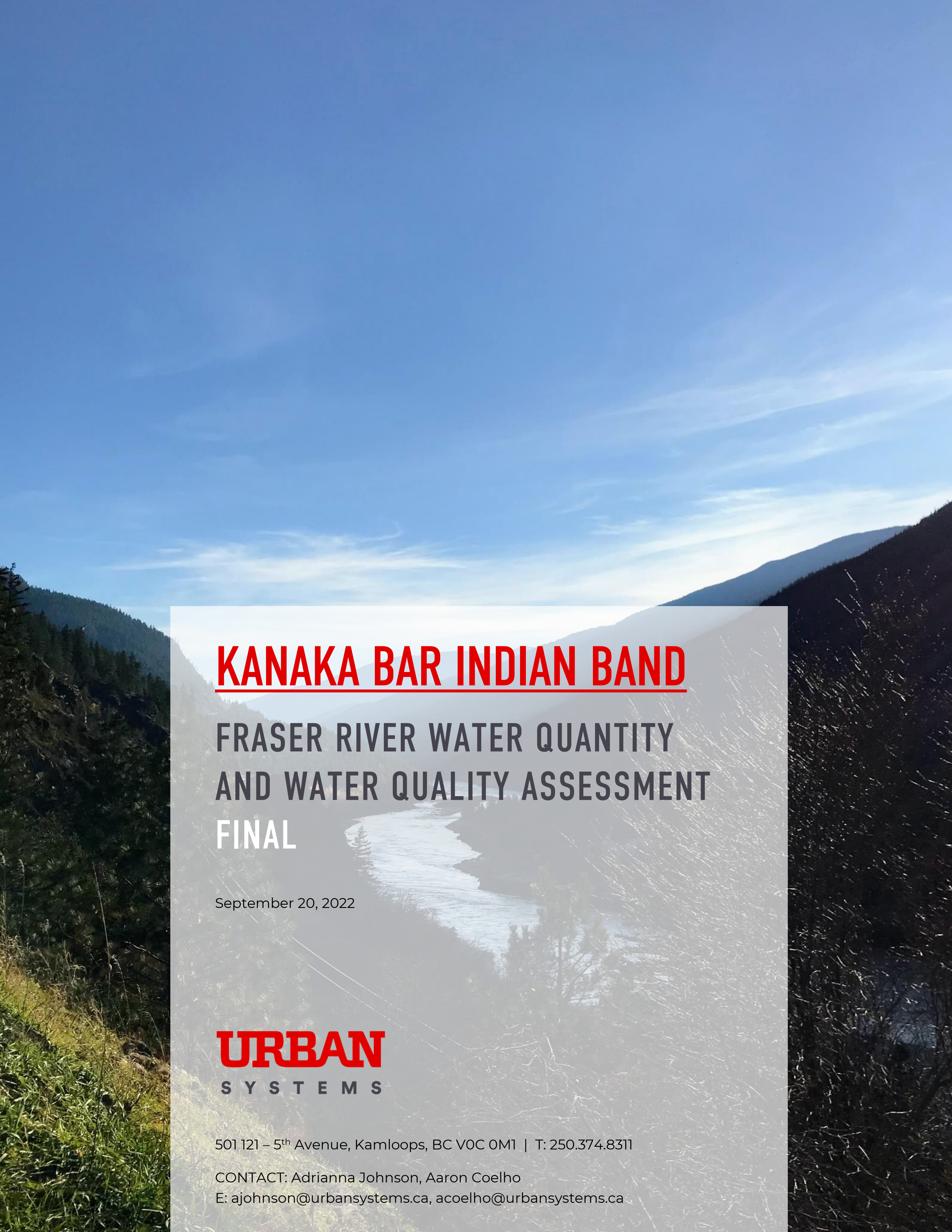

# KANAKA BAR INDIAN BAND

## FRASER RIVER WATER QUANTITY AND WATER QUALITY ASSESSMENT
## FINAL

September 20, 2022

URBAN SYSTEMS

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# CONTENTS



# APPENDICES

# 1.0 INTRODUCTION

The Fraser River is the most extensive river basin in British Columbia, flowing from the Rocky Mountains in the northeast near the Alberta-BC border into the Strait of Georgia in southwest BC (Gray and Tuominen, 1998). At Kanaka Bar, the river flows through approximately 15 km of traditional territory (Chambers and Hocking, 2021). The Thompson River confluences with the Fraser River about 10 km upstream of Kanaka Bar. Within the traditional territory, there are numerous tributaries that drain into the Fraser River from the steep surroundings (Chambers and Hocking, 2021). Due to the steep terrain, most of the tributary streams have limited access for fish spawning or rearing (Chambers and Hocking, 2021). Therefore, at Kanaka Bar, the river acts primarily as a migratory channel for salmon and other fish species, although it may also provide overwintering habitat for steelhead (Chambers and Hocking, 2021).

Concerns about the water quantity and quality of the Fraser River have been raised by Kanaka Bar membership, with emphasis on the declining salmon populations, which have traditionally been fished by the community. In addition to fishing, the river has been traditionally used for travel and recreation. As part of a broader cumulative effects initiative that is underway within the territory, a water quantity and quality assessment of the Fraser River was undertaken to develop a more in-depth understanding of the current state of the river at Kanaka Bar with respect to sources of contamination and climate change impacts.

# 2.0 WATER QUANTITY ASSESSMENT

The intent of the water quantity assessment is to deepen the understanding of changes to seasonal and annual flow patterns within the Fraser River. The assessment includes a hydrometric data review, review of available literature, and a summary of key findings.

Of particular importance is how the Fraser River flow patterns have changed overtime, and what further changes are anticipated in the future due to the impacts of climate change. Where possible, the impacts of these changes were related to Kanaka's values such as the impacts of changes in low flow and high flow regimes on fish passage and spawning.

## 2.1 DATA ANALYSIS

### 2.1.1 METHODOLOGY

The closest hydrometric stations to Kanaka Bar are the Fraser River at Hope and the Fraser River Above Texas Creek, as summarized in the table below (Water Survey of Canada, 2022). The available hydrometric datasets for both stations were downloaded from Water Survey of Canada (WSC). At the time of download, the reviewed hydrometric data for 2020 and 2021 were not yet available; and therefore, were not included in this hydrometric analysis.

**Table 2.1: Fraser River Hydrometric Data**

| Station Number | Station Name | Years of Available Data | Date Range[1] |
|---|---|---|---|
| 08MF005 | Fraser River at Hope | 107 | 1913-2019 |
| 08MF040 | Fraser River Above Texas Creek | 68 | 1952-2019 |

[1] Data for 2020 and 2021 not yet reviewed by WSC.

While the data from both stations were considered, given the more extensive data range for the Fraser River at Hope station (1913 to 2019) compared to the Fraser River Above Texas Creek data range (1952 to 2019), only the data from the Fraser River at Hope station were analyzed as part of this hydrometric assessment. To assess trends, the hydrometric data for the Fraser River at Hope station were divided into four time periods, each consisting of approximately 30 years of data. The four time periods analyzed are summarized below:

- 1912-1938
- 1939-1965
- 1966-1992
- 1993-2019

### 2.1.2 DATA SUMMARY

The annual and monthly data for maximum, mean, and minimum flows recorded for the Fraser River at Hope station are summarized in Figures 2.1 through Figure 2.9. A list of observations is provided below each figure.

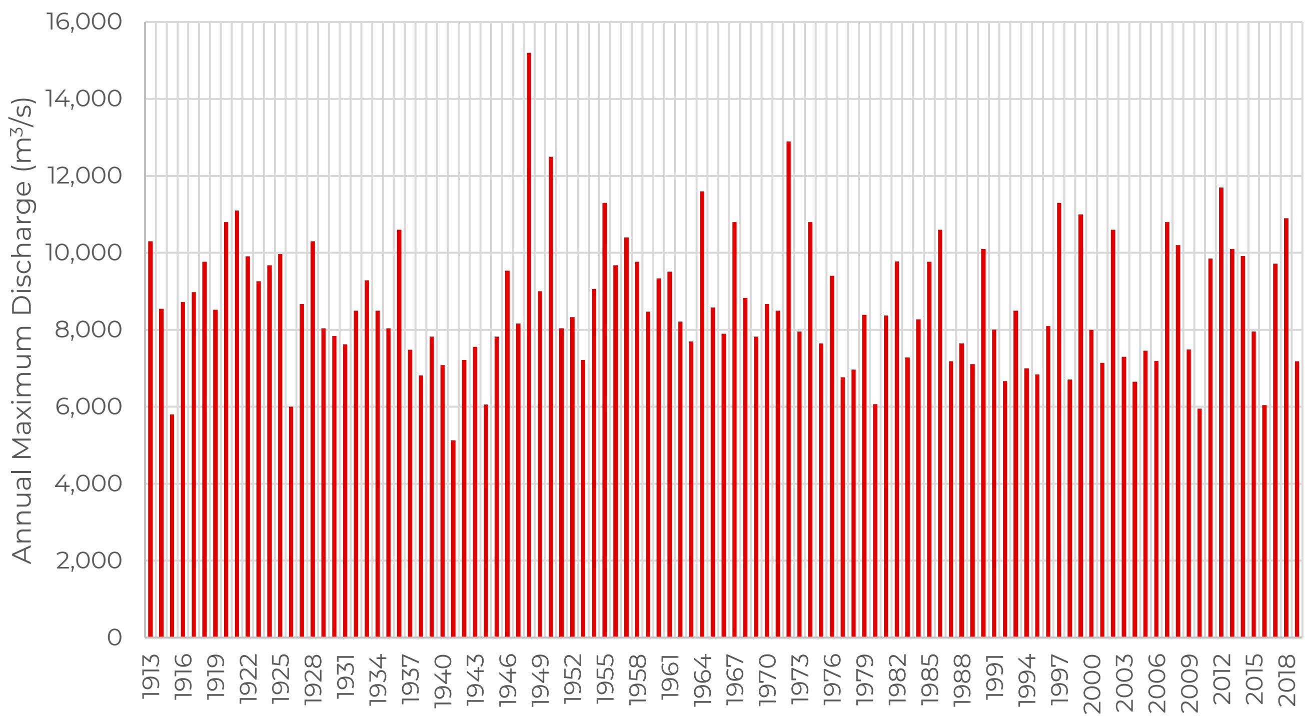


**Figure 2.1: Annual Maximum Discharge - Fraser River at Hope (08MF005) (1913-2019)**

The following points summarize the observations from Figure 2.1:

- Annual maximum discharge is highly variable from year to year.
- No trend was observed in the data based on a Spearman Rank Order Correlation test.
- On average, the annual maximum daily discharge date is June 11.
- The earliest annual maximum daily discharge was observed on May 1, 1934.
- The latest annual maximum daily discharge was observed on July 23, 2001.
- The highest annual maximum discharge on record, 15,200 $m^3/s$, occurred in 1948.
- The lowest annual maximum discharge on record, 5,130 $m^3/s$, occurred in 1941.
- The average annual maximum discharge across the period of record is 8,700 $m^3/s$.

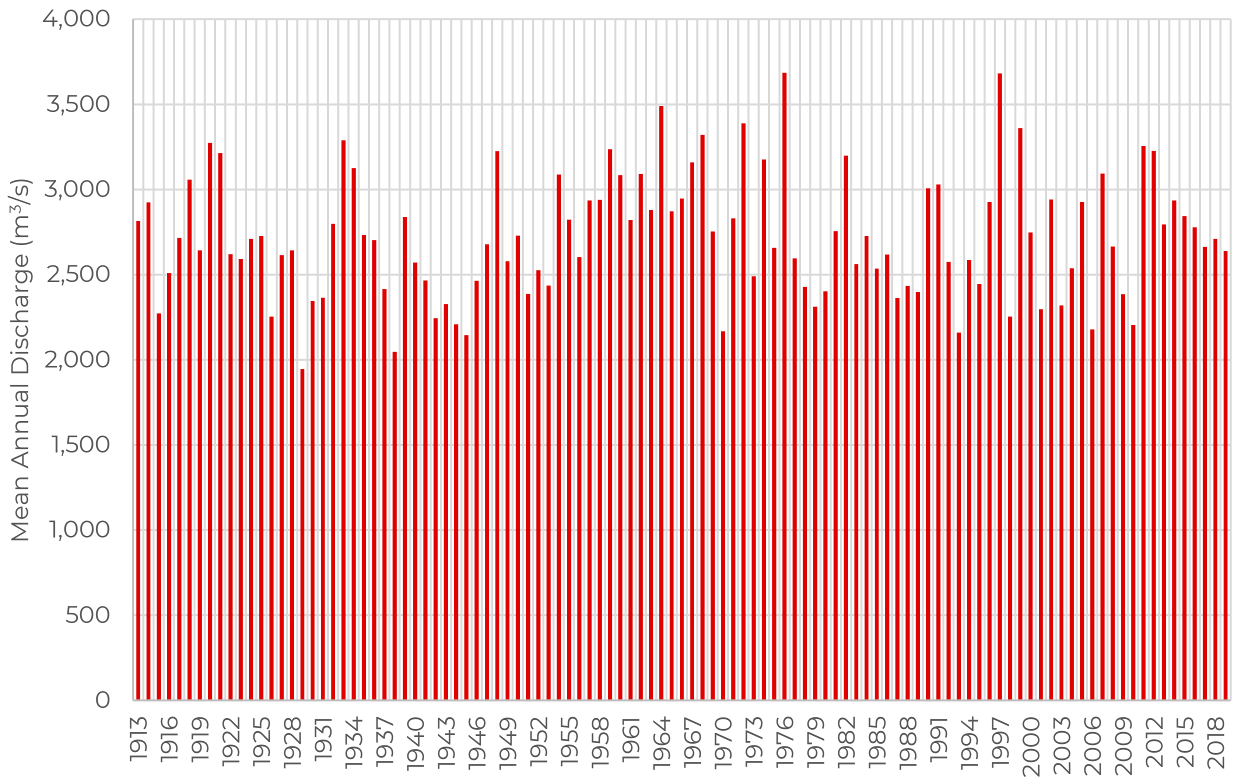


**Figure 2.2: Annual Mean Discharge - Fraser River at Hope (08MF005) (1913-2019)**

The following points summarize the observations from Figure 2.2**:**

- Mean annual discharge is highly variable from year to year.
- No trend was observed in the data based on a Spearman Rank Order Correlation test.
- The highest mean annual discharge on record, 3,685 $m^3/s$, occurred in 1976.
- The lowest mean annual discharge on record, 1,929 $m^3/s$, occurred in 1944.
- The average mean annual discharge across the period of record is 2,720 $m^3/s$.

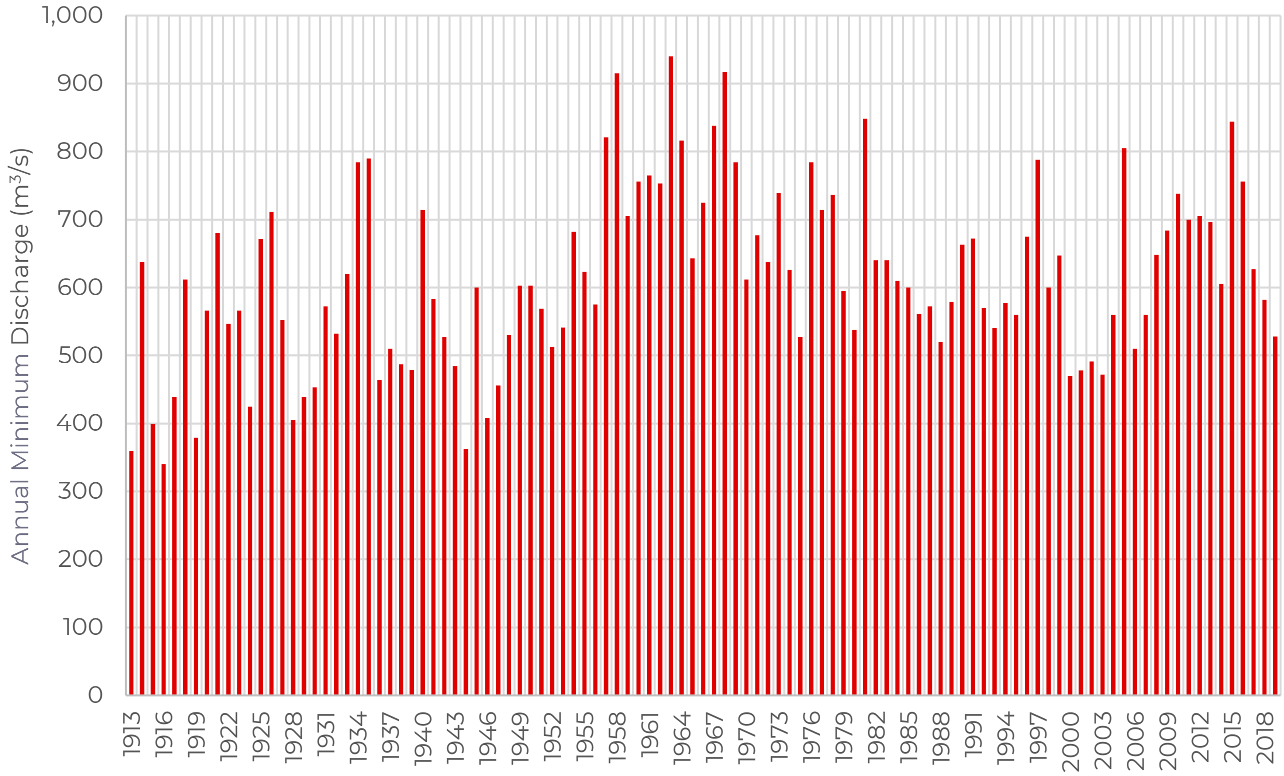


**Figure 2.3: Annual Minimum Discharge - Fraser River at Hope (08MF005) (1913 to 2019)**

The following points summarize the observations from Figure 2.3**:**

- Annual minimum discharge is highly variable from year to year.
- The annual minimum discharge date has ranged from November 24 to April 9 and occurs most commonly between the end of December and early January.
- An upwards trend is observed in the annual minimum discharge data between 1913 and the 2000s, based on the Spearman Rank Order Correlation test at a 1% significance level.
- The highest annual minimum discharge on record, 940 $m^3/s$, occurred in 1963.
- The lowest annual minimum discharge on record, 340 $m^3/s$, occurred in 1916.
- The average annual minimum discharge across the period of record is 614 $m^3/s$.

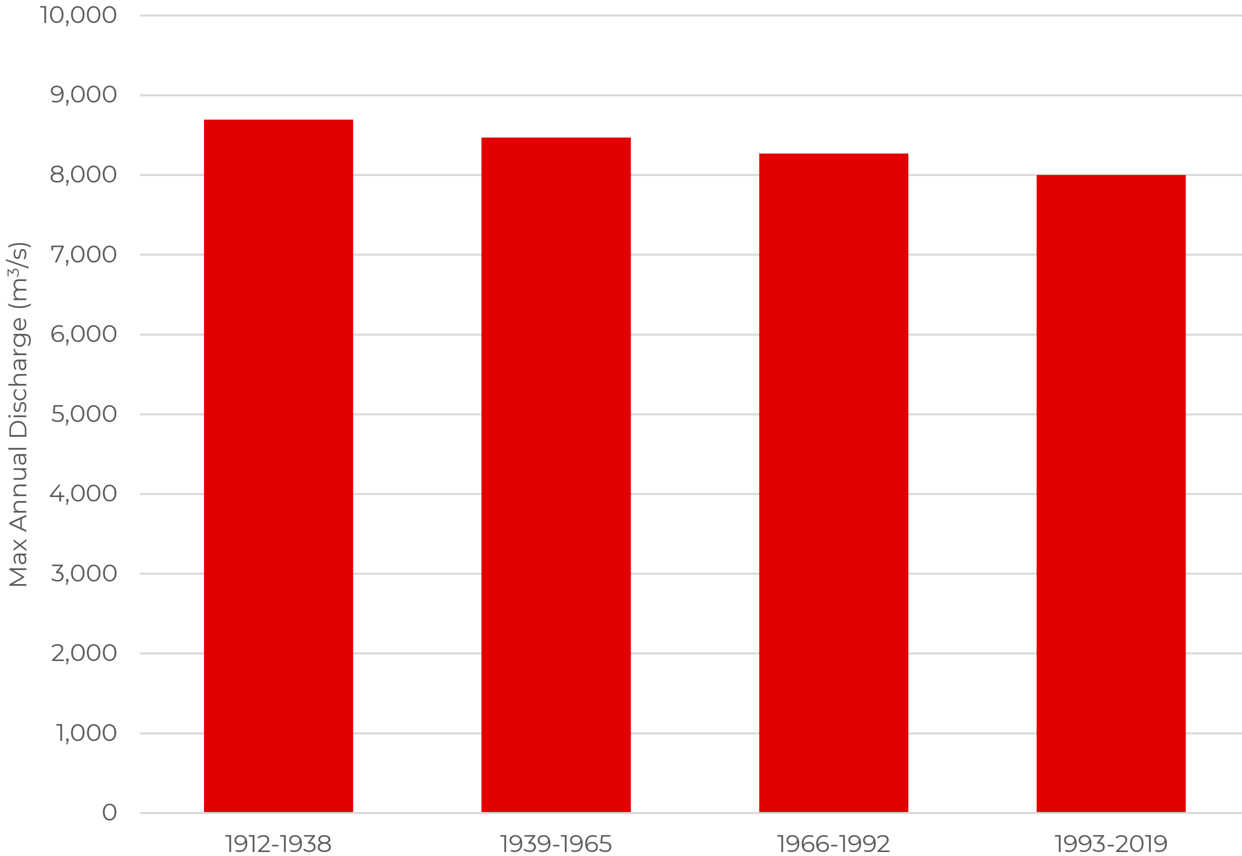


**Figure 2.4: Median Annual Maximum Discharge - Fraser River at Hope (08MF005)**

The figure above shows the annual maximum discharge for each time period, with the median flow year being represented. The following points summarize the observations from Figure 2.4:

- The median annual maximum discharge for each time period has generally been on a slight decline from the beginning of the century to present day.
- The median annual maximum discharge in the 1993-2019 time period has declined 8% when compared to the 1912-1938 range.
- This data indicates only trends in the median annual maximum discharge for each time period, and significant variability in annual maximum discharge still exists from year to year, as observed in Figure 2.1. No downwards trend was observed in the annual maximum discharge data when viewed by individual years.

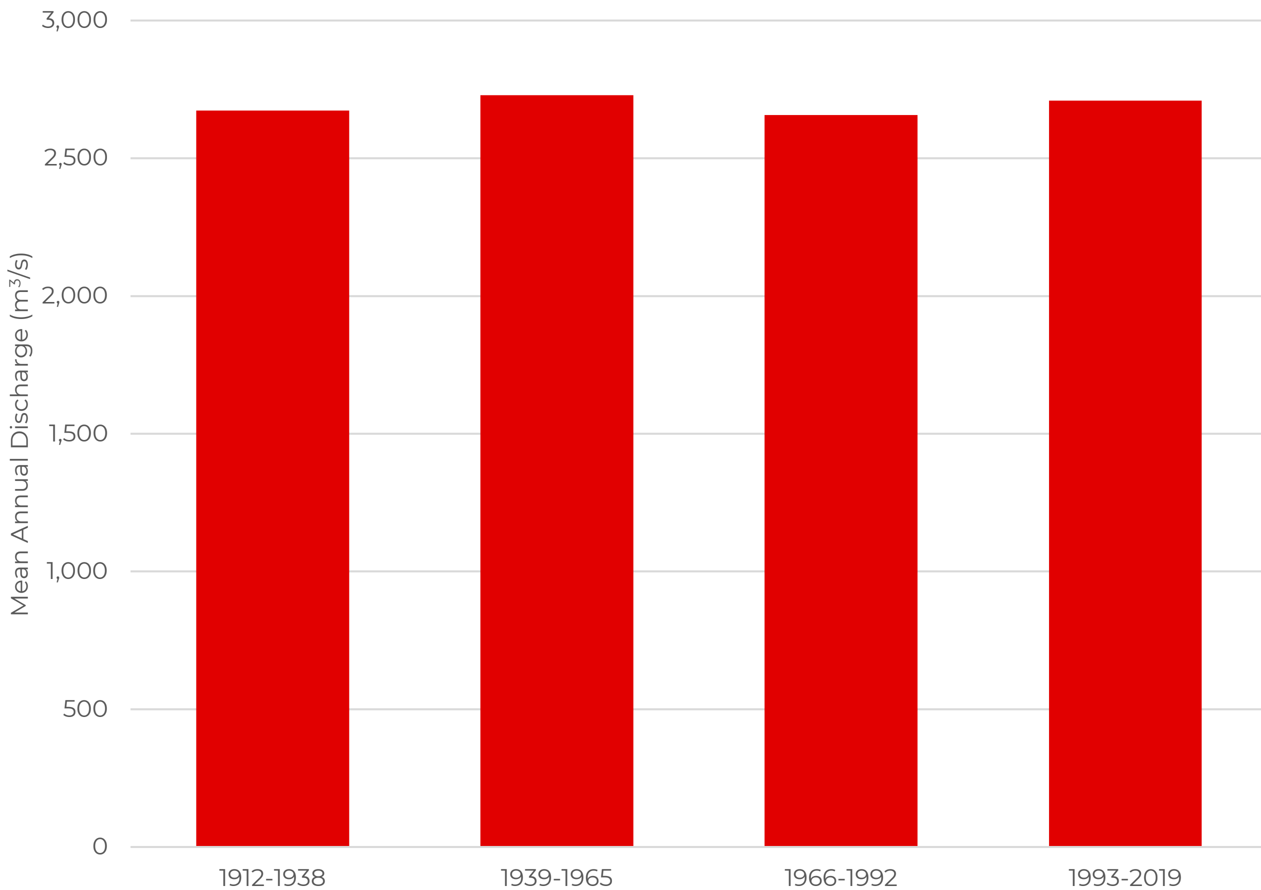


**Figure 2.5: Median Annual Mean Discharge - Fraser River at Hope (08MF005)**

The figure above shows the mean annual discharge for each time period, with the median flow year being represented. The following points summarize the observations from Figure 2.5:

- No significant change has occurred overtime with respect to the median annual mean discharge of the Fraser River.
- This data indicates only trends in the median annual mean discharge for each time period, and significant variability in annual mean discharge still exists from year to year, as observed in Figure 2.2.

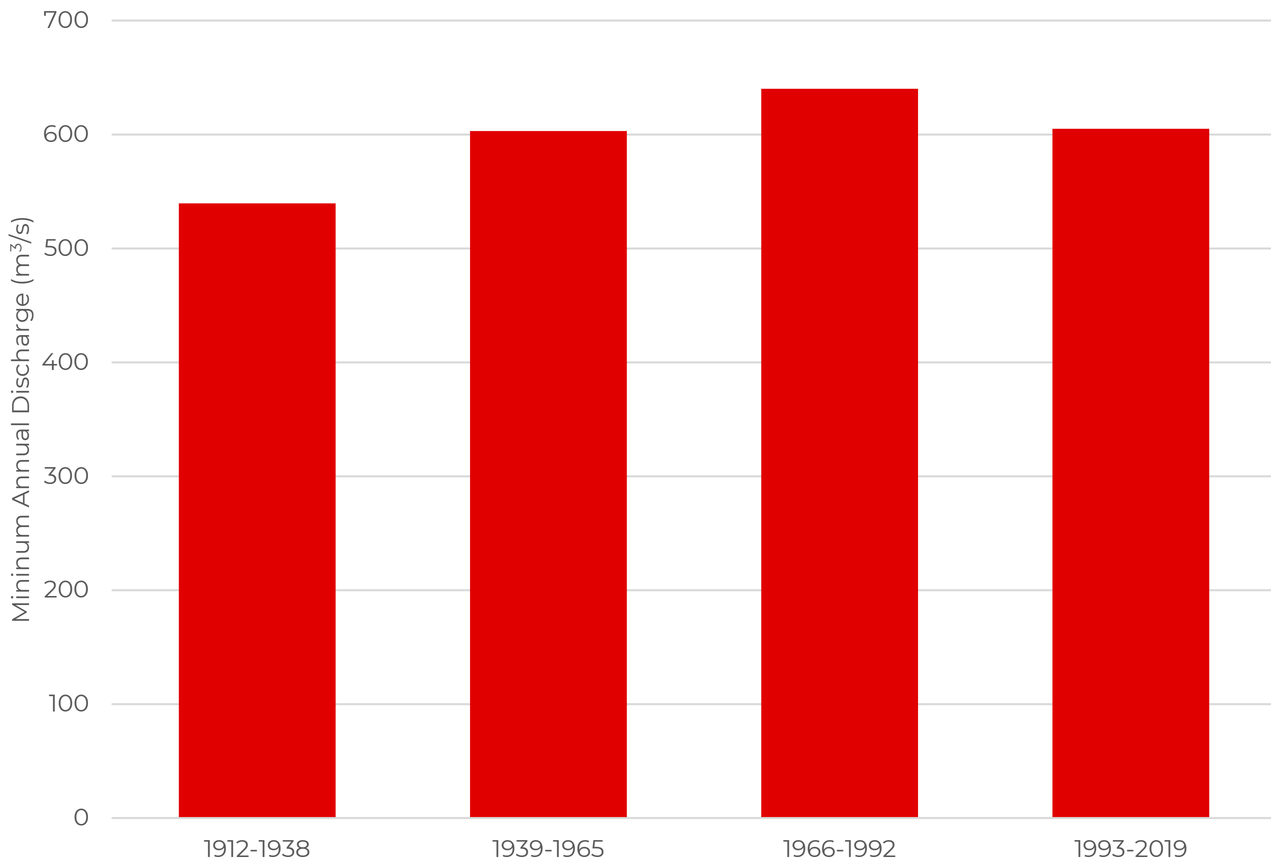


**Figure 2.6: Median Annual Minimum Discharge - Fraser River at Hope (08MF005)**

The figure above shows the annual minimum discharge for each time period, with the median flow year being represented. The following points summarize the observations from Figure 2.6:

- The median annual minimum discharge has increased by 12% from the beginning of the century to present day.
- This data indicates only trends in the median annual minimum discharge for each time period, and significant variability in annual minimum discharge still exists from year to year as observed in Figure 2.3. An upwards trend was also observed in the annual minimum discharge data when viewed by individual years, which increases confidence in this trend.

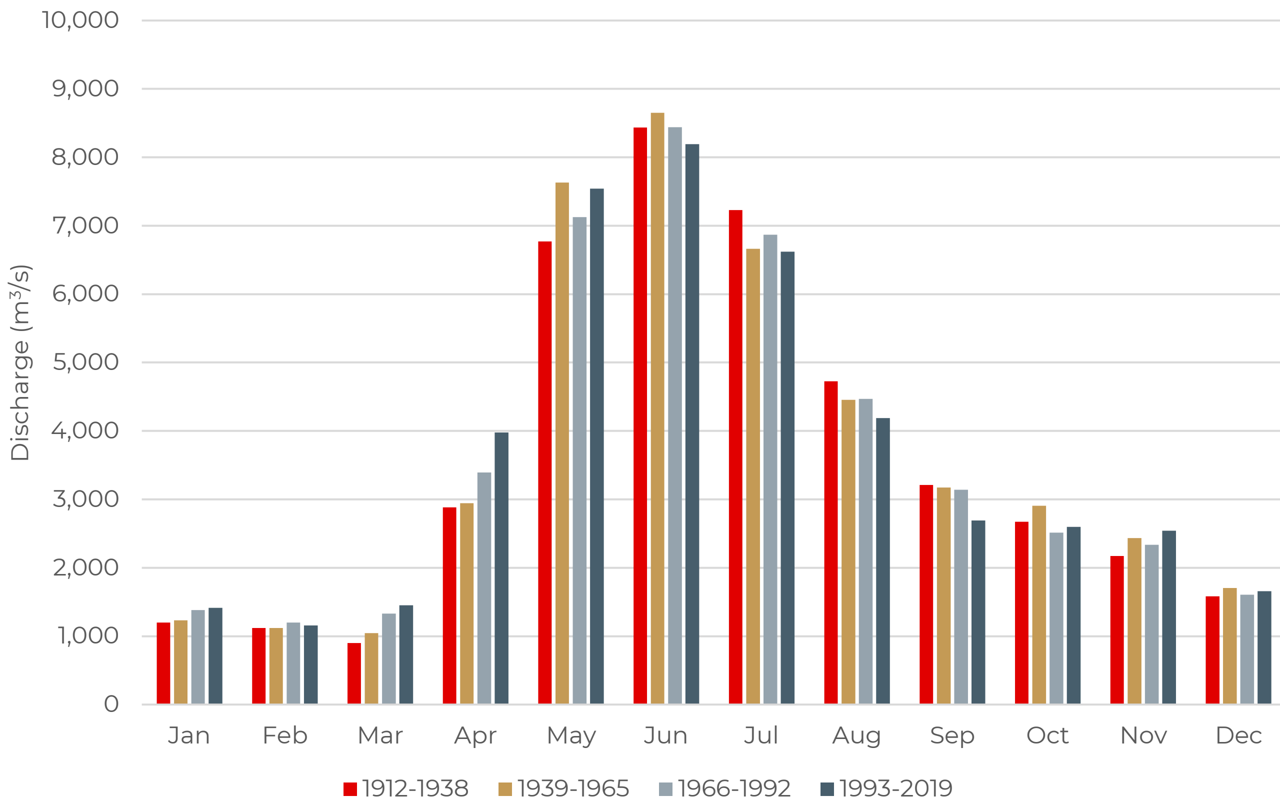


**Figure 2.7: Average Maximum Monthly Discharge - Fraser River at Hope (08MF005)**

In the figure above, the data represent the average maximum monthly discharge for the years included in each time period. The following points summarize the observations from Figure 2.7:

- Average maximum monthly flows for spring (March, April, and May) have been increasing overtime. Over the course of the century, the average maximum monthly flows in March, April and May have increased by 61%, 38%, and 11%, respectively. This data indicates a potential trend suggesting earlier spring melt and freshet.
- Average maximum monthly flows in June, July, August, and September are declining over the period of record. Over the course of the century, the average monthly flows in June, July, August, and September have decreased by 3%, 9%, 11%, and 16%, respectively.
- The increasing trend of March-May flows and the decreasing trend of June-September flows is indicative of a shift in annual flow timing, which would be expected if earlier spring melt and warm temperature conditions occurred.
- Average maximum monthly flows through the winter (December, January, February) have increased slightly over the period of record.

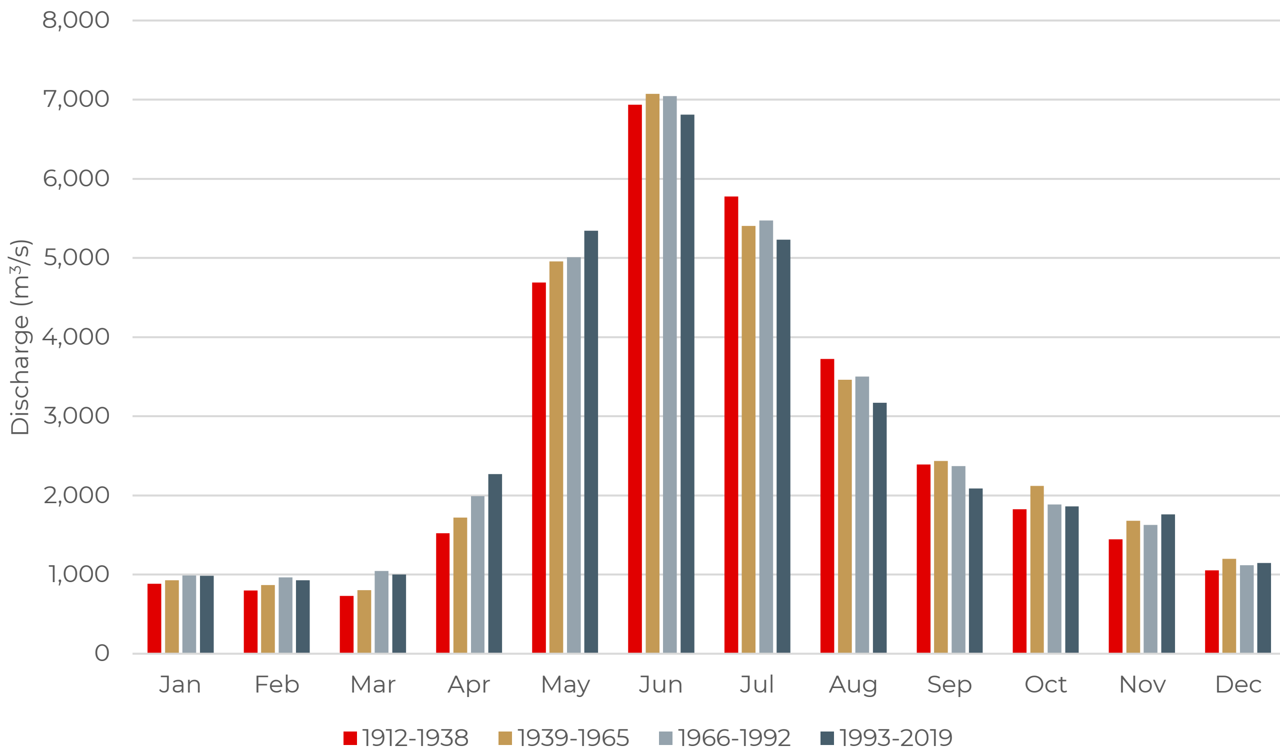


**Figure 2.8: Average Mean Monthly Flows - Fraser River at Hope (08MF005)**

In the figure above, the data represent the average mean monthly discharge for the years included in each time period. The following points summarize the observations from Figure 2.8:

- Average mean monthly flows for spring (March, April, and May) have been increasing overtime. Over the course of the century, the average mean monthly flows in March, April and May have increased by 36%, 49%, and 14%, respectively. This data indicates a potential trend suggesting earlier spring melt and freshet.
- Average mean monthly flows in July, August, and September are declining over the period of record. Over the course of the century, the average monthly flows in July, August, and September have decreased by 9%, 15%, and 13%.
- The increasing trend of March-May flows and the decreasing trend of July-September flows indicates a shift in annual flow timing, with more flow occurring earlier in the year in recent years compared to 100 years ago.
- Average mean monthly flows through the winter (December, January, February) have increased over the period of record. Over the course of the century, the average mean monthly flows in December, January and February have increased by 9%, 11%, and 16%, respectively.

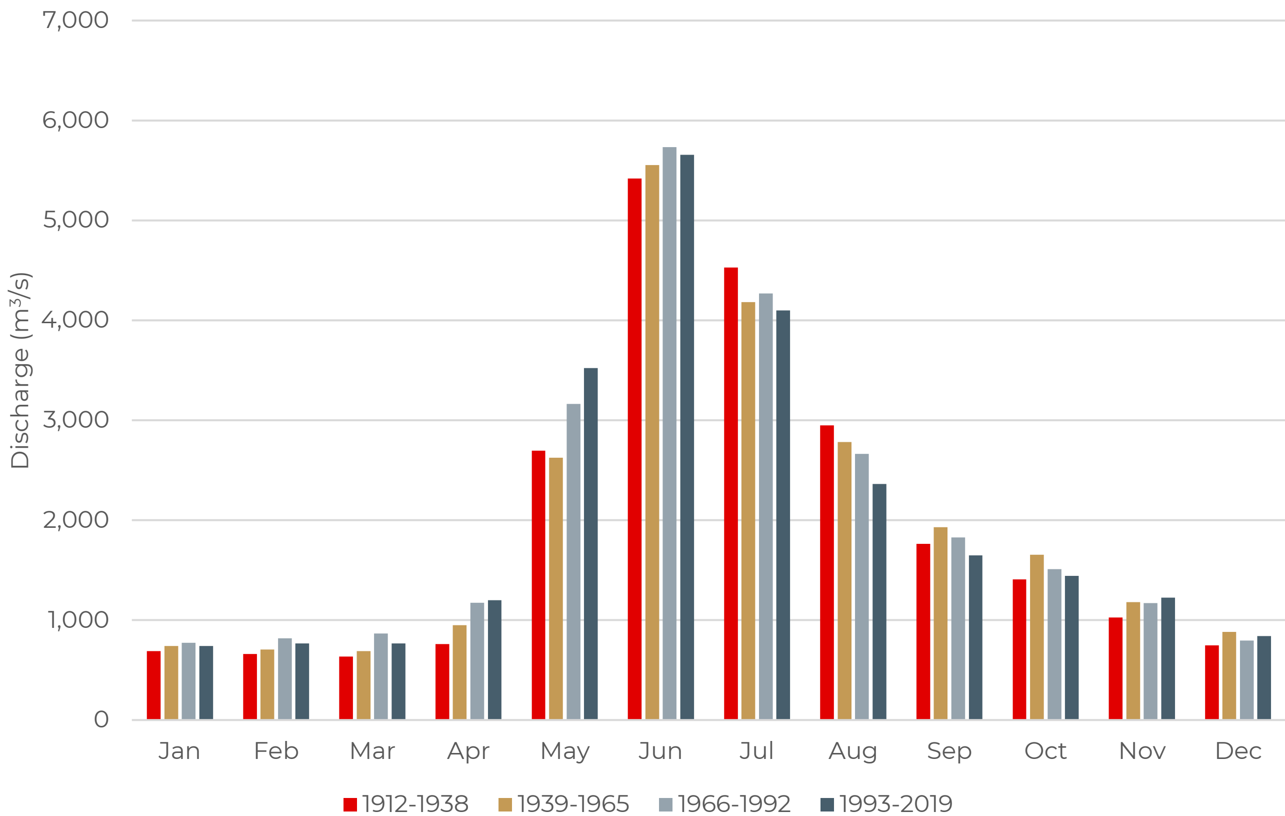


**Figure 2.9: Average Minimum Monthly Flows - Fraser River at Hope (08MF005)**

In the figure above, the data represent the average minimum monthly discharge for the years included in each time period. The following points summarize the observations from Figure 2.9:

- Average minimum monthly flows for spring (March, April, and May) have been increasing overtime. Over the course of the century, the average minimum monthly flows in March, April and May have increased by 21%, 58%, and 31%, respectively. This data suggests an increase in spring base flows within the Fraser River.
- Average minimum monthly flows in July, August, and September are declining over the period of record. Over the course of the century, the average monthly flows in July, August, and September have decreased by 9%, 20%, and 7%, respectively.
- The increasing trend of March-May flows and the decreasing trend of July-September flows indicates a shift in annual flow timing, with more flow occurring earlier in the year in recent years compared to 100 years ago.
- Average minimum monthly flows through the winter (December, January, February) have increased over the period of record. Over the course of the century, the average minimum monthly flows in December, January and February have increased by 13%, 8%, and 16%, respectively.

### 2.1.3 DISCUSSION

Review of the Fraser River at Hope hydrometric data for the period from 1913 to 2019 indicated high variability in the Fraser River flows. Based on these records, the annual maximum discharge is driven by freshet, with peak flows typically occurring between May 1st and July 23rd (WSC, 2022). In general, the lowest flows were recorded during the winter, though flow records indicate that this timing varies. To assess trends, the hydrometric data were divided into four periods: (1) 1912-1938, (2) 1939-1965, (3) 1966-1992, (4) 1993-2019, each consisting of approximately 30 years of data. The median flow year from each of these time periods was then used for trend analysis. Considering the median flows for these time periods, a slight decline in annual maximum discharge was observed, with no significant change in annual mean discharge, and an increase in annual minimum discharge, however, significant variability exists from year to year. Considering the monthly data for these time periods, the analysis indicated an increase in spring flows over time, a decrease in summer flows, and an increase in winter flows. This is supported by records from Fraser River tributaries, which also indicate reduced summer flows (BC Ministry of Environment, 2016). For the Fraser River at Hope station, an increasing trend in March-May flows, paired with a decreasing trend in June-September flows suggests a shift in high flow timing and earlier spring melt.

Assessment of the water quantity for the Fraser Rivers suggests a climate change influence on both the seasonal and annual flow patterns. There is a tendency towards greater variability of streamflow on an annual basis, which has led to increases in the frequency and intensity of low and high flow conditions (University of British Columbia, 2012). Climate change is expected to increase both precipitation and temperature (Pacific Climate Impacts Consortium, 2015). With warmer temperatures, glacial retreat is likely to cause changes in flow timing for some streams and rivers, such as the Fraser River, with reductions in water volume anticipated as a long-term consequence (Ministry of Environment, 2016). Glacial analysis within the territory, for the Kwoiek watershed, indicated glacial retreat for all glaciers studied for the period from 1951 to present, with varying rates of retreat (EDI, 2021). The glaciers within the Kwoiek watershed are projected to continue to retreat with the current emissions scenario suggesting the disappearance of a majority of glacial ice within the watershed by the mid 2080s (EDI, 2021). This glacial retreat has the potential to impact the Fraser River, as glacier water can moderate variability in streamflow, especially during extended periods of summer drought, and can moderate high summer water temperatures (Stahl and Moore, 2006). Additionally, higher levels of precipitation due to climate change may generate a larger snowpack, while warmer temperatures may lead to earlier snowpack depletion, increasing the intensity of high flow conditions (Pacific Climate Impacts Consortium, 2015). Higher temperatures can also result in a greater proportion of precipitation falling as rainfall (Pacific Climate Impacts Consortium, 2015).

It is anticipated that climate change will result in more frequent and more severe rainfall events (International Panel of Climate Change, 2021). In 2021, an atmospheric river resulted in prolonged rainfall, leading to severe flooding, and damage to infrastructure at several locations in BC, including Kanaka Bar. Although the reviewed hydrometric data for 2021 were unavailable at the time of this assessment, the preliminary hydrometric data indicated that a flow of 6,230 $m^3/s$ was recorded at the Fraser River at Hope station on November 15th, 2021 (WSC, 2022). In comparison, the typical high flow during November is approximately 2,500 $m^3/s$. Despite the significant flows caused by the November 2021 event, the annual maximum discharge for the Fraser River at Hope was recorded on June 7th, 2021 (9,760 $m^3/s$). While the timing of the annual maximum discharge currently remains dependent on freshet, given the anticipation that climate change will increase the frequency and severity of rainfall events, there is potential for periodic elevated flow events outside of the typical freshet window. Annual maximum discharge driven by freshet is characteristic of large watersheds within the interior of BC, including the Fraser River. In contrast, watersheds in the coastal areas of BC are commonly rainfall dependent, with annual maximum discharge related to fall and winter rain events. Due to continued climate change, the Fraser River may shift from a snow-dominant hydrologic regime to a more rain-dominant hydrologic regime, which could affect peak flow timing and annual flow patterns (University of British Columbia, 2012).

With the shift in high flows occuring earlier in the year, the associated lower summer flows and increased water temperatures pose risks to the Fraser River salmon populations (Ministry of Environment, 2016). Flow rates and increases in temperature have been linked to the mortality of spawning salmon stocks, with the greatest losses occurring in years with warm river temperatures (Ministry of Environment, 2016). Low flows can result in higher water temperatures, and high flows can generate strong currents, both of which increase the energy demands of migrating salmon (University of British Columbia, 2012). Compared to historical observations, fall salmon runs have been happening earlier in the year (by about 3-6 weeks) and as a result, fish are migrating when the water temperature is approximately 3°C higher (University of British Columbia, 2012). Continued changes to flow and temperature due to climate change are likely to further impact the Fraser River salmon population.

The following summarizes key information regarding the water quantity assessment:

- The Fraser River is a snowmelt dominant watershed, with the annual peak flow occurring June 11th on average. Given the anticipation that climate change will increase the frequency and severity of rainfall events, there is potential for periodic elevated flow events outside of the typical freshet window.
- High flow season generally last from May and July.
- Low flow season generally last from December to March.
- Summer flows have been decreasing between 1912 to 2019.
- Winter flows have generally been increasing from 1912 to 2019.
- Spring flows have been increasing between 1912 to 2019.
- During the 2050s, the Fraser River annual streamflow is projected to increase. Winter and spring flows are projected to increase, summer flows are projected to decrease, and smaller changes are projected for the fall. (Ministry of Environment, 2016)
- There is a tendency towards greater variability of streamflow on an annual basis, which has lead to increases in the frequency and intensity of low and high flow conditions. (University of British Columbia, 2012).
- Long-term trends in river flow and temperature associated with climate change are a risk to Fraser River salmon stocks. Summer low flows have been decreasing between 1912 to 2019 and water temperatures are anticipated to keep increasing. Both low flows and higher water temperatures are linked with declining salmon populations (Ministry of Environment, 2016).

# 3.0 WATER QUALITY ASSESSMENT

The water quality assessment aims to develop an understanding of the current state of the Fraser River at Kanaka Bar with respect to sources of contamination and climate change impacts. The assessment focuses on water quality impacts to aquatic life, with consideration of traditional uses of the river for fishing, travelling, and recreation. The assessment includes a review of existing literature, analysis of available data, evaluation of the 1997 water quality objectives, comparison to BC water quality guidelines, and recommendations, which include a proposed monitoring program.

## 3.1 BACKGROUND

In 1997, water quality objectives were developed for the Fraser River to protect the most sensitive water uses and values of the river (Swain, Walton, and Obedkof, 1997; BC Ministry of Environment and Climate Change Strategy, 2021). At the time of development, the objectives were derived from local water quality, water uses, water movement, wastewater discharges, and other guidelines, including the BC Approved Water Quality Guidelines, which recommend criteria for all waters throughout BC (BC Ministry of Environment and Climate Change Strategy, 2021). Water quality objectives are used in conjunction with other management methods, such as effluent controls and pollution prevention planning, to protect water quality (Swain, Walton, and Obedkof, 1997). Given that these water quality objectives were developed 25 years ago, and considering the regulatory and environmental changes since then, these objectives likely require revision.

In 2021, a guidance document for the derivation of water quality objectives was published, which recognized an ongoing need to develop and update water quality objectives (BC Ministry of Environment and Climate Change Strategy, 2021). The guidance document indicated that the BC Ministry of Environment and Climate Change Strategy (ENV) seeks to engage Indigenous nations in the development of water quality objectives to define the most appropriate objectives for a waterbody (BC Ministry of Environment and Climate Change Strategy, 2021). The document also stated that water quality objectives are intended to support key water initiatives such as managing cumulative effects and climate change (BC Ministry of Environment and Climate Change Strategy, 2021).

## 3.2 WATER QUALITY INFLUENCES

The water quality of the Fraser River is influenced by a wide variety of sources, and therefore assessment of the water quality at Kanaka Bar is complex. To identify potential parameters of concern, non-point sources, point sources, and climate change impacts at and upstream of Kanaka Bar were investigated.

### 3.2.1 NON-POINT SOURCES

Within the Kanaka Bar traditional territory, Fraser River water quality influences are generally limited to non-point sources, including runoff from the nearby highway and railways and inputs related to extreme weather events, such as forest fires and flooding (Chambers and Hocking, 2021). A component of highway runoff emerging as an environmental concern is tire particulates. Ubiquitous tire rubber-derived chemicals, particularly 6PPD-quinone, can cause toxic effects to fish, with research focusing on mortality in juvenile coho salmon. The study suggested that it is unlikely that coho salmon are uniquely sensitive to the contaminant (Tian et al., 2021). As such, more complex contaminants, such as 6PPD-quinone, may be potential parameters of concern. Upstream of Kanaka Bar, runoff from urban areas, agricultural activities, and industrial sites also contributes to the water quality of the river, though the impact of runoff can vary significantly depending on the level of dilution achieved (Gray and Tuominen, 1998). Potential parameters of concern associated with various types of runoff generally include total suspended solids (TSS), turbidity, conductivity, chloride, metals, nutrients (nitrogen and phosphorus), bacteria, and hydrocarbons. Forestry operations within tributary watersheds can also increase TSS, turbidity, and nutrient loadings to the Fraser River, as non-point sources (Chambers and Hocking, 2021; Gray and Tuominen, 1998).

During the gold rush, placer mining occurred at several locations throughout the Fraser Canyon, including near Kanaka Bar. In some cases, mercury was used in sluice boxes to bind gold and improve gold recovery. There is anecdotal evidence from the Stó:lô Nation to suggest that mercury contamination still exists in the Fraser River, especially in gravel bars and sediments (Long, 2006). While the introduction of mercury to the Fraser River occurred historically, the potential for mercury to be reintroduced from sediments may be a relevant non-point source water quality concern. Concerns from the Stó:lô Nation highlighted potential impacts to bottom-feeding sturgeon, with early life stages of sturgeon also inhabiting benthic areas (Long, 2006; Vardy et al., 2015).

### 3.2.2 POINT SOURCES

The main point sources influencing the water quality of the Fraser River upstream of Kanaka Bar are wastewater discharges from pulp and paper mills, municipal wastewater treatment plants, and a mine. Pulp and paper mills at Prince George and Quesnel discharge treated effluent to the Fraser River. Treated municipal wastewater is also discharged to the river at Prince George, Williams Lake, Quesnel, Lillooet, and Lytton. Another pulp mill at Kamloops and municipal wastewater treatment plants at Kamloops and Ashcroft discharge to the Thompson River, which confluences with the Fraser River approximately 10 km upstream of Kanaka Bar (Swain, Walton, and Obedkof, 1997; BC Ministry of Environment and Climate Change Strategy, 2022). The Gibraltar Mine is located near McLeese Lake and discharges tailings impoundment supernatant to the Fraser River at Marguerite (BC Ministry of Environment and Climate Change Strategy, 2022).

#### Pulp and Paper Mills

Pulp and paper mills can vary in design, with different types of processes being used to produce a variety of products. Liquid wastes from these processes undergo wastewater treatment before being discharged to the environment; however, the resulting effluent can still contain a wide variety of contaminants (BC Ministry of Environment, Lands and Parks, 1994). In the early 1990s, pulp and paper mill regulations were introduced to address contamination related to the hazardous by-products produced in the pulp bleaching process and the inconsistencies in wastewater treatment requirements throughout the province (BC Ministry of Environment, Lands and Parks, 1994). A 1998 study indicated significant improvements in pulp and paper wastewater quality since the introduction of these regulations, which resulted in reductions in concentrations of dioxins and furans, polychlorinated biphenyls (PCBs), lead, pentachlorophenol, and some pesticides (Gray and Tuominen, 1998). However, the same study also indicated that despite reductions in these contaminants, a range of other chlorinated and non-chlorinated compounds were measured in pulp mill effluents, along with low levels of polycyclic aromatic hydrocarbons (PAHs) (Gray and Tuominen, 1998). Currently, pulp and paper mill discharges are regulated by both federal and provincial legislation, which involves monitoring adsorbable organic halogens (AOX), which is a laboratory measure of a group of chlorinated organic compounds, TSS, biochemical oxygen demand (BOD), toxicity, and dioxins and furans (also part of AOX) (BC Ministry of Environment, Lands and Parks, 1994). Monitoring is undertaken through the Environmental Effects Monitoring (EEM) program (Environment and Climate Change Canada, 2022). This program uses cyclical monitoring to assess the effectiveness of environmental management measures by evaluating the effects of effluents on fish, fish habitat, and the use of fisheries resources by humans (Environment and Climate Change Canada, 2010).

### Municipal Wastewater

Municipal wastewater discharges are regulated by federal and provincial legislation, both of which stipulate thresholds for effluent volume released, effluent quality criteria, and monitoring requirements (BC Ministry of Environment and Climate Change Strategy, 2022; Environment and Climate Change Canada, 2022). The treatment of municipal wastewater is typically designed to reduce TSS and BOD (Gray and Tuominen, 1998). In addition, wastewater treatment plants are generally required to disinfect prior to discharge through ultra-violet disinfection or the addition of chlorine (BC Ministry of Environment and Climate Change Strategy, 2022). While some wastewater treatment plants are designed to reduce nitrogen and phosphorus, this is not typical. Wastewater treatment plants typically release total phosphorus, with most phosphorus being in the form of orthophosphate, which is biologically available. Various forms of nitrogen are also released, such as ammonia, nitrate, nitrite, and organic nitrogen. Temperature and pH influence the ionization of ammonia, with the un-ionized form being more toxic to fish, and therefore, ammonia is the primary consideration for acute aquatic toxicity (Environment and Climate Change Canada, 2022).

### Mining

The Gilbraltar Mine discharges tailings impoundment supernatant to the Fraser River near Marguerite (BC Ministry of Environment and Climate Change Strategy, 2022). The discharge is regulated by a provincial permit, which specifies a maximum rate of discharge, a discharge period, and discharge quality criteria. The discharge quality criteria focus on TSS, sulphate, nitrogen (including ammonia, nitrate, and nitrite), orthophosphate, dissolved metals (aluminum, iron, manganese) and total metals (antimony, arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, selenium, and zinc). Monitoring of the effluent, river, and sediment is required according to the permit (BC Ministry of Environment and Climate Change Strategy, 2022).

### Train Derailment

Another point source of contamination that has been raised by the community is the 1997 train derailment, which occurred within the vicinity of Kanaka Bar. Some of the derailed cars spilled sulphur into the Fraser River (Chambers and Hocking, 2021). While most of the spilled sulphur was recovered, an unknown amount, mixed with displaced fill, flowed into the river. The incident report indicated that the sulphur likely settled into the river sediments and was not considered an environmental threat (Transportation and Safety Board of Canada, 1997). Fuel also leaked from the derailed cars, which ignited and caused a fire. The incident report indicated that apart from the sulphur, other contaminants such as fuel, were contained and removed (Transportation and Safety Board of Canada, 1997). There have been other train derailments along the Fraser River throughout the history of the railway. While the potential exists for contamination as a result of derailments, assessment of the potential contamination is difficult due to wide variability in contaminant introduction and the short-term nature of the events.

## 3.2.3 CLIMATE CHANGE IMPACTS

In addition to sources of contamination, climate change is important to assess with respect to the water quality of the Fraser River. There are several factors to consider, including warmer temperatures, lower summer flows, and increased frequency of drought and flood events (Fraser Basin Council, 2011). The increased frequency and severity of events, such as forest fires and flooding, increases the potential for erosion, turbidity, and sedimentation. For example, the November 2021 atmospheric river event resulted in severe flooding and damage to infrastructure at Kanaka Bar, with washout into the Fraser River. Increases in particulate matter typically coincide with increases in contaminants that adsorb to these particles, such as metals, nutrients, and bacteria (Gray and Tuominen, 1998). Moreover, forests that are stressed – due to drought, for example – are more vulnerable to diseases and pests. Therefore, climate change impacts to forests can result in changes in forest cover within watersheds, indirectly affecting watershed functions and processes (Fraser Basin Council, 2011).

Climate change also impacts fish migration patterns and survival rates through loss of habitat, warmer water temperatures, lower flows in the summer and fall, and changes to the aquatic ecosystem (Fraser Basin Council, 2011). Studies have indicated that summer temperatures are on a rising trend, with temperatures in recent years reaching levels stressful to salmon and steelhead (DFO, 2021; Chambers and Hocking, 2021). There is a relationship between temperature and dissolved oxygen (DO), in which higher temperatures result in lower DO concentrations (Chambers and Hocking, 2021). Therefore, DO is another parameter that is important to consider with respect to implications to aquatic life (Chambers and Hocking, 2021). Sedimentation in the Fraser River can also cause negative physical effects to fish, such as the abrasion of gills, and changes in behaviour, including impaired migration (Chambers and Hocking, 2021).

Glacial retreat has also been observed within Kanaka Bar territory. As part of the cumulative effects initiative, glacier analysis was undertaken for the Kwoiek watershed to assess glacial climate change impacts. For the period from 1951 to present, glacier extents decreased for all glaciers, with varying rates of retreat (EDI, 2021). The glacial retreat has the potential to impact water temperatures within the Kwoiek Creek watershed and thus, the Fraser River. As mentioned, changes to water temperatures can impact aquatic life, particularly salmon populations.

## 3.3 DATA ANALYSIS

### 3.3.1 METHODOLOGY

There are number of water quality monitoring stations near Kanaka Bar; however, most stations are located on tributary streams, not on the Fraser River. The closest monitoring station to Kanaka Bar on the Fraser River with long-term water quality data is the Fraser River at Hope (BC EMS, 2022). This monitoring station is located approximately 94 km downstream of Kanaka Bar (iMapBC, 2022). Considering the distance between the monitoring station and Kanaka Bar, the water quality data may not represent the water quality conditions within the stretch of river running through Kanaka Bar territory. There are additional tributaries and municipalities located between Kanaka Bar and Hope, which have the potential to influence the water quality within this stretch of river.

The water quality of the Fraser River at Hope station is monitored by the Federal/Provincial Water Quality Monitoring Network. The identification numbers for the station are provided below:

**Fraser River at Hope**

*Provincial EMS ID E206581*

*Federal ID BC08MF0001*

The water quality data for the Fraser River at Hope were downloaded from both: BC Environmental Monitoring System (EMS) and Environment and Climate Change Canada (BC EMS, 2022; Environment and Climate Change Canada, 2022). There were some discrepancies between the two datasets. To ensure consistency, only the data downloaded from Environment and Climate Change Canada were assessed as these data were available as a single download. In cases in which data were unavailable, the BC EMS data were consulted. The records for this monitoring station date back to 1979 and include data for several parameters. The following are examples of the parameters monitored:

- Faecal Coliforms
- TSS
- Turbidity
- True Colour
- Temperature
- DO
- pH
- Nitrate
- Nitrite
- Total Phosphorus
- Total Metals
- Organic Adsorbable Halides (AOX)
- Specific Conductance (Conductivity)
- Chloride

Given that the water quality objectives developed for the Fraser River considered data up to the late 1990s, the following data analysis considers the available data from January 1, 2000 to December 12, 2021 for the Fraser River at Hope monitoring station. Data for the November 2021 atmospheric river event were unavailable. The available data were compared to applicable Fraser River water quality objectives, BC water quality guidelines, and plotted over time to assess potential trends using correlation analysis. A significance level of 0.05 was used in the determination of trends.

### 3.3.2 DATA COMPARISON

Table 3.1 summarizes the comparison of the available water quality data from the Fraser River at Hope monitoring station to existing water quality objectives, for the period from 2000-2021. The table is colour coded accordingly:

(Grey fill) No available data to assess if objective was met.

(Pink fill) Objective not met.

(No fill) Objective met.

**Table 3.1: Fraser River at Hope - Water Quality Objectives Comparison (2000-2021)**

| Fraser River at Hope | | | Water Quality Objective[1] |
|---|---|---|---|
| Parameter (units) | Average | Maximum | |
| Faecal Coliforms (counts/100 mL) | 38<br>63 (90$^{th}$ percentile) | 1,600 | ≤1000 counts/100 mL 90$^{th}$ percentile |
| *Enterococci* (counts/100 mL) | No data available. | | ≤250/100 mL 90$^{th}$ percentile |
| Total Chlorine Residual (µg/L) | No data available. | | Average ≤ 2 µg/L |
| Suspended Solids (TSS) (mg/L) | 64 | 559 | 10 mg/L maximum increase (upstream < 100 mg/L)<br>10% maximum increase (upstream > 100 mg/L) |
| Turbidity (NTU) | 33.2 | 395 | 1 NTU maximum increase (upstream <5 NTU)<br>5 NTU maximum increase (upstream < 50 NTU)<br>10% maximum increase (upstream > 50 NTU) |
| True Colour (TCU) | 18.3 | 241 | 15 TCU maximum (June-September)<br>75 TCU maximum (October-May)<br>10% maximum increase (upstream >15 or 75 TCU, respectively) |
| Temperature (°C) (water) | 8.8 | 22 | Maximum change of 1°C |
| Dissolved Oxygen (DO) (mg/L) | 11.94<br>*Minimum concentration of 8.00. | 16.63 | Higher of 80% saturation or 8.0 mg/L minimum<br>11.0 mg/L when salmonid embryos and larvae present (November-April) |
| pH | 7.92<br>*Minimum pH of 7.50 | 8.16 | 6.5-8.5 |

URBAN SYSTEMS

**Table 3.1: Fraser River at Hope - Water Quality Objectives Comparison (2000-2021) (continued…)**

| Fraser River at Hope | | | Water Quality Objective[1] |
|---|---|---|---|
| Parameter (units) | Average | Maximum | |
| Total Ammonia (mg/L) | No data available. | | Variable depending on temperature and pH. |
| Nitrite (mg/L) | 0.005 | 0.038 | Variable depending on chloride concentration.<br>*Average chloride concentration of 1.3 mg/L (<2 mg/L):<br>0.06 mg/L maximum<br>0.02 mg/L 30-day average |
| Nitrate + Nitrite (mg/L) | 0.083 | 0.166 | 10 mg/L maximum |
| Periphyton (as chlorophyll a) ($mg/m^2$) | No data available. | | 50 $mg/m^2$ maximum |
| Total Lead (µg/g) | No data available. | | 0.8 µg/g maximum in edible fish muscle |
| AOX (Adsorbable Organic Halides) (µg/L) | 55.1<br>(95% confidence interval: 47.1 µg/L, 63.1 ug/L) | 720 | No increase at 95% confidence interval |
| Total PCBs (µg/g) | < 0.2 (µg/g) | | 2.0 µg/g maximum in edible fish muscle<br>0.1 µg/g maximum in whole fish |
| Chlorophenols (mg/L) | No data available. | | Dependent on chlorophenol and pH. |
| Dehydroabietic Acid (µg/L) | No data available. | | Maximum 8 µg/L at pH 7.0<br>Maximum 12 µg/L at pH 7.5 |
| Total Resin Acids (µg/L) | No data available. | | Maximum 25 µg/L at pH 7.0<br>Maximum 45 µg/L at pH 7.5 |
| Dioxins and Furans<br>2,3,7,8-$T_4$CDD equivalents | No data available. | | Maximum (dissolved) 0.06 pg/L in water<br>Maximum 0.25 pg/g (normalized to 1% organic carbon) in sediments<br>Maximum 50 pg/g (wet-weight) in lipids of fish muscle or fish eggs |

[1] Fraser River from Nechako River to Hope.

The comparison of the Fraser River at Hope water quality data to existing water quality objectives, as shown in Table 3.1 above, indicated that for most parameters the available data met corresponding water quality objectives, with exceedances in true colour and AOX. Data for faecal coliforms, DO, pH, nitrite, nitrate + nitrite combined, and total PCBs met applicable objectives. The following notes provide further commentary on the data comparison:

- Water quality objectives for TSS and turbidity are based on a change from a site upstream of a discharge or a series of discharges (i.e., a change from background conditions related to human activity) (Swain, Walton, and Obedkof, 1997). Given that the data considered as part of this assessment represent ambient conditions at the Fraser River at Hope monitoring station, and the water quality is influenced by a series of upstream discharges and cumulative effects, it is unclear if levels of TSS and turbidity met applicable water quality objectives and if these objectives are applicable.
- The water quality objectives for true colour specify maximum true colour levels for different times of the year, with the period from June to September being more stringent than the period from October to May. There were numerous occasions during the June to September period from 2000-2021 when true colour was above the objective maximum.
- The temperature objective indicates a maximum change of 1 °C. Assessment of whether this objective was met could not be made as it was not clear over what period the change may occur (Swain, Walton, and Obedkof, 1997).
- According to the objectives, for the period from November to April, a minimum DO concentration of 11.0 mg/L is required to support buried embryo and alevin life stages (Swain, Walton, and Obedkof, 1997). Based on the available data, there was only one occasion when the DO concentration was below 11.0 mg/L during this period. Outside of the period from November to April, the minimum objective concentration is 8.00 mg/L, which was met on all sampling occasions for the Fraser River at Hope data (Environment and Climate Change Canada, 2022).
- For AOX, the water quality objective indicates no increase at the 95% confidence interval. Data for AOX were available from 2000-2010. Using the available data, the 95% confidence interval was calculated as 47.1 ug/L, 63.1 ug/L (the lower and upper limits of the interval). There were numerous occasions when the AOX concentration exceeded the upper limit of the 95% confidence interval.
- Data for the following parameters were not available for the period from 2000-2021: *Enterococci*, total chlorine residual, total ammonia, periphyton (as chlorophyll a), total lead (in edible fish muscle), chlorophenols, dehydroabietic acid, total resin acids, and dioxins and furans. As a result, it was not possible to assess these parameters with respect to existing water quality objectives.

Recognizing that the water quality objectives for the Fraser River were developed 25 years ago, the BC Approved Water Quality Guidelines were consulted to assess the data in the context of updated criteria. Table 3.2 summarizes the comparison of available water quality data from the Fraser River at Hope monitoring station to BC Approved Water Quality Guidelines for the protection of freshwater aquatic life, for the period from 2000-2021 (BC Ministry of Environment and Climate Change Strategy, 2021). The table is colour coded accordingly:

| | |
|---|---|
| (Grey fill) | No available data to assess if guideline was met. |
| (Pink fill) | Guideline not met. |
| (No fill) | Guideline met. |

For reference, the BC Approved Water Quality Guidelines provide both long-term chronic and short-term acute guidelines.

**Long-term chronic** guidelines are intended to be met over an averaging period to protect the most sensitive species and life stages against sub-lethal and lethal effects for indefinite exposures. For this assessment, the average concentration for the period from 2000-2021 was compared to the long-term chronic guideline.

**Short-term acute** guidelines are intended to protect the most sensitive species and life stages against severe effects such as lethality over a short-term exposure period. For this assessment, the maximum concentration for the period from 2000-2021 was compared to the long-term chronic guideline.

**Table 3.2: Fraser River at Hope – BC Approved Water Quality Guidelines Comparison (2000-2021)**

| Fraser River at Hope | | | Guidelines - Freshwater Aquatic Life | | | |
|---|---|---|---|---|---|---|
| Parameter (units) | Average | Maximum | Long-Term Chronic (Average) | | Short-Term Acute (Maximum) | |
| TSS (mg/L) | 64 | 559 | Change from background of 10 mg/L at any time when background is 25-100 mg/L during high flows or in turbid waters. Change from background of 10% when background is >100 mg/L at any time during high flows or in turbid waters. | | | |
| Turbidity (NTU) | 33.2 | 395 | Change from background of 5 NTU at any time when background is 8-50 NTU during high flows or in turbid waters. Change from background of 10% when background is > 50 NTU at any time during high flows or in turbid waters. | | | |
| Temperature (°C) (water) | 8.8 | 22 | Streams with known fish distribution, ± 1 °C change beyond optimum temperature for each life history phase of the most sensitive salmonid species present. Hourly rate of change not to exceed 1 °C. From guidelines, optimum temperature for migration – maximum is 19.0 °C for chinook salmon, maximum of 15.6 °C for all other salmon species. | | | |
| DO (mg/L) | 11.94 *Minimum concentration of 8.00. | 16.63 | 8 mg/L (all life stages) | 11 mg/L (buried embryo/alevin life stages) | 5 mg/L (all life stages) *instantaneous minimum | 9 mg/L (buried embryo/alevin life stages) *instantaneous minimum |
| pH | 7.92 *Minimum pH of 7.50 | 8.16 | 6.5 to 9.0 | | | |
| Nitrite (mg/L) | 0.005 | 0.038 | 0.02 (guideline variable depending on chloride concentration) *average chloride concentration of 1.3 mg/L | | 0.06 (guideline variable depending on chloride concentration) *average chloride concentration of 1.3 mg/L | |
| Nitrate (mg/L) | 0.08 | 0.15 | 3.0 | | 32.8 | |

**Table 3.2: Fraser River at Hope – BC Approved Water Quality Guidelines Comparison (2000-2021) (continued…)**

| Fraser River at Hope | | | Guidelines - Freshwater Aquatic Life | |
|---|---|---|---|---|
| Parameter (units) | Average | Maximum | Long-Term Chronic (Average) | Short-Term Acute (Maximum) |
| Total Arsenic (µg/L) | 0.81 | 6.54 | - | 5 ug/L (maximum) |
| Total Boron (mg/L) | 0.0047 | 0.0101 | 1.2 | - |
| Total Cobalt (µg/L) | 1.32 | 25.3 | 4 | 110 |
| Total Copper (µg/L) | 3.99 | 47.6 | Both long-term chronic and short-term acute guidelines calculated using BC Biotic Ligand Model (BLM). | |
| Total Iron (mg/L) | 2.28 | 43.3 | - | 0.35 |
| Total Lead (µg/L) | 0.91 | 9.17 | 4.94 (calculated based on average hardness) | 41.9 (calculated based on average hardness) |
| Total Manganese (mg/L) | 0.07 | 1.20 | 0.87 | 1.19 |
| Total Molybdenum (mg/L) | 0.0007 | 0.0012 | 7.6 | 46 |
| Total Selenium (µg/L) | 0.11 | 0.32 | 1 µg/L (water column)<br>*alert concentration<br>2 µg/L WQG (water column) | - |
| Total Silver (µg/L) | 0.03 | 0.20 | 0.05 (based on hardness) | 0.10 (based on hardness) |
| Total Zinc (µg/L) | 6.69 | 94.5 | 7.5 (based on hardness) | 33 (based on hardness) |
| Chloride (mg/L) | 1.3 | 3.5 | 150 | 600 |

The comparison of the Fraser River at Hope water quality data to BC Approved Water Quality Guidelines for the protection of freshwater aquatic life, as shown in Table 3.2 above, indicated that for most parameters the available data met corresponding guidelines. Guidelines were not met for water temperature and several total metals, including arsenic, iron, manganese, silver, and zinc. The following notes provide further commentary on the data comparison:

- Like the water quality objectives, assessment of TSS and turbidity is based on a comparison to background conditions. Given that the data considered as part of this assessment represent ambient conditions at the Fraser River at Hope monitoring station, and the water quality is influenced by a series of upstream discharges and cumulative effects, it is unclear if levels of TSS and turbidity met applicable water quality guidelines and if these guidelines are applicable.
- For temperature, the guidelines specify optimum temperature ranges of specific life stages of salmonids and other fish species (BC Ministry of Environment and Climate Change Strategy, 2021). The stretch of river running through Kanaka Bar territory is primarily used for fish migration. According to the guidelines, the maximum migration temperature is 19.0 °C for chinook salmon, with a maximum of 15.6 °C for all other species. For the available data, there were 6 occasions when the water temperature was above 19.0 °C, and 62 occasions when the water temperature was above 15.6 °C.
- Guidelines for DO, pH, nitrate, and nitrite were met. These guidelines are essentially the same as the water quality objectives, with the exception of nitrate, which has a separate water quality guideline.
- For several total metals, there were occasions when concentrations were above short-term acute guidelines.
    - There were 2 occasions for the dataset when the total arsenic concentration was above the short-term acute guideline.
    - Total iron concentrations for the Fraser River at Hope data were significantly higher than both the long-term chronic and short-term acute guidelines.
    - The maximum concentration of total manganese was slightly above the short-term acute guideline, which was calculated using the average total hardness over the period from 2000-2021. Given that this guideline was estimated and the slight difference in concentration, the significance of this exceedance is questionable.
    - There were 7 occasions when the total silver concentration was above the short-term acute guideline.
    - The concentration of total zinc was above the short-term acute guideline on 9 occasions.
    - Both long-term chronic and short-term acute guidelines for total copper are calculated using a program called BC BLM – this was not completed for this assessment.

In addition to BC water quality guidelines for the protection of freshwater aquatic life, there are also guidelines for primary contact recreational uses, which are important to consider given the traditional uses of the river for travel and recreation. There are BC water quality guidelines for *Escherichia coli* and *Enterococci* to protect primary contact recreation. While no data were available for *E. coli* or *Enterococci*, *E. coli* are one type of faecal coliform. The guideline for *E. coli* is ≤ 200 counts/100 mL as a geometric mean concentration (with a minimum of 5 samples); or ≤ 400 counts/100 mL as a single sample maximum concentration. Assuming all faecal coliforms were *E. coli*, since we only have faecal coliform data for the Fraser River at Hope, the geometric mean faecal coliform concentration in the Fraser River was 15 counts/100 mL (considering the entire dataset), which is below the criterion of ≤ 200 counts/100 mL. There were only 3 occasions when the faecal coliform concentration was above the single sample maximum concentration.

### 3.3.3 TREND ANALYSIS

The available Fraser River at Hope water quality data were plotted over time to assess potential trends using correlation analysis. Trends were assessed for the following parameters and were correlated with time:

- Faecal Coliforms
- TSS
- Turbidity
- True Colour
- Temperature (air, water)
- DO
- pH
- Nitrate
- Nitrite
- Total Phosphorus
- Total Metals
- Organic Adsorbable Halides (AOX)
- Specific Conductance (Conductivity)
- Chloride

The results of the correlation analysis are provided in Table 3.3 below and include only those parameters in which the test statistics indicated trends in the data, using a significance level of 0.05. Trends for total metals were only assessed for total metals with approved BC Water Quality Guidelines for the protection of freshwater aquatic life (BC Ministry of Environment and Climate Change Strategy, 2021).

A summary of the correlation analysis for all parameters is provided in Appendix A.

**Table 3.3: Fraser River at Hope – Trend Analysis (2000-2021)**

| Parameter | Trend |
|---|---|
| pH | Increasing |
| Nitrite | Decreasing |
| Nitrate + Nitrite (Combined) | Increasing |
| Nitrate | Increasing |
| Total Phosphorus | Increasing |
| Total Cadmium | Decreasing |
| Chloride | Increasing |

Decreasing trend.

Increasing trend.

As shown in Table 3.3 above, increasing trends were identified for pH, nitrate + nitrite combined, nitrate, total phosphorus, and chloride. Decreasing trends were determined for nitrite and total cadmium. For the combined analysis of nitrate + nitrite, nitrate typically contributes a much greater proportion to the combined concentration. Therefore, considering the greater contribution from nitrate, the decreasing trend in nitrite is not contradictory.

### 3.3.4 DISCUSSION

Assessment of the water quality of the Fraser River is complex. There are numerous water quality influences at and upstream of Kanaka Bar to consider in discussing the analysis of available water quality data in the context of the 1997 water quality objectives, BC water quality guidelines, potential trends, implications to aquatic life and the traditional uses of the river. Below is a discussion of the parameters assessed.

#### Faecal Coliforms, E. coli, Enterococci

Faecal coliforms, *E.coli*, and *Enterococci* are microbiological indicators, which can be used to identify contamination by faecal matter (Warrington, 2021). For the Fraser River at Hope monitoring station, data were only available for faecal coliforms (Environment and Climate Change Canada, 2022). The concentrations of faecal coliforms for the Fraser River met the water quality objective and trend analysis indicated no trend in faecal coliforms over time.

Considering the traditional uses of the river for both travel and recreation, the BC water quality guidelines for the protection of primary contact recreation were also consulted. The microbiological guidelines for primary contact recreation focus on *E. coli* and *Enterococci*, as these parameters are considered better indicators of gastrointestinal disease, and thus, threats to human health (Warrington, 2021). Data were not available for *E. coli* and *Enterococci*; however, *E. coli* are one type of faecal coliform. Assuming all faecal coliforms were *E. coli*, the geometric mean concentration met the *E. coli* guideline and there were only a few occasions when the concentration was above the single sample maximum. Therefore, there are low concerns with respect to faecal contamination based on the Fraser River at Hope water quality data.

#### TSS, Turbidity, True Colour

The Fraser River is typically characterized by periods of high flows and turbid waters (Gray and Tuominen, 1998). Therefore, high levels of TSS, turbidity, and true colour are generally expected, especially during freshet. Given that the data considered as part of this assessment represent ambient conditions at the Fraser River at Hope monitoring station, and the water quality is influenced by a series of upstream discharges and cumulative effects, it is unclear if levels of TSS and turbidity met applicable water quality objectives/guidelines and if these objectives/guidelines are applicable. The water quality objectives for true colour specify maximum true colour levels for different times of the year. There were numerous occasions during the June to September period (in which criteria are more stringent) when true colour was above the water quality objective. Freshet flows typically occur within this time period, and therefore, increased true colour is not unexpected. Colour is a measure of the depth to which light penetrates in water systems, since the observed colour of water is the result of light scattered back after it has passed through various depths (BC Ministry of Environment, Lands and Parks, 1997). True colour, in particular, is influenced by natural minerals and dissolved organic substances. Dissolved organic substances from anthropogenic sources can contribute to water colouration. The presence of coloured substances in aquatic systems can impact primary and secondary production, macroinvertebrate communities, and thus, fish populations. Colour can also alter the availability, and hence toxicity, of metals to fish (BC Ministry of Environment, Lands and Parks, 1997). Trend analysis did not indicate trends in TSS, turbidity, or true colour, which suggests a consistency in these parameters over time. These parameters will be important to monitor moving forward as climate change can increase the potential for erosion, turbidity, and sedimentation within the Fraser River (Fraser Basin Council, 2011).

## Temperature

For the Fraser River water quality objectives, a maximum change in temperature is specified, yet it is not clear over what period the change may occur (Swain, Walton, and Obedkof, 1997). As a result, assessment of whether the temperature objective was met could not be made. In contrast, the BC water quality guidelines indicate optimum temperatures for specific life stages of fish species (BC Ministry of Environment and Climate Change Strategy, 2021). There were several occasions when the temperature recorded for the Fraser River at Hope was above maximum upper limits for salmon migration (BC Ministry of Environment and Climate Change Strategy, 2021). The Department of Oceans and Fisheries (DFO) Environmental Watch Program collects real-time temperature data from the Fraser River basin to assess impacts to the migration of salmon (DFO, 2021). The DFO temperature data indicated above average temperatures for the Fraser River at Hope, on a rising trend (DFO, 2021).

Trend analysis of the Fraser River at Hope data did not indicate a trend with respect to water temperature. To investigate this further, the average summer temperatures (averaging temperatures over the period from June to August) were analyzed and again, no trends were determined. While these findings are unexpected based on the information provided by DFO, the data represent discrete samples at a single location, with samples typically being taken on a few occasions each year (DFO, 2021; Environment and Climate Change Canada, 2022). Therefore, temperatures are likely on a rising trend, however, the data from the Fraser River at Hope station, and the limitations associated with this data, do not indicate an increase over time.

## DO

There are water quality objectives and guidelines for DO, which specify minimum concentrations for different periods throughout the year. There was only one occasion when the DO concentration was below the minimum required. Concentrations of DO are inversely proportional to temperature, with higher temperatures resulting in lower concentrations of DO (Chambers and Hocking, 2021). Like temperature, analysis did not indicate a trend in DO over time. Based on the real-time data collected by DFO, high temperatures are likely resulting in reduced levels of DO (DFO, 2021).

## pH

The pH data for the Fraser River at Hope station met the water quality objective range and the BC water quality guideline range. However, trend analysis indicated an increasing trend in pH. A potential reason for the increase in pH may be related to a change in measurement – pH can be measured in the field or in a laboratory. The hold time for the laboratory analysis is only 15 minutes since the pH can change due to ongoing chemical reactions (Ministry of Environment and Climate Change Strategy, 2020). As a result, the pH reading is often different if measured in the field compared to laboratory analysis. Another potential reason for the increase in pH may be related to changes within the watershed, such as increased sediment loading from climate change-related impacts or forestry activities in tributary watersheds, since the geology of a watershed can influence the pH of a river system. The increasing pH trend may also be related to improvements in the pH of point source releases or pollution prevention planning, as urbanization tends to decrease pH, not increase it.

## Nutrients

The nutrients considered in this analysis included the nitrogen parameters, nitrite and nitrate, and total phosphorus. Nitrogen is essential for many biological processes, with nitrate, nitrite, and ammonia being the biologically available forms of nitrogen occurring in surface waters (Nordin and Pommen, 2009). Phosphorus is another essential nutrient that can exist as orthophosphate, the biologically available form, and as particulate phosphorus, bound to sediments. Total phosphorus is a measure of all forms of phosphorus combined. While nitrogen and phosphorus are vital to aquatic ecosystems, excess nutrients can lead to the proliferation of algae and rooted plants, which can lower the oxygen content of water, suffocating fish and other aquatic life.

The nitrite and nitrate concentrations for the Fraser River at Hope met the water quality objectives and guidelines. Trend analysis indicated a decreasing trend for nitrite, with an increasing trend for nitrate + nitrite combined, and for nitrate alone. For the combined analysis of nitrate + nitrite, nitrate typically contributes a much greater proportion to the combined concentration. Thus, the increasing trend in nitrate + nitrite aligns with the increasing trend in nitrate. The increasing trend in nitrate may be linked to non-point sources of contamination, such as run-off from agricultural areas, and increased urbanization within the watershed. Nitrate may also be increasing due to point source discharges of municipal wastewater. Still, the nitrate concentrations measured at the Fraser River at Hope monitoring station were significantly lower than both the water quality objectives and guidelines.

Of the different forms of nitrogen, ammonia is the primary consideration for acute aquatic toxicity, however no data were available for the Fraser River at Hope (Environment and Climate Change Canada, 2022). Acute aquatic toxicity is dependent on the concentration of total ammonia and the temperature and pH of the water, with higher temperatures and higher pH increasing the potential for toxic conditions (Swain, Walton, and Obedkof, 1997). Ammonia toxicity will be important to consider given the increasing trends in temperature and pH.

There are no water quality objectives for total phosphorus. For flowing waters, criteria are based on algal growth, or periphyton, measured as chlorophyll a (Swain, Walton, and Obedkof, 1997). No chlorophyll a data were available for the Fraser River at Hope, however, trend analysis indicated an increasing trend in total phosphorus (Environment and Climate Change Canada, 2022). As mentioned, increases in nutrients, such as phosphorus, may increase the potential for algal and aquatic plant growth, however, this potential is likely limited by the turbid water, reduced light penetration, and turbulent flows characteristic of the Fraser River. No data were available for orthophosphate, which further limits the assessment of the potential for plant growth (Environment and Climate Change Canada, 2022). Like the increasing trend in nitrate, runoff from agricultural areas, forestry operations, increased urbanization, and wastewater discharges may introduce higher levels of phosphorus to the river. The increase in total phosphorus may also be related to increases in suspended sediment due to climate change impacts (Gray and Tuominen, 1998).

## Total Metals

For the Fraser River, there is a water quality objective for total lead sampled from edible fish muscle; however, no data were available (Environment and Climate Change Canada, 2022; BC EMS, 2022). In 1997, water quality objectives were not considered for other metals as concentrations were not anticipated to increase due to anthropogenic activity (Swain, Walton, and Obedkof, 1997). To assess this assumption that metal concentrations did not increase, available total metals data for the Fraser River at Hope were compared to corresponding BC water quality guidelines. There were occasions when concentrations of total metals, including arsenic, iron, manganese, silver and zinc, were above short-term acute guidelines. Due to the high sediment load, it is reasonable to expect high particulate metals for the Fraser River. The only trend identified for total metals was a decreasing trend in total cadmium. Data for dissolved metals were not available, though dissolved metals are generally more biologically available compared to metals bound to sediment or complexed with other molecules (Adams et.al, 2020). Therefore, analysis of dissolved metals is likely more suitable for the Fraser River in the assessment of potential implications to aquatic life. Data for mercury were only available until the early 1990s. Given the available data, no water quality objective was proposed for mercury (Swain, Walton, and Obedkof, 1997). There are BC water quality guidelines for the long-term chronic concentration of mercury (BC Ministry of Environment and Climate Change Strategy, 2021).

## AOX

Fraser River water quality objectives were also developed for more complex contaminants, including adsorbable organic halogens (AOX), total polychlorinated biphenyls (PCBs), chlorophenols, dehydroabietic acid, total resin acids, and dioxins and furans (Swain, Walton, and Obedkof, 1997). These types of contaminants are typically associated with wastewater from pulp and paper mills (Swain, Walton, and Obedkof, 1997). Data were available for AOX and total PCBs; however, only 2 data points were recorded for total PCBs, both of which were recorded below detection on the same date (Environment and Climate Change Canada, 2022; BC EMS, 2022). Data for AOX were available from 2000 to 2010. AOX is a more cost-effective, reproducible measure of the total amount of chlorinated constituents present; yet, it is not a direct measure of aquatic health (Swain, Walton, and Obedkof, 1997). A water quality objective was developed for AOX to promote elimination of AOX from pulp and paper discharges in the long-term (Swain, Walton, and Obedkof, 1997). The objective indicates no increase at the 95% confidence interval. There were numerous occasions when the AOX concentration exceeded the upper limit of the 95% confidence interval (Environment and Climate Change Canada, 2022). Trend analysis did not indicate any trends with respect to AOX concentrations. This suggests a consistency in AOX concentrations from 2000 to 2010, which indicates that while the objective was intended to eliminate AOX from discharges, no significant change has occurred. Chlorinated compounds, including the compounds that belong to AOX, can persist in the environment, accumulating in sediments with high organic matter content (BC Ministry of Environment, Lands and Parks, 1994). The lack of trend in AOX may be an indication of this persistence.

## Specific Conductance, Chloride

Specific conductance is a measure of the electrical conductivity of water as a result of the salts dissolved in it. There are no water quality objectives or guidelines for conductivity, but it is important to discuss in relation to chloride. In the natural environment, surface waters tend to have a relatively constant range of conductivity. Thus, specific conductance can be used to measure the impact of human activities, which can increase the amount of dissolved salts in the water (BC Ministry of Environment and Climate Change Strategy, 2022). The chloride ion commonly occurs as a salt and is typically used for road-salting (Canadian Council of Ministers of the Environment, 2011). Trend analysis did not indicate a trend in conductivity; however, an increasing trend was identified for chloride. While the chloride ion is naturally occuring, chloride is often used as an indicator of increasing urbanization within a watershed (i.e., road-salting) (CCME, 2011). Considering the increasing trends in nitrate and total phosphorus, the increasing trend in chloride suggests increased urbanization within the Fraser River watershed, although the lack of a trend in conductivity generates a level of uncertainty. Nevertheless, the levels of chloride detected in the Fraser River were significantly lower than the BC water quality guidelines for the protection of freshwater aquatic life.

# 4.0 SUMMARY

Water quantity and quality assessment of the Fraser River is part of a broader cumulative effects initiative that is underway within Kanaka Bar's traditional territory. The community has expressed concerns relating to the water quantity and quality of the river, emphasizing declining salmon populations as a key concern.

Data from the Fraser River at Hope hydrometric station for the period from 1913-2019 were used to assess water quantity. The data for 2020 and 2021 were preliminary in nature and therefore, not included in the hydrometric analysis. The annual data indicated significant variability in maximum discharge and mean discharge. Currently, the hydrologic regime of the Fraser River is freshet dependent, with the highest flows occuring during the spring. The high flow season generally lasts from May to July. The lowest flows are typically recorded in the winter, with the low flow season lasting from December to March. To assess trends, the hydrometric data were divided into four periods: (1) 1912-1938, (2) 1939-1965, (3) 1966-1992, (4) 1993-2019. Generally, the analysis indicated an increase in spring flows, a decrease in summer flows, and an increase in winter flows. A shift in the timing of freshet was noted, indicating earlier spring melt. The intensity of high and low flow conditions is exacerbated by climate change, with higher levels of both precipitation and temperature anticipated to continue influencing the annual and seasonal flow patterns of the Fraser River. The change in timing of high flows, the strong current generated by high flows, and the warmer temperatures resulting from lower flows have the potential to impact salmon populations and other aquatic life in the Fraser River.

The Fraser River is the most extensive river basin in the province, and as such, the water quality of the river is subject to a complex variety of influences. In 1997, objectives were developed to protect the water quality of the Fraser River. Analysis of the water quality data from the Fraser River at Hope monitoring station was completed for the period from 2000-2021 to understand the current state of the river at Kanaka Bar in the context of the water quality objectives and BC water quality guidelines, while considering potential climate change impacts and implications to aquatic life.

Comparison of the data to the water quality objectives indicated that most criteria were met, with exceedances in true colour and AOX. It was not possible to assess existing water quality objectives for *Enterococci*, total chlorine residual, total ammonia, periphyton (as chlorophyll a), total lead (in edible fish muscle), chlorophenols, dehydroabietic acid, total resin acids, and dioxins and furans as no data were available.

Recognizing that the water quality objectives for the Fraser River were developed 25 years ago, the BC Approved Water Quality Guidelines were consulted to assess the data in the context of updated criteria. Comparison to water quality guidelines for the protection of freshwater aquatic life indicated that for most parameters, the available data met corresponding guidelines. Guidelines were not met for water temperature, with temperatures recorded above the upper limits of the optimum ranges for migrating fish, and several total metals, including arsenic, iron, manganese, silver, and zinc, which were occasionally above short-term acute guidelines. Due to the high sediment load, it is reasonable to expect high total metals concentrations in the Fraser River. The BC water quality guidelines for the protection of primary contact recreation were also consulted given the traditional uses of the river for travel and recreation. Based on the available data, there were low concerns with respect to faecal contamination and threats to human health.

Trend analysis indicated increasing trends for pH, nitrate + nitrite combined, nitrate, total phosphorus, and chloride, and decreasing trends for nitrite and total cadmium. The increasing trend in pH may be related to a potential change in measurement (field testing versus laboratory analysis), changes in sediment loading, with the geology of the watershed influencing the pH increase, or improvements in point source discharges. The increasing trends in nitrate + nitrite combined and nitrate may be a result of agricultural runoff, increased urbanization, or wastewater discharges. The increasing trend in total phosphorus may be influenced by runoff from agricultural areas, forestry operations, increased urbanization, wastewater discharges, or increases in suspended sediment related to climate change impacts. The lack of a trend in AOX, for which a water quality objective was created to eliminate AOX from pulp and paper mill discharges, suggests no significant change has occurred or that perhaps AOX compounds are persisting in the river. The increasing trend in chloride suggests increased urbanization within the watershed, yet a similar trend in conductivity was not identified.

Given that the water quality objectives for the Fraser River were developed 25 years ago, the objectives likely do not reflect the current condition of the river and watershed, especially considering changes in human activity, regulatory changes, and climate change impacts. As an example, despite existing water quality objectives for complex contaminants, such as dioxins and furans, no data were available for assessment of these parameters. Clarification is needed on the relevance of these objectives with respect to the water quality of the Fraser River. The monitoring of additional complex contaminants, 6PPD-quinone for example, should also be further considered. Finally, changes in the flow patterns of the Fraser River since the 1990s should be taken into consideration.

# 5.0 RECOMMENDATIONS

The following monitoring program, as summarized in Table 4.1 below, is recommended to provide site-specific data to further assess the current state of the Fraser River at Kanaka Bar. The recommended monitoring is intended to assess water quality conditions during high flows, to understand sediment and contaminant loading, and during low flows, to assess water quality under conditions with less dilution potential. There are varied periods when salmon (and steelhead) have the potential to be present in the Fraser River within Kanaka Bar territory, depending on species and life history stage (Chambers and Hocking, 2021). To assess implications to aquatic life, especially to salmon populations, monitoring from the spring (during the down-migration of smolts, which represent a more sensitive life stage) through to the fall (during the up-migration of adult salmon) is recommended (Chambers and Hocking, 2021).

A monitoring location within Kanaka Bar territory is to be established at an accessible location. For monthly sampling, field parameters may be measured using a field probe; however, it is recommended that temperature sensors be installed at the monitoring location to measure temperature on a continuous basis. This will allow for in-depth assessment of a potential increasing temperature trend since temperature can fluctuate over short periods of time. As a cost-effective approach, three monitoring events involving laboratory analysis are proposed. It is recommended that this monitoring program be reviewed after 1 year.

**Table 4.1: Recommended Water Quality Monitoring Program**

| Location | Frequency | Field Parameters | Laboratory Parameters |
|---|---|---|---|
| Fraser River at Kanaka Bar (one site to be determined) | Monthly (from March to September) | Temperature (water)[1]<br>DO<br>pH<br>Turbidity | - |
| | 1 event in the spring (to coincide with spring migration and freshet)<br>1 event in the summer (to coincide with summer migration)<br>1 event in the fall (to coincide with fall migration and low flows)<br>*All events to be coordinated with monthly monitoring events. | Temperature (water)<br>DO<br>pH<br>Turbidity | pH<br>TSS<br>Chloride<br>Ammonia<br>Nitrate<br>Total Phosphorus<br>Orthophosphate<br>Dissolved Metals (and hardness) |

[1] Installation of temperature sensors to monitor temperature on a continuous basis is recommended.

In addition to the implementation of a monitoring program, it is recommended that Kanaka Bar engage with ENV to update the water quality objectives for the Fraser River. The 2021 guidance document for the derivation of water quality objectives indicated that engagement from Indigenous nations is sought to synthesize Indigenous knowledge with scientific methods to define the most appropriate water quality objectives for a waterbody (BC Ministry of Environment and Climate Change Strategy, 2021). This water quality assessment and the site-specific water quality data collected at Kanaka Bar will provide the community with information to present to ENV to protect the water uses and values at Kanaka Bar, including the traditional uses of fishing, travel, and recreation.

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# Appendix A

## SUMMARY OF CORRELATION ANALYSIS

**Table A1: Fraser River at Hope - Summary of Normality Tests and Correlation Analysis (2000-2021)**

| Parameter | Data Range | Normality Test | | | | Correlation[1] | |
|---|---|---|---|---|---|---|---|
| | | Test | Test Statistic | P-Value | Test | R-Value | P-Value |
| Faecal Coliforms | 2000-2021 | KS | 0.357 | <0.010 | Spearman | -0.007 | 0.882 |
| TSS | 2011-2021 | KS | 0.240 | <0.010 | Spearman | 0.040 | 0.596 |
| Turbidity | 2000-2021 | KS | 0.239 | <0.010 | Spearman | 0.057 | 0.232 |
| True Colour | 2000-2021 | KS | 0.285 | <0.010 | Spearman | 0.081 | 0.090 |
| Temperature (water) | 2000-2015 | KS | 0.114 | <0.010 | Spearman | 0.040 | 0.444 |
| Summer Temperature (water) | 2000-2015 | RJ (n<25) | 0.988 | >0.100 | Pearson | -0.023 | 0.936 |
| DO | 2000-2021 | KS | 0.104 | <0.010 | Spearman | -0.043 | 0.386 |
| pH | 2000-2021 | KS | 0.120 | <0.010 | Spearman | 0.174 | <0.001 |
| Nitrite | 2009-2021 | KS | 0.271 | <0.010 | Spearman | -0.539 | <0.001 |
| Nitrate | 2009-2015 | KS | 0.082 | 0.015 | Spearman | 0.169 | 0.037 |
| Nitrate and Nitrite | 2009-2015 | KS | 0.070 | 0.044 | Spearman | 0.238 | 0.002 |
| Total Phosphorus | 2000-2021 | KS | 0.220 | <0.010 | Spearman | 0.097 | 0.044 |

**Table A1: Fraser River at Hope - Summary of Normality Tests and Correlation Analysis (2000-2021) (continued...)**

| Parameter | Data Range | Normality Test | | | | Correlation[1] | |
|---|---|---|---|---|---|---|---|
| | | Test | Test Statistic | P-Value | Test | R-Value | P-Value |
| Total Arsenic | 2000-2021 | KS | 0.218 | <0.010 | Spearman | -0.032 | 0.549 |
| Total Boron | 2003-2021 | KS | 0.101 | <0.010 | Spearman | 0.013 | 0.815 |
| Total Cadmium | 2000-2021 | KS | 0.328 | <0.010 | Spearman | -0.540 | <0.001 |
| Total Cobalt | 2000-2021 | KS | 0.260 | <0.010 | Spearman | 0.050 | 0.294 |
| Total Copper | 2000-2021 | KS | 0.239 | <0.010 | Spearman | 0.066 | 0.168 |
| Total Iron | 2000-2021 | KS | 0.257 | <0.010 | Spearman | 0.019 | 0.699 |
| Total Lead | 2000-2021 | KS | 0.233 | <0.010 | Spearman | -0.077 | 0.108 |
| Total Manganese | 2000-2021 | KS | 0.260 | <0.010 | Spearman | 0.083 | 0.084 |
| Total Molybdenum | 2000-2021 | KS | 0.083 | <0.010 | Spearman | 0.084 | 0.081 |
| Total Selenium | 2000-2021 | KS | 0.112 | <0.010 | Spearman | 0.036 | 0.501 |
| Total Silver | 2003-2021 | KS | 0.230 | <0.010 | Spearman | -0.098 | 0.067 |
| Total Zinc | 2000-2021 | KS | 0.239 | <0.010 | Spearman | 0.032 | 0.509 |
| Specific Conductance | 2000-2021 | KS | 0.084 | <0.010 | Spearman | -0.034 | 0.480 |
| Chloride | 2000-2015 | KS | 0.108 | <0.010 | Spearman | 0.163 | 0.002 |

[1] A significance level of 0.05 was used for correlation analysis.