below critical levels. The reduction in water release from Nicklen Creek exacerbates drought conditions in Bessette Creek, emphasizing the need for adaptive water management strategies. Additionally, significant variations in thermal conditions among stations underscore the complex interplay between water release patterns and temperature fluctuations.

To address these challenges effectively, it is crucial to maintain ongoing monitoring of these stations, prioritizing high-flow measurements to enhance the development of rating curves for the high-flow regime. This will subsequently improve the accuracy of LTmad predictions. Additionally, conducting a comprehensive assessment of water withdrawals for irrigation and dam operations is necessary. This entails thorough reviews, investigations, and reassessments of storage and release plans to mitigate challenges and maintain favorable conditions for salmonid habitats. Specifically, reevaluating water release plans from Nicklen Lake Dam and implementing careful water management practices are vital steps to ensure sufficient flow in Bessette Creek and mitigate the adverse impacts of elevated temperatures on aquatic ecosystems.

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1.0 INTRODUCTION

Bessette Creek, encompassing Harris, Duteau, and Creighton creeks, stands as a crucial conservation area for threatened salmon species within the South Thompson watershed. Serving as vital spawning and rearing habitat for Coho (COSEWIC, 2016) and Chinook (COSWEIC, 2018) salmon, alongside being the primary spawning ground for Mabel Lake Rainbow Trout, it faces significant challenges. The late summer/fall spawning period coincides with periods of exceptionally low water levels and high temperatures, posing heightened risks to spawning Chinook, Coho, and Rainbow Trout juveniles. Surveys by the Okanagan Nation Alliance (ONA, 2020) have underscored Bessette Creek's significance for spawning and juvenile rearing, especially upstream of Lumby. Generally, Bessette Creek is home to sensitive fish populations, including Interior Fraser Coho Salmon and South Thompson River – Bessette Creek Chinook Salmon. These fish have been negatively affected by high levels of water withdrawal in the area (McCleary and Thomson, 2021).

Instances of very low flow and dewatering upstream of Lumby are not uncommon (Epp 2014), often influenced by climate dynamics and local water withdrawals for irrigation purpose. During a typical runoff year, the current water allocation results in streamflow levels that fall below the target Environmental Flow Needs (EFNs) during both the spring reservoir refill period and the late summer irrigation period. This results in ongoing reductions in the productive capacity of the aquatic ecosystem. In a drought year, streamflow in Bessette Creek can drop below critical environmental flow thresholds during these same periods. To prevent irreversible harm to the ecosystem due to drought, regulatory intervention and more comprehensive water use planning under the Water Sustainability Act (WSA) may be necessary (McCleary and Thomson, 2021). While historically, several hydrometric stations have monitored streamflows in the watershed, the detection of drought conditions has been hindered by a lack of resources and monitoring stations in key habitats. To address this gap, the ONA installed and operated three hydrometric stations in 2020, providing critical data for regional drought response decision-making. Therefore, the project's specific objectives include:

1. Increase available streamflow data within the Bessette watershed for drought response and water management:
 - a. Operate and maintain two real-time and one manual hydrometric stations.
 - b. Analyze data to develop stage-discharge rating curves and provide continuous streamflow records in real-time.

2. Enhance water quality and quantity to support spawning and rearing of Chinook and Coho salmon in the Bessette watershed:
 - a. Utilize hydrometric data to enhance effectiveness in responding to drought conditions and ensure adequate flow for fish and aquatic life.
 - b. Monitor water temperature and assess potential impacts on salmonids and aquatic habitat.

2.0 STUDY AREA

Bessette Creek, a significant tributary of the Shuswap River, joins the main river approximately 13 km northeast of Lumby village and 15 km upstream from the south end

of Mabel Lake. Spanning 795 km², it covers about 15% of the entire Shuswap Watershed above Mara Lake. The creek's formation near Lumby involves three primary tributaries (Figure 1): Duteau, Harris, and Creighton Creeks. Among these, Harris Creek, along with Nicklen Creek, boasts the largest watershed at around 250 km², while Creighton Creek is the smallest at about 110 km². Elevations vary from 412 m at Bessette Creek's mouth to 2004 m at the summit of Buck Hills in the Harris Creek headwaters (Epp, 2014).

The Ecoregion Classification System by Demarchi (2011) situates Bessette Creek within a transitional zone between the North Okanagan Highland Ecoregion and the Columbia Highlands Ecoregion. The Northern Okanagan Basin Ecoregion, which encompasses valley bottoms and lower elevations in the Bessette Creek basin and its tributaries, experiences a rainshadow effect from the Thompson Plateau and Coast Mountains to the west. This results in relatively dry conditions, albeit with occasional influences of hot subtropical air, especially in summer. The area predominantly features Montane Spruce, Engelmann Spruce-Subalpine Fir, and moist Interior Cedar-Hemlock vegetation zones, varying across the watershed.

The Bessette Creek watershed sustains diverse fish populations, including Chinook and Coho salmon, Salmon, and rainbow trout, both adfluvial and resident.

In 1995, Bessette Creek, along with its tributaries Duteau and Harris Creek, gained recognition as among the "most sensitive salmon streams" in the South Thompson - Shuswap Habitat Management Area due to heightened water demand, as documented in a report within the Department of Fisheries & Oceans - Fraser River Action Plan (Rood and Hamilton, 1995).

Consideration for Bessette Creek as a "Candidate Sensitive Stream" under the Fish Protection Act arose in 2001, spurred by several factors such as dwindling populations of Coho and Chinook salmon and rainbow trout, notably below their potential production levels. Additionally, water scarcity during low-flow periods, particularly in Duteau Creek due to extensive irrigation demands, prompted concern. Proposed recovery efforts included negotiations with the Vernon Irrigation District (now Greater Vernon Services - Water) for enhanced water releases, riparian vegetation restoration, efficient water usage promotion, and, if feasible, additional water storage in the Creighton Creek and Harris Creek watersheds (Ministry of Environment, 2001).

In 2003, Bessette Creek garnered significant attention, rated highly for Species Sensitivity, Innate Capacity to Produce Fish, and Significance as a Habitat Protection Focus Area within the Okanagan Region, as documented by Matthews and Bull (2003).

Subsequent assessments in 2009 highlighted Bessette Creek's plight due to severely low flows, leading to its prominence on the Regional Stream Watch List for low flows in Shuswap tributaries in 2010. It remains a focal point for fish flow restoration efforts in the Shuswap River watershed.

Bessette Creek's Coho salmon are part of the Thompson Coho Conservation Unit, categorized as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Similarly, concerns are raised regarding Chinook salmon stocks, particularly the 4 sub 2's, with declining numbers negatively impacting various stakeholders' fishing opportunities, including commercial, recreational, and First Nations

for sustenance and ceremonial purposes. Furthermore, Bessette Creek and its tributaries play a crucial role in Shuswap Lake rainbow trout spawning.

Generally, there are three monitoring stations along Bessette Creek, two of which are currently active in real-time, while one has been discontinued. Bessette Creek above Lumby Lagoon Outfall (08LC042) lies below the confluence of Duteau Creek. Another station, Bessette Creek above Beaverjack Creek (08LC039), is situated further downstream from 08LC042, encompassing additional inflows (Figure 2).

Additionally, Bessette Creek near Lumby (08LC005) was positioned 100 meters upstream of our active station BES2b at Whitevale Road. This station offers better comparability to our current stations. Hence, our focus remains on the vicinity near Lumby above Duteau Creek, where a 0.16 km dried reach was observed between our stations BES2b at Whitevale Road and BES1 at Horner Road.

Bessette Creek near Lumby (08LC005) boasts 25 years of data spanning from 1919, 1943-1948, 1965-1972, and 1974-1983. It only covers seasonal flow from April to September. Consequently, we utilized its Long-Term Mean Annual Discharge (LTmad) of 1.959 cms (Epp, 2014) for our flow analysis. LTmad estimate of the long-term “naturalized” water supply equals Long-Term Mean Annual Flow (LT MAF) plus long-term mean annual water demand).

Instream Flow Recommendations were provided as a percentage of LTmad for the Bessette Creek Watershed, utilizing data from Bessette Creek WSC station No. 08LC039 (located above Beaverjack Creek). The targeted flow percentage was generally set above 20%LTmad, in accordance with the Okanagan Tenancy Method recommended for environmental flow needs, particularly for Salmon spawning (ONA, 2020). Additionally, a flow rate of 10% LTmad is deemed critical for salmon spawning.

Streamflows between July and September hold significant importance for local fish populations, coinciding with the summer juvenile rearing period for all local salmonids, as well as the migration and spawning period for Chinook Salmon (McGrath and Yuan, 2022). This period also witnesses the highest irrigation demand, lowest summer streamflows, and highest water temperatures. Therefore, we utilized these criteria for further analysis from July to September.

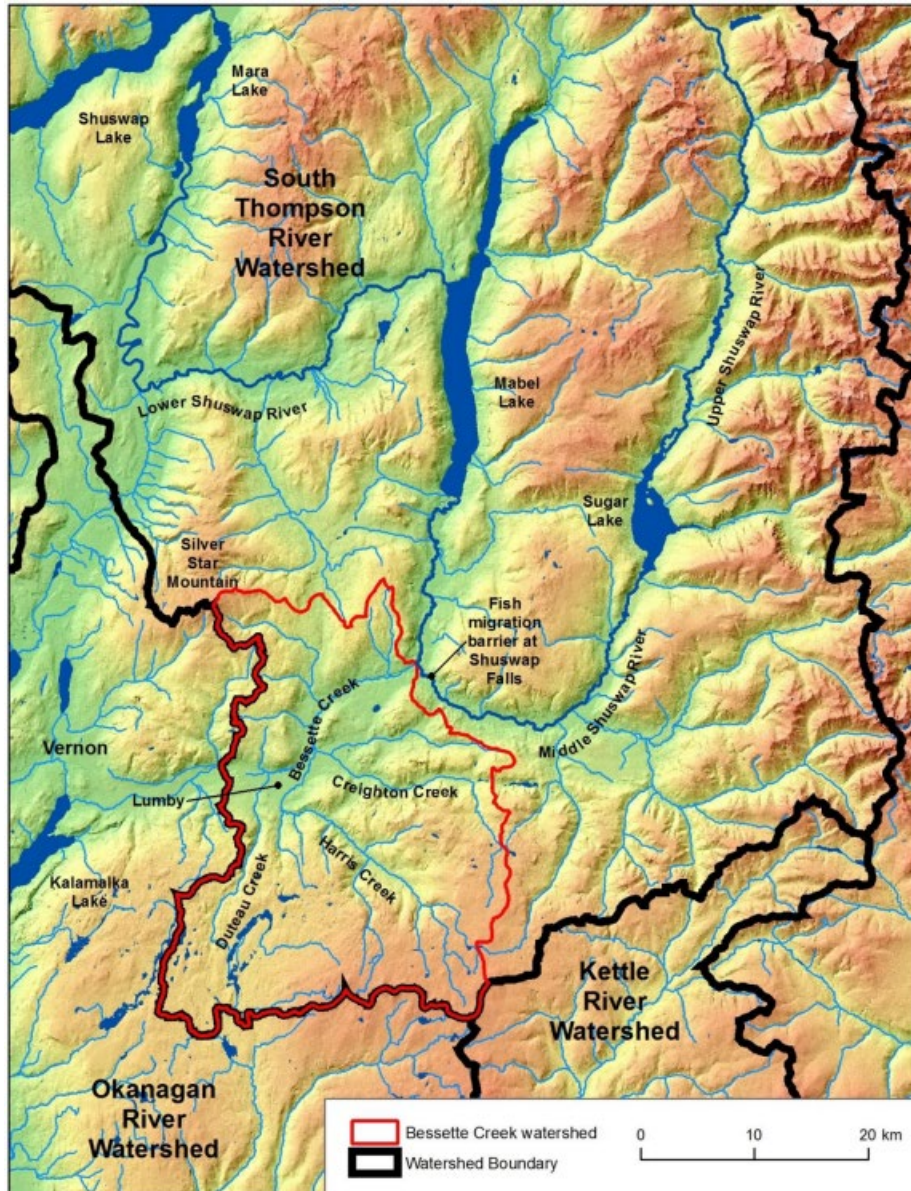


Figure 1 Overview map of the Bessette Creek watershed within the Shuswap and South Thompson River watersheds (Epp, 2014).

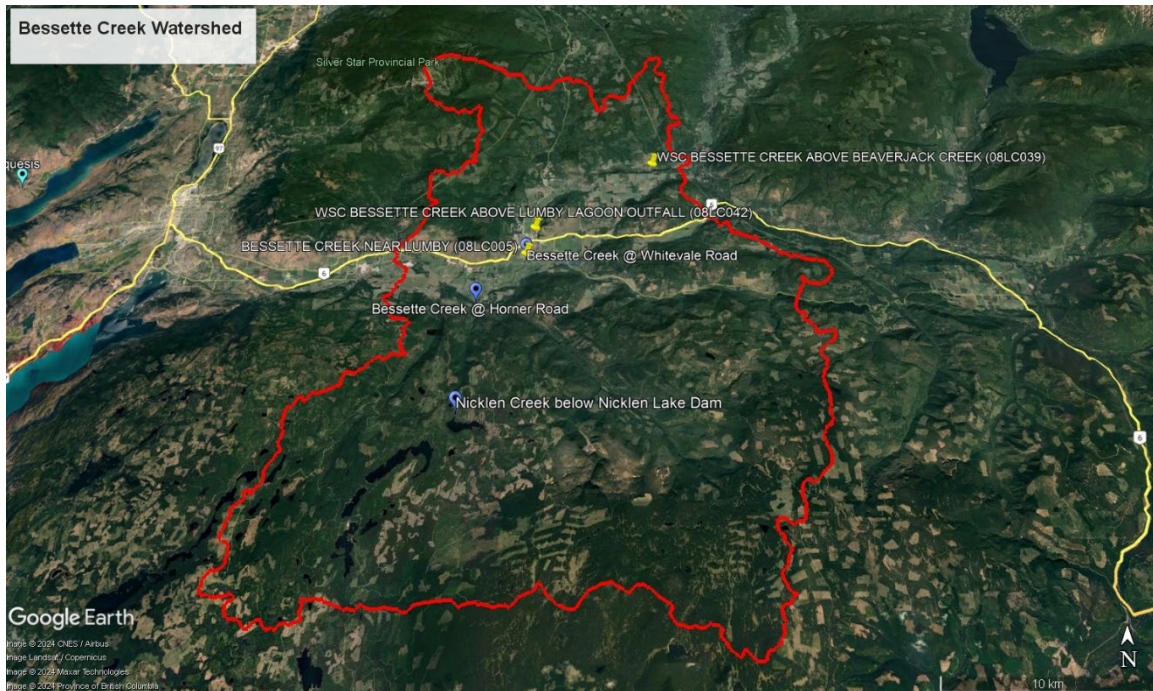


Figure 2 Bessette Creek Hydrometric Monitoring Stations.

3.0 METHODS

A number of data collection efforts were undertaken to gain an understanding of current flow conditions in McDougall Creek, surface water gains and losses and exchanges with groundwater. A detailed description of methods is provided in this section.

3.1 Streamflow and Temperature Monitoring

To gain insights into Bessette Creek's hydrological dynamics, surface water monitoring has been conducted utilizing three strategically positioned hydrometric stations (see Figure):

Station 1 (Bessette Creek at Whitevale Road BES2b, real-time): This station was reinstalled to replace the old discontinued 08LC005 station situated above the confluence of Duteau Creek. The reinstallation took place on July 16, 2020.

Station 2 (Bessette Creek at Horner Road BES1, manual): Installed on July 16, 2020, this station is positioned below the confluence of Nicklen Lake and Harris Creek.

Station 3 (Nicklen Creek below Nicklen Lake Dam): Installed on October 2, 2020, this station serves to monitor water released from Nicklen Lake Dam.

Each hydrometric station is equipped with a metal stilling well, housing a HOBO U20L-04 Water Level Logger (Onset Computer Corporation) for manual stations. The logger records water pressure and temperature at 15-minute intervals. Additionally, two

atmospheric pressure stations with similar loggers are positioned near the water level logger. To ensure accurate measurements, two or three lag bolt benchmarks serve as references for water level surveys. As for real-time stations, it was installed with one INW/Seametrics PS9800 Submersible Pressure Transmitter 4-20 mA and RX3004 4G Remote Monitoring Station with LCD display and GSM/HSPA cellular communications to internet. The station at Nicklen Creek used an Onset RX3000 iridium satellite system with an OTT PLS pressure/temperature sensor.

Field visits, conducted during various flow conditions, encompass moderate post-freshet flows to summer low flows. These visits involve checking the stations and hydrometric cross sections for any damage or disturbance, such as floating debris or sediment infilling. Discharge measurements are collected at carefully selected transects with characteristics conducive to high-quality flow measurements, including laminar flow, uniform depth and velocity, stable banks, and minimal vegetation.

The rigorous methodology ensures the collection of accurate and reliable data, facilitating a comprehensive understanding of the creek's surface water dynamics.

Discharge measurements for Bessette Creek were conducted using a SonTek FlowTracker handheld Acoustic Doppler Velocimeter (ADV), employing acoustic frequency changes from reflections off particles in the flow to determine water velocity. Measurements occurred in 40-second intervals with a top-setting wading rod. The FlowTracker, equipped with built-in quality control checks, ensured measurement reliability. The data collection adhered to standard procedures outlined by RISC (2018), including:

1. Depth and velocity measurements at a minimum of 20 panels across the wetted channel.
2. Panel locations spaced 1/20th or less of the stream width apart, but no less than 10 cm.
3. Each cross-sectional panel accounting for less than 10% of the total discharge in the measurement.
4. Velocity measurements at 60% depth from the surface for water depths below 1 m and at 20% and 80% depth from the surface for depths above 1 m.

Water level measurements at hydrometric stations were obtained using two methods: reading the water level off a staff plate (if present) or surveying the water level relative to benchmarks. Closed loop surveys were conducted with an eye level and stadia rod at an accuracy of 3 mm or less. During field visits, water level fluctuations, especially during high flow conditions, were addressed by conducting surveys twice - upon arrival and prior to leaving the site. Data from water level and atmospheric pressure loggers were periodically uploaded to a portable device. Discharge uncertainty was determined using interpolated variance estimation (IVE) available in the FlowTracker (SonTek, 2019). This meticulous methodology ensured accurate and reliable data collection for assessing Bessette Creek's discharge characteristics.

AQUARIUS Time-Series serves as a robust solution for managing diverse water data with its powerful data processing tools in this study. The methodology outlined below offers a structured approach to harness the capabilities of AQUARIUS, ensuring efficient water data management that aligns with industry standards.

Data Integration and Real-time Quality Assurance: Initiate the process by centralizing hydrologic time series, discrete measurements, and creek gauging data within the AQUARIUS platform. Leverage the user-friendly web interface for quick data entry and integration. AQUARIUS's unique features enable real-time sanity checking, error detection, and automated bias corrections, ensuring the reliability of data. This step establishes a foundation for trustworthy and quality-controlled information.

Rating Curve Development, Calculated Data Production, and Timely Publication: Utilize the gold standard AQUARIUS rating development tool to efficiently create accurate and legally defensible rating curves. Adapt to changing channel conditions by incorporating shifts, blends, and applicability periods. Automate workflows for data production, including mixing sources, running rating curves, and filling gaps. Publish derived data in real-time and generate industry-standard reports using AQUARIUS templates. Whether running reports ad-hoc or on a schedule, this methodology ensures stakeholders receive timely, accurate, and defensible information for effective water resource management. Data computation including stage-discharge model development and maintenance, stage correction, was detailed in (Rainville etc, 2016 and 2022).

By following this systematic approach, we harnessed the full potential of AQUARIUS Time-Series, providing a streamlined and comprehensive solution for water data management.

4.0 RESULTS AND DISCUSSION

4.1 Streamflow

The stations provided key data on streamflow response to any watering restrictions implemented (e.g., Ministerial Order No. M239 under Section 88 of the Water Sustainability Act in 2023). More details of the streamflow analysis are provided as follows.

The recommended flow for Bessette Creek above Duteau Creek or near Lumby is 0.392 cms, representing 20% of LT_{mad}, while the critical flow stands at 0.196 cms, equivalent to 10% of LT_{mad}, derived from station 08LC005. However, the current station (08LC042) monitors combined flows from Duteau Creek and Bessette Creek, thus unable to detect drought conditions specifically at Bessette Creek.

Station 1: Bessette Creek at Whitevale Road BES2b

Observations indicate that August typically witnesses the lowest flow, while May experiences peak flows. Our focus lies on the low flows in July, August and September, coinciding with salmonids migration and spawning.

Long-term Daily Flow Statistics (Table 1 and Figure 3):

The mean annual flow (MAF) measured 1.4 cms from 2020 to 2023 at the Whitevale Road station, which was lower than the 1.804 cms recorded at WSC station 08LC005, without accounting for annual water usage. However, 08LC005 experiences only seasonal flow from April to September, which introduces uncertainty into the calculation of LT_{mad}.

In July, both the mean and median streamflows were below the recommended flows but above the critical flow. However, there were still instances where flows dropped below the critical level, as indicated by P5 flow. Notably, zero flow was recorded in July 2021. August presented more challenging conditions, with mean and median flows falling below the critical level. Zero flow was also observed in August 2021, indicating extreme challenges for salmonids migration and spawning.

September further exacerbated the situation, with both mean and median streamflows lower than the critical flow, indicating severe challenges for salmonids migration and spawning. Even the maximum flow remained below the recommended level, suggesting overall unfavorable conditions for migration and spawning during this period.

The situation deteriorated in 2023, with flows in August and September consistently below the critical flow of 0.196 cms as 10%LT_{mad} (Table 4). The means were only half of the long-term daily mean in August and September, respectively. Additionally, a dried reach of 0.16 km was observed in October 2023 (Figure 4). However, the flows in July appeared slightly better, with the mean above the recommended flow but had chances of flow below the critical flow (P5).

Long-term Monthly Flow Statistics (Table 2):

In July, the mean and median flows were above the recommended flow; however, there were instances where flows dropped below the critical level. In August, all flows were generally below the critical flow except for the maximum and P95 flow, posing significant challenges for salmonids migration and spawning.

Similarly, September's streamflows were all below the critical flow, with only the maximum and P95 flows exceeding this threshold, signifying significant obstacles for salmonids migration and spawning.

Long-term Weekly Flow Statistics (Table 2):

In July, both the mean and median streamflows were above the recommended flows. However, there were still instances where flows fell below the critical level, as indicated by P5 flow. This suggests that while conditions were within an acceptable range for migration and spawning, they were suboptimal.

August presented even more challenging conditions, with streamflows generally below the critical level, except for the maximum and P95 flows. This indicates considerable difficulties for salmonids migration and spawning.

Similar conditions persisted in September, indicating persistent challenges for salmonids migration and spawning.

In summary, both statistical analyses indicate that streamflows in August and September consistently fell below the critical flow. While in July, flows fluctuated widely, ranging from zero flow to above the recommended flow. This implies ongoing challenges for salmonids migration and spawning. Further investigation is warranted regarding water withdrawals for irrigation and dam operations for storage and release plans.

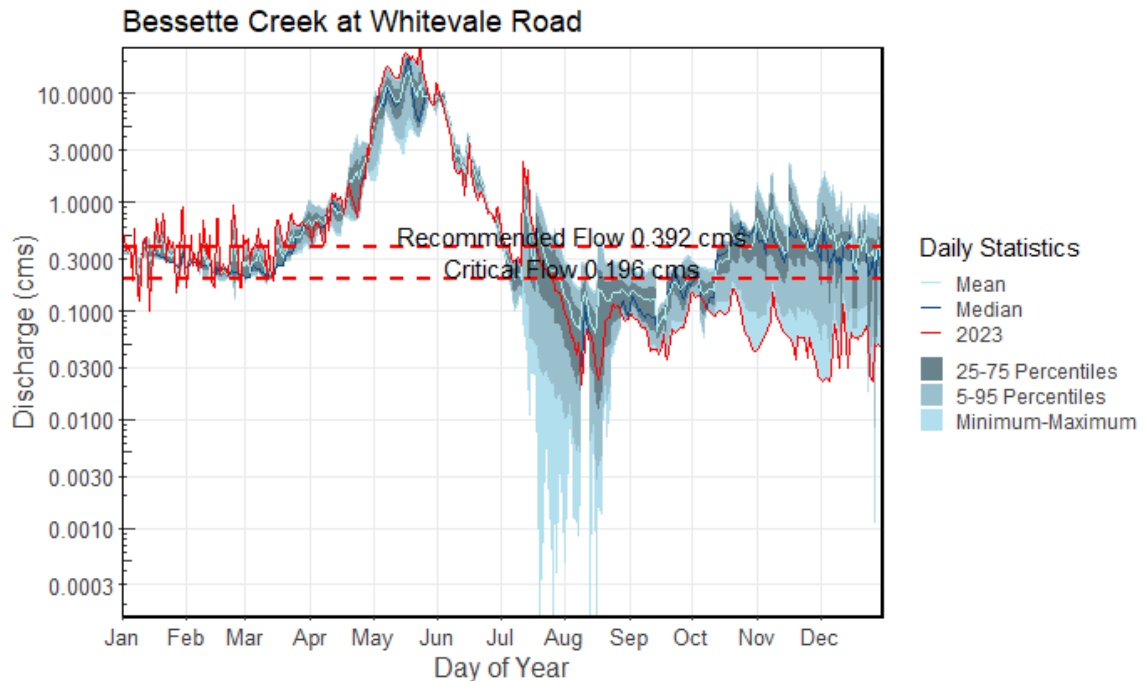


Figure 3 Daily Flow for Bessette Creek at Whitevale Road from July 2020 to December 2023.

Table 1 Long-term daily statistics for Bessette Creek at Whitevale Road from July 2020 to December 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.352	0.309	0.912	0.099	0.192	0.687
Feb	0.285	0.243	0.923	0.122	0.165	0.626
Mar	0.369	0.325	1.060	0.173	0.193	0.703
Apr	1.310	0.925	5.900	0.364	0.444	3.570
May	10.100	8.550	26.300	1.550	2.820	22.300
Jun	3.320	2.090	12.000	0.489	0.688	9.920
Jul	0.353	0.245	2.340	0.000	0.001	1.170
Aug	0.119	0.085	0.452	0.000	0.001	0.288
Sep	0.146	0.120	0.341	0.036	0.044	0.297
Oct	0.329	0.249	1.570	0.043	0.058	0.827
Nov	0.519	0.423	2.360	0.025	0.042	1.480
Dec	0.425	0.359	1.970	0.001	0.024	1.310
Long-term	1.400	0.331	26.300	0.000	0.034	8.300

Table 2 Long-term Monthly statistics for Bessette Creek at Whitevale Road from July 2020 to December 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.352	0.349	0.409	0.298	0.303	0.403
Feb	0.285	0.249	0.386	0.219	0.222	0.373
Mar	0.369	0.339	0.495	0.273	0.280	0.479
Apr	1.310	1.180	1.780	0.988	1.010	1.720
May	9.930	9.840	15.700	4.240	4.800	15.100
Jun	3.320	3.320	3.760	2.870	2.920	3.720
Jul	0.403	0.484	0.646	0.080	0.120	0.630
Aug	0.119	0.067	0.255	0.034	0.037	0.236
Sep	0.152	0.133	0.257	0.068	0.074	0.244
Oct	0.329	0.340	0.546	0.102	0.126	0.526
Nov	0.519	0.630	0.757	0.061	0.130	0.754
Dec	0.434	0.356	0.976	0.049	0.095	0.883
Annual	1.230	1.310	1.840	0.455	0.545	1.800

Table 3 Long-term Weekly statistics for Bessette Creek at Whitevale Road from July 2020 to December 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.340	0.315	0.558	0.253	0.272	0.495
Feb	0.294	0.270	0.491	0.178	0.191	0.460
Mar	0.337	0.298	0.674	0.195	0.205	0.622
Apr	1.080	0.912	3.870	0.363	0.433	3.340
May	9.590	8.770	22.200	1.520	2.170	21.300

Jun	4.160	3.140	10.500	0.818	0.902	9.400
Jul	0.379	0.326	1.180	0.001	0.002	1.040
Aug	0.121	0.073	0.402	0.001	0.003	0.317
Sep	0.134	0.103	0.303	0.045	0.046	0.263
Oct	0.295	0.248	0.826	0.055	0.094	0.739
Nov	0.534	0.469	1.530	0.040	0.048	1.270
Dec	0.430	0.363	1.590	0.024	0.035	1.270
Long-term	1.410	0.349	22.200	0.001	0.043	8.680

Table 4 Daily statistics for Bessette Creek at Whitevale Road for 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.409	0.390	0.912	0.099	0.136	0.807
Feb	0.386	0.320	0.923	0.163	0.164	0.707
Mar	0.495	0.468	0.799	0.192	0.219	0.713
Apr	1.180	1.010	4.260	0.404	0.444	2.950
May	15.700	15.400	26.300	6.040	7.570	24.700
Jun	2.870	1.780	12.000	0.653	0.783	9.040
Jul	0.484	0.305	2.340	0.111	0.142	1.720
Aug	0.067	0.068	0.115	0.021	0.026	0.109
Sep	0.068	0.068	0.140	0.036	0.041	0.098
Oct	0.102	0.100	0.160	0.043	0.046	0.154
Nov	0.061	0.056	0.145	0.025	0.035	0.110
Dec	0.049	0.049	0.117	0.022	0.023	0.079
Long-term	1.840	0.244	26.300	0.021	0.036	13.900



Figure 4 Dried Reach in Bessette Creek in October 2023.

Station 2: Bessette Creek at Horner Road BES1

Observations indicate that the winter season typically witnesses the lowest flow, while May experiences peak flows. Our focus lies on the low flows in July, August, and September, coinciding with salmonid migration and spawning.

Long-term Daily Flow Statistics (Table 5 and Figure 5):

The MAF was 1.17 cm, which was lower than the MAF at the Whitevale station. This bias stemmed from the uncertainty in calculating the high-flow regime based on the development of the rating curve. Our dataset for high-flow measurements is limited. The long-term daily mean in May at Whitevale was predicted to be much higher than that at Horner Road. However, since July, the flow at Horner Road has been higher than that at Whitevale.

In July, both the mean and median streamflows were above the recommended flows. However, there were still instances where flows dropped below the critical level, as indicated by the P5 flow. August presented suboptimal conditions, with mean and median flows falling below the recommended flow but above the critical flow. Instances where flows dropped below the critical level were observed based on the P5 flow, indicating challenges for salmonid migration and spawning.

Similarly, in September, both mean and median streamflows were lower than the recommended flow but above the critical flow, indicating suboptimal conditions for salmonid migration and spawning. Instances where flows dropped below the critical level

were observed based on the P5 flow, suggesting overall unfavorable conditions for migration and spawning during this period.

The situation deteriorated in 2023, with mean flows in August at 2/3 of the long-term daily mean and in September at less than half of the long-term daily mean. In August, the mean and median flows were close to the critical flow of 0.196 cms as 10%LTmad (Table 8). However, there were chances that flow was challenging for salmonid migration and spawning with P5 flow lower than the critical flow. In September, all flows were lower than the critical flow except for the maximum flow. Conditions worsened for salmonid migration and spawning in September.

Long-term Monthly Flow Statistics (Table 6):

In July, the mean and median flows were above the recommended flow; however, there were instances where flows dropped below the recommended flow as indicated by the P5. Generally, it was an optimal condition for salmonid migration and spawning. In August, all flows were generally below the recommended flow except for the maximum and P95 flow but above the critical flow, posing suboptimal conditions for salmonid migration and spawning.

Similarly, September's streamflows were all below the recommended flow, with only the maximum and P95 flows exceeding this threshold. However, there were instances where flows dropped below the critical flow indicated by the P5 flow, signifying obstacles for salmonid migration and spawning.

Long-term Weekly Flow Statistics (Table 7):

In July, both the mean and median streamflows were above the recommended flows. However, there were still instances where flows fell below the critical level, as indicated by the P5 flow. This suggests that while conditions were within an acceptable range for migration and spawning, they were suboptimal.

August presented even more challenging conditions, with streamflows generally below the recommended level, except for the maximum and P95 flows. The flow had chances of dropping below the critical flow indicated by the P5 flow. This indicates difficulties for salmonid migration and spawning.

Similar conditions persisted in September, indicating persistent challenges for salmonid migration and spawning.

In summary, both mean and median flows in August and September consistently fell below the recommended flow with chances of dropping below the critical flow. While in July, flows fluctuated widely, ranging from below critical flow to higher above the recommended flow. This implies ongoing challenges for salmonid migration and spawning, especially in August and September. Further examination is required regarding water withdrawals for irrigation and dam operations to develop strategies for storage and release, ensuring the preservation of optimal conditions for salmonid migration and spawning.

The MAF at the Whitevale Road station (1.4 cms) exceeded that of the Horner Road station. This discrepancy primarily stemmed from uncertainties in rating curve development, particularly at high flow regimes, owing to limited data availability.

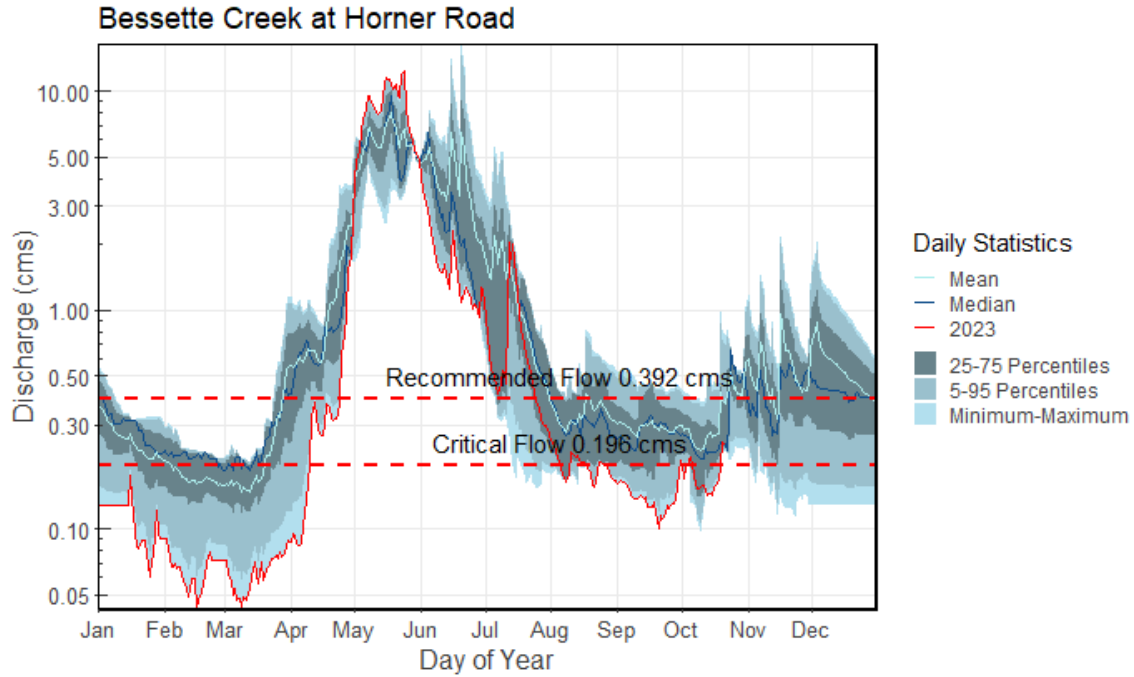


Figure 5 Daily Flow for Bessette Creek at Horner Road from July 2020 to October 2023.

Table 5 Long-term Daily Statistics for Bessette Creek at Horner Road from July 2020 to November 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.262	0.302	0.571	0.061	0.084	0.473
Feb	0.174	0.211	0.308	0.043	0.053	0.289
Mar	0.227	0.207	1.140	0.044	0.049	0.578
Apr	1.080	0.825	4.900	0.084	0.095	3.730
May	5.910	5.620	12.400	1.670	2.500	10.900
Jun	3.970	2.830	16.300	0.727	1.020	8.920
Jul	1.070	0.629	5.620	0.152	0.164	3.880
Aug	0.336	0.288	0.810	0.156	0.166	0.634
Sep	0.291	0.265	0.540	0.101	0.126	0.512
Oct	0.333	0.248	1.190	0.097	0.131	0.757
Nov	0.522	0.454	2.210	0.113	0.124	1.320
Dec	0.537	0.419	2.060	0.128	0.128	1.370
Long-term	1.170	0.373	16.300	0.043	0.083	5.890

Table 6 Long-term Monthly Statistics for Bessette Creek at Horner Road from July 2020 to November 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.262	0.329	0.345	0.112	0.134	0.343

Feb	0.174	0.216	0.241	0.066	0.081	0.238
Mar	0.227	0.258	0.358	0.064	0.083	0.348
Apr	1.080	1.090	1.690	0.465	0.528	1.630
May	5.910	5.940	8.350	3.460	3.710	8.100
Jun	3.970	2.840	7.350	1.730	1.840	6.900
Jul	1.060	0.823	2.310	0.265	0.331	2.110
Aug	0.336	0.310	0.533	0.192	0.192	0.517
Sep	0.291	0.279	0.468	0.139	0.151	0.449
Oct	0.320	0.272	0.560	0.176	0.188	0.520
Nov	0.522	0.676	0.736	0.153	0.205	0.730
Dec	0.537	0.418	1.070	0.128	0.157	1.000
Annual	1.090	1.210	1.370	0.567	0.659	1.350

Table 7 Long-term Weekly Statistics for Bessette Creek at Horner Road from July 2020 to November 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.279	0.312	0.643	0.079	0.085	0.537
Feb	0.180	0.216	0.322	0.052	0.054	0.302
Mar	0.197	0.204	0.776	0.048	0.051	0.391
Apr	0.877	0.723	3.900	0.081	0.089	2.830
May	5.640	5.460	10.800	1.620	1.950	10.500
Jun	4.290	3.770	11.200	1.070	1.140	9.460
Jul	1.230	0.776	4.740	0.162	0.169	4.270
Aug	0.348	0.336	0.710	0.172	0.175	0.637
Sep	0.294	0.260	0.550	0.117	0.123	0.527
Oct	0.315	0.249	0.767	0.118	0.150	0.662
Nov	0.525	0.484	1.460	0.123	0.127	1.110
Dec	0.548	0.423	1.600	0.128	0.128	1.430
Long-term	1.170	0.396	11.200	0.048	0.084	5.930

Table 8 Daily statistics for Bessette Creek at Horner Road for 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.112	0.129	0.176	0.061	0.074	0.134
Feb	0.066	0.067	0.091	0.043	0.048	0.088
Mar	0.064	0.063	0.090	0.044	0.047	0.081
Apr	0.465	0.317	2.640	0.084	0.086	1.650
May	8.350	8.420	12.400	3.870	4.790	11.700
Jun	1.730	1.470	4.110	0.926	1.030	3.360
Jul	0.706	0.524	2.030	0.275	0.292	1.860
Aug	0.195	0.197	0.256	0.156	0.161	0.235
Sep	0.139	0.137	0.205	0.101	0.114	0.165
Oct	0.176	0.162	0.249	0.142	0.144	0.242
Nov	NA	NA	NA	NA	NA	NA

Dec	NA	NA	NA	NA	NA	NA
Long-term	1.250	0.173	12.400	0.043	0.055	8.440

Station 3: Nicklen Creek below Nicklen Lake Dam

The dam was generally scheduled to release water from July to November for storage purposes with licence number of C133597 and C133598. It is owned by Fish & Wildlife Section, Penticton (33811). The contribution from Nicklen Creek will flow into Bessette Creek. The release plan for this year remains the same for irrigation, starting on July 15th with a flow of 0.120 cms. However, the fish bump, beginning on August 15th, will only add 0.060 cms instead of the previous 0.160 cms to the base flow of 0.120 cms, resulting in a total of 0.180 cms instead of 0.280 cms. This reduction is due to the storage reaching only 2/3 of its capacity in 2023, resulting in less water being available for contribution to Bessette Creek. The release amount of 2023 was dropped gradually from 88% of longterm mean value in July to 30% of longterm mean value in November. Less contribution also partially led to the worse drought conditions in Bessette Creek. The last site visit in 2023 was on November 24th, and the flume water level was 0.083m, which was much lower than recorded in the past. However, any measurement less than 1m is not very accurate as there is no staff gauge for the bottom meter, and the main recorder does not measure the bottom meter either (Provincial staff communication).

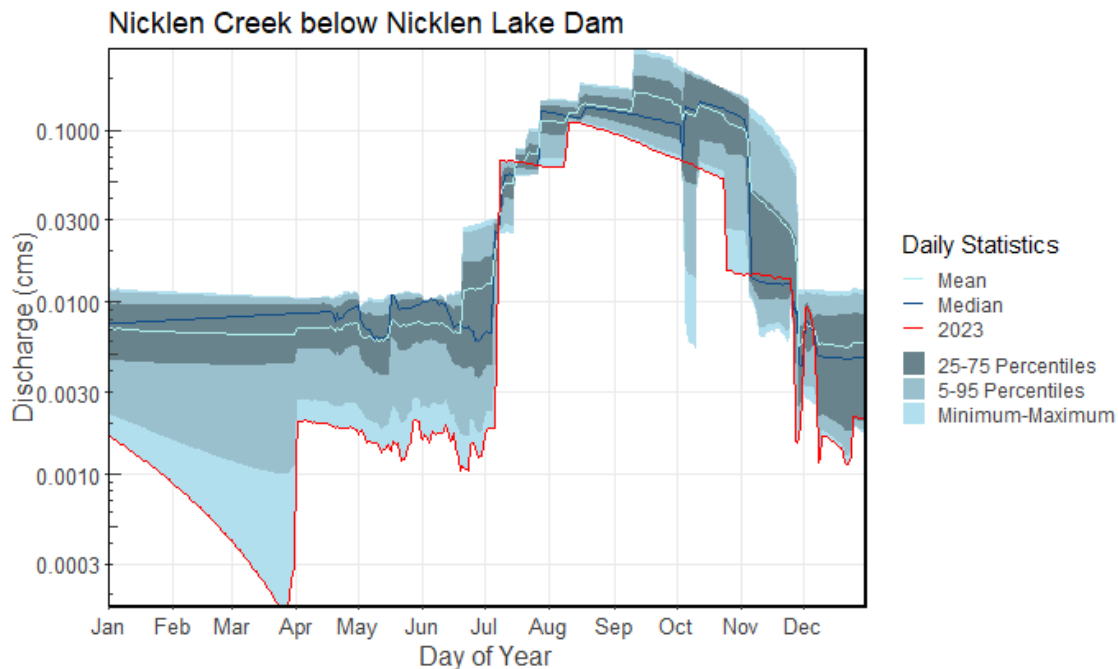


Figure 6 Daily Flow for Nicklen Creek below Nicklen Lake Dam from October 2020 to November 2023.

Table 9 Long-term Daily Statistics for Nicklen Creek below Nicklen Lake Dam from October 2020 to November 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
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Jan	0.007	0.008	0.012	0.001	0.001	0.012
Feb	0.007	0.008	0.011	0.000	0.000	0.011
Mar	0.007	0.008	0.011	0.000	0.000	0.011
Apr	0.007	0.009	0.012	0.001	0.002	0.011
May	0.007	0.009	0.012	0.001	0.001	0.011
Jun	0.009	0.008	0.029	0.001	0.001	0.028
Jul	0.058	0.055	0.149	0.002	0.002	0.129
Aug	0.129	0.127	0.188	0.061	0.062	0.184
Sep	0.150	0.120	0.296	0.069	0.072	0.291
Oct	0.125	0.108	0.243	0.005	0.015	0.224
Nov	0.039	0.014	0.158	0.002	0.005	0.138
Dec	0.006	0.007	0.012	0.001	0.001	0.012
Long-term	0.047	0.011	0.296	0.000	0.001	0.184

Table 10 Long-term Weekly Statistics for Nicklen Creek below Nicklen Lake Dam from October 2020 to November 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.007	0.008	0.012	0.001	0.002	0.011
Feb	0.007	0.008	0.011	0.001	0.001	0.011
Mar	0.007	0.008	0.011	0.000	0.001	0.011
Apr	0.007	0.009	0.011	0.002	0.003	0.011
May	0.007	0.008	0.011	0.002	0.002	0.011
Jun	0.009	0.008	0.017	0.002	0.002	0.016
Jul	0.058	0.061	0.062	0.051	0.052	0.062
Aug	0.129	0.127	0.167	0.093	0.097	0.163
Sep	0.150	0.120	0.247	0.082	0.086	0.234
Oct	0.126	0.130	0.196	0.049	0.053	0.195
Nov	0.039	0.022	0.099	0.012	0.013	0.088
Dec	0.006	0.005	0.012	0.002	0.002	0.011
Annual	0.051	0.055	0.072	0.025	0.027	0.071

Table 11 Long-term Weekly Statistics for Nicklen Creek below Nicklen Lake Dam from October 2020 to November 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.007	0.008	0.012	0.001	0.001	0.012
Feb	0.007	0.008	0.011	0.000	0.001	0.011
Mar	0.007	0.008	0.011	0.000	0.000	0.011
Apr	0.007	0.009	0.012	0.000	0.002	0.011
May	0.007	0.009	0.011	0.001	0.001	0.011
Jun	0.008	0.009	0.028	0.001	0.001	0.025
Jul	0.049	0.054	0.119	0.001	0.002	0.104

Aug	0.126	0.126	0.185	0.062	0.062	0.183
Sep	0.148	0.122	0.292	0.071	0.074	0.286
Oct	0.126	0.096	0.263	0.012	0.026	0.234
Nov	0.048	0.015	0.163	0.006	0.007	0.148
Dec	0.007	0.007	0.035	0.001	0.001	0.012
Long-term	0.046	0.011	0.292	0.000	0.001	0.183

Table 12 Daily statistics for Nicklen Creek below Nicklen Lake Dam for 2023.

Month	Mean	Median	Maximum	Minimum	P5	P95
Jan	0.001	0.001	0.002	0.001	0.001	0.002
Feb	0.001	0.001	0.001	0.000	0.000	0.001
Mar	0.000	0.000	0.000	0.000	0.000	0.000
Apr	0.002	0.002	0.002	0.001	0.002	0.002
May	0.002	0.002	0.002	0.001	0.001	0.002
Jun	0.002	0.002	0.002	0.001	0.001	0.002
Jul	0.051	0.064	0.067	0.002	0.002	0.066
Aug	0.093	0.102	0.111	0.061	0.061	0.111
Sep	0.082	0.081	0.096	0.069	0.070	0.095
Oct	0.049	0.057	0.069	0.015	0.015	0.067
Nov	0.012	0.014	0.015	0.002	0.002	0.015
Dec	0.003	0.002	0.009	0.001	0.001	0.009
Long-term	0.025	0.002	0.111	0.000	0.000	0.100

4.2 Water Temperature

Wherever feasible, juvenile salmonids tend to depart habitats with unsuitable thermal conditions, thereby leaving potentially suitable areas unused and ultimately reducing the stream's carrying capacity. In an extensive review conducted by McCullough (1999) on thermal effects concerning salmonids, it was found that the distributional limit for Chinook and Rainbow Trout in streams is constrained by mean daily water temperatures of 20°C and maximum daily water temperatures ranging from 22°C to 24°C. Beyond these thresholds, the biomass of these species approaches zero, indicating a notable absence. A local field study conducted in nearby Fortune Creek, a tributary to the Lower Shuswap River, demonstrated that juvenile salmonids avoided previously occupied stretches of the creek when maximum daily water temperatures surpassed 22°C. Genetic stock identification of DNA samples confirmed that the juvenile Chinook primarily originated from Bessette Creek (McGrath 2010), suggesting similar thermal tolerances and avoidance behavior among juvenile Chinook in Bessette Creek.

Adult Chinook typically enter Bessette Creek from the Middle Shuswap River in August. Thermal migration impediments become significant for migrating spawners when temperatures exceed 21°C (McCullough 1999). Studies conducted in the Columbia River indicate diminished migration activity among Chinook when temperatures range from 20°C to 21°C (Gonia et al. 2006), a phenomenon akin to Okanagan Sockeye, which

encounter thermal barriers to migration around 21°C (Hyatt et al. 2003). Based on available data, the combined thermal threshold for juvenile and adult salmonids in this study was set at 22°C (McGrath and Yuan, 2022).

Station Bessette Creek at Whitevale Road experienced 8 days with temperatures exceeding 22°C, including one day in July 21, 2023. At Horner Road, Station Bessette Creek recorded 22 days surpassing 22°C, all occurring between 2020 and 2021. Meanwhile, Station Nicklen Creek below Nicklen Lake Dam documented 71 days where temperatures exceeded 22°C, with 11 of those days falling within June, July, and August of 2023. The higher number of hot days at Nicklen Creek can be attributed to its reliance on water released from the Nicklen Lake Dam.

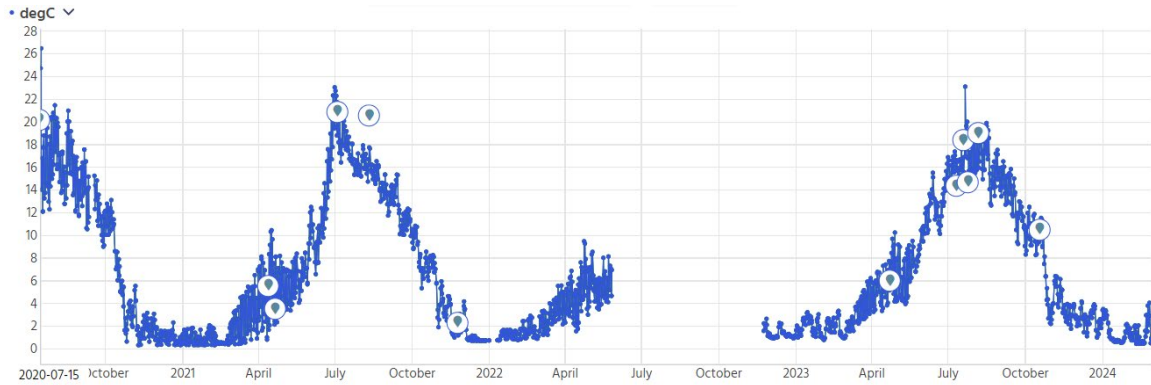


Figure 7 Temperature time-series for Bessette Creek at Whitevale Road BES2B from July 2020 to February 2024.



Figure 8 Temperature time-series for Bessette Creek at Horner Road BES1 from July 2020 to February 2024.

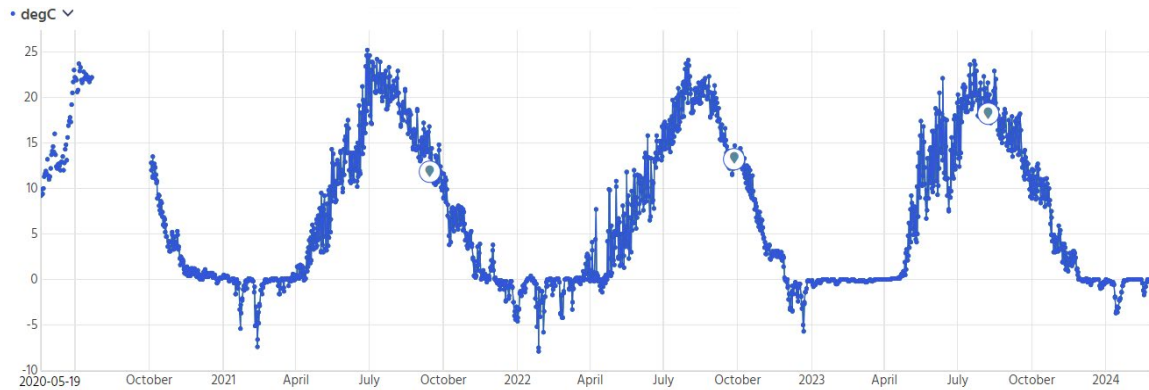


Figure 9 Temperature time-series for Nicklen Creek below Nicklen Lake Dam from October 2020 to February 2024.

5.0 CONCLUSIONS AND RECOMMENDATIONS

These stations provide crucial information for informed decision-making, particularly in light of Ministerial Order No. M239 under section 88 of the Water Sustainability Act. We have the following conclusions based on the surface water monitoring:

- The analysis reveals consistent challenges for salmonid migration and spawning due to streamflows consistently falling below critical levels at Bessette Creek at Whitevale Road, particularly in August and September, indicating a need for proactive management strategies to mitigate these adverse effects. This was further underscored by the observation of a dried reach of 0.16 km in October 2023.
- The analysis highlights consistent suboptimal conditions for salmonid migration and spawning at Bessette Creek at Horner Road, particularly evident in August and September, necessitating comprehensive strategies to address the underlying factors affecting streamflows.
- The uncertainty surrounding LT_{mad} stemmed from the limitations of the old station, which only covered seasonal flow, and the new stations with limited data in high-flow measurements. This limitation significantly impacts the development of the rating curve for the high-flow regime.
- The reduction in water release from Nicklen Creek below Nicklen Lake Dam, particularly during the fish bump period, exacerbated drought conditions in Bessette Creek, highlighting the critical need for adaptive water management strategies to mitigate the impact on downstream ecosystems.
- The temperature data highlights significant variations in thermal conditions among the stations, with one hot day observed at Bessette Creek at Whitevale Road, while Nicklen Creek below Nicklen Lake Dam experienced a notably higher number of hot days, likely due to its dependence on water released from the dam.

Based on the results of this study, we make the following recommendations for future assessment:

1. Sustain ongoing monitoring of these stations to furnish indispensable information for informed decision-making, especially concerning drought management.
2. Incorporating high flow measurements is crucial to enhance the accuracy of rating curve development in the high flow regime. This improvement will lead to more precise calculations of LT_{mad}, and consequently, better assessment of environmental flow needs.
3. To address the ongoing challenges faced by salmonids during migration and spawning, it is imperative to conduct a comprehensive assessment of water withdrawals for irrigation and dam operations. This includes a thorough review, further investigation, and reassessment of storage and release plans, aimed at mitigating challenges and ensuring the preservation of favorable conditions crucial for salmonid migration and spawning. Such an assessment is essential for understanding the impacts of current water management practices on salmonid habitats and populations. By identifying areas for improvement and implementing targeted strategies, stakeholders can work towards maintaining healthy aquatic ecosystems and supporting sustainable salmonid populations.
4. Additionally, to ensure adequate water flow in Bessette Creek during critical periods for salmonid migration and spawning, it is essential to reassess water release plans from Nicklen Lake Dam. This reassessment should consider both short-term demands for irrigation and long-term ecological sustainability. Moreover, effective monitoring and regulation of water release from Nicklen Lake Dam are crucial to mitigate the impact of elevated temperatures on aquatic ecosystems. By carefully managing water releases, stakeholders can help maintain downstream temperatures within suitable ranges for fish and other aquatic organisms, thereby preserving the health and integrity of the ecosystem.

6.0 Responses to Suggestions in the Notification Letter

1. Future projects identify if the project was a benefit to salmonids.
Re: Yes, the project has been beneficial to salmonids. The comprehensive assessment conducted in the project identified persistent challenges for salmonid migration and spawning due to streamflows consistently falling below critical levels at specific locations in Bessette Creek. By addressing these challenges through improved monitoring and adaptive water management strategies, the project aims to mitigate adverse effects on salmonid habitats, ultimately supporting their survival and population growth.
2. Future project reports provide information regarding the additional monitoring stations and whether further information was provided from this project beyond that of the existing WSC station.
Re: Regarding the discontinued station 08LC005, it only captures seasonal flow data from April to September, thereby introducing uncertainty into LT_{mad} calculations. Conversely, the existing WSC station (08LC042) monitors combined flows from Duteau Creek and Bessette Creek, limiting its ability to specifically detect drought conditions in Bessette Creek. Our new hydrometric stations significantly improved both spatial and temporal coverage and data collection,

providing more precise information on streamflow and temperature dynamics within the Bessette watershed. This inclusion in the current report highlights the added value brought by these monitoring stations, further enhancing environmental monitoring efforts.

3. There was interest if a correction factor might be applied to the existing WSC station data once a comparison of 5 years of data between the existing WSC station and the new monitoring stations is completed.

Re: The uncertainty surrounding LT_{mad} stems from the limitations of the old station, which only covered seasonal flow, and the new stations with limited data in high-flow measurements. Incorporating high flow measurements is crucial to enhance the accuracy of rating curve development in the high flow regime. This improvement will lead to more precise calculations of LT_{mad}, and consequently, better assessment of environmental flow needs. This year, we rented an Acoustic Doppler Current Profiler (ADCP) for a different project and have the potential to conduct high flow measurements at Bessette Creek.

Once we obtain more accurate data, especially during the freshet, we can compare the data from our stations and the existing WSC ones. Once this comparison is completed, it will be possible to evaluate the feasibility and potential benefits of applying correction factors to enhance the accuracy of data analysis and interpretation. This process will contribute to improving the reliability of environmental data for effective decision-making in future projects.

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