Subject Matter Expert Report: CLIMATE, WATER TEMPERATURE, STREAMFLOW, AND WATER USE TRENDS

Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population

Prepared for:

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EXECUTIVE SUMMARY

Abundances of juvenile and adult life stages of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WCT) in the upper Fording River (UFR) were substantively lower in 2019 than 2017, indicating a large decline during that two-year period (the Westslope Cutthroat Trout Population Decline Window, referred to as the Decline Window). Teck Coal Limited (Teck Coal) initiated the "Evaluation of Cause" (EoC) to determine whether and to what extent various stressors and conditions played a role in the decline of WCT. Climatic factors and streamflow have the potential to interact with identified stressors and thereby indirectly play a role in the decline. Precipitation and temperature, as well as water uses by Teck Coal influence streamflow by changing water inputs, which in turn affect stream habitat for fish. Water temperature may also directly affect the suitability of stream habitat for fish and fish biological processes (e.g., migration, spawning, incubation).

This document reviews and compiles available climate data (air temperature, precipitation, snow depth), water temperature, streamflow data, and consumptive water use data to evaluate if, and to what extent, climate, flow, and water use may have influenced the WCT decline. Unlike other EoC SME reports, this report does not specifically evaluate these factors as stressors to fish.

Analyses were conducted to identify trends and anomalies in the data. Climatic, streamflow, and water use data were obtained from weather stations within the UFR watershed and reference sites outside of the watershed, hydrometric gauges in the UFR watershed, and groundwater wells (FR_POTWELLS) and surface water Points of Diversion (PODs), respectively. Data were analysed by standard temporal periods (months, years) and separately for each WCT life history period where relevant (spawning migration (April 1 to May 31), spawning (May 15 to July 15), incubation (May 15 to August 31), rearing (July 15 to September 30), over-wintering (or fall) migration (September 1 to October 15), and over-wintering (October 15 to March 31)). Results are focused on comparison between the Decline Window and the years prior to the Decline Window (the historical period).

Climatic, water temperature, streamflow, and water use metrics were variable among years and measurement stations, and interpretation of differences between the Decline Window and the historical period were complicated by data gaps and exceptions. In general, results suggested that:

- Air temperatures were lower during the Decline Window relative to previous years: annual average air temperatures were lower (by 0.6ºC to 1.9ºC) and monthly average air temperatures in February 2019 were the coldest (by up to 16.3ºC) across all years dating back to 2001.
- During the Decline Window relative to previous years, water temperature tended to be cooler and coldest temperatures occurred later in the year: water temperatures were up to 0.3 C and 0.8 °C cooler in 2017-2018 than 2015-2016, the number of days during which mean daily water temperatures were <1°C were greatest in 2019, mean weekly maximum water temperature >1°C below the lower bound of optimum WCT temperature ranges occurred for more WCT life history periods in 2018 and 2019 than in previous years (with the exception of 2012, which

was the same), and minimum annual water temperatures occurred in February in 2018 and 2019, whereas they occurred in December and January in previous years.

- There was no apparent trend in the timing of maximum or minimum annual precipitation, or minimum or maximum monthly precipitation; however, compared to other years, 2018-2019 was drier than the preceding years.
- Snow depths were among the lowest during the Decline Window relative to previous years and maximum snow depths occurred later during the Decline Window than in previous years.
- Average annual streamflow was among the greatest during the Decline Window relative to previous years (2014-2017), although particularly low flows occurred in December 2018 (15 % MAD) and February 2019 (20 % MAD). Average streamflow during the overwintering migration period in 2017 was the lowest on record at both FR_HC1 and FR_FRNTP, but longer streamflow records at the WSC stations indicate that streamflow was lower in 2001.
- Water use upstream of FR_FRNTP, excluding Shandley Pit and Eagle 4 Pit stored water, and Eagle Settling Pond water, was lower during the Decline Window than in previous years. (SNC-Lavalin (2021) concluded that Shandley Pit had minimal hydraulic connection to the UFR and water use from the pit was unlikely to have had a significant effect on water quantity in the Fording River during the Decline Window. Eagle Pit 4 and Eagle Settling Pond do not have a minimum instream flow requirement (IFR) specified in the water licence. This exclusion is understood to be because these locations are in pits or ponds that either have small local drainages not connected with a surface stream, are not directly hydraulically connected to the UFR, and/or have long flow pathways.) Total water use recorded for FR_POTWELLS and PODs associated with FR_FRNTP (excluding Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water) was greatest in 2016 for all WCT life stage periods, except for over-wintering which was greatest in 2015-2016, compared to other years. When Shandley Pit and Eagle 4 Pit stored water, and Eagle Settling Pond are included in the calculations, total water use was greatest in:
    - 2017 for summer rearing, over-wintering migration, and overwintering periods;
    - 2018 for the spawning and incubation periods; and
    - 2019 for the spawning migration period.
- Total water use recorded for PODs downstream of FR_FRNTP and upstream of FR_FRABCHF, including non-licensable water, was greatest for the WCT spawning and spawning migration period in 2019, greatest in the over-wintering period of 2018/2019, greatest in 2018 for the over-wintering migration period, greatest in 2017 for the summer rearing period, and greatest in 2015 for the incubation period, compared to other years.
- Total water use recorded for all PODs (including those PODs without IFRs) and non-licensable water upstream of FR_FRABCHF, was greatest for the WCT spawning

migration and spawning period in 2019, greatest during the incubation period in 2018, greatest for the summer rearing and over-wintering migration periods in 2017, and greatest of the over-wintering period in 2017-2018.

- During the Decline Window, water use (expressed as a % of available water at FR_FRNTP without water use) was greatest during the 2017 over-wintering migration and 2017-2018 over-wintering periods. However, these values are estimates due to gaps in the continuous and manual flow measurements due to ice effects. Total water use from all sources upstream of FR_FRABCHF (expressed as a % of available water at FR_FRABCHF) was greatest during the 2017 over-wintering migration period. The FR_FRABCHF gauge was installed in 2017 and therefore had only three years of data.

Requisite conditions for climate effects to cause the WCT population decline were not evaluated; however, some anomalies were identified. Climate, water temperature, hydrology, and water use were determined to be similar between the Decline Window and the historical period, with the exception of air temperatures in February 2019 and water temperatures during the spawning migration period during the Decline Window. It is unlikely that air temperature or water temperature during these periods were the single or primary cause for the observed decline in WCT, though they may have interacted with other stressors to factor in the observed decline and are identified as anomalies for consideration within other SME stressor reports during analysis of other stressor pathways.

Requisite conditions to contribute to the decline were met, as air temperatures, water temperatures, and snow cover were anomalous during portions of the winter of 2019. These conditions may have interacted with other stressors identified in the Evaluation of Cause; particularly, over-wintering ice conditions during the anomalous winter months of January through early March 2019.

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ACRONYMS AND ABBREVIATIONS

ACIS - Alberta Climate Information Service

DFO - Fisheries and Oceans Canada

EoC – Evaluation of Cause

FHAP - Fish habitat assessment procedure

FRO – Fording River Operations

GHO – Greenhills Operations

HDPE - high density polyethylene

IHA - Indicators of Hydrological Alteration

KWL - Kerr Wood Leidel

MAD - Mean Annual Discharge

PCIC - Pacific Climate Information Consortium

POD - Point of Diversion

QA - Quality Assurance

SME – Subject matter expert

SWE - Snow water equivalent

UFR – Upper Fording River

WCT – Westslope Cutthroat Trout

READER'S NOTE

What is the Evaluation of Cause and what is its purpose?

The Evaluation of Cause is the process used to investigate, evaluate and report on the reasons the Westslope Cutthroat Trout population declined in the upper Fording River between fall 2017 and fall 2019.

Background

The Elk Valley is located in the southeast corner of British Columbia (BC), Canada. It contains the main stem of the Elk River (220 km long) and many tributaries, including the Fording River (70 km long). This report focuses on the upper Fording River, which starts 20 km upstream from its confluence with the Elk River at Josephine Falls. The Ktunaxa First Nation has occupied lands in the region for more than 10,000 years. Rivers and streams of the region provide culturally important sources of fish and plants.

The upper Fording River watershed is at a high elevation and is occupied by only one fish species, a genetically pure population of Westslope Cutthroat Trout *(Oncorhynchus clarkii lewisi)* — an iconic fish species that is highly valued in the area. This population is physically isolated because Josephine Falls is a natural barrier to fish movement. The species is protected under the federal Fisheries Act and the Species at Risk Act. In BC, the Conservation Data Center categorized Westslope Cutthroat Trout as *“imperiled or of special concern, vulnerable to extirpation or extinction.”* Finally, it has been identified as a priority sport fish species by the Province of BC.

The upper Fording River watershed is influenced by various human-caused disturbances including roads, a railway, a natural gas pipeline, forest harvesting and coal mining. Teck Coal Limited (Teck Coal) operates the three surface coal mines within the upper Fording River

Evaluation of Cause

Following identification of the decline in the Westslope Cutthroat Trout population, Teck Coal initiated an Evaluation of Cause process. The overall results of this process are reported in a separate document (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports.

The report that follows this Reader’s Note is one of those Subject Matter Expert Reports.

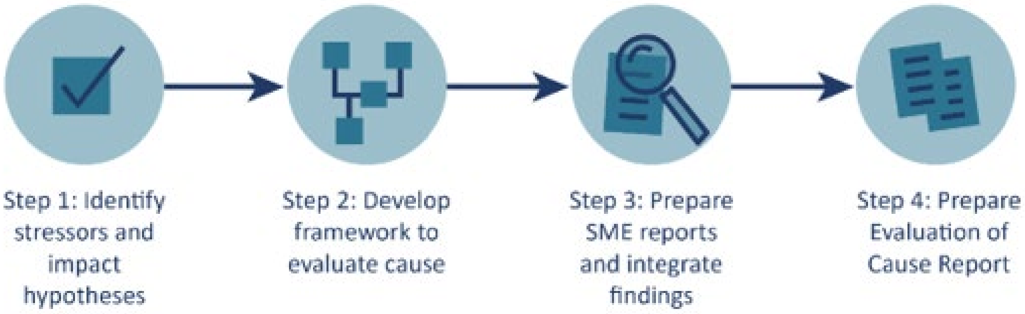
watershed, upstream of Josephine Falls: Fording River Operations, Greenhills Operations and Line Creek Operations.

Monitoring conducted for Teck Coal in the fall of 2019 found that the abundance of Westslope Cutthroat Trout adults and sub-adults in the upper Fording River had declined significantly since previous sampling in fall 2017. In addition, there was evidence that juvenile fish density had decreased. Teck Coal initiated an *Evaluation of Cause* process. The overall results of this process are reported separately (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports such as this one. The full list of SME reports follows at the end of this Reader's Note.

Building on and in addition to the Evaluation of Cause, there are ongoing efforts to support fish population recovery and implement environmental improvements in the upper Fording River.

How the Evaluation of Cause was approached

When the fish decline was identified, Teck Coal established an *Evaluation of Cause Team* (the Team), composed of *Subject Matter Experts* and coordinated by an Evaluation of Cause *Team Lead.* Further details about the Team are provided in the Evaluation of Cause report. The Team developed a systematic and objective approach (see figure below) that included developing a Framework for Subject Matter Experts to apply in their specific work. All work was subjected to rigorous peer review.



Conceptual approach to the Evaluation of Cause for the decline in the upper Fording River Westslope Cutthroat Trout population.

With input from representatives of various regulatory agencies and the Ktunaxa Nation Council, the Team initially identified potential stressors and impact hypotheses that might explain the cause(s) of the population decline. Two overarching hypotheses (essentially, questions for the Team to evaluate) were used:

- Overarching Hypothesis #1: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a single acute stressor[1] or a single chronic stressor[2].
- Overarching Hypothesis #2: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced fish numbers, but cumulatively caused the decline.

The Evaluation of Cause examined numerous stressors in the UFR to determine if and to what extent those stressors and various conditions played a role in the Westslope Cutthroat Trout's decline. Given that the purpose was to evaluate the cause of the decline in abundance from 2017 to 2019[3], it was important to identify stressors or conditions that changed or were different during that period. It was equally important to identify the potential stressors or conditions that did not change during the decline window but may, nevertheless, have been important constraints on the population with respect to their ability to respond to or recover from the stressors. Finally, interactions between stressors and conditions had to be considered in an integrated fashion. Where an *impact hypothesis* depended on or may have been exacerbated by interactions among stressors or conditions, the interaction mechanisms were also considered.

The Evaluation of Cause process produced two types of deliverables:

1. **Individual Subject Matter Expert (SME) reports** (such as the one that follows this Note): These reports mostly focus on impact hypotheses under Overarching Hypothesis #1 (see list, following). A Framework was used to align SME work for all the potential stressors, and, for consistency, most SME reports have the same overall format. The format covers: (1) rationale for impact hypotheses, (2) methods, (3) analysis and (4) findings, particularly

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[1] Implies September 2017 to September 2019.

[2] Implies a chronic, slow change in the stressor (using 2012–2019 timeframe, data dependent).

[3] Abundance estimates for adults/sub-adults are based on surveys in September of each year, while estimates for juveniles are based on surveys in August.

whether the requisite conditions4 were met for the stressor(s) to be the sole cause of the fish population decline, or a contributor to it. In addition to the report, each SME provided a summary table of findings, generated according to the Framework. These summaries were used to integrate information for the Evaluation of Cause report. Note that some SME reports did not investigate specific stressors; instead, they evaluated other information considered potentially useful for supporting SME reports and the overall Evaluation of Cause, or added context (such as in the SME report that describes climate (Wright et al., 2021).

2. **The Evaluation of Cause report** (prepared by a subset of the Team, with input from SMEs): This overall report summarizes the findings of the SME reports and further considers interactions between stressors (Overarching Hypothesis #2). It describes the reasons that most likely account for the decline in the Westslope Cutthroat Trout population in the upper Fording River.

Participation, Engagement & Transparency

To support transparency, the Team engaged frequently throughout the Evaluation of Cause process. Participants in the Evaluation of Cause process, through various committees, included:

Ktunaxa Nation Council

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BC Ministry Environment & Climate Change Strategy

Ministry of Energy, Mines and Low Carbon Innovation

Environmental Assessment Office

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[4] These are the conditions that would need to have occurred for the impact hypothesis to have resulted in the observed decline of Westslope Cutthroat Trout population in the upper Fording River.

Citation for the Evaluation of Cause Report

When citing the Evaluation of Cause Report use:

Evaluation of Cause Team, (2021). *Evaluation of Cause — Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Evaluation of Cause Team.

Citations for Subject Matter Expert Reports

Focus	Citation for Subject Matter Expert Reports
Climate, temperature, and streamflow	Wright, N., Greenacre, D., & Hatfield, T. (2021). *Subject Matter Expert Report: Climate, Water Temperature, Streamflow and Water Use Trends. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Ice	Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. Report Prepared by Ecofish Research Ltd.
Habitat availability (instream flow)	Healey, K., Little, P., & Hatfield, T. (2021). *Subject Matter Expert Report: Habitat availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.
Stranding – ramping	Faulkner, S., Carter, J., Sparling, M., Hatfield, T., & Nicholl, S. (2021). *Subject Matter Expert Report: Ramping and stranding. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.

Focus	**Citation for Subject Matter Expert Reports**
Stranding – channel dewatering	Hatfield, T., Ammerlaan, J., Regehr, H., Carter, J., & Faulkner, S. (2021). *Subject Matter Expert Report: Channel dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.
Stranding – mainstem dewatering	Hocking M., Ammerlaan, J., Healey, K., Akaoka, K., & Hatfield T. (2021). *Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd. Zathey, N., & Robinson, M.D. (2021). *Summary of ephemeral conditions in the upper Fording River Watershed. In Hocking et al. (2021). Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.
Calcite	Hocking, M., Tamminga, A., Arnett, T., Robinson M., Larratt, H., & Hatfield, T. (2021). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd.
Total suspended solids	Durston, D., Greenacre, D., Ganshorn, K & Hatfield, T. (2021). *Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Fish passage (habitat connectivity)	Harwood, A., Suzanne, C., Whelan, C., & Hatfield, T. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. Akaoka, K., & Hatfield, T. (2021). Telemetry Movement Analysis. In Harwood et al. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper*

Focus	Citation for Subject Matter Expert Reports
	Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Cyanobacteria	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd.
Algae / macrophytes	
Water quality (all parameters except water temperature and TSS [Ecofish])	Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Healey, K., & Hatfield, T. (2021). *Calculator to assess Potential for cryoconcentration in upper Fording River.* In Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.
Industrial chemicals, spills and unauthorized releases	Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Branton, M., & Power, B. (2021). *Stressor Evaluation – Sewage.* In Van Geest et al. (2021). *Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.
Wildlife predators	Dean, D. (2021). *Subject Matter Expert Report: Wildlife predation. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.

Focus	Citation for Subject Matter Expert Reports
Poaching	Dean, D. (2021). *Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.
Food availability	Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.
Fish handling	Cope, S. (2020). *Subject Matter Expert Report: Fish handling. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Westslope Fisheries Ltd.
	Korman, J., & Branton, M. (2021). *Effects of capture and handling on Westslope Cutthroat Trout in the upper Fording River: A brief review of Cope (2020) and additional calculations.* Report prepared for Teck Coal Limited. Prepared by Ecometric Research and Azimuth Consulting Group.
Infectious disease	Bollinger, T. (2021). *Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.
Pathophysiology	Bollinger, T. (2021). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.
Coal dust and sediment quality	DiMauro, M., Branton, M., & Franz, E. (2021). *Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Azimuth Consulting Group Inc.

Focus	Citation for Subject Matter Expert Reports
Groundwater quality and quantity	Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population.* Report Prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc.

1. INTRODUCTION

Abundances of adult and juvenile life stages of Westslope Cutthroat Trout (WCT) in the upper Fording River (UFR) have been estimated since 2012 using high-effort snorkel and electrofishing surveys, supported by radio-telemetry and redd surveys (Cope *et al.* 2016). Annual snorkel and electrofishing surveys were conducted in the autumn of 2012-2014, 2017, and 2019. Abundances of both juvenile and adult life stages were substantively lower in 2019 relative to 2017, indicating a large decline during that two-year period between September 2017 and September 2019 (Westslope Cutthroat Trout Population Decline Window, or Decline Window; Cope 2020). The magnitude of the decline as well as refinements in the timing of decline are reviewed in detail by Cope (2020) and Korman (2021).

Teck Coal Limited (Teck Coal) initiated the "Evaluation of Cause" (EoC) to assess factors responsible for the population decline. The EoC evaluates numerous impact hypotheses to determine whether and to what extent various stressors and conditions played a role in the decline of WCT. Given that the primary objective is to evaluate the cause of the sudden decline over a short time period (from 2017 to 2019), it is important to identify stressors or conditions that changed or were different from normal during the Decline Window. However, it is equally important to identify all potential stressors or conditions that did not change during the decline window but nevertheless may be important constraints on the population. Finally, interactions among stressors are also considered in the EoC. Where an impact hypothesis depends on interactions among stressors or conditions, or where the impact may be exacerbated by particular interactions, the mechanisms of interaction are considered as part of the evaluation of specific impact hypotheses.

A project team is evaluating the cause of WCT decline in abundance and is investigating two "overarching" hypotheses:

- Overarching Hypothesis #1: The significant decline in the UFR WCT population was a result of a single acute stressor[5] or a single chronic stressor[6].
- Overarching Hypothesis #2: The significant decline in the UFR WCT population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced WCT numbers, but cumulatively caused the decline.

Ecofish Research Ltd. (Ecofish) was asked to provide support as subject matter expert (SME) for an evaluation of stressors. This report investigates potential anomalies in climate, water temperature, streamflow, and water use, which may have interacted with identified stressors that may have caused or contributed to WCT decline in the UFR during the Decline Window.

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[5] Implies the single acute stressor acted between September 2017 and September 2019.

[6] Implies a chronic slow change in the stressor (using 2012-2019 timeframe, data dependent).

1.1. Background

1.1.1. Overall Background

This document is one of a series of SME reports that supports the overall EoC of the UFR WCT population decline (Evaluation of Cause Team 2021). For general information, see the preceding Reader's Note.

1.1.2. Report-specific Background

This report presents trends and anomalies in climatic factors. Unlike other EoC SME reports, this report does not specifically evaluate these factors as stressors to fish.

Climatic factors, such as air temperature and precipitation, water temperature, and streamflow (also referred to as flow) can directly and indirectly affect fish survival and productivity. Precipitation amounts and types (e.g., rain or snow), as well as the timing of precipitation events, and the timing, frequency and magnitude of water use by Teck Coal directly influence streamflow by changing water inputs, which, in turn, affect stream habitat for fish. Similarly, air and water temperature also affect streamflow (e.g., hot temperatures and freeze-up conditions can both cause reductions in flow), and temperatures may also directly affect the suitability of stream habitat and fish biological processes (e.g., migration, spawning, incubation), given that fish have species and life stage-specific optimal temperature ranges. Thus, climatic factors and flow may have played a role in the documented UFR WCT decline. However, although climatic factors, water temperature, and streamflow may, in extreme cases, directly cause mortality of fish, in most cases they will play an influencing role, interacting with other potential WCT stressors. For example, heavy precipitation may increase flows, or freeze-up may decrease flows, both of which could reduce the availability and suitability of habitat for WCT.

Climatic factors, including air temperature, precipitation, and snow depth, along with water temperature, streamflow, and water use (which impacts flow) by Teck Coal are considered for the EoC of WCT decline. However, because climate, water temperature, and streamflow are relevant to multiple mechanisms (i.e., may influence multiple individual stressors), no single cause-effect relationship was identified, and no pathways of effects were mapped. Instead, climatic factors and streamflow were investigated to inform investigations presented in other reports that address stressors directly. For example, low flow could influence whether fish can access over-wintering habitat, but this is better investigated directly through evaluation of fish passage conditions (e.g., water depth or velocity at specific locations) and over-wintering habitat conditions than indirectly through analysis of flow. Nevertheless, the analysis of flow can provide important context or corroboratory information and may identify additional effect pathways to investigate.

1.1.3. Author Qualifications

Todd Hatfield, Ph.D., R.P.Bio.

This project is being led by Todd Hatfield, Ph.D., a registered Professional Biologist and Principal at Ecofish Research Ltd. Todd has been a practising biological consultant since 1996 and he has focused his professional career on three core areas: environmental impact assessment of aquatic resources, environmental assessment of flow regime changes in regulated rivers, and conservation biology of freshwater fishes. Since 2012, Todd has provided expertise to a wide array of projects for Teck Coal: third party review of reports and studies, instream flow studies, environmental flow needs assessments, aquatic technical input to structured decision making processes and other decision support, environmental impact assessments, water licensing support, fish community baseline studies, calcite effects studies, habitat offsetting review and prioritizations, aquatic habitat management plans, streamflow ramping assessments, development of effectiveness and biological response monitoring programs, population modelling, and environmental incident investigations.

Todd has facilitated technical committees as part of multi-stakeholder structured decision making processes for water allocation in the Lower Athabasca, Campbell, Quinsam, Salmon, Peace, Capilano, Seymour and Fording rivers; he has been involved in detailed studies and evaluation of environmental flows needs and effects of river regulation for Lois River, China Creek, Tamihi Creek, Fording River, Duck Creek, Chemainus River, Sooke River, Nicola valley streams, Okanagan valley streams, and Dry Creek. Todd was the lead author or co-author on guidelines related to water diversion and allocation for the BC provincial government and industry, particularly as related to the determination of instream flow for the protection of valued ecosystem components in BC. He has worked on numerous projects related to water management, fisheries conservation, and impact assessments, and developed management plans and guidelines for industry and government related to many different development types. Todd is currently in his third 4-year term with COSEWIC (Committee on the Status of Endangered Wildlife in Canada) on the Freshwater Fishes Subcommittee.

Nicole Wright, Ph.D, PWS, P.Geo

Nicole Wright, the primary technical lead for this project, is a registered Professional Geoscientist with a Ph.D. in hydrology. Nicole has 17 years of experience designing, planning, and executing hydrological studies and monitoring programs with a focus on aquatic ecology, climate, and water resources. She has led studies identifying local and regional challenges presented by climate change and evaluating implications for instream flow needs and water resource management, and conducting various surface energy and water balance studies, including an assessment of potential impacts of permafrost thaw on runoff in northern watersheds.

Nicole has designed, implemented, and reported on several studies for Teck Coal Ltd since 2015. These studies include an assessment of hyporheic flows and calcite effects in relation to fish incubation on the UFR and its tributaries, an evaluation of surface and subsurface hydrology in the seasonally drying reach of the UFR, and regional flow analyses to support Teck water licence applications. Recently, Nicole led an instream flow assessment to evaluate potential effects of water diversion from Goddard Marsh in the Elk River Valley. She has also provided an environmental assessment review of the potential effects to climate and hydrology from the Quinette Teck mining project.

Nicole presents study results and contributes her technical expertise at regulatory and stakeholder meetings for various projects, including more than a dozen presentations to BC ENV in support of client impact assessment projects. Nicole has authored peer-reviewed publications in scientific journals and in-conference proceedings, environmental assessments, EAC amendments, and scoping, baseline, and monitoring reports. Her technical reviews encompass a wide range of hydrological issues, including the regulatory framework for surface and groundwater management in British Columbia; potential impacts to instream, wetland, and riparian condition and functions from proposed hydroelectric, pipeline, and mine projects; and hydrological guidance for wetland and river restoration.

1.2. Objectives

The objective of this report is to review and compile available information to evaluate if, and to what extent, climatic factors, water temperature, streamflow, and water use (due to its potential impact to streamflow) may have influenced the stressors investigated for the EoC of the UFR WCT decline. Thus, the investigation conducted in this report is unlike other EoC investigations in that, rather than directly investigating the potential for a stressor to have caused or contributed to the documented WCT decline, it supports the evaluation of Hypothesis 1 and Hypothesis 2 as they relate to other stressors.

1.3. Approach

This report provides a review and analysis of air temperature, water temperature, precipitation, snow depth, streamflow, and water use data from within the UFR watershed and from reference sites in nearby geographical proximity (Map 1). These data, along with Teck Coal operational water use information, supported an analysis used to determine if there were anomalies in climatic factors or hydrology during the Decline Window that may have interacted with other stressor and thereby caused or contributed to the WCT population decline observed in the UFR.

Given the wide range of data types, their spatial and temporal coverage, and the general objective of providing results to support further analysis of other stressors, we present the results as a series of tables, graphs, and bulleted text to facilitate efficient review of the material. These results are focused on providing a comparison between the Decline Window and the years prior to the decline window (2012-2016; referred to as the historical period). However, some caution is warranted when reviewing results of multiple comparisons with large datasets, such as presented here, because the likelihood of finding one or more statistically significant results increases with the number of comparisons made. With multiple statistical tests and very large datasets, this increased likelihood of a significant result can be controlled for with a Bonferroni correction procedure. We have not undertaken formal statistical tests, and therefore cannot implement a correction; however, we suggest a general caution is warranted and readers should bear this potential bias in mind and not place undue weight on single events or comparisons unless there is mechanistic support for their importance (i.e., other stressor evaluations support attaching biological significance to the event).

2. METHODS

2.1. Trends and anomalies

Trends and anomalies in the data were analysed by standard temporal periods (months, years) and water temperature, streamflow and water use were also examined separately for each WCT life stage periodicity (Table 1). In general, trends and anomalies were identified in the context of specific variables and their relevance to WCT life stages by comparing data during the WCT Population Decline Window (September 2017 to September 2019) with data for preceding years. For example, the assessment included identifying the relative frequency with which the coldest temperature recorded during the Decline Window occurred in other years. Wherever possible, stations with long-term records (>40 years) were used to corroborate trends found at the stations with shorter data records. Specific methods and data sources are described in the following sections.

Table 1. Periodicity of Westslope Cutthroat Trout in the upper Fording River watershed.

	Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
Life Stage	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Spawning migration													■	■	■	■	■	■	■	■																												
Spawning																			■	■	■	■	■	■	■	■																						
Incubation (egg & alevin)																			■	■	■	■	■	■	■	■	■	■	■	■	■	■																
Summer Rearing (≥7° C)																											■	■	■	■	■	■	■	■	■	■												
Over-wintering migration																																	■	■	■	■	■	■										
Over-wintering	■	■	■	■	■	■	■	■	■	■	■	■																											■	■	■	■	■	■	■	■	■	■
Juvenile migration[1]																																																

[1] No defined periodicity.

2.1.1. Air Temperature

Air temperature data were obtained from seven weather stations located in the UFR watershed and three stations with similar geographical characteristics located outside of the watershed (Map 1); the latter sites provide regional temperature data that were compared to air temperatures observed within the watershed (referred to here as reference stations). All data were provided to us as daily averages. Available information on the air temperature monitoring locations, including coordinates, elevation, period of record, and source of data, are provided in Table 2. All data were reviewed for completeness; six stations within the watershed (FRO_TCR, FRO_BRNPLAT, FRO_A Spoil, FRO_CSP, FRO_WWT, and EC Fording River Cominco) had sufficient data during the Decline Window for further evaluation. Though data from FRO_BRNPLAT were evaluated, caution was used given the extensive data gap from November 2017 to June 2018. Air temperature at FRO_WWT in 2019 were used to extend the data record at EC Fording River Cominco (referred to herein as EC Cominco) to obtain a 50-year record[7]. Air temperatures recorded at the reference stations had similar seasonal and annual trends to each other and to the stations within the UFR watershed; however, Lost Creek South reference station recorded consistently lower temperatures in all seasons than the other sites and was therefore omitted from this summary.

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[7] This approach can lead to error or bias on the data, due to differences in elevation and sensors used to measure air temperature and precipitation parameters. FRO_WWT is located approximately 2 km north of the EC Fording River Cominco climate station, but at a similar elevation. A regression analysis of daily average air temperatures at FRO_WWT and at EC Fording River Cominco from 2013-2017 resulted in a high correlation (R = 0.996; EC_Cominco Air Temp = 0.992015 * FRO_WWT Air Temp + 0.223291). Data gaps and missing air temperature data at EC Fording River Cominco prior to 2019 were transferred or infilled from regional stations using regression equations corrected for elevation differences. These data were provided by Teck and methods are described in Golder (2020).

Table 2. Location, elevation, period of record, data source, and data gaps for the weather stations in the UFR watershed and at reference sites (FLNRO Round Prairie and Lost Creek South).

Station Name	Location Description	Coordinates		Elevation	Period of Record		Source of	Data Gaps
		Northing	Easting	(masl)	Start	End	Data	
FRO_TCR	Turn Creek reclamation area	5566069	652272	1,795	24-Oct-2012	18-Dec-2019	Teck	Jan 2013; Feb 2014
FRO_BRNPLAT	Brownie Creek	5563044	655866	2,253	27-Nov-2013	25-Sep-2019	Teck	Nov 2017; Jan-Mar 2018
FRO_A-Spoil	A Spoil	5562748	650696	1,744	01-Nov-2014	19-Dec-2019	Teck	none
FR_KC6	Kilmarnock Creek upstream of diversion	5560624	657363	1,799	23-Oct-2019	31-Dec-2019	Teck	Nov 23-26; Dec 7-10
FRO_CSP	C Spoil Geonor	5559029	651547	1,690	09-Oct-2013	31-Oct-2019	Teck	none
FRO_WWT	Wastewater Treatment Facility	5558213	652477	1,616	21-Dec-2013	31-Dec-2019	Teck	none
EC Fording River Cominco	Environment Canada Station 1157630	5550416	650223	1,585	05-Jan-1970	31-Dec-2019	Teck	none[5]
Lost Creek South	Adjacent UFR watershed to east	5563044	655866	2,130	01-Sep-2008	31-Oct-2019	ACIS[3]	none
FLNRO[1] Round Prairie	Adjacent UFR watershed to west	5560465	663517	2,094	01-Mar-1980	17-Dec-2019	PCIC[4]	Dec 27-31, 2004; Jan 2005; Feb 18- Mar 8 2012; Feb 1 - Mar 15, 2017; Feb 18 - Mar 11, 2018; Feb 8 - Mar 7, 2019;
EC Sparwood[2]	Environment Canada station 1157630 and 1157631 at Sparwood	5512461	652528	1,140	01-Jan-2008	07-Nov-2019	PCIC	1-4 days every few months since January 2008

[1] FLNRO = Ministy of Forestry and Land Natural Resources Office

[2] Environment Canada (EC) Sparwood station 1157630 was also used to obtain climate normals for the region; its period of record extends back to 1980.

[3] Alberta Climate Information Service; http://www.agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

[4] Pacific Climate Information Consortium; https://data.pacificclimate.org/portal/pcds/map/

[5] Missing air temperature data were transferred from regional stations as described in Golder 2020.

Air temperature data were reviewed to identify trends and anomalies during the Decline Window, relative to historical data (pre-September 2017). Analysis of air temperature data involved computing the following summary statistics for each station: mean, minimum, and maximum air temperatures for each month of the record, and number of days with mean daily temperature >18°C and number of days with mean daily temperature <1°C and < -10°C (representing thresholds for "warm", "cold", and "very cold" temperatures based on mean annual temperatures). The summary statistics were computed from daily averages.

2.1.2. Water Temperature

Water temperature data were collected from three monitoring stations in the UFR (Map 1). Data were provided to Ecofish as 15-minute averages. All data were reviewed for gaps. Water temperature data below 0°C are typically excluded during the quality assurance (QA) process because this indicates that the location of the sensor was likely frozen in ice[8]; however, these sub-0°C data were used in this analysis to help identify anomalies. Monitoring station locations, periods of record, and the % complete of the data are provided in Table 3.

Table 3. Location, period of record, and % complete of water temperature data for the monitoring stations on the Fording River.

Station Name	Coordinates		Elevation	Period of Record		
	Northing	Easting	(masl)	Start	End	% Complete[1]
FR_HC1	5566469	652219	1,711	22-Jul-2010	31-Dec-2019	79.8
FR_FRNTP	5561675	651122	1,635	22-Jul-2010	31-Dec-2019	81.0
FR_FRABCHF	5553693	654779	1,551	06-Oct-2017	31-Dec-2019	97.0

[1] Based on the number of days with data available for a minimum of 21 hours. The low % complete for FR_HC1 and FR_FRNTP is largely due to a flood event in 2013 that damaged the sensors; the sensors were re-installed the following year.

Water temperature has the potential to influence a number of biological processes, including the timing of fish migration and spawning, and incubation success. Water temperature data were reviewed to identify trends and anomalies in the data records during the Decline Window, relative to historical data (2010-2017 for FR_HC1 and FR_FRNTP)). Table 4 describes the summary statistics calculated for water temperature and the methods of calculation. Water temperature data were analyzed to provide mean, minimum, and maximum water temperatures for each month of the record, number of days with mean daily temperature >18°C, <1°C, and between 13°C and 15°C (i.e., within the optimal temperature range for WCT), fish growing season length, and total degree-days in the growing season. The lower threshold (<1°C) is based on Oliver and Fidler (2001); the upper threshold (>18°C) is near

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[8] Liquid water (also known as supercooled water) can occur when water temperature sensor readings are <0°C.

the upper incipient lethal temperature for WCT of 19.6°C (Bear *et al.* 2007). Prolonged temperature extremes (mean weekly maximum temperature) were compared to optimum temperature ranges for WCT life stages as described in the provincial water quality guidelines for the protection of aquatic life for Cutthroat Trout (Oliver and Fidler 2001). There are no specific guidelines for WCT so we used the general Cutthroat Trout guidelines.

The guidelines for the protection of aquatic life (BC WQG) state: "Where fish distribution information is available, then mean weekly maximum water temperatures should only vary by ±1.0°C beyond the optimum temperature range of each life history phase (incubation, rearing, migration and spawning) for the most sensitive salmonid species present" (Oliver and Fidler 2001). Accordingly, mean weekly maximum water temperatures (MWMxT) were compared to the optimum temperature range for Cutthroat Trout rearing (7 to 16°C, modified from Oliver and Fidler 2001). The BC WQG optimum temperature range for WCT spawning migration, spawning, and incubation was adjusted to local conditions based on information provided in Cope *et al* (2016). The preferred temperature range of WCT spawning migration is 5-10ºC based on the start of spawning movements in the region and temperature at which spawning occurs (Cope *et al* 2016). Local WCT spawning activity occurs when water temperatures are 7-10ºC, and incubation when temperatures are 7-12ºC (Cope *et al.* 2016).

Table 4. Description of water temperature metrics and methods of calculation.

Parameter	Description	Method of Calculation
Monthly water temperature statistics	Average, minimum, and maximum temperatures on a monthly basis	Calculated from temperatures observed at or interpolated to 15-min intervals.
Number of days with extreme daily-mean temperature	>18°C and <1°C	Total number of days with daily-mean water temperature >18°C and <1°C
Number of days within the optimal daily-mean temperature	13°C - 15°C	Total number of days with daily-mean water temperature between 13°C - 15°C
Degree days in growing season	The beginning of the growing season is defined as the beginning of the first week that average stream temperatures exceed and remain above 7°C; the end of the growing season is defined as the last day of the first week that average stream temperature dropped below 7°C (modified from Coleman and Fausch 2007).	Daily average water temperatures were summed over this period (i.e., from the first day of the first week when weekly average temperatures reached and remained above 7°C until the last day of the first week when weekly average temperature dropped below 7°C)
Rate of water temperature change	Hourly rate of change in water temperature	Calculated from temperatures observed at or interpolated to 15-min intervals. The hourly rate of change was set to the difference between temperature data points that are separated by one hour and was assigned to the avarage time for these data points.
MWMxT	Mean Weekly Maximum Temperature	A 1-week moving-average filter is applied to the record of daily-maximum water temperatures inferred from hourly data; e.g., if MWMxT = 15°C on August 1, 2008, this is the average of the daily-maximum water temperatures for the 7 days from July 29 to August 4. MWMxT is calculated for every day of the year.

2.1.3. Precipitation

Precipitation data were obtained from seven weather stations located in the UFR watershed, and three reference stations (Map 1). Data were provided by Teck or downloaded from the Pacific Climate Information Consortium (PCIC) Data Portal[9] or Alberta Climate Information Service (ACIS) database[10]. All data were reviewed for gaps and had sufficient precipitation data during the Decline Window for further evaluation; data from FRO_BRNPLAT were evaluated with caution given the data gap from November 2017 to June 2018. Daily precipitation data at FRO_WWT in 2014, 2015, and 2019 were used to extend the data record at EC Cominco to obtain a 50-year record[11]. Available precipitation monitoring locations are provided in Table 5. Only two reference stations (FLNRO Round Prairie and EC Sparwood) were used in this summary as Lost Creek South had lower seasonal precipitation than all other locations, possibly due to greater interception loss given the station is in a conifer forest. Note that local undercatch[12] factors are unknown and were therefore not considered in this analysis.

All data were provided as hourly or daily precipitation; hourly values were converted to daily totals for analysis. The FRO-CSP station measures and records both precipitation and rainfall so that total daily snowfall could be computed (as precipitation minus rainfall). In addition, daily snowfall was measured and recorded at both EC Sparwood and EC Fording River at Cominco stations.

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[9] Data are collated from a number of different organizations and are available at: https://data.pacificclimate.org/portal/pcds/map/

[10] Available at: https://www.agriculture.alberta.ca/acis/weather-data-viewer.jsp

[11] Data gaps and missing air temperature data at EC Fording River Cominco (including the years 2016-2018) were transferred or infilled from other regional stations using regression equations corrected for elevation differences. These data were provided by Teck and methods are described in Golder (2020). Note that this approach can lead to errors or bias in the data given different data collection methods and site conditions (e.g., vegetation cover, elevation, etc.).

[12] "Undercatch" is the difference between the rainfall recorded by a rain gauge and the amount reaching the ground surface. Undercatch is often higher for rain gauges with rims above the ground surface and is affected by wind speed and vegetation cover.

Table 5. **Location, elevation, precipitation parameters, period of record and data gaps for the climate stations in the UFR watershed and at reference sites.**

Station Name	Coordinates		Elevation	Parameters			Period of Record		Data Gaps
	Northing	Easting	(masl)	Precipitation	Rainfall	Snowfall[4]	Start	End	
FRO_TCR	5566069	652272	1,795	x	-	-	24-Oct-2012	18-Dec-2019	Jan 2013; Feb 2014
FRO_BRNPLAT	5563044	655866	2,253	x	-	-	27-Nov-2013	25-Sep-2019	Nov 2017 to Jun 2018; Sep. 2018
FRO_A-Spoil	5562748	650696	1,744	x	-	-	01-Nov-2014	19-Dec-2019	none
FR_FRNTP	5561675	651122	1,635	-	x	-	01-Jan-2016	28-Sep-2019	none
FRO_CSP	5559029	651547	1,690	x	x	x	09-Oct-2013	31-Oct-2019	none
FRO_WWT	5558213	652477	1,616	x	-	-	21-Dec-2013	31-Dec-2019	none
EC Fording River Cominco	5550416	650223	1,585	x	x	x	01-Jan-1970	31-Dec-2019	none[5]
FLNRO[1] Round Prairie	5560465	663517	2,094	x	-	-	22-Jun-2001	17-Dec-2019	Dec 27-31, 2004; Jan 2005; Feb 18- Mar 8 2012; Feb 1 - Mar 15, 2017; Feb 18 - Mar 11, 2018; Feb 8 - Mar 7, 2019;
Lost Creek South[2]	5563044	655866	2,130	x	-	-	01-Sep-2008	31-Dec-2019	none
EC Sparwood[3]	5512461	652528	1,140	x	x	x	01-Jan-2008	07-Nov-2019	1-4 days every few months since January

[1] FLNRO = Ministry of Forestry and Land Natural Resources Office; data obtained from Pacific Climate Information Consortium; https://data.pacificclimate.org/portal/pcds/map/

[2] Data obtained from Alberta Climate Information Service; http://www.agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

[3] Environment Canada (EC) Sparwood station 1157630 was also used to obtain climate normals for the region; its period of record extends back to 1980..

[4] Snowfall was computed as Precipitation minus Rainfall in mm at FRO_CSP, and measured at the EC station.

[5] Missing data at this Environment Canada (EC) station were transferred from regional stations as described in Golder 2020.

"-" = no data available

Except where noted, data were obtained from Teck.

The precipitation data were reviewed to identify trends and anomalies during the Decline Window, relative to historical data. Analysis of these data involved computing the total, minimum and maximum precipitation for each month of the record. The percentage of snowfall to total precipitation was computed for FRO_CSP.

2.1.4. Snow Depth and Water Equivalent

Snow depth data were obtained from six weather stations in the UFR watershed and at the EC Sparwood reference station (Map 1). All data were reviewed for gaps, and all but the EC Fording River Cominco station had sufficient snow data during the Decline Window for further evaluation; however, data from FRO_BRNPLAT were used with caution due to the data gap from November 2017 to June 2018.

In addition to snow depth, snow water equivalent[13] data were obtained from three snow pillow stations located outside of the UFR watershed, but at similar elevations (Map 1). Snow water equivalent at the reference snow pillow stations had similar seasonal and annual trends to each other and to the stations within the UFR watershed; thus, for brevity, only one reference snow pillow station (Morrissey Ridge) was included in this summary.

Available information on the monitoring locations is provided in Table 6. All data were provided as daily snow depth (m) or water equivalent (mm).

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[13] The amount of liquid water contained in the snowpack.

Table 6. Location, elevation, period of record and data gaps of snow depth monitoring stations in the UFR watershed.

Station Name	Coordinates		Elevation	Period of Record		Data Gaps
	Northing	Easting	(masl)	Start	End	
FRO_TCR	5566069	652272	1,795	24-Oct-2012	18-Dec-2019	Jan 2013; Feb 2014
FRO_BRNPLAT	5563044	655866	2,253	27-Nov-2013	25-Sep-2019	Nov 2017 to Jun 2018; Sep. 2018
FRO_BRNSSLP	5563044	655866	2,240	27-Nov-2013	24-Sep-2019	none
FRO_A-Spoil	5562748	650696	1,744	01-Nov-2014	19-Dec-2019	none
FRO_WWT	5558213	652477	1,616	21-Dec-2013	31-Dec-2019	none
EC Fording River Cominco[1]	5550416	650223	1,585	01-Jan-1970	12-Apr-2017	1-31 days per month since July 2008
Lost Creek South[2]	5563044	655866	2,130	01-Sep-2008	31-Dec-2019	none
Floe Lake (2C14P)[3]	5656842	560470	2,090	01-Oct-1992	31-Dec-2019	Missing 1993, 1994, and 7-30 days per month since 1994
Morrissey Ridge (2C09Q)[3]	5478855	645689	2,139	15-Oct-1983	31-Dec-2019	Discontinuous prior to 1985. Data complete since November 2013

[1] EC = Environment Canada; data obtained from Pacific Climate Information Consortium; https://data.pacificclimate.org/portal/pcds/map/

[2] Data obtained from Alberta Climate Information Service; http://www.agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

[3] Snow pillow stations. Data obtained from the BC River Forecast Centre; https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data/automated-snow-weather-station-data

Other station data were provided by Teck.

Snow depth and water equivalent data were reviewed to identify trends and anomalies during the Decline Window, relative to historical data. Analysis of these data involved computing the average, minimum and maximum snow depth and/or water equivalent for each month of the record.

2.1.5. Streamflow

Streamflow data were obtained from three hydrometric gauges in the UFR watershed (Map 1, Table 7). Stage data were recorded by the hydrometric gauges and converted to flow using site-specific stage-flow relationships developed by Kerr Wood Leidel (KWL). Data were QA'd by KWL and provided to Ecofish as 15-minute averages. All data were then reviewed by Ecofish for gaps and the flow data time series were converted to daily averages for further analysis.

To provide historical context from a longer times series, daily streamflow from the Water Survey of Canada (WSC) Fording River at the Mouth station (08NK018) and WSC Line Creek at the Mouth station (08NK022) were also reviewed (Map 1, Table 7).

Table 7. Location, period of record and % complete for gauged flow data from monitoring stations in the UFR watershed.

Station Name	**Coordinates**		**Drainage**	**MAD**	**Period of Record**		**% Complete**[2]
	Northing	**Easting**	**(km^2)**	**(m^3/s)**	**Start**[1]	**End**	
FR_HC1	5566469	652219	47	0.906	01-May-98	01-Sep-19	15-100[5]
FR_FRNTP	5561675	651122	106	1.778	09-May-97	01-Sep-19	32-96[6]
FR_FRABCHF	5553693	654779	196	2.440	07-Oct-17	01-Sep-19	88-100
WSC FR at the Mouth[3]	5528989	653247	614	8.022	01-Jan-70	01-Sep-19	100
WSC Line Creek at the Mouth[4]	5528806	655622	138	2.652	23-Apr-71	01-Sep-19	100

[1] Data for FR_HC1, FR_FRNTP available prior to 2010 were excluded from this calculation due to large gaps and intermittent seasonal and average coverage

[2] The total number of days that flow was available in a given year.

[3] Data obtained from Water Survey of Canada (WSC) 08NK018

[4] Data obtained from Water Survey of Canada (WSC) 08NK022

[5] 84-100% complete for year-on-year records between Sept. 1, 2014 to Sept. 1, 2019

[6] 55-90% complete for year-on-year records between Sept. 1, 2014 to Sept. 1, 2019

Ecologically relevant statistics were used to describe trends and anomalies in hydrology and to flag potential effects to fish populations in the UFR. Statistical summaries were based on Richter *et al.*'s (1996) widely used "*Indicators of Hydrological Alteration*" (IHA), which comprise a set of metrics to characterize flow regimes. A subset of the full suite of IHA metrics was used, including timing, magnitude, duration, and frequency of mean, and median and extreme (minimum and maximum) flows (see Table 8). The IHA statistics were calculated using the R package by Law (2013). Inter-annual variations in these metrics were examined in the Decline Window relative to long-term data at the WSC gauge to identify anomalies.

Table 8. Hydrologic metrics used to characterize anomalies in flow regime; a subset of metrics from Richter *et al.* (1996).

IHA Indicator	Indicator Metric
Magnitude of Monthly Water Conditions	Mean value for each calendar month
Magnitude and Duration of Annual Extreme Water Conditions	Annual minimum 1, 3, 7, and 30-day flow means Annual maximum 1, 3, 7, and 30-day flow means
Timing of Annual Extreme Water Conditions	Julian date of each annual 1 day minimum Julian date of each annual 1 day maximum

2.1.6. Water Use

Water use, for the purpose of this report, is defined as FRO's surface water consumptive use at Points of Diversion (PODs) and the consumptive groundwater use from groundwater wells for potable water. There are six potable water use wells (referred to collectively as FR_POTWELLS) and 22 licensed PODs associated with FRO located above Chauncey Creek (Map 2). Based on water quality data collected at the potable wells and the Fording River, the potable wells are thought to have a hydraulic connection with surface water in the Fording River (SNC-Lavalin 2021) and were therefore summarized herein. The degree to which the river and wells are connected is uncertain, but SNC-Lavalin (2021) reviewed extraction rates in relation to flows from the Fording River and concluded that the potential flow reduction in the Fording induced by the extraction from the wells is unlikely to have played a significant role in the decline because there was no change in the pumping rates during the Decline Window. The wells are nevertheless included in the tally of water use to ensure a fulsome description of water use and possible effects on surface flow in the Fording River.

The Province determined that four of the 22 PODs (189633 [aka Eagle Settling Pond], 189638 (aka Eagle Pit 4), 189640 (aka Turnbull Pit), and 189642 (aka Henretta Pit)) can be excluded from a minimum instream flow requirement (IFR) or environmental flow needs (EFN) threshold specified in the water licence. The rationale for exclusion of these PODs is understood to be that these locations are in pits or ponds that either have small local drainages not connected with a surface stream, are not directly hydraulically connected to the UFR, and/or have long travel times. These four PODs are indicated in yellow on Map 2. No water use occurred during the Decline Window at POD 189640 (Turnbull Pit) or 189642 (Henretta Pit) and were therefore not summarized herein. Results were presented with and without water use from POD 189633 (Eagle Settling Pond) and 189638 (Eagle Pit 4).

Another POD, 189629 (Shandley Pit stored water), underwent an assessment to determine if it is hydraulically connected to the Fording River (O'Neill 2020). The conceptual hydraulic connection was found to be minimal; it was conservatively estimated to take over 9 years for water to percolate the 200 m distance between the UFR and Shandley Pit stored water (O'Neill 2020). This model has not been field verified and bedrock structural discontinuities (e.g., faults) that may act as preferential groundwater flow pathways were not characterized. Given the uncertainty, results were presented here by tallying water use with and without this water source. SNC-Lavalin (2021) noted that the estimated contribution of water stored in Shandley Pit to baseflow in the Fording River is small (<0.5%) with relatively long travel times, and concluded that water use from Shandley Pit is unlikely to have played a significant role in the decline.

Evaluation of groundwater use on Fording River flows during the Decline Window related to the Turnball Pit Development and Lake Mountain Pit Development is provided in SNC-Lavalin (2021). A comparison of water use during the decline window versus prior to the decline window depends critically on assumptions of hydraulic connectivity of the stored water sources and development of a detailed site-wide hydrology model. Such a model was not available for the EoC analyses, so we adopted a simplified approach by tallying water use with and without these water sources and did not account for time lags between use and surface flow. As such, the tallies of water use when expressed as % of surface flow are reasonable representations of water demand at those times, but provide only a coarse estimate of surface flow in the absence of water use.

Water use tallies provided in this report do not include water use from seepage return wells. The seepage return wells are an authorized works in the water licence, and are not listed as a POD in the licence because they are recycled water from the toe of the South Tailings Pond. Thus, water use from the seepage return wells is already tracked through PODs under the Coal Washing Licence.

Other locations not included in the licences are the Maintenance and Services Settling Ponds, the North Loop Settling Pond, and Smith Ponds. These are located between the FR_FRNTP and FR_FRABCHF compliance monitoring points (Map 2). FLNRO did not include water use from these ponds in water licences because they are small areas of local surface runoff and as such, were deemed not to fall within the licensing jurisdiction of the *Water Sustainability Act* (FLNRO 2017) and are considered non-licensable water by FLNRO. There was no water use from the Maintenance and Services Settling Ponds from 2015-2019. Water use from the other two non-licensable local drainages (North Loop Settling Pond and Smith Ponds) was relatively small, but was included in the tally of total water use to ensure a fulsome description of water use in the UFR.

Total daily water use recorded at all aforementioned water use locations since January 1, 2015 were provided by Teck to Ecofish. Table 9 provides a summary of the eight licensed PODs at nine locations, and two non-licensable locations that were used in this assessment, including location, type of water use, and period of record. The FR_POTWELLS consist of six wells (named FR_PW91, FR_PW92, FR_PW93, FR_PW94, FR_PW95, and FR_PW96) used for potable water (SNC-Lavalin 2017). Data were available since January 2015, with only a six-day gap in August 2017. Table 10 provides a summary of all other licensed PODs and non-licensable locations; there was no water use from the locations between 2015-2019.

Water use data were reviewed to identify trends and anomalies during the Decline Window, relative to historical data (2015-2017). POD data records by Teck improved following issuing of the current water licences in 2017; we have used the available records to describe water use from 2015 and on. All data were reviewed for gaps. To estimate the total amount of water available for fish if there had been no water use in the UFR watershed (herein referred to as total water available), the total daily water use was added to the total average daily streamflow; this calculation was computed over the duration of each WCT life stage (Table 1). The total water use over the duration of each WCT life stage was then divided by the total water available at FR_FRNTP (Measuring Point B) or FR_FRABCHF (Measuring Point C), depending on the compliance point for the POD. FR_POTWELLS were included in the water use totals when calculating the total water available at FR_FRNTP, and water use totals at non-licensable locations were included in the calculation of total water available at FR_FRABCHF. The total water use for all PODs, the FR_POTWELLS, and non-licensable locations over the duration of each WCT life stage was also divided by the total water available at FR_FRABCHF, regardless of the compliance point. The SNC-Lavalin (2021) report also reviews consumptive water use by looking at total water use by POD and average monthly use of all PODs prior to and during the Decline Window.

Table 9. **Summary of the points of diversion (PODs) and non-licensable water in the upper Fording River watershed used to evaluate water use as % of the available UFR streamflow.**

Licenced Water Source	Water Source Detail	POD Number	Minimum Instream Flow Threshold[1]	Compliance Measuring Point[2]	Water Desciption	Total Water Use Data				
						2015	2016	2017	2018	2019
Kalmakoff Pond		PD23455	Y	B	Settling Pond Attenuated		x	x		
Swift Pit	I pit	PD189629	Y	B	Stored	x	x	x		
	Shandley Pit	PD189629	Y	B	Stored	x	x	x	x	x
	Lake Mountain Pit	PD64428	Y	B	Settling Pond Attenuated					x
Liverpool Sediment Pond	Lee's Lake	PD189635	Y	B	Settling Pond Attenuated	x	x			
FR_POTWELLS		None	N	Not Applicable	Potable	x	x	x	x	x
Eagle Pit 4		PD189638	N	Not Applicable	Stored			x	x	x
Eagle Settling Ponds		PD189633	N	Not Applicable	Settling Pond Attenuated	x	x	x	x	x
Kilmarnock Control Pond		PD61147	Y	C	Settling Pond Attenuated	x	x	x		
Kilmarnock Phase 1 Secondary Pond		PD189654	Y	C	Settling Pond Attenuated				x	x
North Loop Settling Pond		Not Applicable[3]	N	Not Applicable	Settling Pond Attenuated [4]	x	x	x	x	x
Smith Ponds[3]		Not Applicable[3]	N	Not Applicable	Settling Pond Attenuated [4]	x	x			

[1] As specified in the water licence

[2] Measuring Point B = FR_FRNTP; Measuring Point C = FR_FRABCHF

[3] Non-licensable water source

[4] Local catchment not associated with a stream

Table 10. Summary of the points of diversion (PODs) and non-licensable water in the upper Fording River watershed with no water use data from 2015-2019.

Licenced Water Source	POD Number	Minimum Instream Flow Threshold[1]	Compliance Measuring Point[2]	Water Description
Henretta Lake/Pond	PD189644	Y	A	Direct
Henretta Pit	PD189642	N	Not Applicable	Stored
Turnbull Pit	PD189640	N	Not Applicable	Stored
Ben's Pit	PD186965	Y	C	Stored
Eagle Pit 6	PD189638	N	Not Applicable	Stored
Post Sediment Pond	PD189660	Y	B	Settling Pond Attenuated
Clode Settling Pond	PD189631	Y	B	Settling Pond Attenuated
Lake Mountain Settling Pond	PD189662	Y	B	Settling Pond Attenuated
Lake Mountain Creek downstream of Settling Pond	PD77714	Y	B	Direct
Fording River at the South Tailings Pond	PD23430	Y	B	Direct
Kilmarnock Phase 1 Primary	PD189652	Y	C	Settling Pond Attenuated
Kilmarnock Phase 2 Primary Pond	PD189656	Y	C	Settling Pond Attenuated
Kilmarnock Phase 2 Secondary Pond	PD189658	Y	C	Settling Pond Attenuated
Swift Creek Sediment Pond	PD189620	Y	C	Settling Pond Attenuated
Cataract Creek Sediment Pond	PD189627	Y	C	Settling Pond Attenuated
Maintenance and Services (M&S) Settling Pond	Not Applicable[3]	N	Not Applicable	Settling Pond Attenuated [4]

[1] As specified in the water licence

[2] Measuring Point A = FR_FRHC1; Measuring Point B = FR_FRNTP; Measuring Point C = FR_FRABCHF

[3] Non-licensable water source

[4] Local catchment not associated with a stream

2.2. Evaluation of Requisite Conditions

As noted in Section 1, climatic factors and flow are expected to play an influencing role, interacting with other potential WCT stressors, rather than directly causing fish mortality. The analysis of climatic factors and flow can therefore provide important context or corroboratory information and may identify additional effect pathways to investigate. The focus of the analysis is therefore to identify and draw attention to anomalies for further analysis under other stressor pathways. To maintain consistency with other SME stressor reports we provide consideration of anomalies using the evaluation framework of requisite conditions. Requisite conditions were defined to help identify anomalous climate (weather) and hydrology events that may have played a substantive role in the WCT population decline. Requisite conditions (Table 11) were based on spatial extent and location, timing and duration of events and on the intensity (magnitude) of events in relation to WCT life stage periodicity. Results from the climate and hydrology analyses were compared against requisite conditions as a means to flag potentially influential events.

Table 11. Requisite conditions for climate and hydrology to cause or contribute to the WCT population decline.

Spatial Extent	The anomalous event affected broad areas in the UFR mainstem and tributaries
Duration	Not specified; judged in combination with intensity
Location	The anomalous event occurred throughout much or all of the UFR
Timing	The anomalous event occurred during the Decline Window and exceeded guidelines (in the case of water temperature) during any of the key WCT life stage periods
Intensity	Identify anomalous events relative to historic; exceedance of thresholds for water temperature

A **requisite condition** was met when anomalous weather, streamflow or water use during the Decline Window (relative to the historical period) had the potential for impacting a large portion of the UFR fish population as inferred by the spatial and temporal (e.g., timing, duration and intensity) extent.

3. RESULTS

3.1. Air Temperature

Given the large data gaps for some stations, this report focuses on the longest and most complete data records available, while providing sufficient stations to represent the spatial and temporal variation in air temperatures across the watershed. Figure 1 presents air temperature as a seven-day running average, and a summary table of monthly averages is provided in Table 12. A summary of all historical air temperature data is available upon request. A comparison of average annual mean, minimum and maximum air temperatures before and during the Decline Window is provided in Table 13. The annual average statistics provided in the tables and text below were computed from

September of one year to September of the next to better represent conditions during the Decline Window and to avoid interruptions by the calendar year end.

- Annual average air temperatures were 0.6ºC to 1.9ºC colder during the Decline Window compared to pre-Decline Window temperatures across all stations, except for FRO_A-Spoil and EC Fording River Cominco, which recorded warmer annual average air temperatures (0.1ºC and 0.5ºC, respectively) during the Decline Window (Table 13).
- Minimum annual average air temperatures were 2.1ºC lower, on average, during the Decline Window than the pre-Decline Window across all stations, with the exception of FRO_CSP, which had similar minimum temperatures during both periods (Table 13).
    - Monthly average air temperatures in February 2019 were the coldest temperatures (up to 16.3ºC colder) recorded in February across all years at stations with records dating back to 2001 (Table 12). Monthly average air temperature in February 2019 was a 1-in-50-year event, recorded at the EC Cominco station. Within the longer-term record (dating back to 1970) at EC Cominco, February air temperatures in 1989 (-14.8ºC) were similar to 2019, but not colder than 2019 (-15.2ºC).
    - Daily average air temperatures declined more than 20ºC over two days in February 2019, following a period of warm January temperatures (Figure 2). Air temperatures remained low throughout February and the beginning of March.
- Maximum annual average air temperatures were 0.1ºC to 1.9ºC colder at three stations during the Decline Window compared to historical data; while the remaining stations recorded marginally warmer air temperatures (0.1ºC to 0.3ºC) during the Decline Window (Table 13).

Figure 1. Seven-day running average air temperature within the UFR watershed and at the FLNRO Round Prairie (RP) reference site.

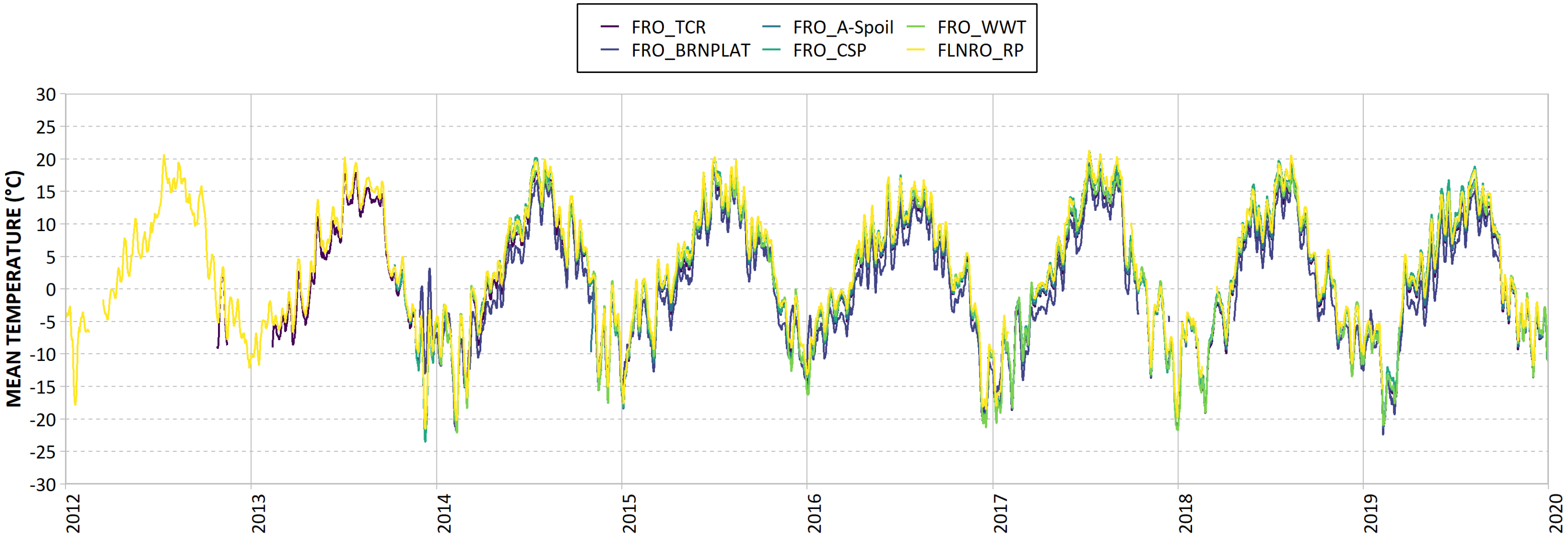


Table 12. **Monthly mean air temperatures within the UFR watershed and at reference sites (FLNRO Round Prairie and EC Sparwood) from 2012-2019.**

		Air Temperature (°C)												Sept-Sept
Year	**Climate Station**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average**
2012	FRO_TCR	-	-	-	-	-	-	-	-	-	-1.5	-3.0	-	-
	FRO_BRNPLAT	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_A-Spoil	-	-	-	-	-	-	-	-	-	-	-	-	
	FRO_CSP	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_WWT	-	-	-	-	-	-	-	-	-	-	-	-	
	EC Cominco	-8.0	-10.6	-2.7	0.6	6.7	8.6	12.9	13.9	9.7	1.3	-1.2	-10.2	2.7
	FLNRO Round Praire	**-8.3**	-6.1	-2.2	2.9	6.3	9.3	16.5	16.0	12.3	1.3	-2.7	-7.9	3.3
	EC_Sparwood	-6.1	-5.3	0.3	5.5	8.3	11.9	**17.7**	16.1	11.9	3.9	0.3	-6.1	5.2
2013	FRO_TCR	-	-6.6	-4.2	-1.4	6.3	9.5	15.0	13.7	9.5	0.5	-6.1	-10.6	1.9
	FRO_BRNPLAT	-	-	-	-	-	-	-	-	-	-	5.4	-6.1	-
	FRO_A-Spoil	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_CSP	-	-	-	-	-	-	-	-	-	0.1	-6.1	-10.8	-
	FRO_WWT	-	-	-	-	-	-	-	-	-	-	-	-6.5	-
	EC Cominco	-8.0	-4.7	-3.1	1.0	7.9	10.6	14.9	14.5	10.2	2.4	-6.1	**-10.5**	1.4
	FLNRO Round Praire	-7.5	-4.4	-2.6	0.0	8.2	11.0	16.4	15.2	10.6	1.9	-5.1	-9.7	2.1
	EC_Sparwood	-5.8	-2.1	-0.3	3.2	10.3	13.0	**17.2**	16.9	12.4	4.1	-3.4	-7.5	4.1
2014	FRO_TCR	-9.9	-	-5.4	0.0	4.8	9.1	16.1	13.2	7.9	4.5	-7.1	-8.0	2.6
	FRO_BRNPLAT	-7.9	**-14.2**	-6.4	-2.6	2.6	6.6	14.4	11.5	6.5	2.3	-8.2	-8.3	1.5
	FRO_A-Spoil	-	-	-	-	-	-	-	-	-	-	-7.2	-8.1	-
	FRO_CSP	-8.0	-13.0	-4.1	1.2	6.8	10.9	17.9	14.5	8.7	4.7	-7.2	-8.2	3.4
	FRO_WWT	-7.8	-13.3	-4.3	1.0	5.9	9.8	16.4	13.6	8.2	5.1	-6.7	-7.7	3.1
	EC Cominco	-7.8	-13.3	-4.3	1.0	5.9	9.8	16.4	13.6	8.2	5.1	-6.7	-7.7	3.1
	FLNRO Round Praire	-6.7	-12.1	-4.4	1.6	6.6	10.2	17.7	14.8	9.4	5.7	-6.3	-6.9	4.1
	EC_Sparwood	-5.1	-10.3	-2.4	4.5	8.9	12.5	**18.9**	16.7	10.5	7.9	-4.6	-5.7	5.8
2015	FRO_TCR	-7.6	-4.1	-0.6	1.0	6.0	12.5	13.6	13.4	6.9	4.5	-5.4	-8.9	2.6
	FRO_BRNPLAT	-7.3	-5.7	-2.6	-0.9	4.5	11.5	12.6	13.1	5.4	3.7	-5.9	**-9.6**	1.1
	FRO_A-Spoil	-7.6	-4.1	-0.4	1.4	6.4	12.9	14.2	13.8	7.2	4.8	-5.6	-9.0	2.8
	FRO_CSP	-7.6	-3.8	-0.3	2.6	8.1	14.4	15.4	14.5	7.4	4.5	-5.8	-9.1	3.3
	FRO_WWT	-7.6	-3.4	-0.1	2.0	6.7	13.2	14.3	13.6	7.4	4.5	-5.3	-8.7	3.1
	EC Cominco	-7.6	-3.4	-0.1	2.0	6.7	13.2	14.3	13.6	7.4	4.5	-5.3	-8.7	3.1
	FLNRO Round Praire	-6.5	-2.9	0.7	3.1	7.8	14.4	15.3	15.3	8.5	6.1	-4.3	-7.4	4.1
	EC_Sparwood	-5.1	-0.5	3.3	5.2	9.4	15.8	**17.2**	16.6	10.1	7.3	-2.5	-5.0	6.0
2016	FRO_TCR	-6.8	-3.8	-1.8	5.2	6.4	10.5	11.9	12.3	7.1	1.1	-0.8	-13.7	1.4
	FRO_BRNPLAT	-7.2	-5.7	-4.2	3.0	4.1	8.4	9.7	11.0	5.1	-1.1	-2.7	**-14.8**	-0.2
	FRO_A-Spoil	-6.9	-3.7	-1.5	5.5	6.9	10.9	12.3	12.8	7.5	1.2	-0.7	-13.8	1.6
	FRO_CSP	-6.7	-3.7	-0.8	6.6	8.4	12.1	13.5	13.7	7.9	1.3	-1.1	-13.8	2.4
	FRO_WWT	-6.8	-3.2	-0.7	5.7	7.2	11.2	12.7	12.8	7.7	1.8	-0.7	-13.5	1.9
	EC Cominco	-6.8	-3.2	-0.7	5.7	7.2	11.2	12.7	12.8	7.7	1.8	-0.7	-13.5	1.9
	FLNRO Round Praire	-5.6	-2.2	-0.3	6.9	8.1	12.1	13.3	14.2	8.4	1.9	0.2	-12.4	3.8
	EC_Sparwood	-5.1	0.3	2.9	8.5	9.8	13.5	**16.0**	16.0	10.4	4.6	2.5	-11.0	4.4
2017	FRO_TCR	-12.8	-9.5	-3.2	0.3	6.6	10.7	16.4	14.8	8.9	0.8	-5.0	-13.4	1.0
	FRO_BRNPLAT	-12.1	-10.6	-5.6	-2.3	4.9	8.6	15.4	13.4	7.3	-1.4	-	-5.9	-
	FRO_A-Spoil	-12.9	-9.6	-3.3	0.5	6.8	11.1	17.0	15.4	9.4	0.9	-5.2	-13.4	1.2
	FRO_CSP	-12.9	-8.8	-2.4	1.7	8.6	12.9	18.6	16.6	10.0	0.7	-4.9	**-13.6**	2.1
	FRO_WWT	-13.1	-9.2	-2.4	1.5	7.2	11.5	16.7	15.0	9.3	1.3	-4.4	-13.5	1.5
	EC Cominco	-13.1	-9.2	-2.4	1.5	7.2	11.5	16.7	15.0	9.3	2.3	-3.3	-12.4	2.2
	FLNRO Round Praire	-11.2	0.9	-0.6	1.5	8.6	12.8	**18.9**	17.0	11.3	1.6	-4.5	-11.0	2.8
	EC_Sparwood	-11.2	-6.8	-0.1	4.6	10.2	14.0	18.5	17.3	11.7	4.3	-1.4	-10.6	4.1
2018	FRO_TCR	-6.8	**-13.3**	-4.9	-0.5	9.0	9.3	14.0	13.6	5.5	0.4	-4.8	-8.3	0.4
	FRO_BRNPLAT	-	-	-	3.0	8.2	7.1	12.4	12.7	3.7	-0.7	-6.1	-9.9	-1.1
	FRO_A Spoil	-7.0	-13.0	-4.5	-0.1	9.6	9.7	14.6	14.0	5.9	0.6	-4.6	-8.4	0.7
	FRO_CSP	-6.6	-12.6	-3.3	1.4	11.7	11.3	16.6	15.0	6.5	0.5	-4.7	-8.3	1.7
	FRO_WWT	-6.7	-13.3	-3.8	0.4	9.9	10.2	14.7	13.8	6.4	0.8	-4.3	-8.1	1.1
	EC Cominco	-6.2	-12.6	-3.2	1.3	10.6	10.9	15.4	14.0	7.5	1.6	-3.3	-6.7	1.4
	FLNRO Round Praire	-6.1	-10.4	-1.7	1.0	11.2	10.8	16.1	15.6	6.9	1.6	-3.8	-7.3	1.9
	EC_Sparwood	-4.5	-10.6	-1.3	3.2	12.3	12.9	**17.3**	16.2	9.5	3.6	-1.3	-4.9	3.8
2019	FRO_TCR	-7.2	-15.7	-4.8	0.4	5.3	9.5	11.8	13.1	7.0	-2.6	-6.5	-6.1	-
	FRO_BRNPLAT	-7.2	**-16.6**	-6.0	-2.4	2.9	7.3	10.1	11.5	6.9	-	-	-	-
	FRO_A-Spoil	-6.9	-15.5	-4.6	0.8	5.8	9.8	12.3	13.7	7.5	-2.3	-6.4	-6.7	-
	FRO_CSP	-7.2	-14.3	-3.5	2.4	8.0	12.2	13.9	15.2	8.5	-2.0	-	-	-
	FRO_WWT	-7.4	-15.2	-4.4	1.5	6.5	10.6	12.5	13.7	8.1	-1.6	-6.2	-6.1	-
	EC Cominco[1]	-7.4	-15.2	-4.4	1.5	6.5	10.6	12.5	13.7	8.1	-1.6	-6.2	-6.1	-
	FLNRO Round Praire	-6.2	-15.4	-0.1	1.8	7.0	11.0	13.2	14.7	8.3	-1.5	-5.3	-4.4	-
	EC_Sparwood	-4.6	-13.7	-1.4	4.8	9.6	13.1	15.0	**15.9**	10.6	1.1	-1.0	-	-

Notes:

Shaded values denote minimum and maximum for each station

Bolded values denote annual minimum and maxima

Minimums and maxima were only highlighted or bolded where a full year of data were available

[1] Due to the strong correlation in average daily air temperatures, FRO_WWT data were used to fill the 2019 data gap.

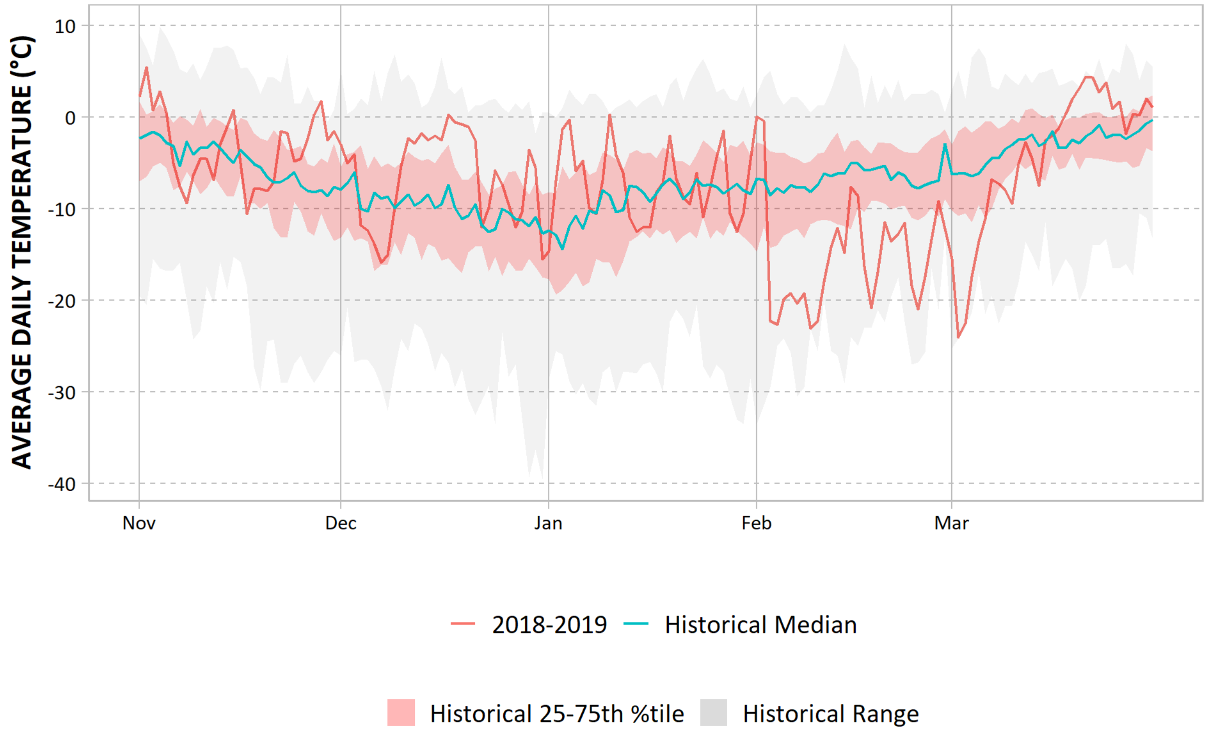
Table 13. **Difference in annual[1] mean, minimum, and maximum air temperature before and during the Decline Window. A negative difference represents a decrease in temperatures.**

Climate Station	Period	Air Temperature (°C)		
		Mean	Minimum	Maximum
FRO_TCR	Pre-Decline Window (2013-2017)	2.1	-23.3	20.3
	Decline Window	0.7	-25.3	20.5
	Difference	-1.4	-2.0	0.2
FRO_BRNPLAT[1]	Pre-Decline Window (2014-2017)	0.8	-22.1	20.2
	Decline Window	-1.1	-28.6	18.3
	Difference	-1.9	-6.5	-1.9
FRO_A-Spoil	Pre-Decline Window (2015-2017)	2.2	-23.3	20.7
	Decline Window	2.4	-24.7	20.8
	Difference	0.2	-1.4	0.1
FRO_CSP	Pre-Decline Window (2014-2017)	2.8	-24.2	22.4
	Decline Window	1.9	-24.2	22.3
	Difference	-0.9	0.0	-0.1
FRO_WWT	Pre-Decline Window (2014-2017)	2.7	-24.4	20.3
	Decline Window	1.6	-25.1	20.0
	Difference	-1.1	-0.7	-0.3
EC Fording River Cominco	Pre-Decline Window (1970-2017)	1.3	-17.1	22.0
	Decline Window	1.8	-20.7	20.8
	Difference	0.5	-3.6	-1.2
FLNRO Round Praire	Pre-Decline Window (2001-2017)	3.0	-22.6	22.6
	Decline Window	2.4	-24.0	22.9
	Difference	-0.6	-1.4	0.3
EC_Sparwood	Pre-Decline Window (1980-2017)	4.7	-31.7	25.3
	Decline Window	4.0	-32.3	25.6
	Difference	-0.7	-0.6	0.3

[*] Air temperatures were computed from September of one year to September of the following year to match the timing of the Decline Window (September 2017 to September 2019).

[1] Decline Window for FRO_BRNPLAT includes statistics for 2018-2019 only, due to data gaps.

Figure 2. **Average daily air temperature for the Fording River EC Cominco station during the winter periods of 1970-2019. Air temperatures in 2019 were estimated from data at FRO_WWT.**



The number of days with extreme daily air temperatures are provided in Table 14 for a sample of stations.

- Air temperatures were <1°C more frequently in 2018 compared to other years for stations FRO_TCR, FRO_CSP, and FRO_WWT, while air temperatures were more frequently <-10ºC at these stations, and at FRO_A-Spoil, in 2017. Overall, air temperature data indicate cold conditions were more prevalent during the Decline Window at most stations in the UFR than in previous years.
    - The number of days <1°C in 2018 was similar for all three stations and ranged from 181 to 187 days, while in 2019 the number of days ranged from 115 to 186 days depending on the station. The largest number of days <1°C since 2014 occurred in 2018 at FRO_TCR, FRO_A-Spoil, FRO_CSP, and FRO_WWT, but in 2014 at FRO_BRNPLAT and FLNRO Round Prairie.
    - The number of cold days (<1°C) increased by 24 days from 2016 to 2017 at FRO_CSP, 26 days at FRO_WWT, and by 34 days at FRO_TCR.

  - The number of days <-10ºC in 2017 was similar for all four stations and ranged from 60-63 days; the least number of days <-10ºC was 27-28 days in 2016 for the same stations. While the number of days <-10ºC is greater in 2017 than in 2019, 2019 February and early March air temperatures were the coldest on record for these stations (as described previously).
  - No generalization was made for FRO_BRNPLAT and the reference site FLNRO Round Prairie due to the number of data gaps in winter months (Table 2).
- Air temperatures were >18°C more frequently in 2017 compared to other years for all stations and were less frequently >18°C in 2016 and 2019 for most stations. Overall, air temperatures during the Decline Window were >18°C for either similar or fewer days than in the several preceding years,
  - FRO_BRNPLAT, FRO_WWT, FRO_TCR, and FRO_A-Spoil had a similar number of days >18°C in 2017 (13, 10, 15, and 21 days, respectively), and had the least number of days (1 to 3 days) >18°C in 2016 and 2019.
  - FRO_CSP had 33 days >18°C in 2017 (most) and 8 days >18°C in 2016 (least).
  - The FLNRO reference station had 36 days >18°C in 2017 (most) and 8 days >18°C in 2010 and 2016 (least).

Table 14. Summary of the number of days with mean daily air temperatures >18°C <1°C, and <-10°C.

Station	Year	Record Length (days)[1]	Days T_{air} < -10°C	Days T_{air} < 1°C	Days T_{air} > 18°C
FRO_TCR	2013	324	21	143	7
	2014	315	33	124	13
	2015	365	37	147	12
	2016	366	28	149	1
	2017	365	60	183	15
	2018	365	46	187	10
	2019	352	53	179	2
FRO_BRNPLAT	2014	358	47	**200**	7
	2015	365	36	183	12
	2016	366	35	194	1
	2017	290	38	151	13
	2018[2]	255	20	96	7
	2019	268	40	126	2
FRO_A-Spoil	2015	365	36	147	17
	2016	366	27	148	2
	2017	365	**63**	179	21
	2018	365	44	185	14
	2019	363	52	186	2
FRO_CSP	2014	365	53	164	23
	2015	365	32	140	27
	2016	366	27	148	8
	2017	365	60	172	33
	2018	365	39	182	22
	2019	304	39	115	12
FRO_WWT	2014	365	56	162	11
	2015	365	33	133	12
	2016	366	27	140	2
	2017	365	61	166	10
	2018	365	43	181	9
	2019	365	58	178	3
FLNRO Round Praire	2002	365	39	186	17
	2003	365	36	178	34
	2004	361	15	154	12
	2005	333	24	133	11
	2006	365	26	161	31
	2007	365	34	162	27
	2008	366	33	178	14
	2009	365	46	182	16
	2010	365	22	162	8
	2011	360	38	179	17
	2012	346	22	148	22
	2013	365	25	170	18
	2014	365	45	163	24
	2015	365	18	129	27
	2016	366	22	136	8
	2017	320	39	127	**36**
	2018	343	25	154	20
	2019	321	15	131	9

[1] The number of days that have observations for 21 hours or more.

[2] Air temperature data at FRO_BRNPLAT were missing from Dec. 15, 2017 to April 21, 2018.

Notes:

Shaded values denote maximum number of days for each station

Bolded values denote overall maximum number of days

3.2. Water Temperature

3.2.1. Overview

Water temperature data at FR_HC1 and FR_FRNTP were available from 2010-2019, and from October 2017 through 2019 at FR_FRABCHF. Due to gaps in the record at FR_HC1 and FR_FRNTP prior to 2015 and the short period of record at FR_FRABCHF, this review focused on water temperature from 2015-onwards at FR_HC1 and FR_FRNTP. Data prior to 2015 were used for the assessment of water temperature during the growing season and during the WCT key life stages where there was a continuous data record. Seven-day running averages of water temperature are presented in Figure 3. Table 15 presents monthly summary statistics for the available data. A summary of all historical water temperature data, including manual measurements, is available upon request.

- Warmest monthly average water temperatures occur in July and August across stations and years.
    - Maximum mean monthly water temperatures in July and August range from 8.5°C to 11.1°C from 2015 to 2017 and 8.4°C to 10.5°C from 2018 to 2019 (Table 15).
- Coldest monthly average water temperatures occur in December in 2012, 2015 and 2016, and in December, January, and February during the Decline Window.
    - Minimum mean monthly water temperatures in December and January range from 0.35°C to 0.69°C from 2015 to 2016 and 0.1°C to 1.1°C from 2017 to 2019. The minimum mean monthly water temperature recorded in December 2012 was 1.9ºC.
        - Unlike other years on record, minimum annual water temperatures occurred in February in 2018 and 2019 at all stations with data. The magnitude difference in mean February water temperature in 2018 compared to other years was 0.3 °C and 0.8°C at FR_HC1 and FR_FRNTP, respectively.
        - In 2019, the minimum mean monthly water temperature at FR_FRNTP was -1.51°C, a large decline from the mean January 2019 water temperature of 0.25°C and associated with low air temperatures (Section 3.1).
- Overall, water temperature at FR_HC1 and FR_FRNTP was slightly cooler (up to 0.3°C and 0.8°C, respectively) in 2017-2019 compared to 2015-2016.
    - The largest decrease in monthly water temperature (1.8ºC) at FR_FRNTP between 2015-2016 and 2017-2019 occurred in June, while at FR_HC1 a decrease of 2.4ºC was observed in July between 2015-2016 and 2017-2019. The significance of these cooler water temperatures to WCT is assessed further in the following sections.

Figure 3. **Daily average water temperature at monitoring stations in the UFR watershed. Abnormal water temperatures in late 2012 to early 2013 at FR_HC1 were the result of sensor malfunction.**

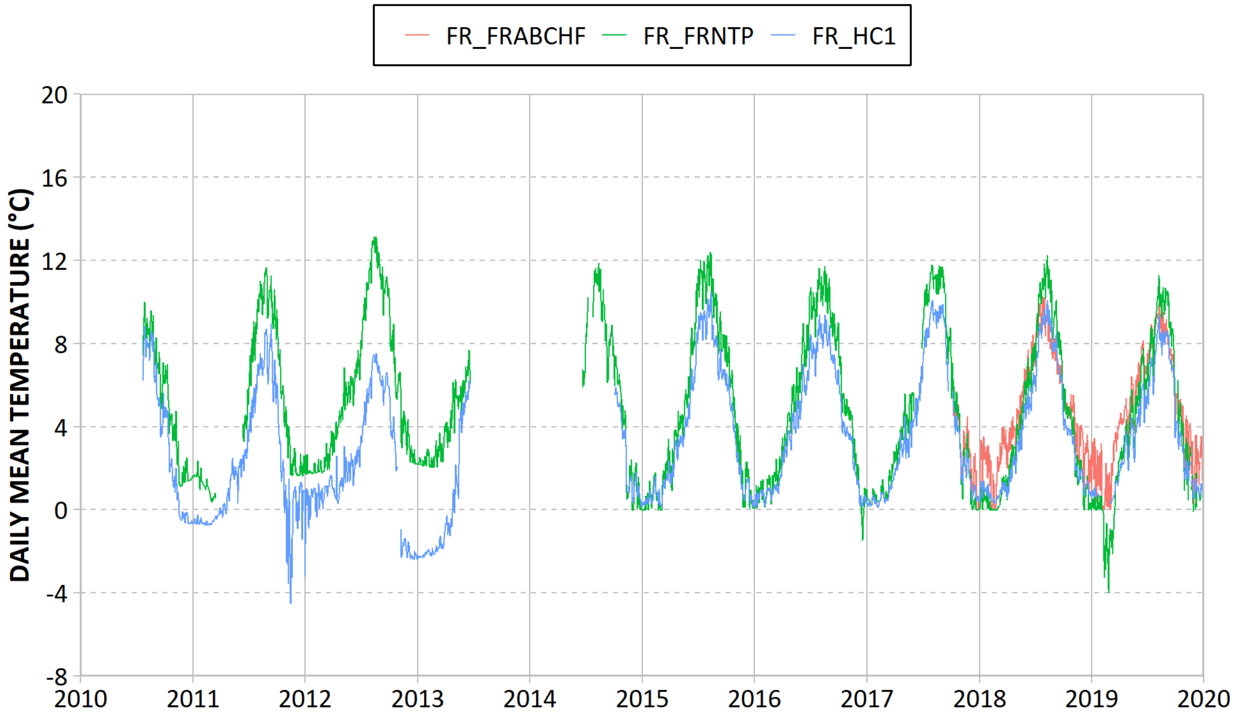


Table 15. Average monthly water temperature at the UFR watershed monitoring stations.

Year	Station	Water Temperature (°C)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	FR_HC1	-	-	-	-	-	-	-	-	-	-	-	-
	FR_FRNTP	-	-	-	-	-	-	-	8.51	6.52	5.05	2.37	1.65
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2011	FR_HC1	-	-	-	-	-	-	-	-	-	-	-	-
	FR_FRNTP	1.64	1.09	-	-	-	-	7.71	10.56	9.75	6.24	2.80	1.89
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2012	FR_HC1	0.64	0.63	1.11	-	1.90	2.39	4.79	6.93	6.02	3.61	-	-
	FR_FRNTP	1.90	1.94	2.62	4.00	5.66	6.61	9.97	12.39	10.75	7.23	4.40	2.66
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2013*	FR_HC1	-	-	-	-	-	-	-	-	-	-	-	-
	FR_FRNTP	2.29	2.42	2.96	4.15	5.48	-	-	-	-	-	-	-
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2014*	FR_HC1	-	-	-	-	-	-	-	-	-	4.88	1.87	0.88
	FR_FRNTP	-	-	-	-	-	-	11.80	10.58	8.02	6.02	2.10	0.85
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2015	FR_HC1	0.44	0.78	1.21	2.35	3.74	6.39	9.03	9.02	6.74	5.05	1.70	0.78
	FR_FRNTP	**0.35**	0.86	1.57	3.00	4.72	8.19	**11.12**	10.88	8.16	6.25	2.26	0.90
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2016	FR_HC1	**0.62**	0.71	1.24	3.05	4.45	6.35	7.92	8.52	7.07	4.41	2.63	0.58
	FR_FRNTP	0.69	0.91	1.88	3.76	5.73	8.15	10.07	**10.64**	8.84	5.64	3.48	0.46
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	-	-	-
2017	FR_HC1	0.37	0.47	0.97	2.52	3.47	5.33	8.57	9.46	8.17	4.13	2.05	0.79
	FR_FRNTP	0.53	0.65	1.46	3.23	4.68	-	10.43	**11.13**	9.32	5.25	2.17	**0.31**
	FR_FRABCHF	-	-	-	-	-	-	-	-	-	4.55	2.95	1.23
2018	FR_HC1	0.95	0.50	0.92	1.74	3.69	5.48	8.10	8.93	6.89	3.85	2.10	1.05
	FR_FRNTP	0.50	**0.04**	0.86	2.22	4.44	6.73	9.83	**10.53**	8.23	4.77	2.26	0.60
	FR_FRABCHF	2.33	1.06	2.93	3.51	5.19	7.04	9.16	8.47	6.76	4.95	3.68	2.34
2019	FR_HC1	-	-	0.91	2.53	3.54	5.12	6.62	8.42	7.01	3.21	1.63	0.93
	FR_FRNTP	0.25	**-1.51**	0.14	3.08	4.49	6.33	7.96	**10.18**	8.97	3.75	2.08	-
	FR_FRABCHF	2.00	0.86	2.65	4.39	5.33	6.93	8.09	9.01	7.35	4.43	2.83	2.34

Notes:
Shaded values denote minimum and maximum for each station, where there is a full year of data.
Bolded values denote annual minimum and maximum
"-" denotes months where less than three weeks (21 days) of data were available
* The missing data in 2013-2014 for FR_HC1 and FR_FRNTP is due to a large flood event.

3.2.2. Daily Mean Extreme Water Temperature

The number of days with extreme daily water temperatures are provided in Table 16.

- Mean daily water temperatures did not exceed 18°C at any stations across all years.
- Water temperatures were <1°C more frequently in 2017 and 2019 compared to other years at FR_HC1 and in 2018 and 2019 at FR_FRNTP. Both stations had the least number of days <1°C in 2012.
  - FR_HC1 had 101 days <1°C in 2019 (most) and 65 days <1°C in 2012 (least).
  - FR_FRNTP had 107 days <1°C in 2019 (most) and 0 days <1°C in 2012 (least).
  - The low water temperatures observed in 2019 are associated with low air temperatures, as described in Sections 3.1 and 3.2.1.

Table 16. Summary of the number of days with mean daily water temperatures >18°C, and <1°C.

Station	Year	Record Length (days)[1]	Days T_{water} <1°C	Days T_{water} >18°C
FR_HC1	2012	285	65	0
	2013	0	-	-
	2014	88	-	-
	2015	362	86	0
	2016	366	91	0
	2017	351	98	0
	2018	347	83	0
	2019	305	101	0
FR_FRNTP	2010	162	-	-
	2011	269	23	0
	2012	366	0	0
	2013	170	-	-
	2014	194	28	0
	2015	363	80	0
	2016	351	51	0
	2017	330	88	0
	2018	351	93	0
	2019	280	107	0
FR_FRABCH	2017	351	98	0
	2018	363	21	0
	2019	362	36	0

[1] The number of days that have observations for 21 hours or more.

"-" = insufficient data were available

3.2.3. Daily Mean Optimum Water Temperature

The number of days in each year when mean daily water temperatures were within the optimal temperature range for WCT (13°C - 15°C) were calculated for each station. Results from this analysis show that mean daily water temperatures were almost always below the optimal range at each of the three monitoring stations (Figure 4). At FR_HC1 and FR_FRABCHF there were no days in the record when mean daily water temperatures were in the optimal range, while at FR_FRNTP mean daily water temperatures were only within the optimal range for 5 days in 2012 and 3 days in 2014, but not in any other monitoring years where there was sufficient data (Table 17).

Sub-daily water temperature records indicate that mean daily water temperatures were typically lower than the optimal range (13°C - 15°C) for WCT, but diurnal fluctuation in water temperatures meant that during summer months water temperatures at FR_FRNTP were frequently within this range for a portion of each day. To provide additional comparison, the total time (in days) that water temperatures were within optimal range was calculated on a cumulative basis from sub-daily (15-minute interval) water temperature records (Table 17). The results of this calculation showed water temperatures were within optimum range for less than 12 days across all years at FR_FRNTP and 0.4 days or less across all years at FR_FRABCHF. Water temperatures were below optimum for the period of record at FR_HC1.

Figure 4. Mean daily water temperature at each station compared to the optimum temperature range for WCT (13ºC -15ºC).

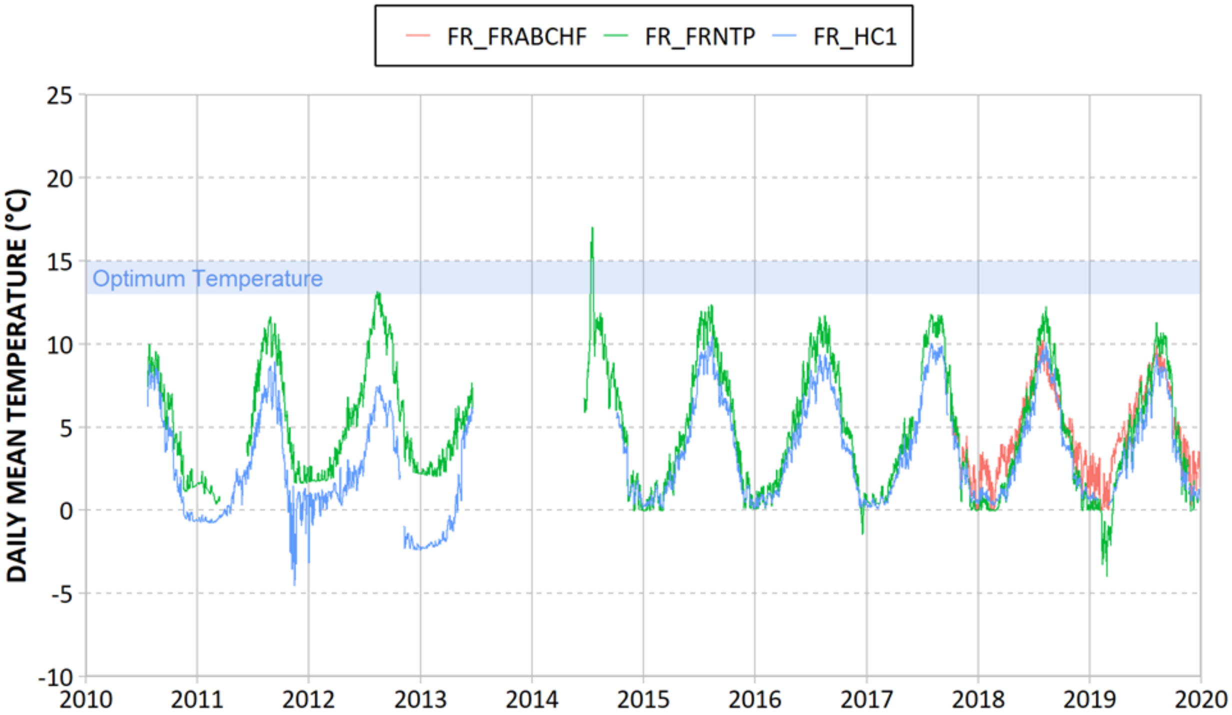


Table 17. Number of days with water temperature in optimal range for WCT (13°C - 15°C).

Station	Year	Record Length (days)[1]	Days Mean T_{water} Optimal (13°C - 15°C)	Cumulative Days T_{water} Optimal[2] (13°C - 15°C)
FR_HC1	2012	285	0	0
	2013	0	-	-
	2014	88	-	-
	2015	362	0	0
	2016	366	0	0
	2017	351	0	0
	2018	347	0	0
	2019	305	0	0
FR_FRNTP	2010	162	-	-
	2011	269	0	7
	2012	366	5	11.6
	2013	170	-	-
	2014	194	3	7.9
	2015	363	0	10
	2016	351	0	6.8
	2017	330	0	8.9
	2018	351	0	6.1
	2019	280	0	2.3
FR_FRABCHF	2017	351	0	0
	2018	363	0	0.4
	2019	362	0	0

[1] The number of days that have observations for 21 hours or more.

[2] Cumulative time when temperatures were within optimal range (15-min interval data)

"-" = insufficient data were available

3.2.4. Growing Season and Degree-days

The length of the growing season and the number of degree-days in the growing season (defined in Table 4) are important to Cutthroat Trout growth and recruitment (Coleman and Fausch 2007). One degree-day is accumulated for each degree above 0°C that occurs for one day; thus, a span of 10 days at 10°C would be measured as 100 degree-days, etc. Where the growing season is less than 800 degree-days, recruitment failure may occur, 800 to 900 degree-days may sustain recruitment in some years, and regular recruitment is expected where more than 900 degree-days are attained (Coleman and Fausch 2007). These thresholds may not be accurate for the upper Fording, but nevertheless offer useful reference points for the purpose of interannual comparisons. A data summary that characterizes the growing season by year and location for the UFR watershed is provided in Table 18.

- The growing season commenced between early-May and mid-July and ended between mid-September and early November. The length of the growing season ranged from 16 days at FR_HC1 (in 2012) to 192 days at FR_FRNTP (in 2012), with annual degree-days ranging from 116 to 1,659 between 2012-2019 (Table 18).
- There is a large variation in the number of degree-days across stations and between years.
    - Over the period of record, FR_FRNTP and FR_FRABCHF had 800 or more degree-days in the growing season, while FR_HC1 had <800 degree-days. Generally, 2018 and 2019 had less degree-days than other years on record at FR_HC1 (with the exception of 2012, which was lower) and FR_FRNTP.
    - The number of degree-days varied from a low of 800 in 2019 to a high of 1,659 in 2012 at FR_FRNTP.
    - The number of degree-days at FR_HC1 ranged from 116 degree-days in 2012 to 700 degree-days in 2017.

Table 18. Growing season metrics for UFR watershed.

Site	Year	Number of days with valid data[1]	Growing Season Data Summary				
			Start Date	End Date	Length (days)	Gap (days)	Degree-Days
FR_HC1	2012	285	18-Jul	6-Oct	16	4	116
	2013	0	-	-	-	-	-
	2014	88	-	-	-	-	-
	2015	362	4-Jun	25-Oct	74	0	645
	2016	366	31-May	19-Oct	85	0	674
	2017	351	14-Jun	23-Oct	79	0	700
	2018	347	7-Jul	13-Sep	69	0	582
	2019	305	11-Jun	1-Oct	55	0	432
FR_FRNTP	2010	162	-	-	-	-	-
	2011	269	28-Jun	2-Nov	128	1	1,070
	2012	366	2-May	10-Nov	192	0	1,659
	2013	170	-	-	-	-	-
	2014	194	23-Jun	7-Nov	137	0	1,198
	2015	321	18-May	1-Nov	168	3	1,444
	2016	351	2-Jun	6-Oct	127	0	1,089
	2017	330	14-Jun	2-Oct	111	16	1,000
	2018	351	21-Jun	26-Sep	98	1	921
	2019	280	6-Jul	1-Oct	88	4	800
FR_FRABCHF	2017	81	-	-	-	-	-
	2018	363	15-May	7-Nov	176	3	1,243
	2019	362	22-May	25-Oct	157	0	1,131

[1] The number of days that have observations for 21 hours or more.

"-" denotes values that could not be calculated due to data gaps exceeding 14 consecutive o 28 cumulative days during the growing season

3.2.5. Mean Weekly Maximum Water Temperature

Table 19, Table 20, Table 21 presents results at each station (FR_HC1, FR_FRNTP, and FR_FRABCHF, respectively) for MWMxT for the UFR watershed, including completeness of the data record and the minimum and maximum MWMxT during the WCT life stage periodicity. The table also shows the percentage of MWMxT data that were above, within, and below the optimum ranges for the different WCT life stages, as well as the percentage of MWMxT data that were greater than 1°C above and below the optimum ranges.

- Site FR_HC1 had the highest proportion of days with water temperatures below the lower threshold of optimum water temperature for all life stages.

- Site FR_FRNTP had the highest proportion of days with water temperatures above the upper threshold of optimum water temperature for all life stages.

Spawning Migration

- No stations exceeded the upper threshold of optimum water temperature for spawning migration (10°C).
- The lower threshold of optimum water temperature for spawning migration (5°C) was exceeded at all stations and years, with the exception of FR_FRABCHF in 2019 and FR_FRNTP in 2012, 2013, 2016, 2017, and 2019.
    - At FR_HC1, water temperatures were below the lower threshold of optimum water temperature for spawning migration 100% of the time in 2012 and 51-59% of the time in 2017, 2018, and 2019.
    - At FR_FRNTP, water temperatures were below the lower threshold of optimum water temperature for spawning migration 0-16% of the time in 2017-2019, compared to 0-31.3% of the time in 2012-2016.

Spawning

- The upper threshold optimum water temperature for spawning (10°C) was exceeded at FR-FRNTP in all years except 2011, 2013, and 2019, and in 2018 at FR_FRABCHF; no exceedances occurred during this period at FR_HC1.
- The lower threshold of optimum water temperature for spawning (6°C) was exceeded at all stations and years with the exception of:
    - FR_FRNTP in 2012, 2013, and 2016; and
    - FR_FRABCHF in 2018.
- At FR_FRNTP, water temperatures were below the lower threshold of optimum water temperature for spawning 12.9% of the time in 2019; based on the available data, water temperature for spawning was below the optimum threshold at this station 31.3% of the time in 2011.
- No trend in exceedances of optimum water temperature for spawning was observed at FR_HC1 over the period of record.

Incubation

- The upper threshold of optimum water temperature for incubation (12°C) was exceeded 7.4-63% of the time at FR_FRNTP over the period of record; no exceedances occurred at FR_HC1 or FR_FRABCHF.
    - At FR_FRNTP, water temperatures were above the upper threshold of optimum water temperature for incubation 7.4-63% of the time in 2017-2019, compared to 38.5-57.5% of the time in previous years.
- The lower threshold of optimum water temperature for incubation (7°C) was exceeded at all stations and years with the exception of FR_FRNTP in 2012, 2014 and 2016, and FR_FRABCHF in 2018.
    - At FR_FRNTP, water temperatures were below the lower threshold of optimum water temperature for incubation only 0.9 % of the time in 2015 and 2018.
    - No trend in the proportion of days below the lower threshold of optimum water temperature for incubation was observed at FR_HC1 or FR_FRNTP over the period of record. However, water temperatures were below the lower threshold of optimum water temperature for incubation for a greater amount of time in 2012 at FR_HC1 and in 2011 at FR_FRNTP across all years.

Rearing

- The upper threshold of optimum water temperature for rearing (16°C) was exceeded at FR_FRNTP in 2014; no other stations exceeded the threshold.
- The lower threshold of optimum water temperature for rearing (7°C) was exceeded at FR_HC1 in 3.8-7.7% of all records in 2012, 2018 and 2019, and in 2.6% of records at FR_FRABCHF in 2019.
    - No trend in the proportion of days below optimum water temperature for rearing was observed at FR_HC1 over the period of record.

Table 19. Cold and warm water temperature assessment for Westslope Cutthroat Trout using MWMxT at FR_HC1.

Station	Species	Life Stage			Year	Percent Complete	MWMxT (°C)		% of MWMxT				
		Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
FR_HC1	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2012	82	1.1	3.1	100	100	0.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	2.3	5.4	100	100	0.0	0.0	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		100	2.3	8.1	60.6	74.3	25.7	0.0	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	5.4	8.1	7.7	59.0	41.0	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2014	0.0	-	-	-	-	-	-	-
		Spawning (May 15 to July 15)	7-10	62		0.0	-	-	-	-	-	-	-
		Incubation (May 15 to Aug. 31)	7-12	110		0.0	-	-	-	-	-	-	-
		Rearing (July 15 to Sept. 30)	7-16	79		0.0	-	-	-	-	-	-	-
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2015	100	2.2	5.4	43	82	18.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	4.1	10.2	32.3	43.5	48.4	8.1	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		100	4.1	10.9	18.3	24.8	75.2	0.0	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	6.8	10.9	0.0	6.4	93.6	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2016	100	3.2	5.8	31	57	41.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	5.0	8.8	27.4	50.0	50.0	0.0	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		100	5.0	9.8	15.6	28.4	71.6	0.0	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	6.8	9.8	0.0	7.7	92.3	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2017	100	2.6	5.4	59	93	6.6	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	3.6	9.2	46.8	62.9	37.1	0.0	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		100	3.6	10.9	26.6	35.8	64.2	0.0	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		89.7	6.3	10.9	0.0	5.7	94.3	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2018	100	1.5	5.9	51	84	16.4	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	4.5	9.5	41.9	67.7	32.3	0.0	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		100	4.5	10.5	23.9	38.5	61.5	0.0	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	5.2	10.5	3.8	11.5	85.9	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2019	100	2.6	5.8	59	87	11.5	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		96.8	3.1	7.8	53.3	88.3	11.7	0.0	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		95.4	3.1	9.6	30.8	51.0	49.0	0.0	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		92.3	4.7	9.6	5.6	8.3	91.7	0.0	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Cope et al. 2016).
Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Cope et al. 2016).
"-" = data unavailable or if present only cover less than <50 % of the period

Table 20. Cold and warm water temperature assessment for Westslope Cutthroat Trout using MWMxT at FR_FRNTP.

Station	Species	Life Stage			Year	Percent Complete	MWMxT (°C)		% of MWMxT				
		Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
FR_FRNTP	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2011	0.0	-	-	-	-	-	-	-
		Spawning (May 15 to July 15)	7-10	62		51.6	3.3	10.4	31.3	46.9	46.9	6.3	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		72.5	3.3	15.2	12.7	19.0	36.7	44.3	39.2
		Rearing (July 15 to Sept. 30)	7-16	79		100	10.4	15.2	0.0	0.0	100	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2012	100	5.5	8.5	0.0	0.0	100.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	6.8	11.8	0.0	9.7	69.4	21.0	14.5
		Incubation (May 15 to Aug. 31)	7-12	110		100	6.8	16.3	0.0	5.5	54.1	40.4	38.5
		Rearing (July 15 to Sept. 30)	7-16	79		100	11.2	16.3	0.0	0.0	88.5	11.5	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2013	100	5.2	8.7	0.0	0.0	100.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		58.1	6.3	9.1	0.0	41.7	58.3	0.0	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		33.0	-	-	-	-	-	-	-
		Rearing (July 15 to Sept. 30)	7-16	79		0.0	-	-	-	-	-	-	-
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2014	0.0	-	-	-	-	-	-	-
		Spawning (May 15 to July 15)	7-10	62		41.9	-	-	-	-	-	-	-
		Incubation (May 15 to Aug. 31)	7-12	110		67.0	8.2	22.1	0.0	0.0	28.8	71.2	57.5
		Rearing (July 15 to Sept. 30)	7-16	79		100	8.9	22.1	0.0	0.0	91.0	9.0	7.7
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2015	98.4	3.7	8.3	5.0	15.0	85.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	5.8	14.6	1.6	16.1	33.9	50.0	38.7
		Incubation (May 15 to Aug. 31)	7-12	110		100	5.8	15.2	0.9	9.2	29.4	61.5	50.5
		Rearing (July 15 to Sept. 30)	7-16	79		100	9.5	15.2	0.0	0.0	100	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2016	100	5.2	8.7	0.0	0.0	100.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	7.2	13.7	0.0	0.0	35.5	64.5	41.9
		Incubation (May 15 to Aug. 31)	7-12	110		100	7.2	14.7	0.0	0.0	43.1	56.9	38.5
		Rearing (July 15 to Sept. 30)	7-16	79		100	9.5	14.7	0.0	0.0	100	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2017	100	4.3	9.3	0.0	19.7	80.3	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		54.8	5.6	13.2	8.8	14.7	38.2	47.1	44.1
		Incubation (May 15 to Aug. 31)	7-12	110		74.3	5.6	14.9	3.7	6.2	19.8	74.1	63.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	9.1	14.9	0.0	0.0	100	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2018	100	2.5	7.9	16.4	36.1	63.9	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	6.0	13.8	1.6	11.3	69.4	19.4	14.5
		Incubation (May 15 to Aug. 31)	7-12	110		100	6.0	14.7	0.9	6.4	53.2	40.4	33.9
		Rearing (July 15 to Sept. 30)	7-16	79		100	6.8	14.7	0.0	1.3	99	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2019	100	4.4	8.1	0.0	26.2	73.8	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	4.5	10.9	12.9	16.1	72.6	11.3	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		99.1	4.5	13.8	7.4	9.3	59.3	31.5	7.4
		Rearing (July 15 to Sept. 30)	7-16	79		94.9	7.6	13.8	0.0	0.0	100	0.0	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Cope et al. 2016).

Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Cope et al. 2016).

"-" = data unavailable or if present only cover less than <50 % of the period

Table 21. Cold and warm water temperature assessment for Westslope Cutthroat Trout using MWMxT at FR_FRABCHF.

Station	Species	Life Stage			Year	Percent Complete	MWMxT (°C)		% of MWMxT				
		Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
FR_FRABCHF	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2017	0.0	-	-	-	-	-	-	-
		Spawning (May 15 to July 15)	7-10	62		0.0	-	-	-	-	-	-	-
		Incubation (May 15 to Aug. 31)	7-12	110		0.0	-	-	-	-	-	-	-
		Rearing (July 15 to Sept. 30)	7-16	79		0.0	-	-	-	-	-	-	-
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2018	100	3.9	8.4	4.9	24.6	75.4	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		96.8	6.8	12.8	0.0	8.3	70.0	21.7	15.0
		Incubation (May 15 to Aug. 31)	7-12	110		98.2	6.8	12.8	0.0	4.7	82.2	13.1	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	6.2	12.8	0.0	5.1	94.9	0.0	0.0
	Westslope Cutthroat Trout	Spawning Migration (April 1 to May 31)	5-10	61	2019	100	5.0	8.9	0.0	0.0	100.0	0.0	0.0
		Spawning (May 15 to July 15)	7-10	62		100	5.3	10.7	6.5	14.5	71.0	12.9	0.0
		Incubation (May 15 to Aug. 31)	7-12	110		100	5.3	12.1	3.7	8.3	89.9	1.8	0.0
		Rearing (July 15 to Sept. 30)	7-16	79		100	5.7	12.1	2.6	6.4	93.6	0.0	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Cope et al. 2016).

Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Cope et al. 2016).

"-" = data unavailable or if present only cover less than <50 % of the period

3.3. Precipitation

Results focus on the most complete data records, while providing sufficient stations to represent the spatial and temporal variation in precipitation across the watershed. Figure 5 presents total monthly precipitation for six of the seven weather stations within the UFR watershed[14] and the FLNRO reference station located adjacent to the watershed. A table with monthly totals is provided in (Table 22). The annual precipitation totals provided in the table and text below were computed from September of one year to September of the next to better represent conditions during the Decline Window and to allow continuation across the calendar year end. For historical context, cumulative precipitation during the Decline Window is plotted relative to historical data (1980-2019) at the EC Sparwood station in Figure 6.

Precipitation is variable across years and sites, with differences in total annual precipitation as high as 564 mm between sites within the watershed. Precipitation during winter months at FR_TCR, FRO_A-Spoil, and FR_FRNTP is lower than at other stations in some years; this may reflect differences in measurement methods between stations.

- There is no apparent consistency in the timing of maximum or minimum annual precipitation, the highest and lowest total precipitation for each station occurred in different years, though generally there is less recorded precipitation during winter months. This may be due to the inability of gauges to accurately measure snowfall. This apparent deficiency is accounted for in Section 2.1.4 with the analysis of water equivalents.
- There is no apparent trend in the timing of maximum monthly precipitation; depending on station and year, it occurred as early as January and March and as late as November.
    - In 2016-2017 maximum monthly precipitation occurred in October at all stations, while in 2018-2019 maximum monthly precipitation occurred in June and July. A review of the longer data records at the FLNRO and EC climate stations indicates that 2014-2015, 2015-2016, and 2016-2017 were anomalous and peak precipitation typically occurs in spring and summer.
- There is no apparent trend in the timing of minimum monthly precipitation, which has occurred in every month except September; though long-term records show minimum monthly precipitation has occurred in September (e.g., in 2011 and 2012).
- In general, 2016-2017 had a wetter fall, while both 2017-2018 and 2018-2019 had a wetter summer (depending on station); though fall 2019 data were not evaluated as they are outside the Decline Window. The long-term data record (1980-2019) at EC Sparwood, shows

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[14] FR_FRNTP was not installed until January 2016, so was excluded from the figure, but monthly data are provided in Table 22.

2017 was wetter while 2018 was similar to the historical median for most months. 2019 was drier but had a wetter summer than 2018 (Figure 6).

Total monthly snowfall (mm) computed for FRO_CSP is shown in Figure 7 and summarized in Table 23; and a summary of total snowfall relative to total precipitation (expressed as a %) at FRO_CSP is provided in Table 24. For historical context, cumulative snowfall during the Decline Window is plotted relative to historical data (1980-2019) at the EC Sparwood station in Figure 8.

- Snowfall at FRO_CSP was greatest in the 2013-2014 and 2017-2018 winters, and lowest in 2015-2016 and 2018-2019.
    - Maximum snowfall typically occurred in November (2014, 2015, and 2017), but has occurred as late as February (2017) and March (2014); and
    - Snowfall was recorded in the summer of 2015, 2016, and 2019.
- At FRO_CSP, a smaller percentage of total precipitation fell as snow in October 2014 and 2016, November 2018, April 2016, and May 2018 compared to other years.
- Snowfall in 2016-2017 was lower than normal until February when a large snowfall event occurred, resulting in a higher-than-normal snowpack for the winter (Figure 8). The opposite occurred in 2018-2019; snowfall occurred earlier (October) than normal, but the winter had less total snowfall compared to the historical record.

Figure 5. Total monthly precipitation at six weather stations in the UFR watershed and at the FLNRO reference site located adjacent to the watershed.

Table 22. Total monthly and annual precipitation within the UFR watershed and at the FLNRO reference site.

		Total Precipitation[1] (mm)												
Year	Station	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total Annual
2012-2013	FRO_TCR	-	25.1	19.7	-	-	0.0	14.5	27.5	126.6	**231.2**	50.5	78.4	573.6
	FRO_BRNPLAT	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_A-Spoil	-	-	-	-	-	-	-	-	-	-	-	-	-
	FR_FRNTP	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_CSP	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_WWT	-	-	-	-	-	-	-	-	-	-	-	-	-
	EC_Cominco	3.5	96.3	73.5	69.4	32.6	121.9	54.8	48.8	109.8	136.4	44.1	80.1	871.1
	FLNRO Round Prairie	19.3	76.2	43.4	6.6	15.0	13.4	31.4	38.0	69.8	113.8	28.0	26.0	480.9
	EC_Sparwood	-	-	-	-	-	-	-	-	-	-	-	-	-
2013-2014	FRO_TCR	100.9	28.8	0.0	1.1	0.0	-	28.1	19.4	47.6	102.1	16.1	51.9	396.1
	FRO_BRNPLAT	-	-	-	-	-	-	-	-	-	11.8	28.5	72.8	-
	FRO_A-Spoil	-	-	-	-	-	-	-	-	-	-	-	-	-
	FR_FRNTP	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_CSP	-	26.0	96.7	32.8	71.5	64.1	116.5	51.9	65.5	68.1	24.6	37.8	655.7
	FRO_WWT	-	-	-	6.9	31.1	42.1	54.1	31.6	52.2	62.8	24.3	39.9	-
	EC_Cominco[1]	**144.4**	29.5	93.6	18.1	31.1	42.1	54.1	31.6	52.2	62.8	24.3	39.9	623.7
	FLNRO Round Prairie	71.0	18.0	26.8	7.0	2.8	1.2	0.0	64.6	58.8	50.8	12.4	23.2	336.6
	EC_Sparwood	-	-	-	-	-	-	-	-	-	-	-	-	-
2014-2015	FRO_TCR	64.8	57.1	64.3	1.9	1.7	13.7	53.0	19.8	28.3	77.2	57.2	79.6	518.6
	FRO_BRNPLAT	51.5	54.5	73.7	92.5	48.4	53.2	67.7	60.9	11.0	87.6	83.6	74.6	759.2
	FRO_A-Spoil	-	-	34.6	17.9	0.0	0.0	0.0	10.5	30.7	67.2	40.4	59.7	-
	FR_FRNTP	-	-	-	-	-	-	-	-	-	-	-	-	-
	FRO_CSP	69.1	54.7	117.4	29.0	59.5	55.5	83.0	23.1	0.0	53.8	57.7	55.4	658.3
	FRO_WWT	59.9	42.3	51.0	15.9	30.4	35.8	57.4	16.9	35.8	64.0	60.3	51.5	521.2
	EC_Cominco	59.9	42.3	51.0	15.9	30.4	35.8	57.4	16.9	35.8	64.0	60.3	51.5	521.2
	FLNRO Round Prairie	56.2	43.4	45.6	22.2	21.4	27.8	50.0	14.0	37.0	39.6	63.0	39.2	459.4
	EC_Sparwood	-	21.0	**135.3**	36.4	28.0	38.8	82.2	7.5	62.0	42.8	24.8	51.2	530.0
2015-2016	FRO_TCR	58.7	41.7	0.0	0.0	0.0	0.0	5.8	29.2	109.1	37.5	95.7	13.6	391.3
	FRO_BRNPLAT	49.3	35.9	115.1	59.5	35.6	37.7	45.2	41.2	99.4	46.5	**170.2**	57.3	792.8
	FRO_A-Spoil	54.8	38.1	32.7	4.7	0.0	0.0	0.0	21.3	80.2	36.1	108.0	44.8	420.7
	FR_FRNTP[2]	-	-	-	-	9.8	6.0	9.1	7.6	44.1	16.4	51.6	14.9	-
	FRO_CSP	7.0	16.5	129.2	54.2	31.2	32.2	46.1	28.2	89.4	31.0	119.0	34.6	618.6
	FRO_WWT	37.0	29.5	64.4	28.0	13.9	14.1	23.7	32.4	79.1	28.1	115.7	51.8	517.7
	EC_Cominco	37.0	29.5	64.4	28.0	13.9	14.1	23.7	32.4	79.1	28.1	115.7	51.8	517.7
	FLNRO Round Prairie	32.4	28.4	64.8	27.8	5.0	18.2	30.0	22.6	70.2	33.6	62.6	27.6	423.2
	EC_Sparwood	41.8	43.0	94.4	74.0	25.0	27.2	42.6	19.8	68.4	18.4	48.6	25.2	528.4
2016-2017	FRO_TCR	30.6	**119.4**	4.9	0.0	0.0	0.0	0.0	77.3	75.7	59.2	33.1	11.9	412.1
	FRO_BRNPLAT	34.5	76.2	28.9	33.4	16.4	54.0	52.2	75.7	63.7	53.5	32.2	30.0	550.9
	FRO_A-Spoil	33.6	90.4	16.2	0.0	0.0	4.1	35.7	65.7	42.5	39.5	1.2	0.0	328.9
	FR_FRNTP	17.5	48.1	11.7	1.7	4.2	9.0	20.3	25.1	25.2	12.1	12.0	3.7	190.6
	FRO_CSP	40.8	104.1	43.3	46.4	20.1	84.6	93.2	56.7	3.0	39.0	26.9	20.0	578.2
	FRO_WWT	50.3	147.2	25.5	20.5	11.4	55.5	56.5	72.1	48.1	40.0	23.1	12.7	562.9
	EC_Cominco	50.3	147.2	25.5	20.5	11.4	55.5	56.5	72.1	48.1	40.0	23.1	12.7	562.9
	FLNRO Round Prairie	24.0	83.8	19.2	6.2	12.4	0.0	21.6	72.0	37.4	30.2	14.8	9.4	331.0
	EC_Sparwood	48.0	122.4	44.8	45.8	12.6	89.2	90.6	76.0	39.8	29.6	19.6	7.6	626.0
2017-2018	FRO_TCR	27.9	88.8	44.0	0.0	0.0	0.0	0.0	37.8	29.4	111.3	63.3	24.0	426.5
	FRO_BRNPLAT	27.9	39.4	-	-	-	-	-	-	-	66.6	109.1	18.8	-
	FRO_A-Spoil	3.3	53.9	1.8	1.6	0.1	2.5	18.3	30.0	24.3	89.2	52.8	26.1	303.9
	FR_FRNTP	7.8	24.4	16.0	0.3	8.1	9.0	17.4	18.9	6.8	35.5	19.5	3.9	167.6
	FRO_CSP	20.3	91.5	**134.9**	20.4	83.7	68.3	99.1	50.0	2.3	82.5	56.0	22.6	731.5
	FRO_WWT	16.1	60.0	72.9	28.3	26.6	39.1	59.0	46.2	24.8	64.7	53.6	19.5	510.8
	EC_Cominco	16.1	70.8	85.5	34.6	51.2	34.9	37.5	36.4	21.5	47.4	35.3	19.6	490.7
	FLNRO Round Prairie	8.4	47.8	47.0	3.4	3.4	0.0	0.0	90.4	21.2	40.0	45.2	17.0	323.8
	EC_Sparwood	9.0	83.2	88.0	38.0	54.6	38.4	41.2	27.0	18.2	40.2	29.9	16.6	484.3
2018-2019	FRO_TCR	64.1	24.6	18.4	0.0	0.0	0.0	0.2	45.0	47.6	128.6	**143.5**	85.3	557.3
	FRO_BRNPLAT	-	1.8	45.6	49.2	19.2	36.5	14.9	55.6	48.8	125.7	116.0	80.0	593.3
	FRO_A-Spoil	56.8	16.9	11.9	0.0	-	-	1.6	23.6	38.2	22.4	2.8	-	-
	FR_FRNTP	14.6	9.7	10.1	3.6	2.7	5.8	2.0	12.8	17.8	28.7	47.4	14.5	169.7
	FRO_CSP	52.7	40.2	36.2	71.2	29.2	44.2	17.5	56.4	55.0	101.8	109.1	46.5	659.9
	FRO_WWT	44.9	22.9	20.2	24.6	9.4	25.9	15.0	36.5	51.8	95.2	102.0	46.1	494.5
	EC_Cominco	47.5	49.1	22.6	36.8	-	-	-	-	-	-	-	-	-
	FLNRO Round Prairie	34.4	30.8	26.8	16.2	25.4	0.2	17.2	41.2	35.4	87.2	81.2	30.4	426.4
	EC_Sparwood	38.3	54.0	20.8	40.4	27.2	37.4	4.8	30.0	38.4	78.0	90.0	35.6	494.9

[1] FRO_WWT was used to fill the missing years at EC_Cominco in 2014, 2015 and 2019.

[2] FR_FRNTP recorded daily rainfall only

Notes:

Shaded values denote the monthly minimum and maximum precipitation at each station, per year (discretion was used in years with missing months)

Bolded values denote annual monthly maximum precipitation within the watershed

Figure 6. **Cumulative precipitation recorded at the EC Sparwood climate station during the Decline Window relative to historical (1980-2019) data.**

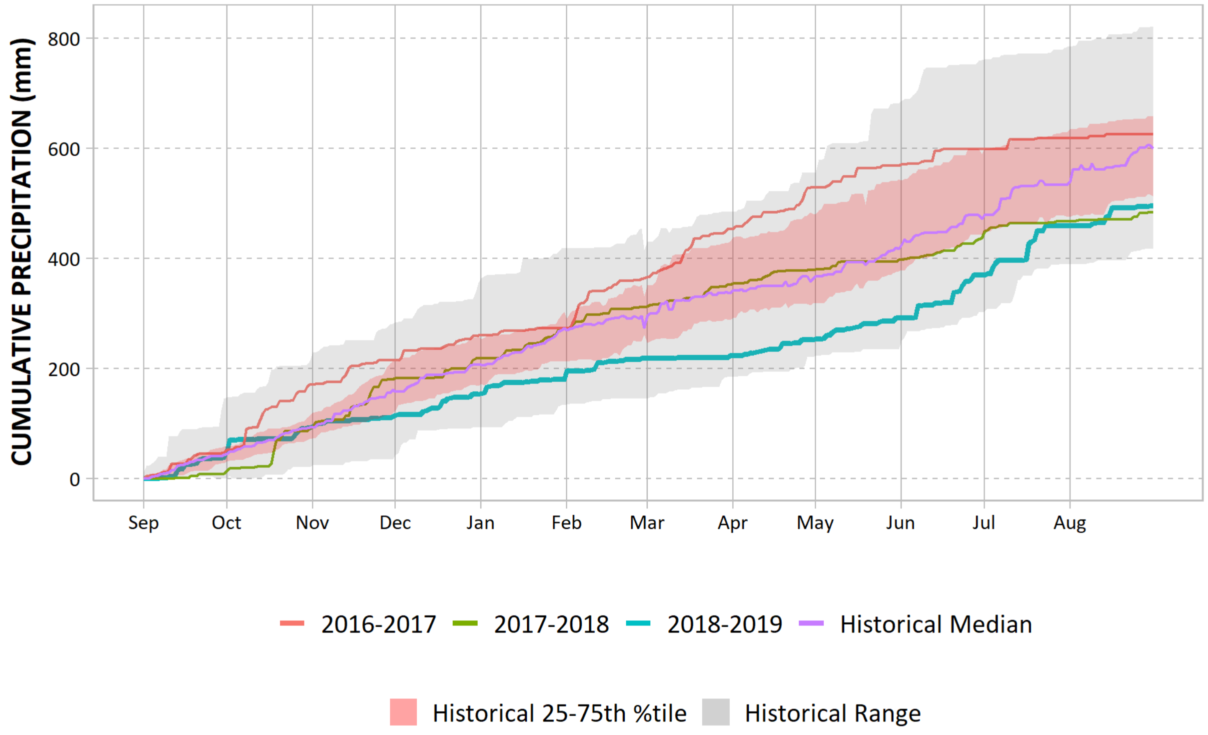


Figure 7. **Total monthly snowfall at FRO_CSP over the period of record.**

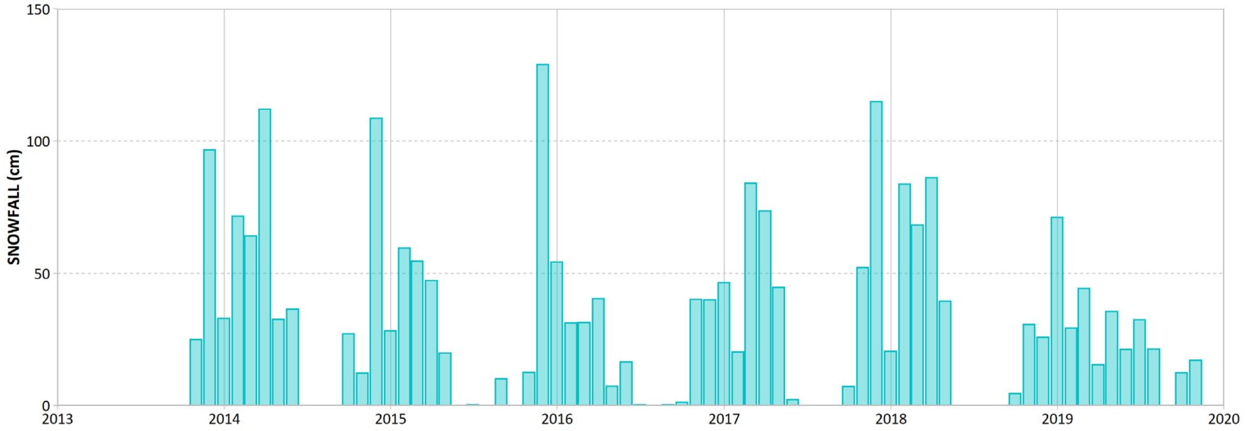


Table 23. Total monthly and annual snowfall at FRO_CSP over the period of record.

Total Snowfall (mm) at FRO_CSP													
Year	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
2013-2014	-	24.9	96.7	32.8	71.5	64.1	**112.0**	32.5	36.3	0.0	0.0	0.0	471.0
2014-2015	27.1	12.2	**108.6**	28.2	59.5	54.5	47.3	19.8	0.0	0.2	0.0	10.1	367.5
2015-2016	0.0	12.4	**128.9**	54.2	31.2	31.3	40.3	7.4	16.4	0.3	0.0	0.3	322.7
2016-2017	1.1	40.0	40.0	46.4	20.1	**84.0**	73.6	44.6	2.1	0.0	0.0	0.0	352.0
2017-2018	7.1	52.1	**115.0**	20.4	83.7	68.3	86.2	39.3	0.0	0.0	0.0	0.0	**472.1**
2018-2019	4.4	30.6	25.8	**71.2**	29.2	44.2	15.4	35.5	21.1	32.4	21.4	0.0	331.1

Notes:

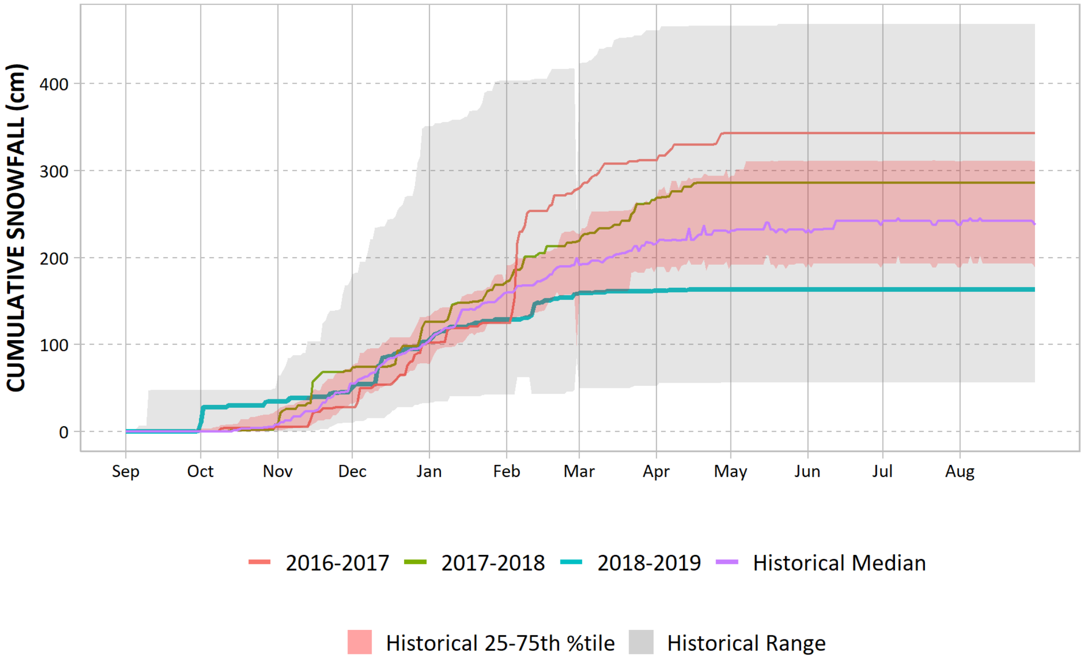
Shaded values denote maximum for each month, excluding June and July

Bolded values denote annual maximum (from Sep-Apr)

Table 24. Percentage of total monthly snowfall to total monthly precipitation at FR_CSP.

% Snowfall to Total Precipitation at FRO_CSP												
Year	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
2013-2014	-	95.6	100.0	100.0	100.0	100.0	96.1	62.7	55.4	0.0	0.0	0.0
2014-2015	39.2	22.4	92.6	97.1	100.0	98.2	56.9	85.6	-	0.4	0.0	18.1
2015-2016	-	75.4	99.8	100.0	100.0	97.1	87.4	26.0	18.3	0.9	0.0	0.7
2016-2017	2.8	38.4	92.3	100.0	100.0	99.3	79.0	78.6	70.4	0.0	0.0	0.0
2017-2018	35.0	57.0	85.2	100.0	100.0	100.0	87.0	78.7	0.0	0.0	0.0	0.0
2018-2019	8.4	76.2	71.1	100.0	100.0	100.0	87.7	62.9	38.4	31.8	19.6	0.0

Figure 8. **Cumulative snowfall recorded at the EC Sparwood climate station during the Decline Window relative to historical (1980-2019) data.**



3.4. Snow Depth and Water Equivalent

Annual and monthly snow depth statistics for the monitoring stations within the UFR watershed are provided in Table 25, and displayed graphically in Figure 9.

- Snow depths were greatest in 2017-2018 at FR_TCR, FRO_A-Spoil, and FRO_WWT. The largest snowpack was 0.84 m at FRO_A-Spoil in 2017-2018.
    - The greatest snow depths occurred between January and March at most sites and in most years; maximum snow depths generally occurred in January from 2013-2014 to 2015-2016 but more frequently were one or two months later (February or March) in subsequent years, except at FRO_BRNSSLP.
- Snow depths were generally lowest in 2014-2015, but 2018-2019 was also low at most stations (Figure 9). Cumulative snow water equivalent at the Morrissey Ridge snow pillow station shows 2018-2019 had a lower-than-normal snowpack (Figure 10).

Figure 9. Mean monthly snow depth at monitoring stations within the UFR.

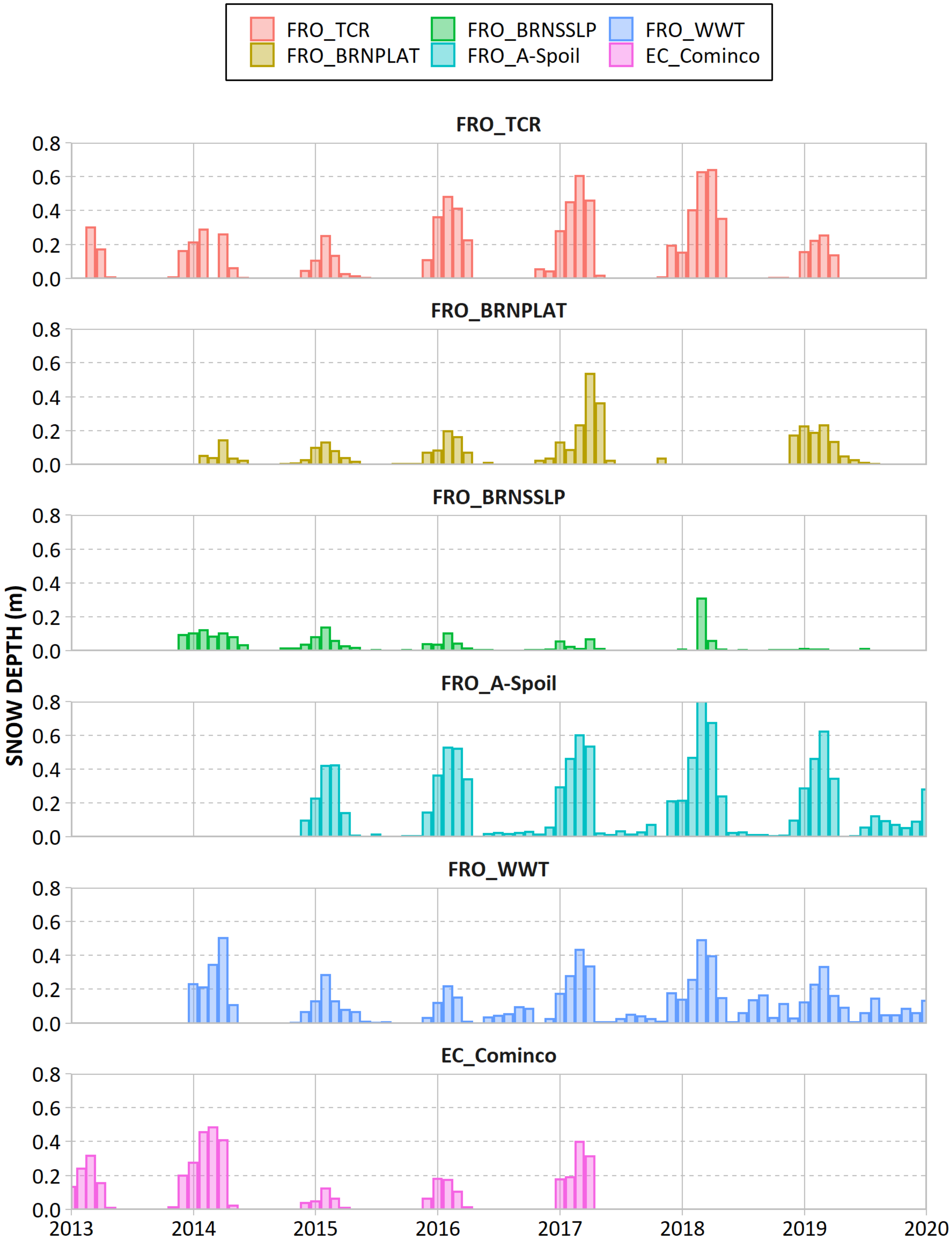


Table 25. Monthly snow depth statistics for monitoring stations in the UFR watershed.

Stations	Year	Average monthly snow depth (m)												Annual
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Average (m)
FRO_TCR	2013-2014	0.00	0.01	0.16	0.21	0.29	-	0.26	0.06	0.00	0.00	-	-	0.11
	2014-2015	0.00	0.00	0.04	0.10	0.25	0.13	0.03	0.01	0.00	0.00	0.00	0.00	0.05
	2015-2016	0.00	0.00	0.11	0.36	0.48	0.41	0.22	0.00	-	-	-	-	0.20
	2016-2017	0.02	0.05	0.04	0.28	0.45	0.60	0.46	0.02	0.00	-	-	-	0.21
	2017-2018	0.01	0.01	0.19	0.15	0.40	0.63	**0.64**	0.35	0.00	-	-	0.00	**0.24**
	2018-2019	0.00	0.00	0.00	0.15	0.22	0.25	0.14	0.00	0.00	-	-	-	0.09
FRO_BRNPLAT	2013-2014	-	-	0.00	0.05	0.05	0.04	0.14	0.03	0.02	-	-	-	0.05
	2014-2015	0.00	0.01	0.03	0.10	0.13	0.08	0.04	0.01	0.00	0.00	0.00	0.00	0.03
	2015-2016	0.00	0.00	0.07	0.08	0.20	0.16	0.07	0.00	0.01	-	-	0.00	0.06
	2016-2017	0.00	0.02	0.04	0.13	0.09	0.23	0.53	**0.36**	0.02	-	-	-	**0.16**
	2017-2018	0.01	0.04	-	-	-	-	-	-	-	0.14	0.30	0.24	0.14
	2018-2019	-	0.07	0.17	0.22	0.19	0.23	0.13	0.05	0.03	0.01	0.00	0.00	0.10
FRO_BRNSSLP	2013-2014	-	-	0.09	0.10	0.12	0.08	0.10	0.08	0.03	0.00	0.00	0.00	**0.06**
	2014-2015	0.01	0.01	0.04	0.08	0.14	0.06	0.03	0.02	0.00	0.00	0.00	0.00	0.03
	2015-2016	0.01	0.00	0.04	0.04	0.10	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.02
	2016-2017	0.00	0.01	0.01	0.06	0.02	0.01	0.07	0.01	0.00	-	-	-	0.02
	2017-2018	0.00	0.01	0.00	0.01	0.04	**0.31**	0.06	0.01	0.00	0.00	0.00	0.00	0.04
	2018-2019	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
FRO_A-Spoil	2013-2014	-	-	-	-	-	-	-	-	-	-	-	-	-
	2014-2015	-	-	0.10	0.23	0.42	0.42	0.14	0.01	0.00	0.01	0.00	0.00	0.13
	2015-2016	0.00	0.00	0.14	0.36	0.53	0.52	0.34	0.00	0.02	0.02	0.02	0.02	0.17
	2016-2017	0.03	0.01	0.06	0.29	0.46	0.60	0.53	0.02	0.01	0.03	0.01	0.03	0.17
	2017-2018	0.07	0.00	0.21	0.21	0.47	**0.84**	0.67	0.24	0.02	0.03	0.01	0.01	**0.23**
	2018-2019	0.01	0.01	0.10	0.29	0.46	0.62	0.34	0.00	0.00	0.06	0.12	0.09	0.17
FRO_WWT	2013-2014	-	-	-	0.23	0.21	0.34	0.50	0.11	0.00	0.00	0.00	0.00	0.15
	2014-2015	0.00	0.00	0.07	0.13	0.28	0.13	0.08	0.07	0.01	0.00	0.00	-	0.07
	2015-2016	0.00	0.00	0.03	0.12	0.22	0.15	0.01	0.00	0.04	0.04	0.05	0.09	0.06
	2016-2017	0.08	0.00	0.03	0.17	0.28	0.43	0.34	0.00	0.01	0.02	0.05	0.04	0.12
	2017-2018	0.02	0.01	0.18	0.14	0.26	**0.49**	0.39	0.15	0.01	0.06	0.13	0.16	**0.17**
	2018-2019	0.03	0.11	0.03	0.12	0.23	0.33	0.16	0.09	0.01	0.06	0.14	0.05	0.11
EC Fording River Cominco	2013-2014	0.00	0.02	0.27	0.39	0.57	**0.71**	0.53	0.03	0.00	0.00	0.00	0.00	0.21
	2014-2015	0.00	0.00	0.06	0.06	0.18	0.09	0.02	0.15	0.00	0.00	0.00	0.00	0.05
	2015-2016	0.00	0.00	0.10	0.28	0.30	0.16	0.06	0.00	0.00	0.00	0.00	0.00	0.08
	2016-2017	0.00	0.00	0.00	0.28	0.43	0.57	0.47	0.00	-	-	-	-	**0.22**
	2017-2018	-	-	-	-	-	-	-	-	-	-	-	-	-
	2018-2019	-	-	-	-	-	-	-	-	-	-	-	-	-

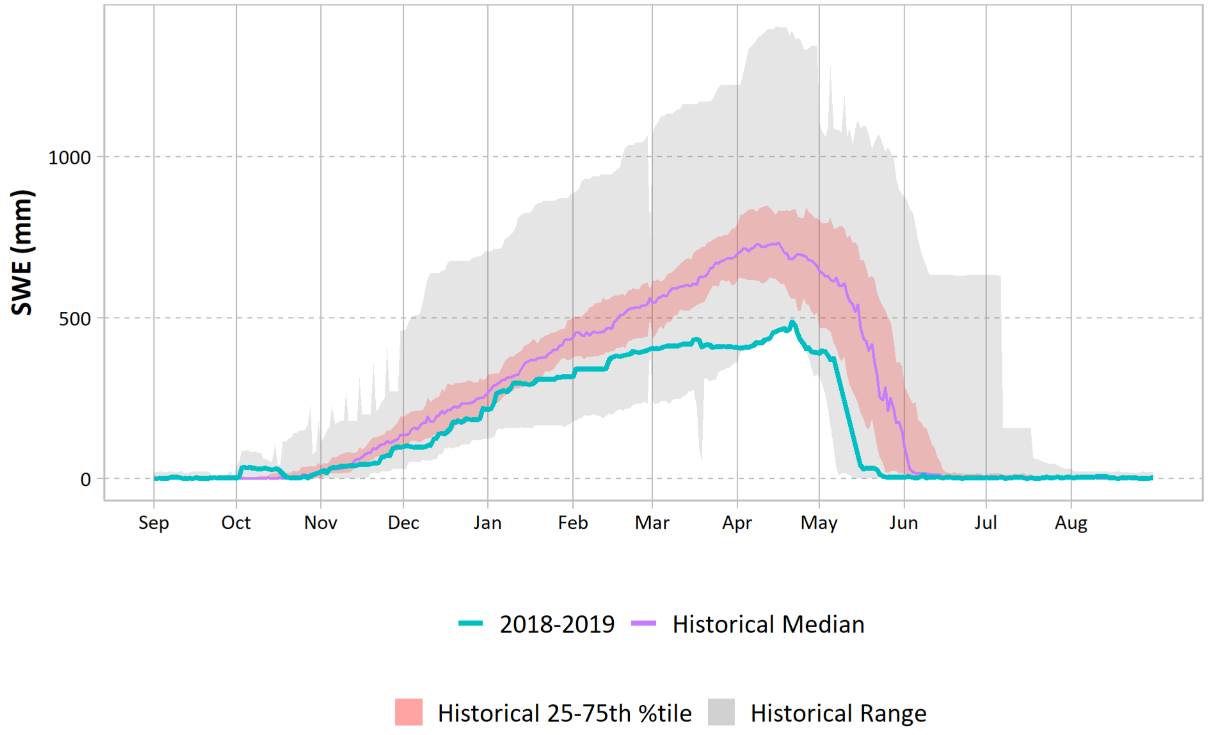
Notes:

"-" = no data available

Shaded values denote the maximum monthly snow depth at each station, per year

Bolded values denote annual monthly maximum snow depth within the watershed, and maximum annual snow depth for each station

Figure 10. **Cumulative snow water equivalent (SWE) during the Decline Window relative to the historical SWE at Morrissey Ridge.**



3.5. Streamflow

3.5.1. Overview

Annual streamflow statistics at the hydrometric gauges in the UFR watershed and the WSC Line Creek gauge are summarized in Table 26 and mean daily streamflow for all stations are displayed in Figure 11. Mean monthly streamflow at FR_HC1 and FR_FRNTP during the Decline Window is expressed as a percentage of mean annual discharge (MAD) in Table 27. The annual average statistics provided in the table and text below were computed from September of one year to September of the next to better represent conditions during the Decline Window and to avoid interruptions by the calendar year end. Due to gaps in the record and the short period of record at FR_FRABCHF, the review focused on streamflow from 2014-onwards at FR_HC1 and FR_FRNTP. Data prior to 2014 were used for the assessment of streamflow during the WCT key life stages where there was a continuous data record. The streamflow record at the WSC Fording River at Mouth gauge was used to provide historical context. Streamflow data for Line Creek (WSC Line Creek at Mouth gauge), a tributary of the Fording River, is provided as a reference stream due to its long record (1971-2019).

Average annual streamflow was greatest in 2018-2019 at FR_HC1 (Measuring Point A) and in 2016-2017 at FR_FRNTP (Measuring Point B) (Table 26). The lowest average annual streamflow since 2014 occurred in 2014-2015 at both gauges. For reference, the highest annual average streamflow at the WSC FR station (13.1 m^3/s) occurred in 1971-1972, and the lowest streamflow (4.22 m^3/s) occurred in 2000-2001.

Annual mean monthly streamflow was greatest in May or June at both FR_HC1 and FR_FRNTP, depending on the year (Table 27). During the Decline Window, annual mean monthly flow was greatest in May 2017-2018 at both gauges, with flow as a percentage of mean annual discharge (%MAD; discharge meaning streamflow) exceeding 400%. Streamflow was higher at both gauges in June 2013 when a flood event occurred that damaged the gauges; during this event, peak flow at FR_FRNTP was estimated as 140 m^3/s (>7000% MAD) (KWL 2014).

The lowest mean monthly streamflow at FR_HC1 occurred in March 2016 (approximately 20% MAD) and February 2018 (17% MAD). The month in which the lowest average streamflow occurred at FR_HC1 could not be determined in 2018-2019 due to a data gap in January and February 2019; however, monthly streamflow in December 2018 (15% MAD) was lower than the 2017-2018 observed minimum streamflow. Data gaps in continuous streamflow during winter months due to ice effects meant the lowest monthly streamflow at FR_FRNTP could not be determined; however, mean flows in February 2019 (20 % MAD) were the lowest of any month from September 2016 to September 2019. Manual streamflow measurements made in January, February and December 2018 were used to estimate mean flows in these months. These measurements indicate that streamflow during January and February 2018 may have been similar to flows measured in February 2019.

Table 26. Annual streamflow statistics for hydrometric stations in the UFR.

Year[1]	Streamflow (m^3/s)														
	FR_HC1			FR_FRNTP			FR_FRABCHF			FR at the Mouth - WSC 08NK018			LC at the Mouth - WSC 08NK022		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
2010-2011	3.8	2.06	7.474	5.61	0.78	17.13	-	-	-	9.04	1.36	54.00	1.89	0.58	7.42
2011-2012	6.02	0.36	15.44	5.36	0.70	21.63	-	-	-	11.41	1.36	65.10	2.23	0.57	10.08
2012-2013	0.81	0.02	7.08	1.07	0.50	1.56	-	-	-	11.26	1.48	195.0	2.98	0.59	12.35
2013-2014	1.46	0.26	9.361	1.98	0.07	16.89	-	-	-	9.22	0.95	58.60	2.86	0.66	11.38
2014-2015	0.79	0.11	4.67	1.57	0.26	6.84	-	-	-	6.26	1.58	32.80	2.27	0.56	7.59
2015-2016	0.81	0.18	3.79	1.60	0.21	7.25	-	-	-	6.04	1.22	21.40	1.76	0.64	4.86
2016-2017	0.97	0.16	10.73	2.55	0.42	11.16	-	-	-	7.87	1.55	46.40	1.87	0.48	5.06
2017-2018	1.07	0.09	7.36	1.91	0.30	14.13	2.83	0.79	21.15	7.22	1.19	50.00	2.06	0.54	7.65
2018-2019	1.09	0.12	5.46	2.10	0.29	9.19	2.23	0.67	10.08	6.12	1.56	29.29	1.76	0.50	7.82

[1] Calculated from September to September. The records for FR_HC1 and FR_FRNTP have large data gaps during the period 2010-2014 and should be reviewed with caution, as should minimum flows in all years due to data gaps as a result of ice effects. Data prior to 2010 are not shown.

Shaded values denote minimum and maximum average streamflow for years 2014 onwards.

Figure 11. **Average daily streamflow (m^3/s) at the hydrometric gauges in the UFR watershed from 2010-2019. Lower plot shows streamflow on a log scale.**

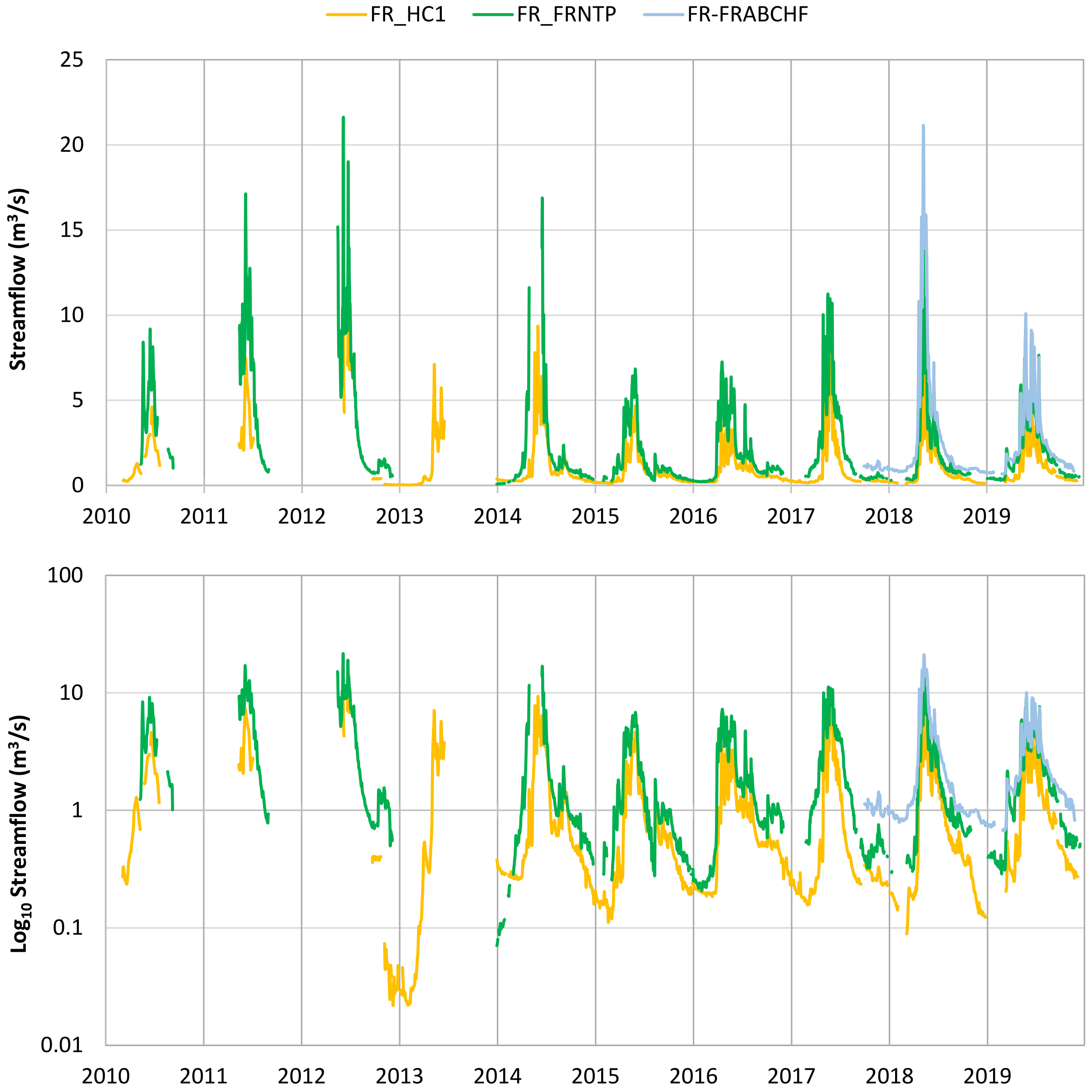


Table 27. Mean monthly streamflow at FR_HC1 and FR_FRNTP during the Decline Window, expressed as percent mean annul discharge (MAD).

Station	Month	2016-2017		2017-2018		2018-2019	
		Mean Flow (m^3/s)	% MAD	Mean Flow (m^3/s)	% MAD	Mean Flow (m^3/s)	% MAD
FR_HC1	Sept	0.51	57	0.25	28	0.50	56
	Oct	0.55	61	0.32	36	0.38	42
	Nov	0.48	53	0.27	30	0.25	28
	Dec	0.33	36	0.24	27	0.14	15
	Jan	0.23	25	0.19	20	-	-
	Feb	0.19	21	0.15	17	-	-
	Mar	0.18	20	0.17	19	0.37	41
	Apr	0.34	37	0.60	66	0.36	40
	May	3.59	396	4.15	458	1.54	170
	June	3.87	427	2.54	281	3.14	346
	July	1.06	117	1.51	166	2.39	264
	August	0.37	40	0.66	73	1.12	124
FR_FRNTP	Sept	0.78	44	0.56	32	0.81	46
	Oct	0.96	54	0.39	22	0.66	37
	Nov	0.96	54	0.51	29	0.70	39
	Dec	0.76	43	0.50	28	0.42	23
	Jan	-	-	0.33	18	0.41	23
	Feb	-	-	0.36	20	0.36	20
	Mar	0.82	46	0.38	21	0.89	50
	Apr	1.87	105	1.48	83	1.21	68
	May	6.44	362	7.52	423	3.30	185
	June	6.25	352	3.27	184	5.55	312
	July	3.08	173	1.94	109	4.31	242
	August	1.26	71	1.03	58	2.09	118

Mean annual discharge (MAD) based on average flows measured since January 2014. Earlier records were excluded due to being affected by data gaps: FR_HC1 = 0.906 m^3/s, and FR_FRNTP = 1.778 m^3/s

"-" denotes months in which continuous data were unavailable due to ice effects and there were < 5 manual measurements

Values shaded in grey are computed from manual measurements made between 5-8 times in the month

Mean daily streamflow time series for FR_HC1, FR_FRNTP, and FR_FRABCHF are presented in Figure 12, Figure 13, and Figure 14, respectively. The summary is focused on FR_HC1 and FR_FRNTP data because these stations have longer records.

- Peak streamflow occurred earlier in 2016 and 2018 than in other years.
- Peak streamflow was highest in 2017 at FR_HC1 and in 2018 at FR_FRNTP over the period of record.

- Streamflows were lower in the spring of 2019, peaked later, and were of a lower magnitude than previous years (2017 and 2018), though summer streamflows were highest in 2019 (particularly at FR_FRNTP) compared to previous years.
- Streamflows were lowest during the summer and fall of 2017 at FR_HC1, and during the summer of 2015 and fall of 2017 at FR_FRNTP. Note there are gaps in the continuous streamflow record during winter months for all stations, when the sensors were affected by ice conditions. To characterize streamflow during these conditions, manual flow measurements were collected by FRO and are included within the continuous time series shown for each gauge below.

Mean daily streamflow at WSC Fording River (08NK018) and WSC Line Creek (08NK002) during the Decline Window relative to the period of record (1970-2019 and 1971-2019, respectively) is shown in Figure 15 and Figure 16. The annual streamflow pattern was similar between the two stations during the Decline Window, though the magnitude of flow was much less at WSC Line Creek.

Figure 12. Daily streamflow (m^3/s) at FR_HC1 (Measuring Point A) from 2010-2019.

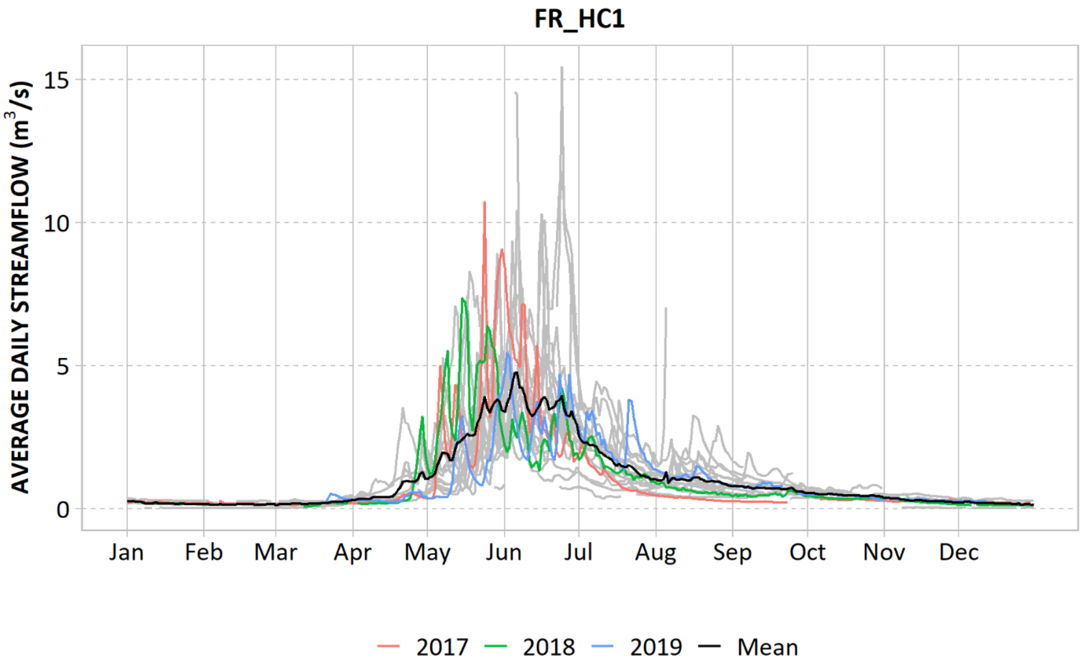


Figure 13. Daily streamflow (m^3/s) at FR_FRNTP (Measuring Point B) from 2010-2019.

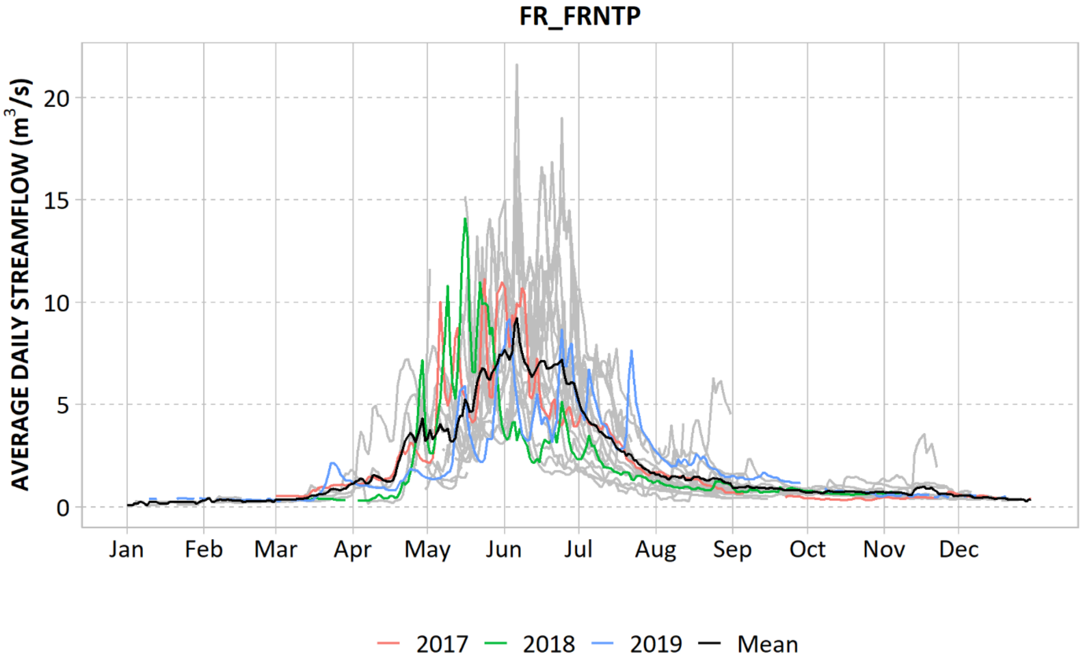


Figure 14. Daily streamflow (m^3/s) at FR_FRABCHF (Measuring Point C) from 2017-2019. The gauge was installed in October 2017.

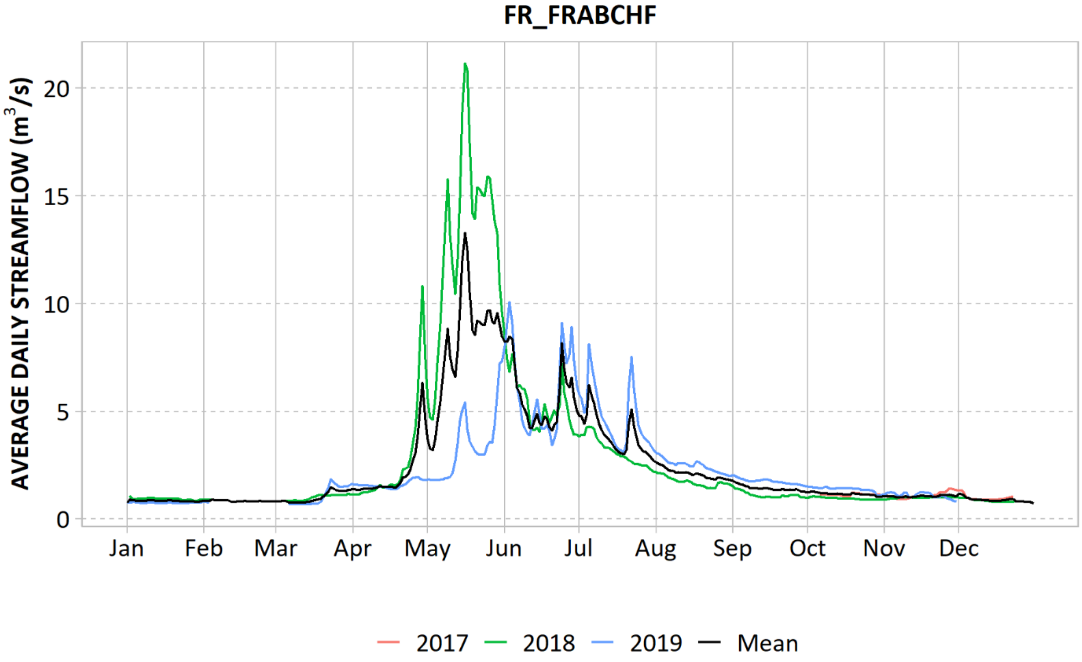


Figure 15. Daily streamflow (m^3/s) at WSC Fording River at the Mouth gauge (08NK018) for the period of record (1970-2019). Streamflow during the Decline Window is shown in color.

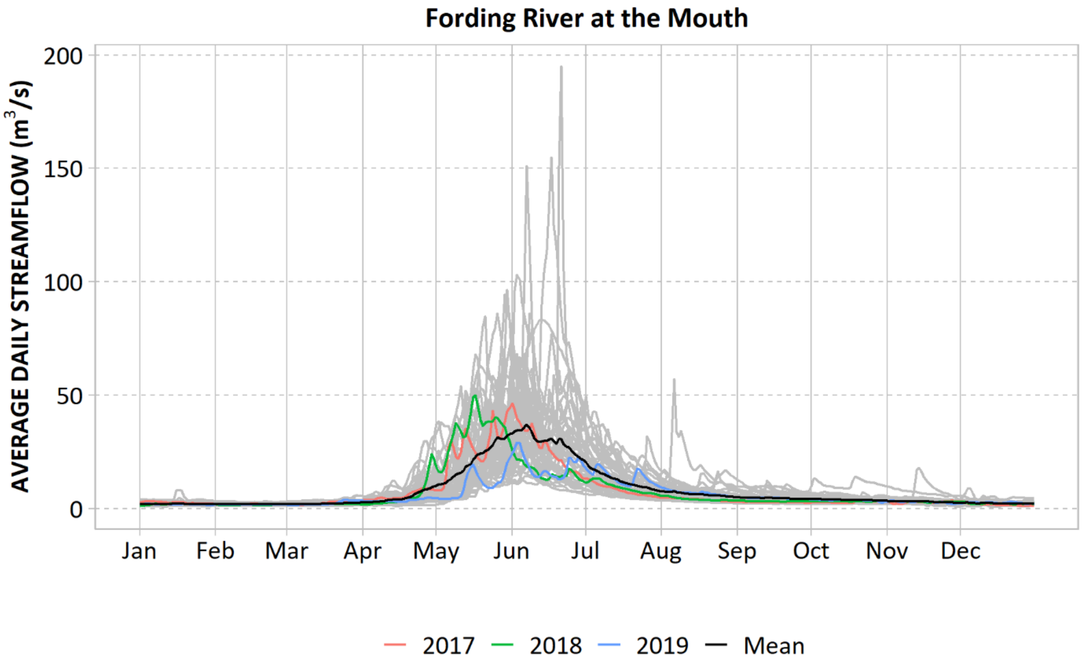
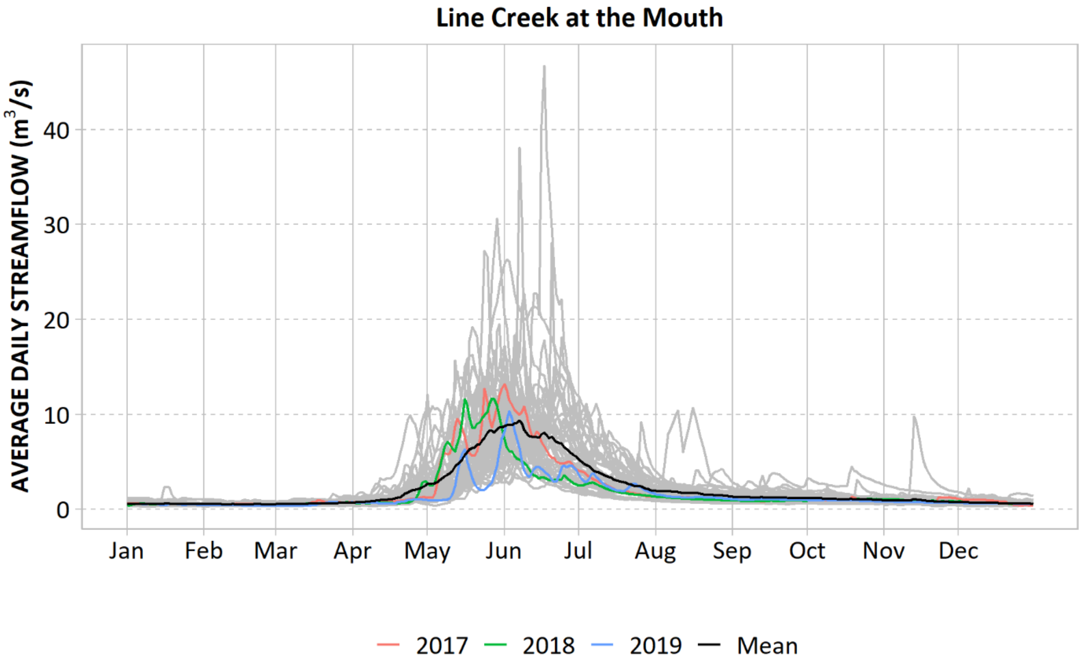


Figure 16. Daily streamflow (m^3/s) at WSC Line Creek at the Mouth gauge (08NK022) for the period of record (1970-2019).



3.5.2. Magnitude of Flow During Key WCT Life Stage Periods

Mean daily streamflow at the UFR hydrometric gauges during each of the WCT life stages is summarized in Table 28 (for FR_HC1), Table 29 (for FR_FRNTP), Table 30 (for the WSC Fording River gauge 08NK018) and Table 31 (for the WSC Line Creek gauge 08NK002). The tables provide flows only for periods with a complete data record, except for the spawning migration period; for this period, flows in 2017, 2018, and 2019 are displayed (in italics) despite not having full data coverage.

Mean flow during spawning migration period was lowest the 2010 at FR_HC1, and in 2002 at FR_FRNTP. Mean flow was highest in 2000 at FR_HC1 and in 2014 at FR_FRNTP. Note that there are a number of years with less than full data coverage for this period.

- Mean flow was highest during the WCT spawning and incubation periods in 2005[15] at FR_HC1, and lowest in 2008. At FR_FRNTP, mean flow was highest during the WCT spawning and incubation periods in 2012[15], and lowest in 2016.
- Mean flow during the summer rearing period was highest in 2009 at FR_HC1 and in 2012 at FR_FRNTP; lowest mean flow during this period occurred in 2017 at FR_HC1 and in 2001 at FR_FRNTP.
- Mean flow during the fall migration period was lowest in 2017 at both stations, and highest in 2014 at FR_HC1 and in 2019 at FR_FRNTP. Note there are several years with less than full data coverage for this period.
- Mean flow during the over-wintering period was lowest in 2016 (2016-2017 winter) at FR_HC1 and in 2015 (winter of 2015-2016) at FR_FRNTP. Considering the years with the most complete data for the overwintering period, mean flow during this period was highest in 2014 (winter of 2014-2015) at both FR_HC1 and FR_FRNTP. At FR_FRNTP, mean flow during the over-wintering period was highest in the winter of 2016-2017, but data were missing for January and February. Note there are several other years with less than full data coverage for this period, and manual flow measurements were used in the data summary.
- At the WSC Fording River gauge, mean flow was lowest during all WCT life stages in 2001; the same was true for the WSC Line Creek gauge, except the flow was lowest during the overwinter period in 1987. The timing of maximum mean flow varied for each of the periods but highest flows for all periods occurred prior to the Decline Window at both WSC gauges.
    - Mean flow during the spawning migration period was highest in 1981 at the WSC Fording River gauge, and highest in 1972 at the WSC Line Creek gauge.
    - Mean flow during the spawning and incubation was highest in 1972 at both WSC gauges.

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[15] Information from KWL (2014) indicates that mean flow during the spawning and incubation periods was likely much greater in 2013 due to the flood event in June.

- Mean flow during the summer rearing period was highest in 1993 at the WSC Fording River gauge, and highest in 1976 at the WSC Line Creek gauge.
- Mean flow during the over-wintering migration and over-wintering periods were highest at both WSC gauges in 2005 and the winter of 2005-2006, respectively.

Table 28. Mean daily streamflow at FR_HC1 during key WCT life stages.

Station	Year	Mean Streamflow (m^3/s)					
		Spawning Migration[1]	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering[2]
		April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
FR_HC1	1998	-	2.60	2.01	0.77	0.64	-
	1999	-	3.66	3.02	1.52	0.76	-
	2000	1.68	2.81	2.30	1.18	-	
	2001	1.56	2.22	1.83	-		
	2002	-	4.39	3.37	1.42	-	
	2003	-	2.97	2.29	0.70	-	
	2004	-	2.24	2.00	1.59	-	
	2005	-	4.44	3.73	-	-	
	2006	-	3.85	3.01	1.00	-	
	2007						
	2008	-	0.67	0.61	0.44	-	
	2009	1.59	3.14	2.82	1.68	-	
	2010	1.01	2.32	-	-		-
	2011	-	3.36	-	-		
	2012	-	-	-	-	0.39	-
	2013	1.75	-	-	-		-
	2014	1.51	4.04	3.00	0.96	0.85	0.36
	2015	-	2.16	1.76	0.65	0.61	-
	2016	-	1.66	1.52	0.97	0.55	0.26
	2017	*1.97*	3.33	2.49	0.42	0.29	0.32
	2018	*2.37*	3.10	2.41	0.78	0.45	0.28
	2019	*0.95*	2.56	2.17	1.36	0.63	

[1] Streamflow is shown for 2017-2019, because it is the Decline Window, but data are missing for the period.

[2] Overwintering period starts October 15 of the stated year and goes to March 31 in following year.

"-" = a partial data record and blanks indicate there are no data for the period.

Shaded values represent the minimum and maximum flow for each life stage, excluding incomplete data in italics

Peak flow in 2013 is not represented as the station was damaged during a flood event that occurred on June 19-21, with an estimated peak flow at FR_FRNTP of 140-150 m^3/s

Table 29. Mean daily streamflow at FR_FRNTP during key WCT life stages.

Station	Year	Mean Streamflow (m^3/s)					
		Spawning Migration[1]	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering[2]
		April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
FR_FRNTP	1997	-	4.24	3.31	0.87	0.64	-
	1998	4.29	6.68	4.95	1.12	0.62	-
	1999	-	6.82	5.36	2.27	0.83	-
	2000	3.40	5.34	4.31	-	-	
	2001	3.70	3.41	2.62	0.68	-	
	2002	2.62	8.46	6.17	-	-	
	2003	3.25	8.37	6.11	-	-	
	2004	3.22	4.34	3.78	-	-	
	2005	-	6.87	-	-	-	
	2006	-	5.11	3.85	0.87	-	
	2007	-	-	-	-	-	
	2008	-	7.11	-	-	-	
	2009	-	3.01	2.86	-	-	
	2010	-	4.74	4.02	-	-	
	2011	-	7.92	5.89	1.63	-	
	2012	-	9.11	6.85	2.32	0.82	-
	2013	-	-	-	-	-	-
	2014	6.26	-	-	1.37	1.10	*0.63*
	2015	-	2.76	2.19	0.83	0.77	0.39
	2016	-	2.32	2.10	1.55	0.70	*0.86*
	2017	*2.98*	4.57	3.48	1.40	0.53	*0.44*
	2018	*4.76*	5.54	4.34	1.51	0.76	*0.59*
	2019	*2.25*	4.70	4.01	1.79	2.51	

[1] Streamflow is shown for 2017-2019, because it is the Decline Window, but data are missing for the period.

[2] Overwintering period starts October 15 of the stated year and goes to March 31 in following year.

"-" = a partial data record with > 2 months of data are missing; and italic values = < 2 months of data missing.

Blanks indicate there are no data for the period.

Shaded values represent the minimum and maximum flow for each life stage, excluding incomplete data in italics

Peak flow in 2013 is not represented as the station was damaged during a flood event that occurred on June 19-21, with an estimated peak flow at FR_FRNTP of 140-150 m^3/s.

Table 30. Mean daily streamflow at WSC Fording River at the Mouth station (08NK018) during key WCT life stage periods.

Station	Year	Mean Flow (m^3/s)					
		Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering[1]
		April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September	September 1 to October 15	October 15 to March 31
WSC 08NK018	1970	8.78	25.04	18.74	4.16	2.84	1.88
	1971	15.03	29.82	23.77	7.37	3.99	2.41
	1972	18.10	46.10	37.98	11.82	6.33	2.92
	1973	10.81	23.62	18.22	5.11	3.54	2.21
	1974	12.45	35.95	27.79	9.24	4.30	2.29
	1975	10.59	33.12	24.66	8.53	5.01	3.12
	1976	18.95	22.84	20.83	11.83	5.68	2.42
	1977	9.25	12.19	10.52	5.58	4.58	2.34
	1978	11.94	27.95	21.96	9.14	5.28	2.43
	1979	11.69	21.01	16.36	4.36	2.92	1.81
	1980	18.48	21.42	17.26	5.68	4.67	2.75
	1981	20.39	39.28	29.94	9.51	3.60	2.12
	1982	10.45	24.45	18.65	5.57	4.38	2.37
	1983	10.65	18.08	14.43	5.64	2.70	1.93
	1984	6.83	17.97	13.95	4.91	3.22	1.82
	1985	12.03	16.37	13.07	4.95	5.12	2.37
	1986	17.10	26.47	20.92	5.91	5.31	2.89
	1987	16.38	11.42	10.48	6.44	2.97	1.67
	1988	11.58	16.91	13.25	3.37	2.33	1.83
	1989	10.71	14.30	11.54	5.52	4.46	2.34
	1990	15.92	30.42	24.90	10.50	4.66	2.75
	1991	20.15	40.32	30.50	9.22	4.39	2.57
	1992	10.92	16.19	12.95	8.17	5.02	2.50
	1993	11.78	24.00	20.41	13.09	6.86	3.26
	1994	14.95	16.52	13.19	4.76	3.02	2.30
	1995	7.76	32.55	24.91	8.21	3.71	2.93
	1996	11.12	30.17	22.99	7.90	6.01	3.16
	1997	17.81	29.13	22.73	6.26	4.23	2.51
	1998	16.69	27.85	21.40	5.84	3.40	2.22
	1999	12.84	25.20	19.84	7.94	3.80	3.72
	2000	11.68	16.43	12.96	5.10	3.87	2.34
	2001	6.77	10.77	8.56	3.16	2.17	1.77
	2002	9.54	33.75	25.23	7.21	4.19	2.44
	2003	12.36	22.46	17.21	4.35	2.94	2.71
	2004	7.77	12.67	11.35	8.96	7.24	3.53
	2005	10.84	27.79	21.65	9.14	8.94	5.41
	2006	17.43	27.71	21.46	5.72	4.07	2.94
	2007	15.32	24.32	18.66	4.96	3.66	2.64
	2008	12.86	28.49	21.52	5.80	3.82	2.18
	2009	7.54	16.03	13.78	7.10	3.93	2.59
	2010	9.20	20.83	16.23	6.95	6.20	2.81
	2011	11.01	30.70	22.87	6.99	4.18	2.85
	2012	19.52	36.04	27.62	10.44	3.97	3.01
	2013	18.56	35.49	27.42	8.73	5.60	2.80
	2014	15.51	31.09	23.74	7.43	5.86	2.97
	2015	11.87	14.66	12.00	5.01	4.10	2.48
	2016	14.07	11.68	10.41	6.13	4.33	3.23
	2017	16.36	22.93	17.70	4.38	2.75	2.20
	2018	19.76	22.37	17.34	4.99	3.28	2.42
	2019	7.06	16.00	13.40	8.02	4.25	-

[1] Overwintering period starts on October 15 of the previous year and goes to March 31 of current year.

Table 31. Mean daily streamflow at WSC Line Creek at the Mouth station (08NK022) during key WCT life stage periods.

Station	Year	Mean Flow (m^3/s)					
		Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering[1]
		April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September	September 1 to October 15	October 15 to March 31
WSC 08NK022	1971	3.86	7.47	5.96	2.08	0.94	0.48
	1972	5.52	13.46	10.61	2.65	1.64	0.76
	1973	2.80	5.69	4.40	1.25	0.79	0.60
	1974	2.81	10.22	7.85	2.73	1.19	0.53
	1975	2.48	7.96	5.79	2.06	1.35	0.82
	1976	5.39	7.63	6.97	3.26	1.46	0.64
	1977	2.39	2.88	2.52	1.36	1.06	0.52
	1978	2.94	7.28	5.72	2.41	1.50	0.66
	1979	2.87	5.37	4.18	1.17	0.80	0.49
	1980	4.92	5.08	4.11	1.51	1.22	0.69
	1981	4.94	9.70	7.46	2.59	1.11	0.68
	1982	2.99	7.03	5.41	1.57	1.24	0.67
	1983	3.02	5.12	4.14	1.64	0.79	0.56
	1984	1.90	5.28	4.10	1.48	1.06	0.57
	1985	3.21	4.53	3.58	1.22	1.27	0.64
	1986	4.80	7.67	5.92	1.25	1.36	0.74
	1987	4.16	3.01	2.79	1.80	0.71	0.43
	1988	3.11	4.55	3.57	0.89	0.66	0.50
	1989	2.66	3.97	3.18	1.51	1.14	0.70
	1990	3.89	7.45	6.05	2.60	1.21	0.81
	1991	4.98	10.62	7.97	2.42	1.18	0.72
	1992	3.06	4.38	3.46	2.06	1.27	0.74
	1993	3.00	6.12	5.17	3.25	1.55	0.73
	1994	3.74	4.24	3.37	1.21	0.80	0.59
	1995	2.24	7.74	5.90	1.93	1.03	0.79
	1996	2.94	8.96	6.67	2.23	1.54	0.83
	1997	4.07	7.28	5.65	1.58	1.15	0.71
	1998	5.13	7.44	5.70	1.47	0.87	0.58
	1999	3.25	6.53	5.13	1.90	1.01	1.22
	2000	3.12	4.54	3.56	1.35	1.01	0.55
	2001	1.72	2.57	2.05	0.77	0.60	0.56
	2002	2.36	8.17	6.20	1.99	1.26	0.66
	2003	3.24	5.97	4.63	1.30	0.95	0.92
	2004	2.35	3.51	3.08	2.19	1.72	1.06
	2005	3.06	6.80	5.36	2.39	2.62	1.52
	2006	4.38	6.65	5.25	1.51	1.18	0.83
	2007	4.39	6.36	4.92	1.32	0.98	0.67
	2008	3.44	7.05	5.37	1.45	1.05	0.60
	2009	1.87	3.73	3.20	1.72	0.97	0.67
	2010	2.13	5.43	4.24	1.87	1.55	0.73
	2011	2.43	7.50	5.64	1.97	1.13	0.72
	2012	4.24	9.56	7.25	2.66	1.16	0.93
	2013	4.79	9.00	6.85	2.09	1.58	0.86
	2014	3.50	6.87	5.41	2.20	1.84	0.90
	2015	2.96	4.05	3.45	1.75	1.45	0.75
	2016	4.66	3.43	2.93	1.45	1.22	0.86
	2017	4.01	6.51	5.01	1.27	0.95	0.75
	2018	4.37	5.52	4.31	1.19	0.96	0.68
	2019	1.81	3.92	3.17	1.49	0.98	0.64
	2020	3.24	7.17	5.48	1.41	0.80	

[1] Overwintering period starts on October 15 of the previous year and goes to March 31 of current year.

3.5.3. Magnitude and Duration of Mean Extreme Flow

- The magnitude and duration of extreme flow, represented as the 1, 3, 7, and 30-day minimum and maximum flow at FR_HC1 and FR_FRNTP (stations with the most complete records) are presented for each WCT life stage in Figure 17 to Figure 22. The mean magnitude of high and low flow extremes of various duration provide measures of environmental stress during the year, though these extremes may be ecologically important for maintaining habitat features (e.g., flushing flows and channel maintenance flows) and triggers for the reproduction of certain species (Richter *et al*. 2006). Note that there are several years, including during the flood event in June 2013 and during the Decline Window, with less than full data coverage for all the WCT periods (see Table 28 and Table 29). These years were not included in the assessment, though flows during the Decline Window are shown in the figures.

- During the spawning migration period, the magnitude and duration of high flow at FR_HC1 were greater in 2013 compared to other years. At FR_FRNTP, flows were higher for a longer duration in 1998. Minimum 30-day flow at FR_HC1 during the spawning migration period was lowest in 2000. At FR_FRNTP, the magnitude and duration of minimum flow were lowest in 2003 (30-day) and 2004 (7-day). This summary excludes flows in 2017, 2018, and 2019 due to an incomplete data record during this period.

- During the spawning period, the magnitude and duration of high flow at FR-HC1 was greater in 2002 (7-day) and 2017 (30-day) in the spawning period compared to other years. At FR_FRNTP, flows were higher for a longer duration in 2002, 2003 and 2012. During the spawning period, minimum 30-day flows in occurred in 2005 at FR_HC1, and in 2012 at FR_FRNTP.

- During the incubation period, the magnitude and duration of high flow at FR_HC1 was greatest in 2002 (7-day) and 2017 (30-day); whereas, high flow at FR_FRNTP occurred for longer in 2002, 2003, and 2012. During the incubation period, 30-day minimum flows occurred in 2005 and 2009 at FR_HC1. The minimum 30-day flow occurred in 2010 at FR_FRNTP.

- Maximum flows for all durations during the summer rearing period occurred in 2009 at FR_HC1, and in 2012 and 2019 at FR_FRNTP. Minimum flows during the summer rearing period occurred in 2004 at FR_HC1 and in 2019 at FR_FRNTP.

- During the over-wintering migration period, maximum flow for all durations occurred in 2014 at FR_HC1. At FR_FRNTP, 7-day maximum flow occurred in 2014 and 30-day maximum flow occurred in 2017 and 2018. The minimum 7-day flow during the over-wintering migration period occurred in 2014, whereas the minimum 30-day flow occurred in both 1999 and 2019 at FR_HC1. At FR_FRNTP, minimum 7-day flow during this period occurred in 2017 and 30-day minimum flow occurred in 2014

- Over-wintering high flows were greatest for all durations in the winter of 2016-2017 at both FR_HC1 and FR_FRNTP. The minimum 7-day and 30-day flow during the overwinter period occurred in 2018-2019 at FR_HC1 and FR_FRNTP. Note that there are several years with less than full data coverage for this period due to frozen conditions.

Summary statistics of magnitude and duration of extreme flow were computed for the WSC Fording River at the Mouth gauge and the WSC Line Creek at the Mouth gauge. The resultant plots are provided in Figure 23 to Figure 28 for the Fording River gauge and Figure 29 to Figure 34 for the Line Creek gauge, and summarized below.

- Spawning migration maximum 30-day flow was highest in 1981, 1991, and 2018 at the WSC Fording River gauge, and highest in 1972 and 1976 at WSC Line Creek gauge. Minimum 30-day flow during this period occurred in 2016 at the WSC Fording River gauge, and in 1975 at the WSC Line Creek gauge.
- Spawning and incubation maximum 30-day flow occurred in 1972 and were also lowest for a longer in 1972 at both WSC gauges. Minimum 30-day flow at the WSC Fording River gauge occurred in 1972 and 2012 during the spawning period, and in 1976 and 1993 during the incubation period. At the WSC Line Creek gauge, minimum 30-day flow occurred in 1987 during the spawning period and in 2001 during the incubation period.
- Summer rearing flows were highest and occurred for a longer duration in 1976 at both WSC gauges. Minimum flows during the same period occurred in 1976 (90-day) and 1993 (30-day) at the WSC Fording River gauge, and in 2001 (30-day and 90-day) at the WSC Line Creek gauge.
- Over-wintering migration maximum flows occurred in 2005 at both WSC gauges; minimum flows for this period across all years also occurred in 2005 at the WSC Fording River gauge. Minimum flows for the over-wintering migration period occurred in 2001 at the WSC Line Creek gauge.
- Over-wintering flows were highest in the winter of 1999-2000 (for 1-day, 3-day and 7-day flows) and in 2005-2006 (for 30-day and 90-day flows) at the WSC Fording River gauge; the same was true at the WSC Line Creek gauge with the exception that 30-day maximum flow occurred in 1999-2000 and not 2005-2006. Minimum 30-day flows for the same period occurred in the 2005-2006 winter at the WSC Fording River gauge, and in the 1987-1988 winter at the WSC Line Creek gauge.

Figure 17. Magnitude and duration of annual extreme streamflow (m^3/s) at FR_HC1 and FR_FRNTP during WCT spawning migration (April 1 to May 31). Note the y-axis range is different for each station.

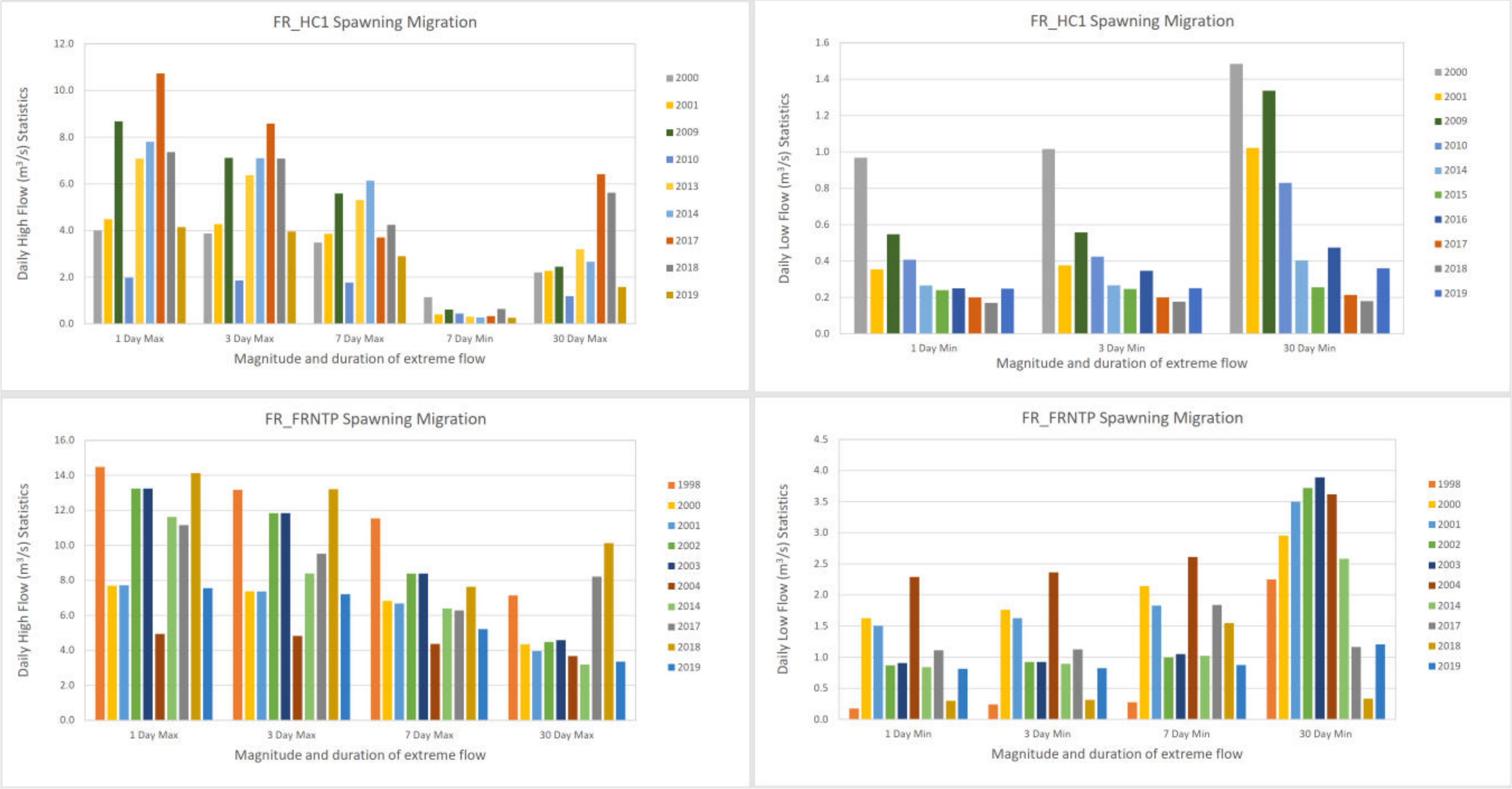


Figure 18. **Magnitude and duration of annual extreme streamflow (m^3/s) at FR_HC1 and FR_FRNTP during WCT spawning (May 15 to July 15). Note the y-axis range is different for each station.**

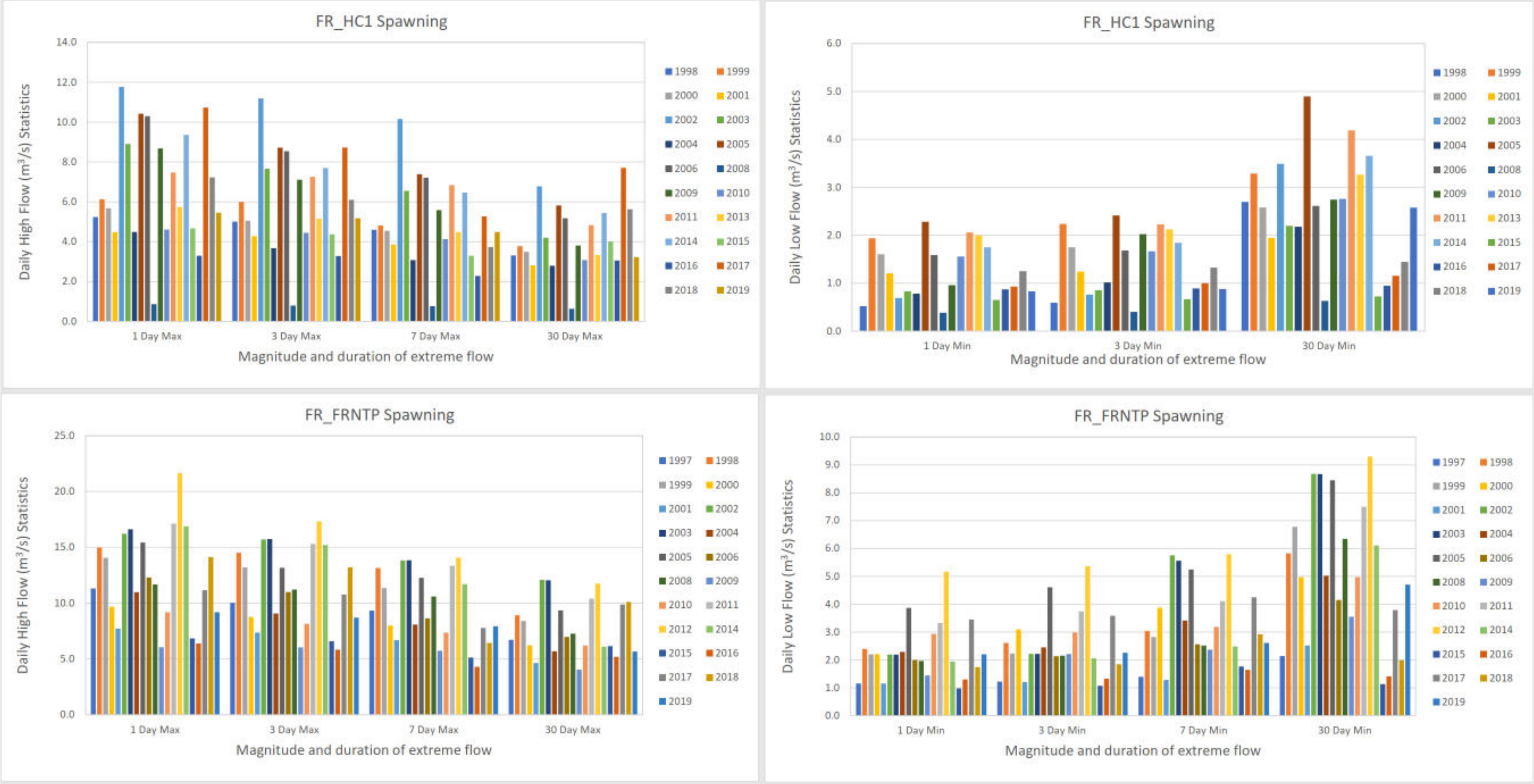


Figure 19. Magnitude and duration of annual extreme streamflow (m^3/s) at FR_HC1 and FR_FRNTP during WCT incubation (May 15 to August 31). Note the y-axis range is different for each station.

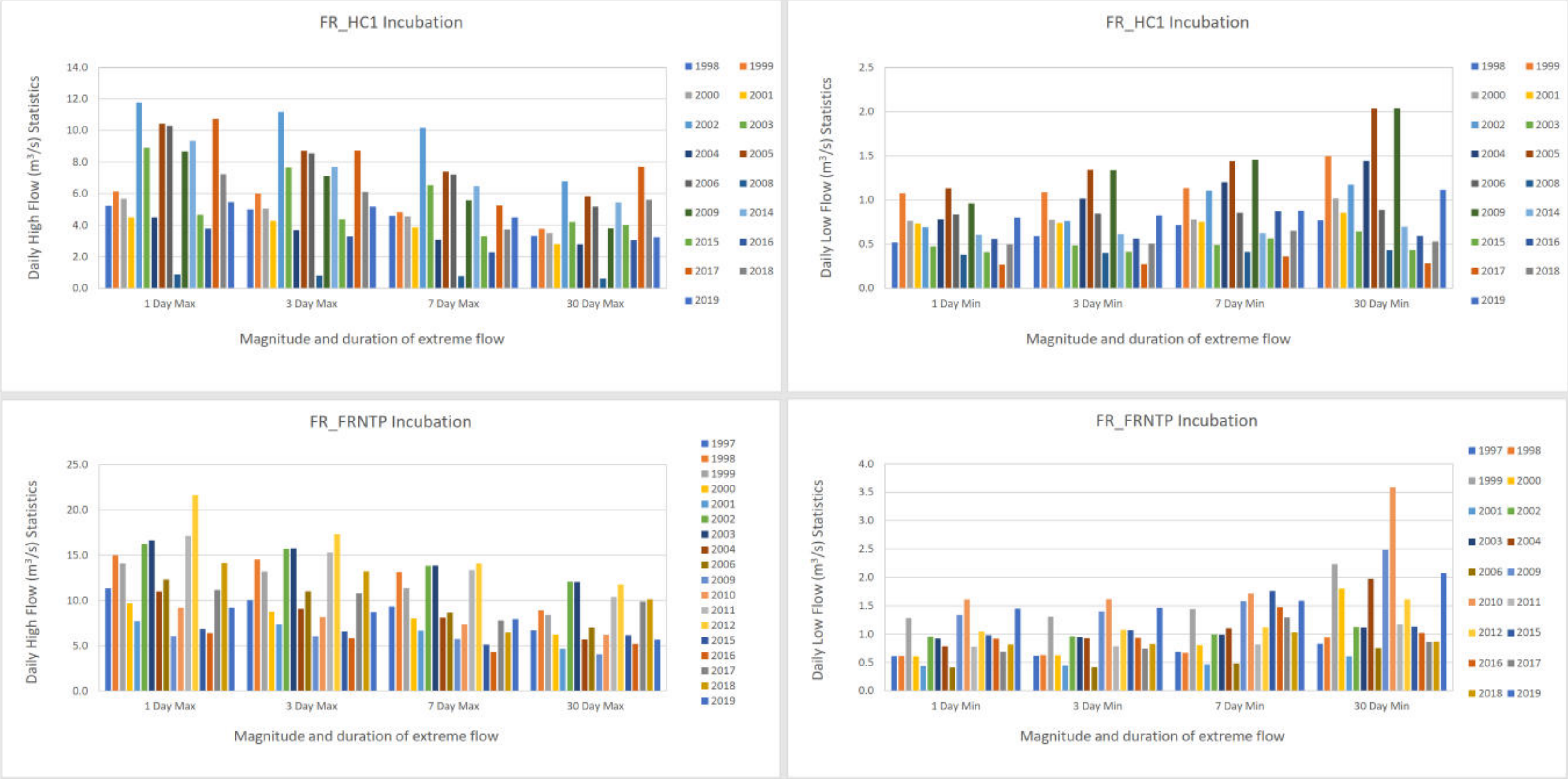


Figure 20. Magnitude and duration of annual extreme streamflow (m^3/s) at FR_HC1 and FR_FRNTP during WCT summer rearing (July 15 to September 30). Note the y-axis range is different for each station.

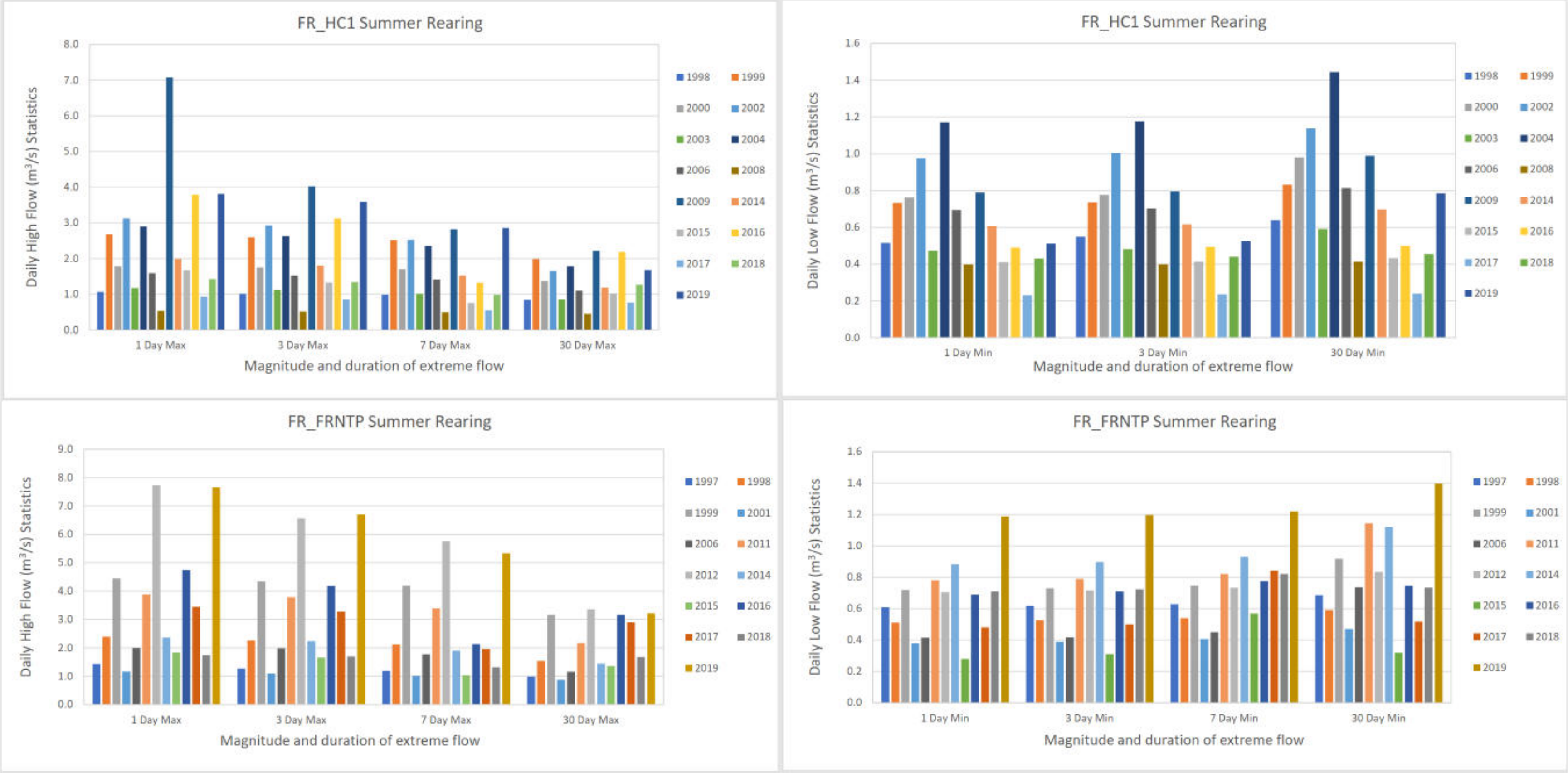


Figure 21. Magnitude and duration of annual extreme streamflow (m^3/s) at FR_HC1 and FR_FRNTP during WCT over-wintering migration (September 1 to October 15). Note the y-axis range is different for each station.

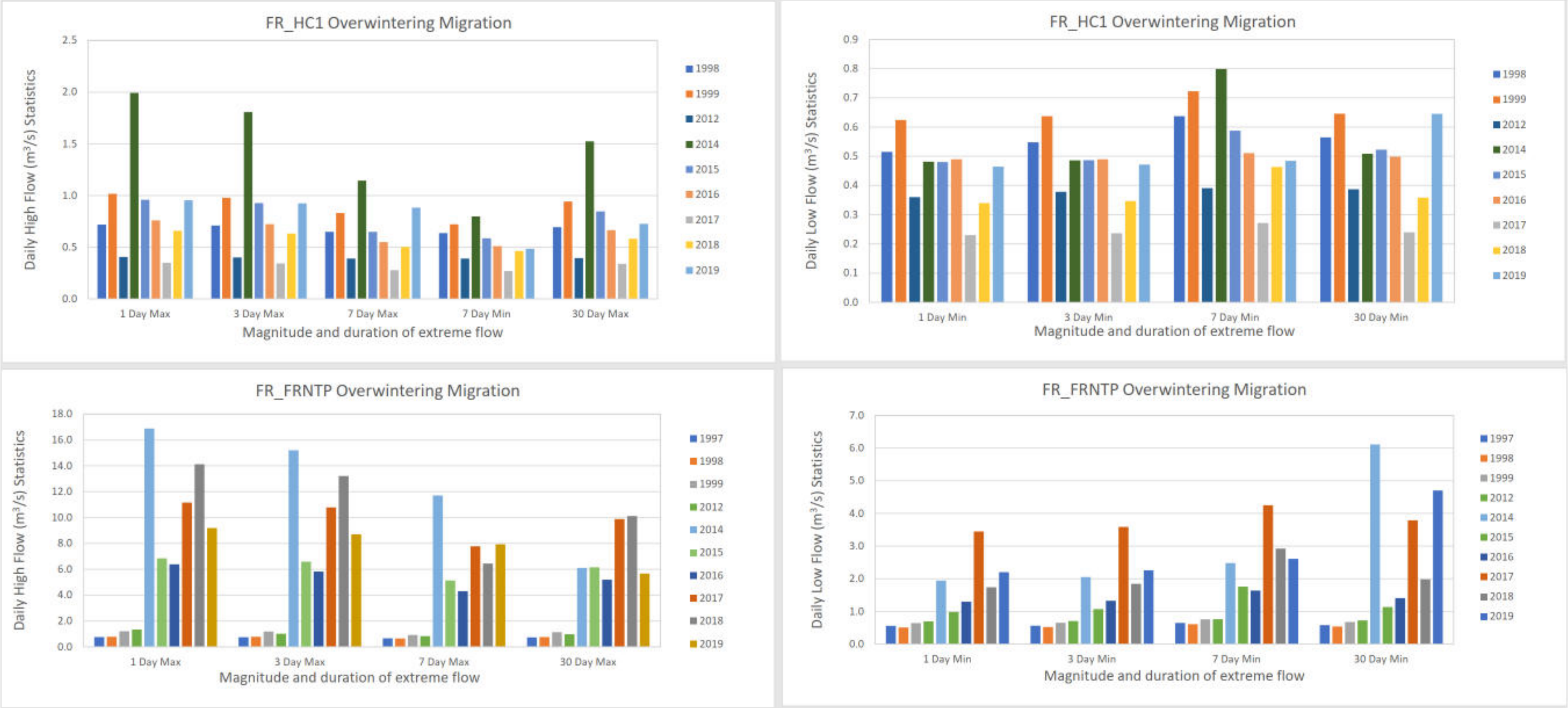


Figure 22. Magnitude and duration of annual extreme streamflow (m^3/s) at FR_HC1 and FR_FRNTP during WCT over-wintering (October 15 to March 31). Note the y-axis range is different for each station.

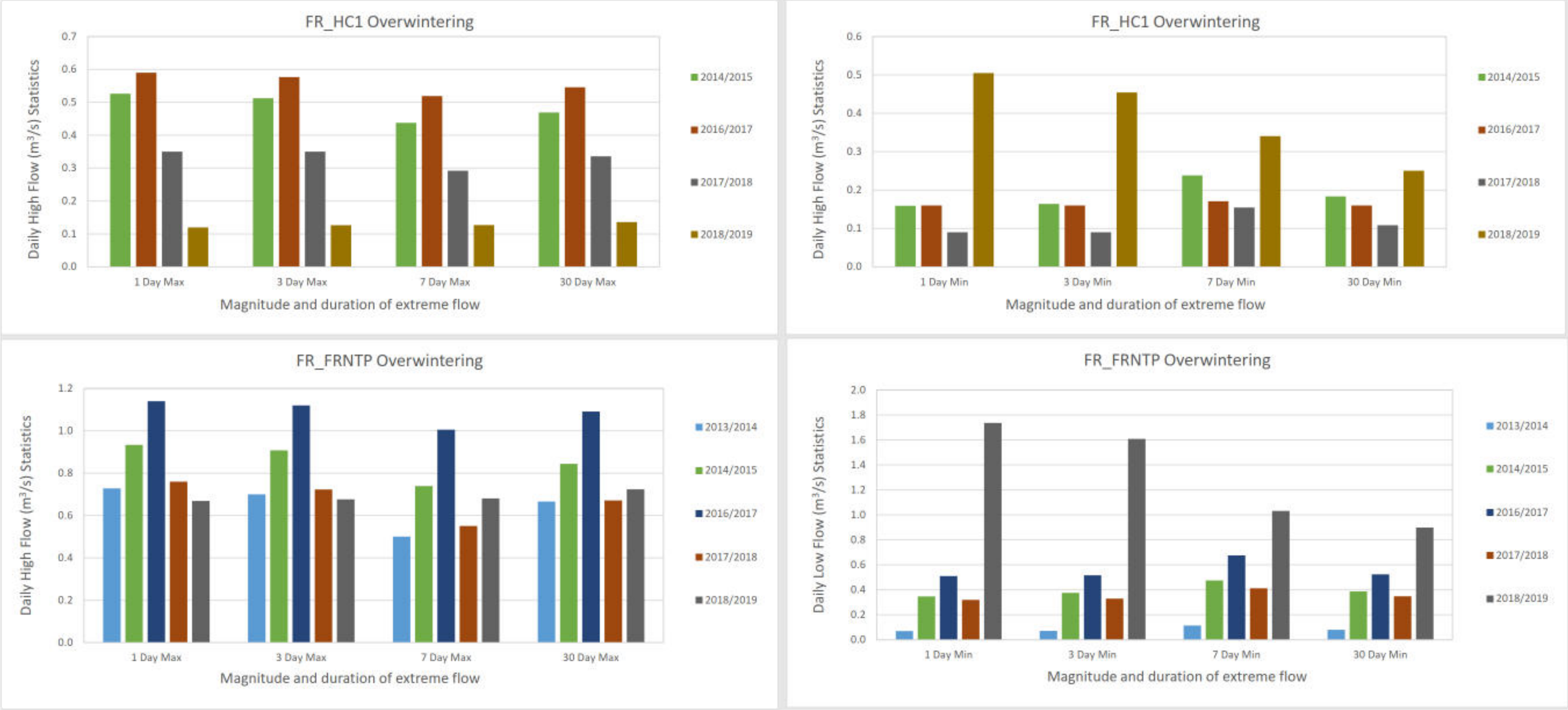
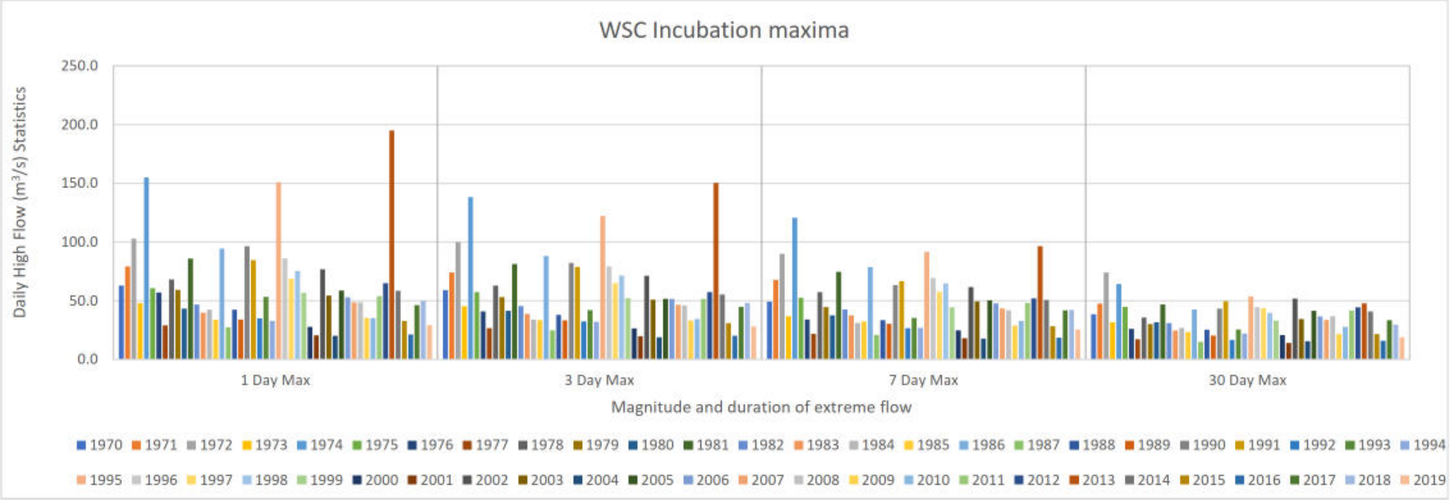


Figure 23. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Fording River at the Mouth station (08NK018) during WCT spawning migration (April 1 to May 31). Note the y-axis range is different for each statistic.

Figure 24. Magnitude and duration of annual extreme streamflow (m³/s) at the WSC Fording River at the Mouth station (08NK018) during WCT spawning (May 15 to July 15). Note the y-axis range is different for each statistic.

Figure 25. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Fording River at the Mouth station (08NK018) during WCT incubation (May 15 to August 31). Note the y-axis range is different for each statistic.



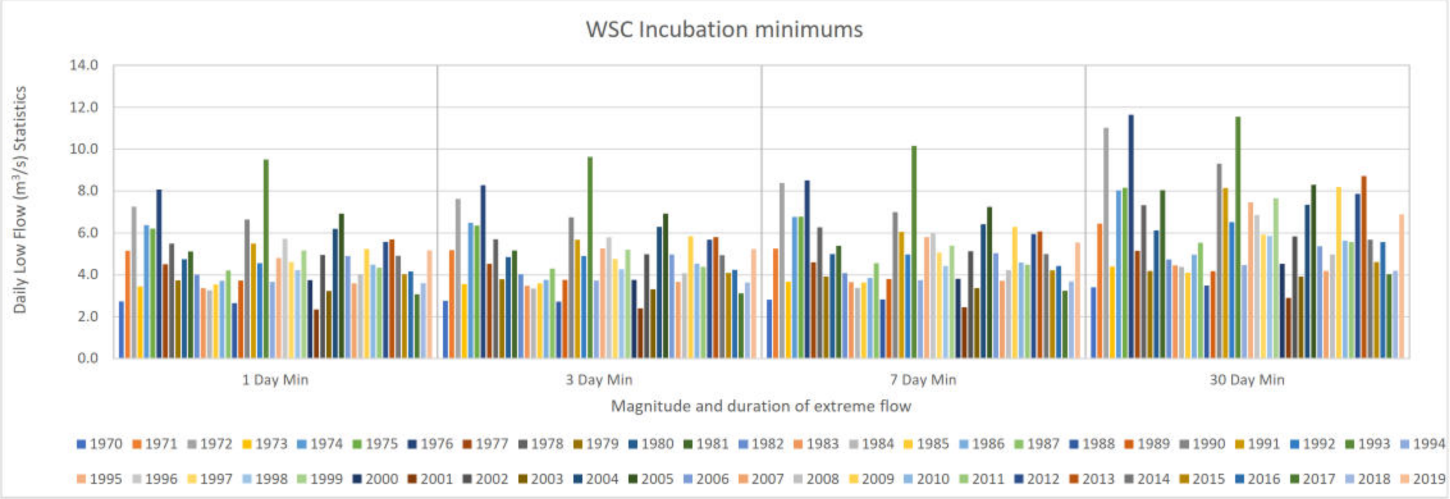


Figure 26. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Fording River at the Mouth station (08NK018) during WCT summer rearing (July 15 to September 30). Note the y-axis range is different for each statistic.

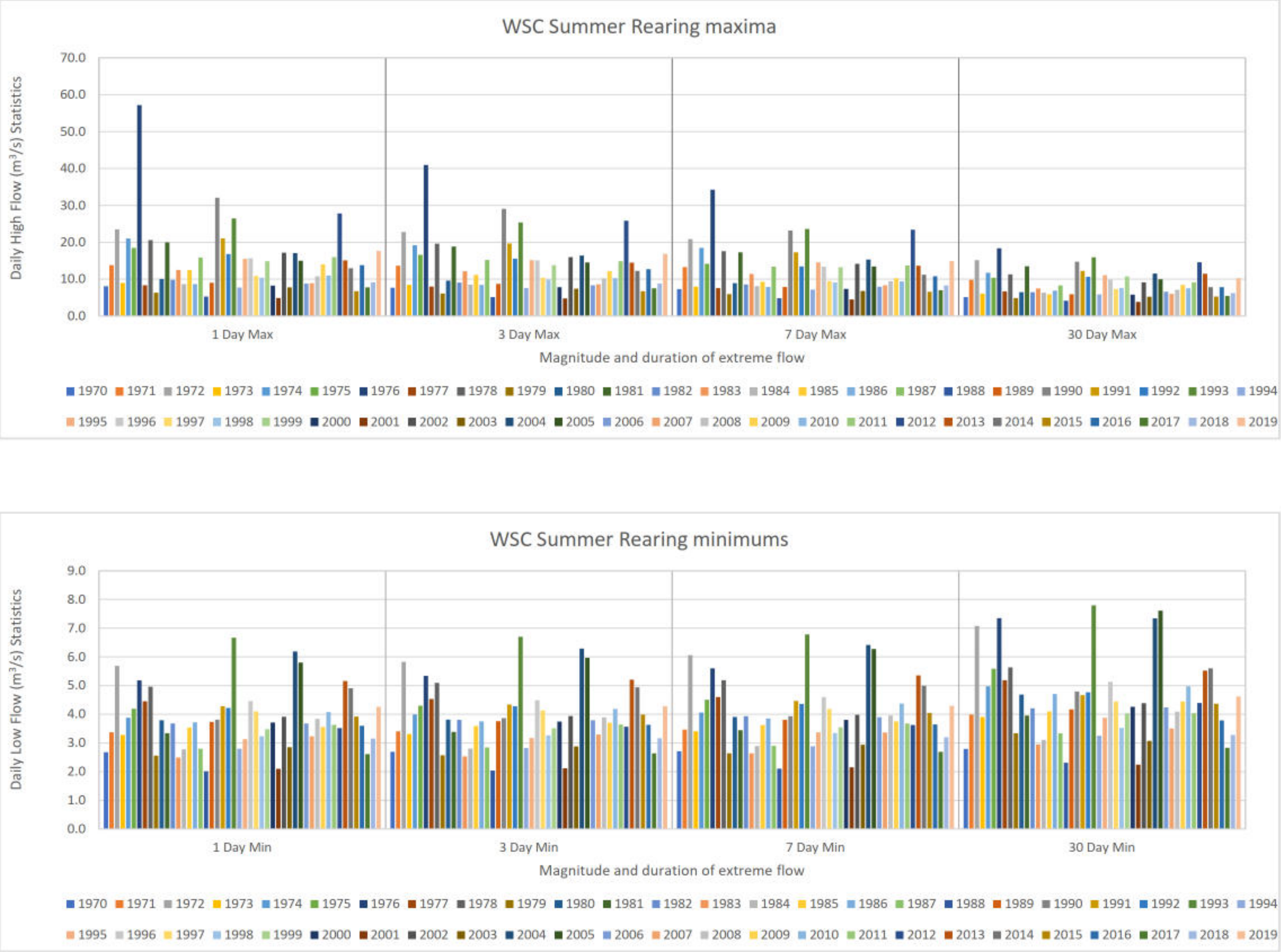
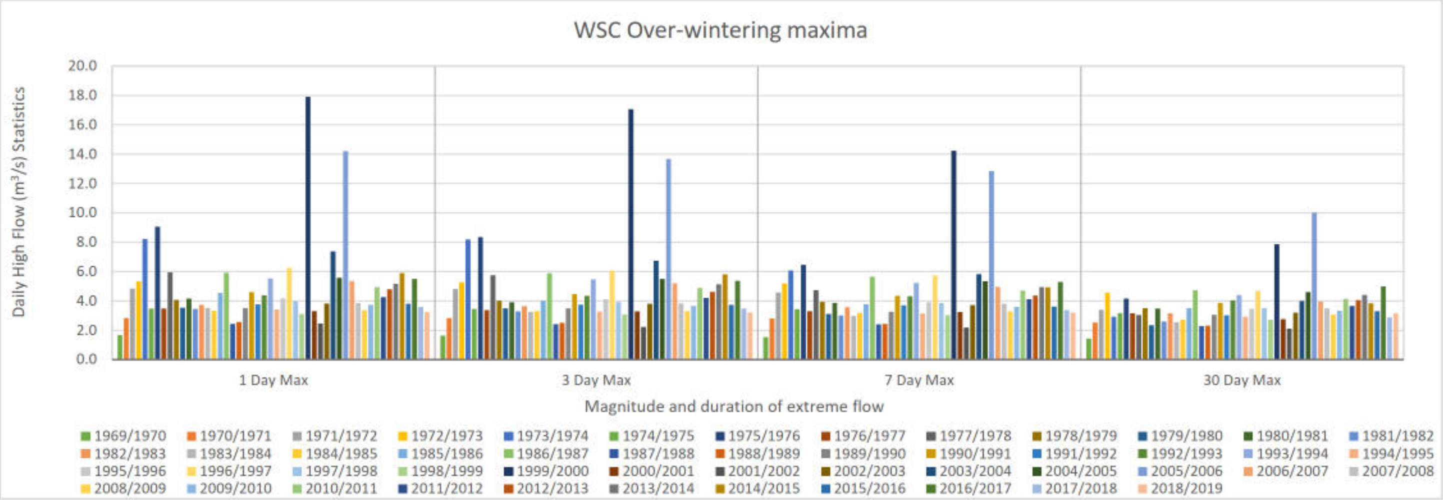


Figure 27. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Fording River at the Mouth station (08NK018) during WCT over-wintering migration (September 1 to October 15). Note the y-axis range is different for each statistic.

Figure 28. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Fording River at the Mouth station (08NK018) during WCT over-wintering (October 15 to March 31). Note the y-axis range is different for each statistic.



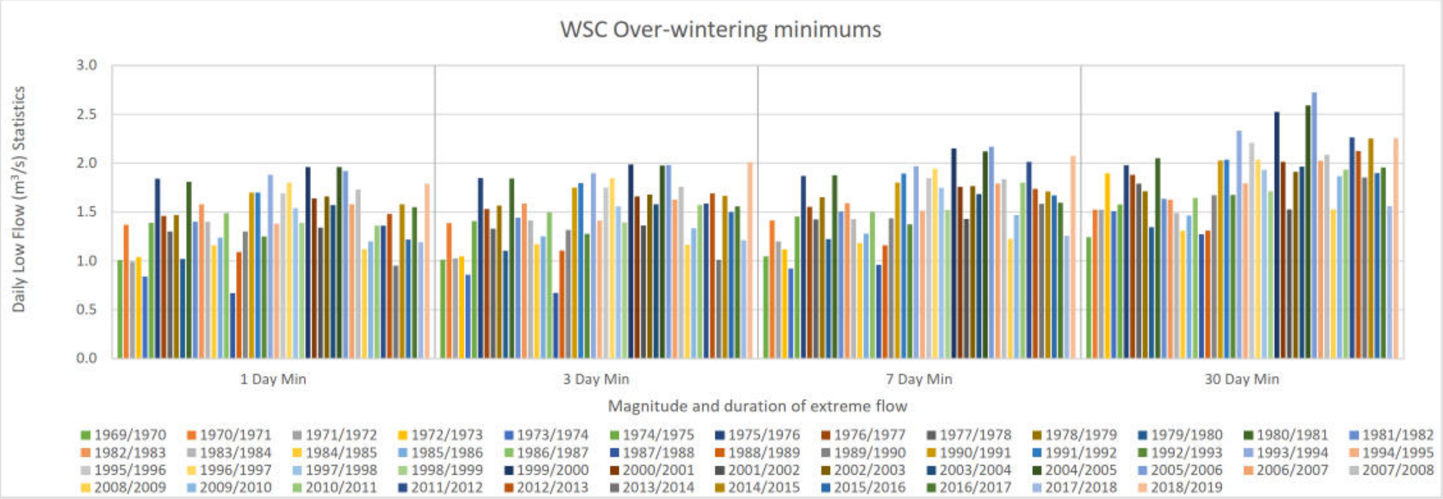
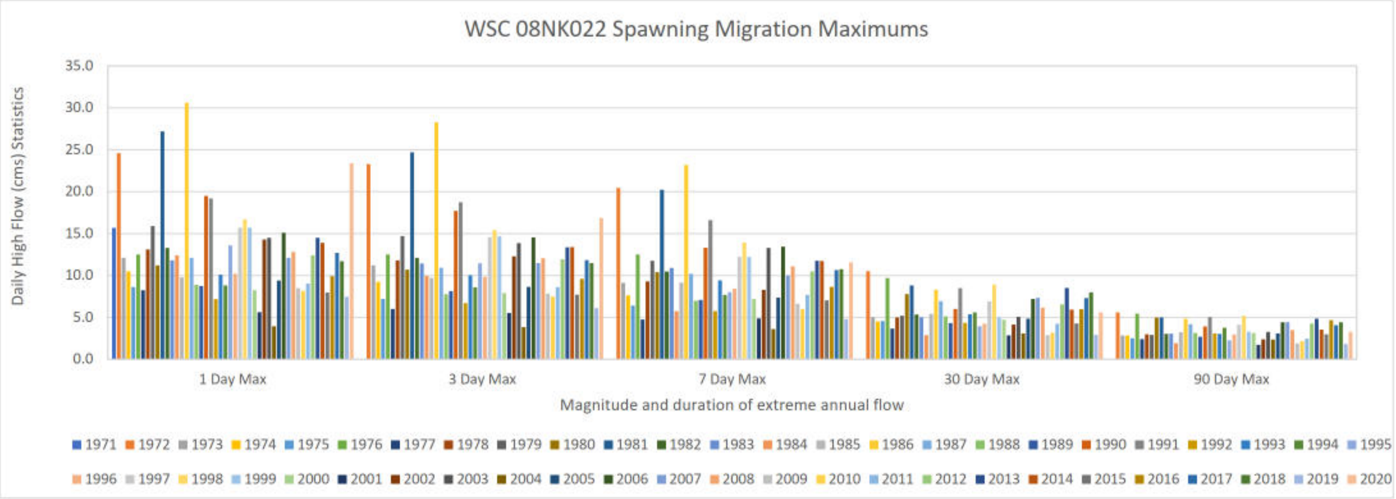


Figure 29. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Line Creek at the Mouth station (08NK022) during WCT spawning migration (April 1 to May 31). Note the y-axis range is different for each statistic.



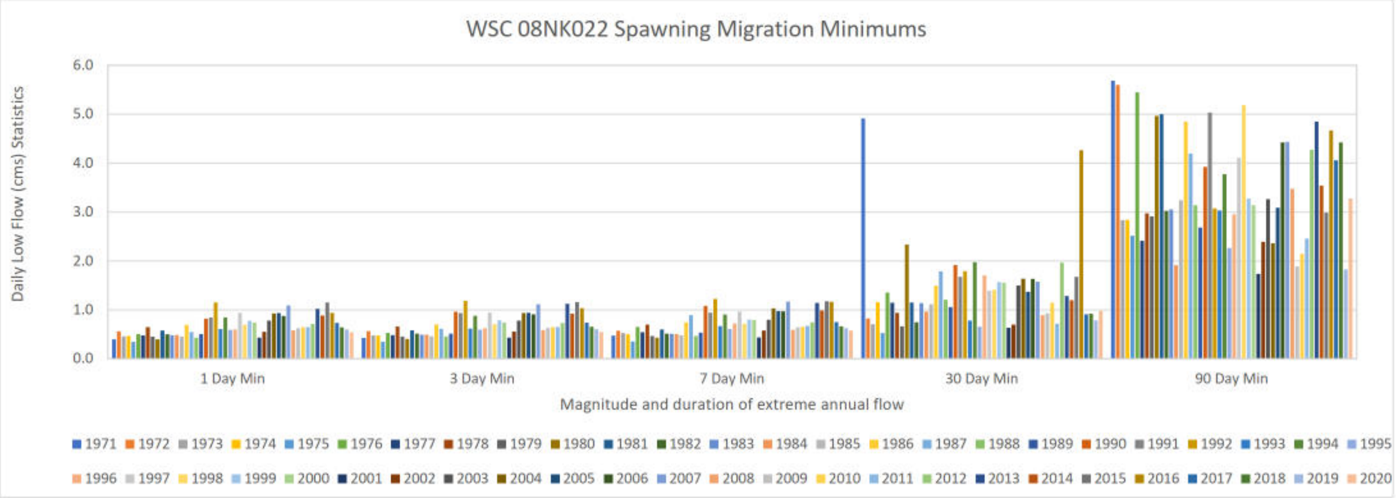
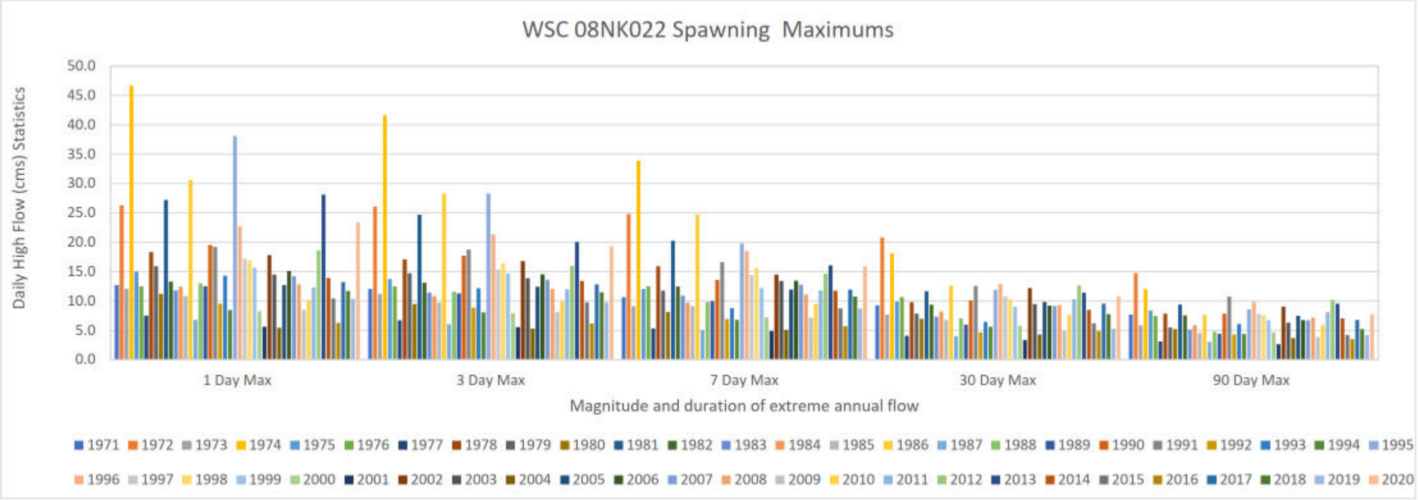


Figure 30. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Line Creek at the Mouth station (08NK022) during WCT spawning (May 15 to July 15). Note the y-axis range is different for each statistic.



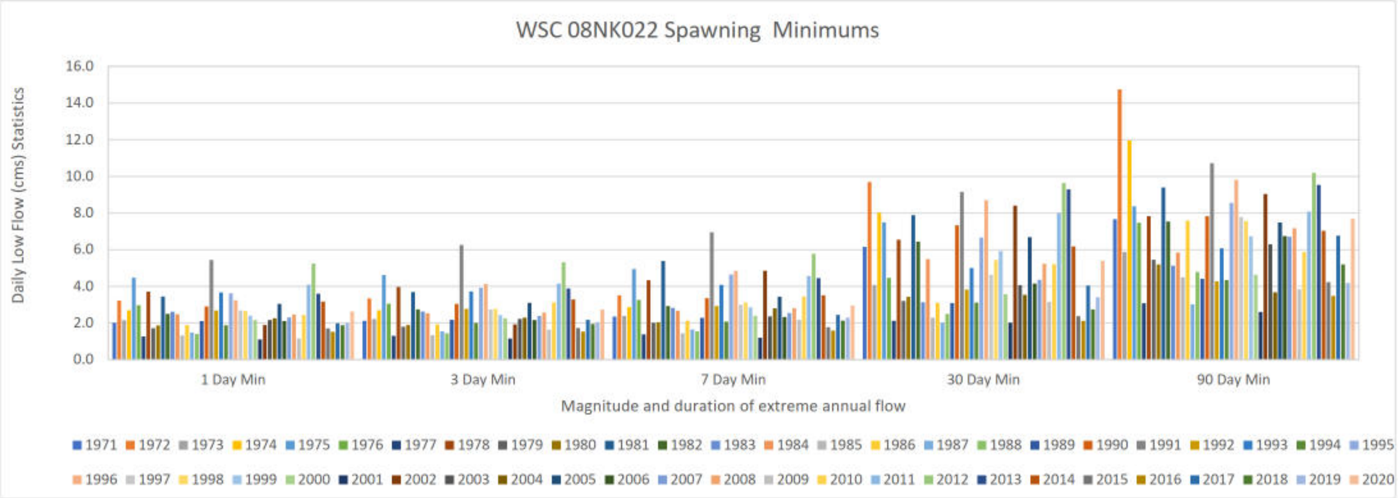
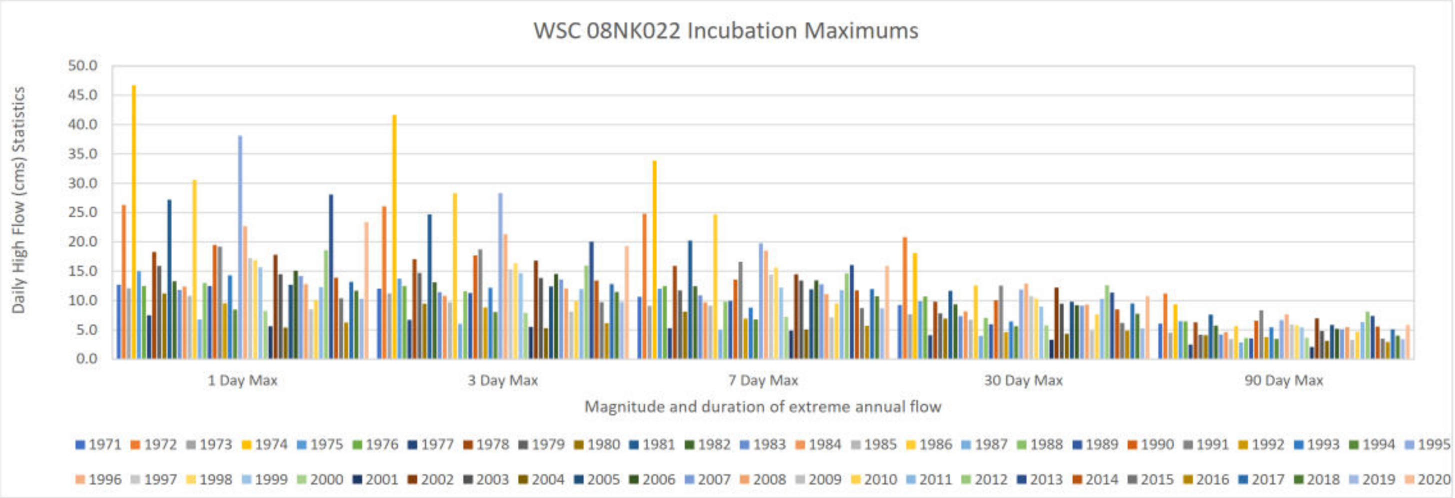


Figure 31. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Line Creek at the Mouth station (08NK022) during WCT incubation (May 15 to August 31). Note the y-axis range is different for each statistic.



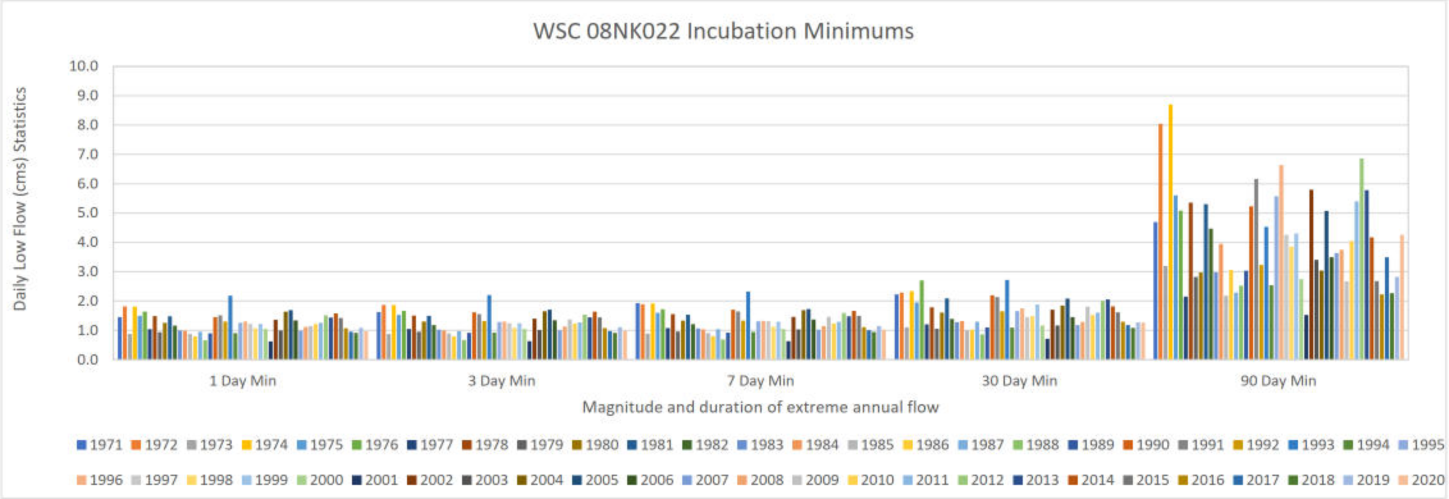
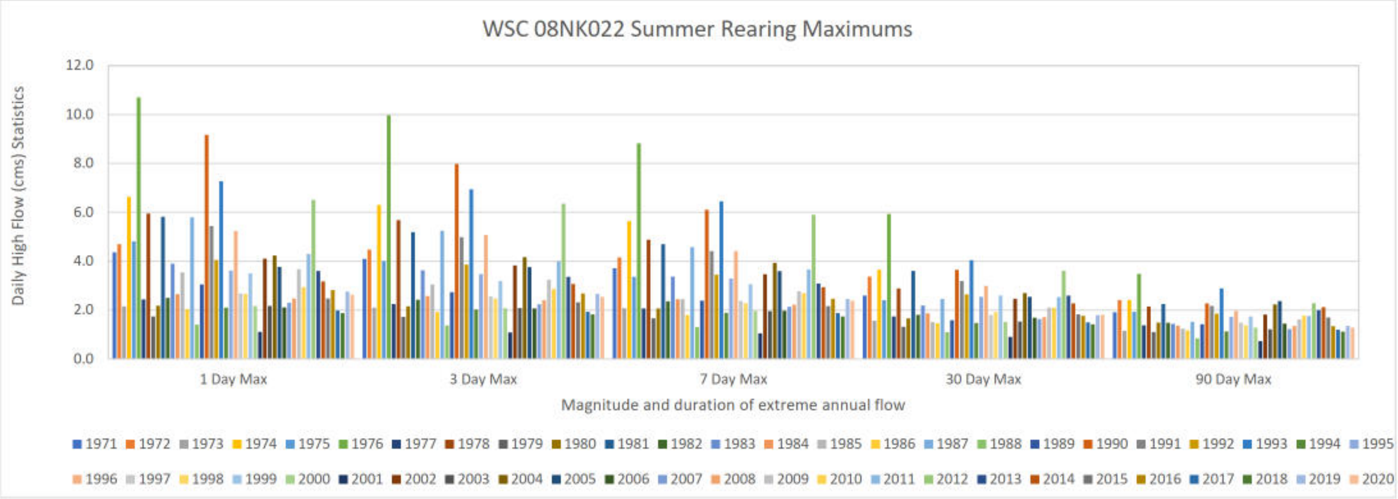


Figure 32. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Line Creek at the Mouth station (08NK022) during WCT summer rearing (July 15 to September 30). Note the y-axis range is different for each statistic.



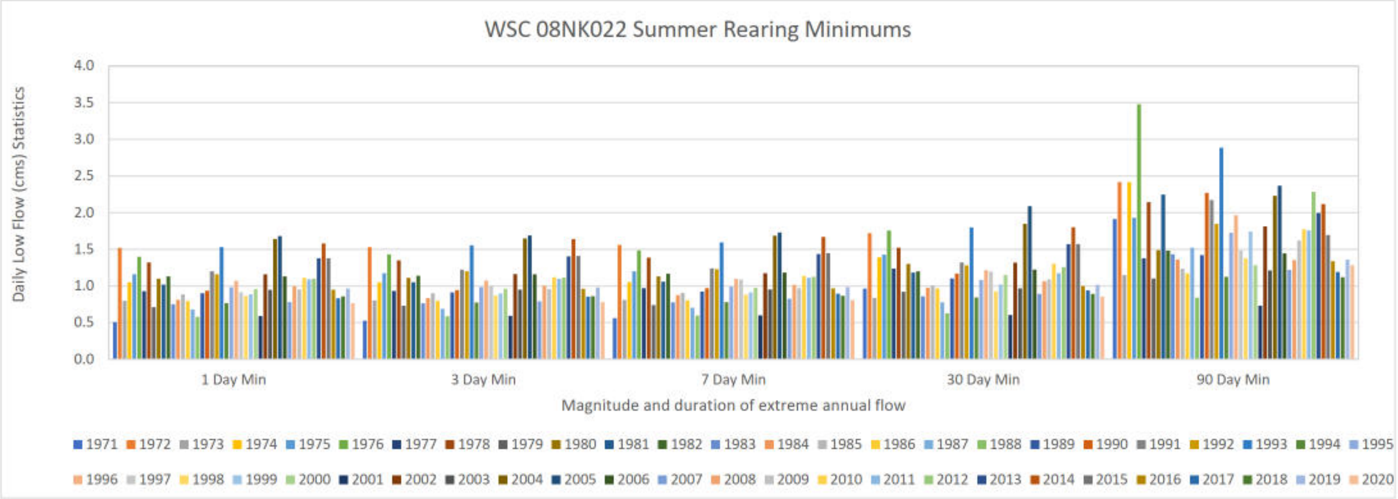
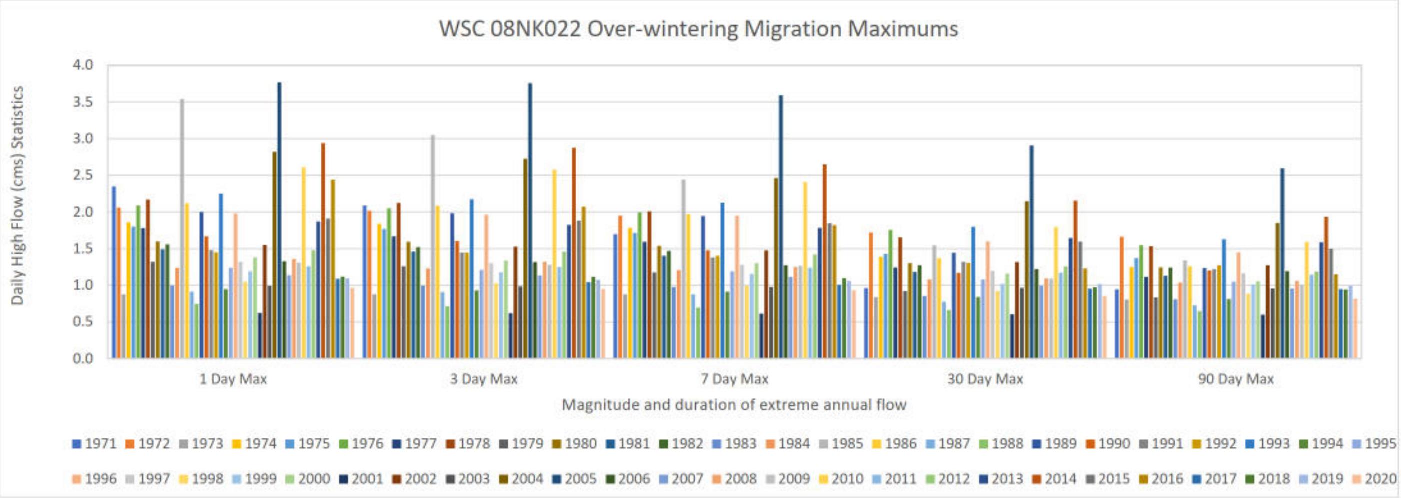


Figure 33. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Line Creek at the Mouth station (08NK022) during WCT over-wintering migration (September 1 to October 15). Note the y-axis range is different for each statistic.



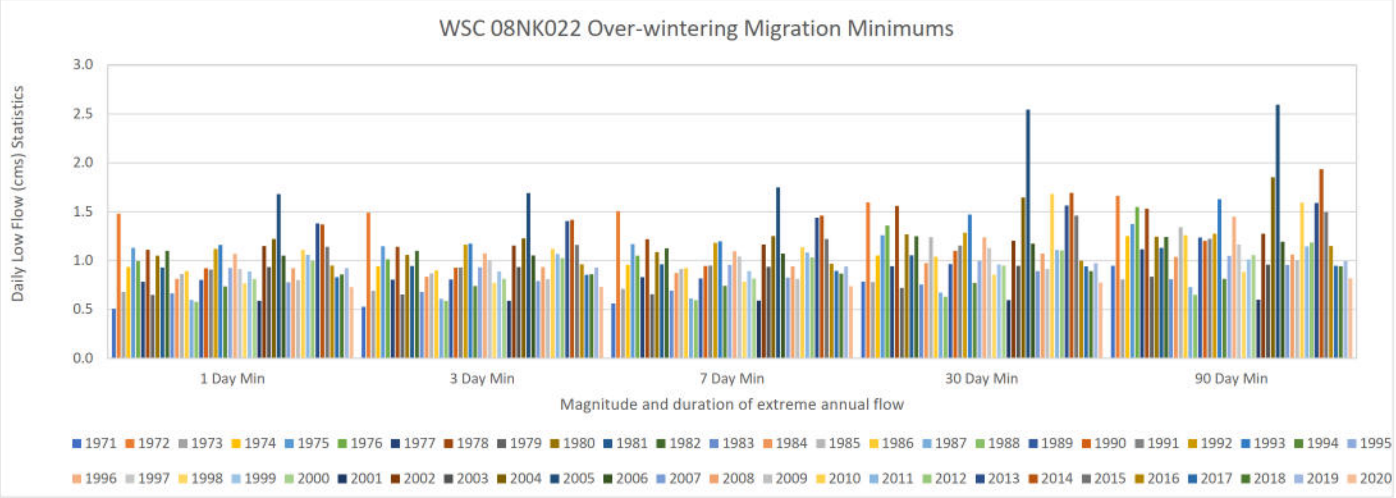
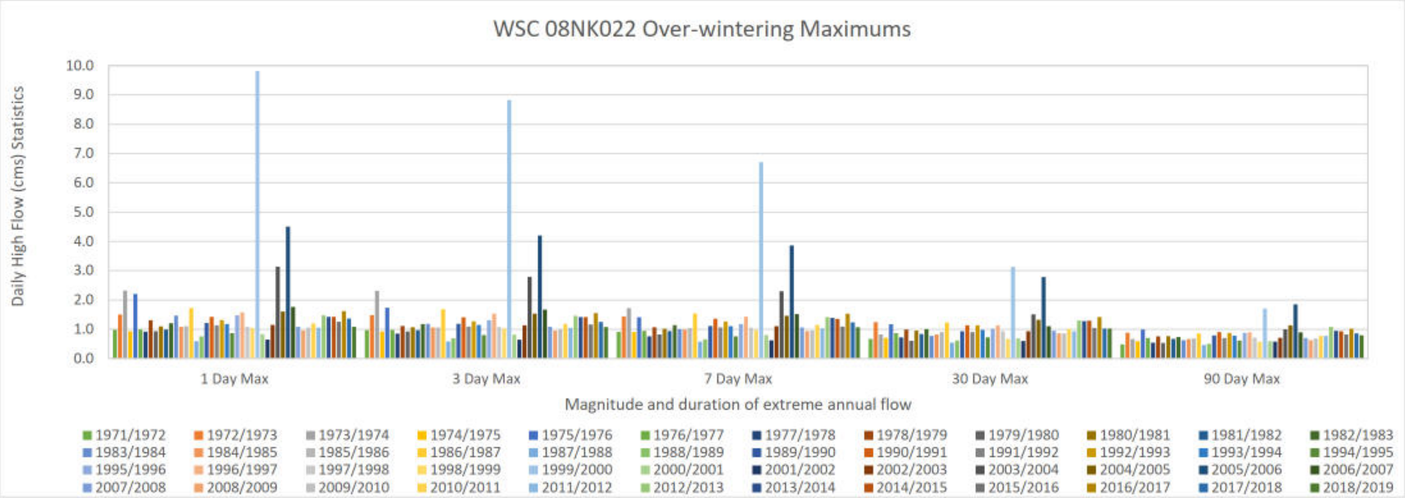
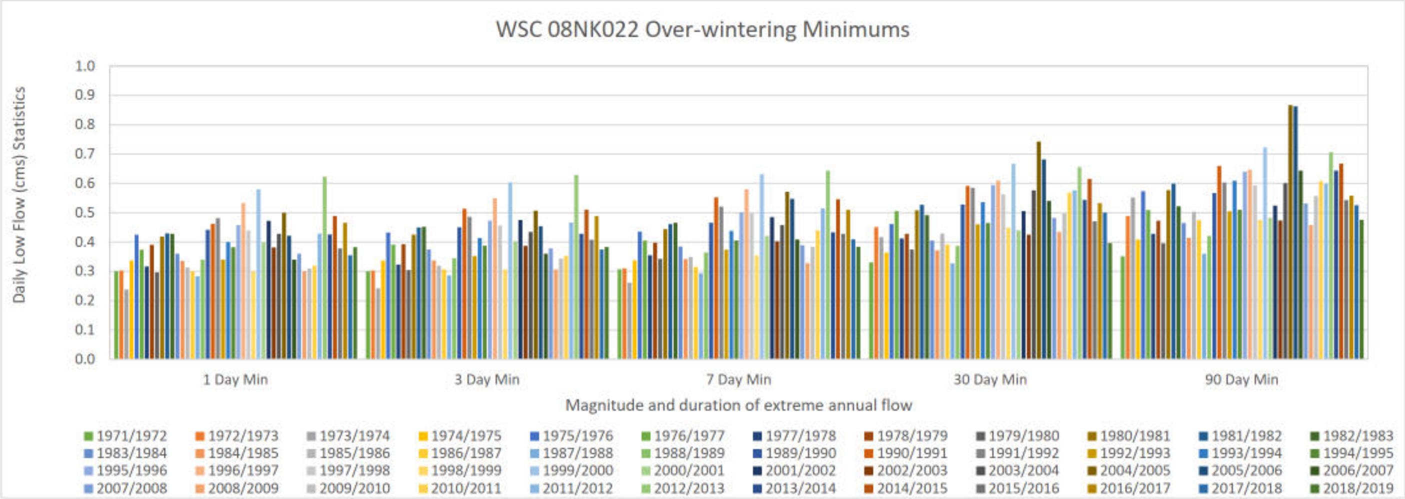


Figure 34. Magnitude and duration of annual extreme streamflow (m^3/s) at the WSC Line Creek at the Mouth station (08NK022) during WCT over-wintering (October 15 to March 31). Note the y-axis range is different for each statistic.





3.5.4. Timing of Mean Extreme Flow

The timing of annual flow extremes at each station during each WCT life stage period is provided in Table 32 to Table 37. Due to the short period of record at FR_FRABCHF, the review focused on streamflow from FR_HC1 and FR_FRNTP; years with a month or more of missing data were removed. For historical context, the timing of annual flow extremes at the WSC Fording River at the Mouth station (08NK018) and Line Creek at the Mouth (08NK022) during each WCT life stage period is also provided.

- The timing of minimum and maximum daily flow during the spawning migration period was variable across years at all stations. These timings may not be reliable given the data gaps during this period.
- The timing of minimum and maximum annual flow was similar across years at all stations during the spawning migration, incubation, summer rearing, and over-wintering migration periods.
- The timing of minimum and maximum flows was variable at all stations during the over-wintering period, with minimum flows occurring in November through March, and maxima occurring in October through March. However, these timings may not be reliable given the data gaps during this period.

Table 32. Timing of annual extreme (minimum and maximum) flow during the WCT spawning migration period.

Year	Date of Annual Extreme Flow							
	FR_HC1		FR_FRNTP		WSC 08NK018		WSC 08NK022	
	Min	Max	Min	Max	Min	Max	Min	Max
1970	-	-	-	-	15-Apr	26-May	-	-
1971	-	-	-	-	1-Apr	31-May	4-May	12-May
1972	-	-	-	-	4-Apr	19-May	4-Apr	31-May
1973	-	-	-	-	5-Apr	18-May	10-Apr	19-May
1974	-	-	-	-	4-Apr	27-May	1-Apr	27-May
1975	-	-	-	-	2-Apr	16-May	2-Apr	31-May
1976	-	-	-	-	1-Apr	11-May	1-Apr	23-May
1977	-	-	-	-	2-Apr	11-May	2-Apr	11-May
1978	-	-	-	-	4-Apr	22-May	6-Apr	21-May
1979	-	-	-	-	2-Apr	27-May	4-Apr	26-May
1980	-	-	-	-	1-Apr	27-May	1-Apr	26-May
1981	-	-	-	-	14-Apr	26-May	13-Apr	24-May
1982	-	-	-	-	5-Apr	26-May	7-Apr	25-May
1983	-	-	-	-	1-Apr	30-May	1-Apr	29-May
1984	-	-	-	-	1-Apr	31-May	1-Apr	30-May
1985	-	-	-	-	1-Apr	25-May	6-Apr	23-May
1986	-	-	-	-	3-Apr	29-May	2-Apr	29-May
1987	-	-	-	-	1-Apr	9-May	1-Apr	1-May
1988	-	-	-	-	1-Apr	13-May	1-Apr	13-May
1989	-	-	-	-	4-Apr	10-May	4-Apr	10-May
1990	-	-	-	-	1-Apr	30-May	1-Apr	30-May
1991	-	-	-	-	1-Apr	21-May	1-Apr	19-May
1992	-	-	-	-	1-Apr	8-May	14-Apr	8-May
1993	-	-	-	-	2-Apr	16-May	1-Apr	15-May
1994	-	-	-	-	1-Apr	12-May	1-Apr	12-May
1995	-	-	-	-	1-Apr	31-May	1-Apr	31-May
1996	-	-	-	-	3-Apr	29-May	5-Apr	29-May
1997	-	-	-	-	10-Apr	17-May	11-Apr	17-May
1998	-	-	07-Apr	31-May	1-Apr	31-May	1-Apr	28-May
1999	-	-	-	-	7-Apr	26-May	11-Apr	26-May
2000	26-Apr	22-May	27-Apr	23-May	1-Apr	23-May	1-Apr	23-May
2001	11-Apr	25-May	03-May	25-May	3-Apr	26-May	15-Apr	25-May
2002	-	-	30-Apr	21-May	4-Apr	31-May	4-Apr	31-May
2003	-	-	10-May	21-May	7-Apr	26-May	7-Apr	30-May
2004	-	-	16-May	05-May	2-Apr	5-May	1-Apr	5-May
2005	-	-	-	-	3-Apr	18-May	3-Apr	17-May
2006	-	-	-	-	1-Apr	19-May	1-Apr	19-May
2007	-	-	-	-	7-Apr	19-May	4-Apr	19-May
2008	-	-	-	-	1-Apr	26-May	4-Apr	21-May
2009	30-Apr	30-May	-	-	1-Apr	31-May	4-Apr	31-May
2010	01-Apr	31-May	-	-	13-Apr	20-May	15-Apr	20-May
2011	-	-	-	-	9-Apr	27-May	14-Apr	26-May
2012	-	-	-	-	7-Apr	17-May	7-Apr	17-May
2013	01-Apr	12-May	-	-	1-Apr	13-May	1-Apr	13-May
2014	02-Apr	24-May	01-Apr	02-May	3-Apr	24-May	1-Apr	24-May
2015	-	-	-	-	8-Apr	27-May	12-Apr	27-May
2016	-	-	-	-	1-Apr	24-Apr	1-Apr	24-Apr
2017	-	-	-	-	3-Apr	31-May	2-Apr	24-May
2018	-	-	-	-	2-Apr	17-May	7-Apr	27-May
2019	-	-	-	-	18-Apr	31-May	17-Apr	31-May

Table 33. Timing of annual extreme (minimum and maximum) flow during the WCT spawning period.

Year	Date of Annual Extreme Flow							
	FR_HC1		FR_FRNTP		WSC 08NK018		WSC 08NK022	
	Min	Max	Min	Max	Min	Max	Min	Max
1970	-	-	-	-	16-Jul	7-Jun	-	-
1971	-	-	-	-	9-Jul	9-Jun	9-Jul	16-May
1972	-	-	-	-	11-Jul	3-Jun	11-Jul	2-Jun
1973	-	-	-	-	16-Jul	18-May	16-Jul	19-May
1974	-	-	-	-	20-May	17-Jun	18-May	17-Jun
1975	-	-	-	-	27-May	20-Jun	28-May	21-Jun
1976	-	-	-	-	16-Jul	17-May	16-Jul	23-May
1977	-	-	-	-	16-Jul	8-Jun	16-Jul	8-Jun
1978	-	-	-	-	16-Jul	6-Jun	16-Jul	5-Jun
1979	-	-	-	-	16-Jul	27-May	16-Jul	26-May
1980	-	-	-	-	16-Jul	27-May	16-Jul	26-May
1981	-	-	-	-	16-Jul	26-May	18-May	24-May
1982	-	-	-	-	16-Jul	14-Jun	16-Jul	25-May
1983	-	-	-	-	22-Jun	30-May	11-Jul	29-May
1984	-	-	-	-	16-Jul	31-May	27-May	30-May
1985	-	-	-	-	16-Jul	25-May	15-Jul	8-Jun
1986	-	-	-	-	16-Jul	29-May	16-Jul	29-May
1987	-	-	-	-	15-Jul	16-May	4-Jul	16-May
1988	-	-	-	-	16-Jul	8-Jun	16-Jul	8-Jun
1989	-	-	-	-	9-Jul	7-Jun	9-Jul	7-Jun
1990	-	-	-	-	17-May	30-May	16-May	30-May
1991	-	-	-	-	16-Jul	21-May	16-Jul	19-May
1992	-	-	-	-	27-Jun	10-Jul	27-Jun	9-Jul
1993	-	-	-	-	26-Jun	2-Jun	11-Jun	2-Jun
1994	-	-	-	-	14-Jul	28-May	16-Jul	27-May
1995	-	-	-	06/07-Jun[1]	16-May	7-Jun	16-Jul	7-Jun
1996	-	-	-	-	16-May	8-Jun	16-May	9-Jun
1997	-	-	13-Jul	01-Jun	16-Jul	1-Jun	16-Jul	1-Jun
1998	19-May	27-May	16-Jul	01-Jun	16-Jul	1-Jun	16-Jul	1-Jun
1999	16-Jul	24-May	17-May	26-May	17-May	26-May	16-May	26-May
2000	16-May	09-Jun	16-May	10-Jun	16-Jul	23-May	16-Jul	23-May
2001	16-Jul	25-May	16-Jul	25-May	16-Jul	26-May	16-Jul	25-May
2002	18-May	24-Jun	17-May	16-Jun	16-May	17-Jun	18-May	17-Jun
2003	15-Jul	29-May	17-May	16-Jun	16-Jul	26-May	16-Jul	30-May
2004	16-May	04-Jun	16-May	11-Jun	16-May	12-Jun	16-May	7-Jun
2005	25-May	06-Jun	07-Jul	05-Jun	15-Jul	18-Jun	15-Jul	12-Jun
2006	16-Jul	16-Jun	16-Jul	16-Jun	16-Jul	19-May	16-Jul	19-May
2007	-	-	-	-	16-Jul	6-Jun	16-Jul	5-Jun
2008	11-Jul	01-Jun	12-Jul	02-Jun	16-Jul	26-May	16-Jul	21-May
2009	16-May	30-May	16-May	16-Jun	16-May	31-May	16-May	31-May
2010	16-Jul	21-Jun	07-Jul	14-Jun	16-May	24-Jun	16-May	24-Jun
2011	30-May	06-Jun	16-Jul	06-Jun	16-Jul	7-Jun	18-May	8-Jun
2012	-	-	28-May	06-Jun	15-Jul	6-Jun	29-May	6-Jun
2013	-	-	-	19-21-Jun[1]	16-Jul	21-Jun	16-Jul	20-Jun
2014	16-Jul	04-Jun	-	-	15-Jul	24-May	16-Jul	24-May
2015	15-Jul	03-Jun	11-Jul	04-Jun	10-Jul	3-Jun	10-Jul	2-Jun
2016	10-Jul	06-Jun	10-Jul	27-May	10-Jul	27-May	12-Jul	27-May
2017	16-Jul	24-May	16-Jul	25-May	16-Jul	1-Jun	16-Jul	1-Jun
2018	16-Jul	16-May	16-Jul	17-May	16-Jul	17-May	16-Jul	27-May
2019	23-May	02-Jun	23-May	03-Jun	23-May	3-Jun	23-May	3-Jun

[1] Flood events that washed out the hydrometric gauges; hence no min flow dates provided.

Table 34. Timing of annual extreme (minimum and maximum) flow during the WCT incubation period.

Year	Date of Annual Extreme Flow							
	FR_HC1		FR_FRNTP		WSC 08NK018		WSC 08NK022	
	Min	Max	Min	Max	Min	Max	Min	Max
1970	-	-	-	-	31-Aug	7-Jun	-	-
1971	-	-	-	-	31-Aug	9-Jun	13-Aug	16-May
1972	-	-	-	-	11-Jul	3-Jun	31-Aug	2-Jun
1973	-	-	-	-	29-Aug	18-May	28-Aug	19-May
1974	-	-	-	-	30-Aug	17-Jun	22-Aug	17-Jun
1975	-	-	-	-	15-Aug	20-Jun	15-Aug	21-Jun
1976	-	-	-	-	29-Jul	6-Aug	28-Jul	23-May
1977	-	-	-	-	24-Jul	8-Jun	11-Aug	8-Jun
1978	-	-	-	-	31-Aug	6-Jun	15-Aug	5-Jun
1979	-	-	-	-	10-Aug	27-May	22-Aug	26-May
1980	-	-	-	-	31-Aug	27-May	31-Aug	26-May
1981	-	-	-	-	31-Aug	26-May	31-Aug	24-May
1982	-	-	-	-	25-Aug	14-Jun	31-Aug	25-May
1983	-	-	-	-	31-Aug	30-May	31-Aug	29-May
1984	-	-	-	-	31-Aug	31-May	31-Aug	30-May
1985	-	-	-	-	8-Aug	25-May	7-Aug	8-Jun
1986	-	-	-	-	27-Aug	29-May	24-Aug	29-May
1987	-	-	-	-	31-Aug	16-May	31-Aug	16-May
1988	-	-	-	-	31-Aug	8-Jun	31-Aug	8-Jun
1989	-	-	-	-	16-Aug	7-Jun	16-Aug	7-Jun
1990	-	-	-	-	31-Aug	30-May	28-Aug	30-May
1991	-	-	-	-	31-Aug	21-May	31-Aug	19-May
1992	-	-	-	-	31-Aug	10-Jul	31-Aug	9-Jul
1993	-	-	-	-	15-Aug	2-Jun	15-Aug	2-Jun
1994	-	-	-	-	29-Aug	28-May	29-Aug	27-May
1995	-	-	-	-	31-Aug	7-Jun	31-Aug	7-Jun
1996	-	-	-	-	31-Aug	8-Jun	30-Aug	9-Jun
1997	-	-	29-Aug	01-Jun	31-Aug	1-Jun	31-Aug	1-Jun
1998	19-May	27-May	31-Aug	01-Jun	31-Aug	1-Jun	31-Aug	1-Jun
1999	31-Aug	24-May	31-Aug	26-May	31-Aug	26-May	31-Aug	26-May
2000	28-Aug	09-Jun	25-Aug	10-Jun	26-Aug	23-May	24-Aug	23-May
2001	31-Aug	25-May	31-Aug	25-May	31-Aug	26-May	31-Aug	25-May
2002	18-May	24-Jun	30-Aug	16-Jun	30-Aug	17-Jun	31-Aug	17-Jun
2003	30-Aug	29-May	31-Aug	16-Jun	31-Aug	26-May	31-Aug	30-May
2004	16-May	04-Jun	06-Aug	11-Jun	6-Aug	12-Jun	5-Aug	7-Jun
2005	-	-	-	-	7-Aug	18-Jun	7-Aug	12-Jun
2006	15-Aug	16-Jun	30-Aug	16-Jun	30-Aug	19-May	31-Aug	19-May
2007	-	-	-	-	25-Aug	6-Jun	30-Aug	5-Jun
2008	-	-	-	-	30-Aug	26-May	31-Aug	21-May
2009	16-May	30-May	31-Aug	16-Jun	16-May	31-May	16-May	31-May
2010	20-Jul	21-Jun	-	-	27-Aug	24-Jun	31-Aug	24-Jun
2011	-	-	30-Aug	06-Jun	30-Aug	7-Jun	30-Aug	8-Jun
2012	-	-	31-Aug	06-Jun	31-Aug	6-Jun	31-Aug	6-Jun
2013	-	-	-	-	31-Aug	21-Jun	30-Aug	20-Jun
2014	13-Aug	04-Jun	-	-	19-Aug	24-May	21-Aug	24-May
2015	13-Aug	03-Jun	15-Aug	04-Jun	14-Aug	3-Jun	14-Aug	2-Jun
2016	30-Aug	17-Jul	30-Aug	27-May	31-Aug	27-May	31-Aug	27-May
2017	29-Aug	24-May	30-Aug	25-May	31-Aug	1-Jun	30-Aug	1-Jun
2018	29-Aug	16-May	22-Aug	17-May	31-Aug	17-May	31-Aug	27-May
2019	31-Aug	02-Jun	30-Aug	02-Jun	31-Aug	3-Jun	31-Aug	3-Jun

Table 35. Timing of annual extreme (minimum and maximum) flow during the WCT summer rearing period.

Year	Date of Annual Extreme Flow							
	FR_HC1		FR_FRNTP		WSC 08NK018		WSC 08NK022	
	Min	Max	Min	Max	Min	Max	Min	Max
1970	-	-	-	-	3-Sep	16-Jul	-	-
1971	-	-	-	-	23-Sep	16-Jul	23-Sep	20-Jul
1972	-	-	-	-	30-Sep	24-Jul	30-Sep	25-Jul
1973	-	-	-	-	30-Sep	16-Jul	19-Sep	16-Jul
1974	-	-	-	-	30-Sep	16-Jul	25-Sep	16-Jul
1975	-	-	-	-	30-Sep	16-Jul	30-Sep	16-Jul
1976	-	-	-	-	30-Sep	6-Aug	30-Sep	16-Aug
1977	-	-	-	-	30-Sep	15-Aug	30-Sep	25-Aug
1978	-	-	-	-	4-Sep	19-Jul	4-Sep	19-Jul
1979	-	-	-	-	30-Sep	16-Jul	30-Sep	17-Jul
1980	-	-	-	-	12-Sep	10-Aug	10-Sep	12-Aug
1981	-	-	-	-	30-Sep	25-Jul	30-Sep	25-Jul
1982	-	-	-	-	3-Sep	16-Jul	3-Sep	16-Jul
1983	-	-	-	-	26-Sep	17-Jul	30-Sep	17-Jul
1984	-	-	-	-	19-Sep	16-Jul	19-Sep	16-Jul
1985	-	-	-	-	8-Aug	13-Sep	7-Aug	13-Sep
1986	-	-	-	-	27-Aug	28-Jul	24-Aug	17-Jul
1987	-	-	-	-	29-Sep	23-Jul	30-Sep	22-Jul
1988	-	-	-	-	24-Sep	16-Jul	22-Sep	16-Jul
1989	-	-	-	-	16-Aug	16-Jul	16-Aug	16-Jul
1990	-	-	-	-	29-Sep	26-Jul	29-Sep	26-Jul
1991	-	-	-	-	25-Sep	16-Jul	29-Sep	16-Jul
1992	-	-	-	-	11-Sep	16-Jul	11-Sep	25-Jul
1993	-	-	-	-	30-Sep	16-Jul	30-Sep	16-Jul
1994	-	-	-	-	30-Sep	17-Jul	30-Sep	17-Jul
1995	-	-	-	-	30-Sep	16-Jul	28-Sep	16-Jul
1996	-	-	-	-	15-Sep	16-Jul	15-Sep	16-Jul
1997	-	-	29-Sep	16-Jul	30-Sep	16-Jul	23-Sep	16-Jul
1998	14-Sep	20-Jul	16-Sep	16-Jul	17-Sep	16-Jul	30-Sep	16-Jul
1999	23-Sep	20-Jul	27-Sep	20-Jul	24-Sep	16-Jul	30-Sep	16-Jul
2000	28-Aug	17-Jul	-	-	29-Sep	16-Jul	28-Sep	16-Jul
2001	-	-	15-Sep	25-Jul	27-Sep	16-Jul	25-Sep	16-Jul
2002	05-Sep	16-Jul	-	-	29-Sep	16-Jul	25-Sep	16-Jul
2003	30-Aug	23-Jul	-	-	30-Sep	16-Jul	30-Sep	16-Jul
2004	31-Jul	26-Aug	-	-	6-Aug	27-Aug	5-Aug	28-Aug
2005	-	-	-	-	9-Sep	17-Jul	8-Sep	17-Sep
2006	17-Sep	16-Jul	30-Aug	17-Jul	17-Sep	16-Jul	19-Sep	16-Jul
2007	-	-	-	-	16-Sep	19-Jul	16-Sep	16-Jul
2008	05-Sep	24-Jul	-	-	30-Sep	16-Jul	8-Sep	16-Jul
2009	30-Sep	05-Aug	-	-	30-Sep	16-Jul	30-Sep	16-Jul
2010	-	-	-	-	4-Sep	21-Sep	4-Sep	16-Jul
2011	-	-	30-Aug	19-Jul	26-Sep	16-Jul	30-Sep	16-Jul
2012	-	-	30-Sep	16-Jul	30-Sep	16-Jul	30-Sep	18-Jul
2013	-	-	-	-	17-Sep	16-Jul	27-Sep	16-Jul
2014	13-Aug	07-Sep	30-Sep	08-Sep	19-Aug	16-Jul	21-Aug	16-Jul
2015	13-Aug	16-Aug	15-Aug	17-Aug	30-Sep	17-Jul	30-Sep	21-Jul
2016	07-Sep	17-Jul	23-Sep	18-Jul	17-Sep	18-Jul	21-Sep	19-Jul
2017	23-Sep	16-Jul	23-Sep	16-Jul	30-Sep	16-Jul	13-Sep	16-Jul
2018	10-Sep	19-Jul	13-Sep	16-Jul	19-Sep	16-Jul	11-Sep	16-Jul
2019	30-Sep	21-Jul	27-Sep	21-Jul	30-Sep	22-Jul	30-Sep	23-Jul

Table 36. Timing of annual extreme (minimum and maximum) flow during the WCT over-wintering migration period.

Year	Date of Annual Extreme Flow							
	FR_HC1		FR_FRNTP		WSC 08NK018		WSC 08NK022	
	Min	Max	Min	Max	Min	Max	Min	Max
1970	-	-	-	-	3-Sep	2-Oct	-	-
1971	-	-	-	-	23-Sep	1-Sep	23-Sep	1-Sep
1972	-	-	-	-	16-Oct	6-Sep	5-Oct	14-Sep
1973	-	-	-	-	16-Oct	7-Sep	16-Oct	1-Sep
1974	-	-	-	-	16-Oct	1-Sep	16-Oct	1-Sep
1975	-	-	-	-	2-Oct	1-Sep	2-Oct	1-Sep
1976	-	-	-	-	16-Oct	13-Sep	16-Oct	3-Sep
1977	-	-	-	-	16-Oct	5-Sep	16-Oct	5-Sep
1978	-	-	-	-	16-Oct	16-Sep	16-Oct	28-Sep
1979	-	-	-	-	15-Oct	1-Sep	14-Oct	1-Sep
1980	-	-	-	-	12-Sep	21-Sep	16-Oct	20-Sep
1981	-	-	-	-	15-Oct	2-Sep	14-Oct	2-Sep
1982	-	-	-	-	16-Oct	28-Sep	14-Oct	27-Sep
1983	-	-	-	-	16-Oct	5-Sep	16-Oct	3-Sep
1984	-	-	-	-	19-Sep	21-Sep	19-Sep	21-Sep
1985	-	-	-	-	3-Sep	13-Sep	15-Oct	13-Sep
1986	-	-	-	-	22-Sep	11-Oct	22-Sep	9-Oct
1987	-	-	-	-	16-Oct	1-Sep	16-Oct	2-Sep
1988	-	-	-	-	1-Oct	9-Sep	22-Sep	25-Sep
1989	-	-	-	-	10-Oct	6-Sep	9-Oct	6-Sep
1990	-	-	-	-	1-Oct	1-Sep	2-Oct	6-Oct
1991	-	-	-	-	16-Oct	1-Sep	16-Oct	1-Sep
1992	-	-	-	-	11-Sep	27-Sep	16-Oct	24-Sep
1993	-	-	-	-	13-Oct	3-Sep	15-Oct	1-Sep
1994	-	-	-	-	14-Oct	1-Sep	14-Oct	1-Sep
1995	-	-	-	-	30-Sep	1-Sep	8-Oct	1-Sep
1996	-	-	-	-	15-Sep	6-Oct	15-Sep	1-Oct
1997	-	-	-	-	13-Oct	4-Sep	23-Sep	4-Sep
1998	-	-	-	-	16-Oct	1-Sep	16-Oct	1-Sep
1999	-	-	-	-	7-Oct	1-Sep	30-Sep	1-Sep
2000	-	-	-	-	16-Oct	9-Sep	9-Oct	3-Sep
2001	-	-	-	-	15-Oct	7-Sep	10-Oct	6-Sep
2002	-	-	-	-	15-Oct	7-Sep	15-Oct	7-Sep
2003	-	-	-	-	15-Oct	9-Sep	12-Oct	1-Sep
2004	-	-	-	-	13-Oct	1-Sep	9-Oct	1-Sep
2005	-	-	-	-	9-Sep	2-Oct	8-Sep	17-Sep
2006	-	-	-	-	17-Sep	2-Sep	15-Oct	1-Sep
2007	-	-	-	-	16-Sep	3-Oct	16-Sep	11-Oct
2008	-	-	-	-	13-Oct	23-Sep	13-Oct	24-Sep
2009	-	-	-	-	12-Oct	2-Sep	12-Oct	4-Sep
2010	-	-	-	-	4-Sep	21-Sep	4-Sep	22-Sep
2011	-	-	-	-	26-Sep	8-Oct	16-Oct	1-Sep
2012	-	-	01-Oct	16-Oct	2-Oct	1-Sep	3-Oct	1-Sep
2013	-	-	-	-	17-Sep	30-Sep	27-Sep	29-Sep
2014	14-Oct	07-Sep	14-Oct	08-Sep	14-Oct	8-Sep	16-Oct	8-Sep
2015	01-Oct	12-Sep	03-Oct	14-Sep	10-Oct	16-Sep	16-Oct	21-Sep
2016	07-Sep	10-Oct	07-Oct	10-Oct	17-Sep	10-Oct	21-Sep	9-Oct
2017	23-Sep	08-Oct	16-Oct	01-Sep	16-Oct	1-Sep	13-Sep	4-Oct
2018	16-Oct	24-Sep	16-Oct	01-Sep	19-Sep	1-Sep	11-Sep	7-Oct
2019	16-Oct	13-Sep	11-Oct	13-Sep	9-Oct	1-Sep	6-Oct	10-Sep

Table 37. Timing of annual extreme (minimum and maximum) flow during the WCT over-wintering period.

Year	Date of Annual Extreme Flow							
	FR_HC1		FR_FRNTP		WSC 08NK018		WSC 08NK022	
	Min	Max	Min	Max	Min	Max	Min	Max
1969/1970	-	-	-	-	7-Jan	19-Feb	-	-
1970/1971	-	-	-	-	6-Feb	16-Oct	-	-
1971/1972	-	-	-	-	27-Jan	26-Mar	26-Jan	27-Mar
1972/1973	-	-	-	-	7-Dec	23-Oct	6-Dec	16-Oct
1973/1974	-	-	-	-	12-Jan	16-Jan	12-Jan	16-Jan
1974/1975	-	-	-	-	28-Mar	16-Oct	9-Feb	15-Oct
1975/1976	-	-	-	-	16-Mar	4-Dec	11-Mar	4-Dec
1976/1977	-	-	-	-	5-Jan	16-Oct	5-Jan	16-Oct
1977/1978	-	-	-	-	22-Nov	30-Mar	21-Nov	30-Mar
1978/1979	-	-	-	-	1-Jan	16-Oct	11-Mar	3-Nov
1979/1980	-	-	-	-	29-Jan	18-Dec	29-Jan	17-Dec
1980/1981	-	-	-	-	10-Feb	28-Dec	10-Feb	28-Dec
1981/1982	-	-	-	-	6-Jan	21-Feb	6-Jan	21-Feb
1982/1983	-	-	-	-	19-Feb	18-Oct	22-Mar	22-Oct
1983/1984	-	-	-	-	12-Feb	4-Nov	19-Feb	3-Nov
1984/1985	-	-	-	-	4-Feb	16-Oct	4-Feb	16-Oct
1985/1986	-	-	-	-	18-Feb	28-Oct	18-Feb	27-Oct
1986/1987	-	-	-	-	16-Jan	17-Oct	26-Feb	27-Oct
1987/1988	-	-	-	-	15-Dec	16-Oct	1-Feb	15-Oct
1988/1989	-	-	-	-	26-Dec	16-Oct	26-Jan	6-Nov
1989/1990	-	-	-	-	15-Feb	11-Nov	17-Feb	11-Nov
1990/1991	-	-	-	-	30-Dec	14-Nov	29-Feb	10-Nov
1991/1992	-	-	-	-	20-Feb	30-Mar	14-Dec	31-Mar
1992/1993	-	-	-	-	28-Nov	27-Oct	18-Feb	23-Oct
1993/1994	-	-	-	-	8-Feb	16-Oct	10-Feb	15-Oct
1994/1995	-	-	-	-	6-Jan	27-Oct	6-Jan	26-Oct
1995/1996	-	-	-	-	5-Feb	30-Nov	3-Feb	29-Nov
1996/1997	-	-	-	-	14-Mar	16-Oct	13-Mar	16-Oct
1997/1998	-	-	-	-	4-Dec	18-Oct	12-Jan	17-Oct
1998/1999	-	-	-	-	22-Dec	27-Mar	22-Dec	25-Mar
1999/2000	-	-	-	-	11-Jan	14-Nov	20-Jan	12-Nov
2000/2001	-	-	-	-	11-Dec	17-Oct	9-Feb	18-Oct
2001/2002	-	-	-	-	27-Nov	8-Jan	2-Jan	8-Jan
2002/2003	-	-	-	-	22-Dec	17-Oct	26-Feb	15-Oct
2003/2004	-	-	-	-	3-Jan	22-Oct	3-Jan	20-Oct
2004/2005	-	-	-	-	4-Jan	17-Oct	5-Jan	11-Dec
2005/2006	-	-	-	-	17-Feb	19-Oct	18-Feb	18-Oct
2006/2007	-	-	-	-	13-Jan	8-Nov	12-Jan	7-Nov
2007/2008	-	-	-	-	22-Jan	17-Oct	28-Jan	15-Oct
2008/2009	-	-	-	-	16-Dec	16-Oct	15-Dec	21-Oct
2009/2010	-	-	-	-	8-Dec	18-Oct	7-Dec	17-Oct
2010/2011	-	-	-	-	11-Jan	16-Oct	23-Nov	15-Oct
2011/2012	-	-	-	-	18-Jan	16-Oct	18-Jan	15-Oct
2012/2013	-	-	-	-	24-Feb	20-Oct	10-Feb	9-Nov
2013/2014	-	-	1-Jan	31-Mar	7-Dec	16-Oct	31-Jan	17-Oct
2014/2015	22-Feb	31-Mar	7-Mar	30-Mar	29-Dec	29-Mar	28-Dec	27-Mar
2015/2016	-	-	-	-	3-Feb	16-Oct	3-Feb	13-Nov
2016/2017	5-Mar	16-Oct	12-Mar	16-Nov	15-Dec	16-Oct	7-Mar	16-Oct
2017/2018	12-Mar	20-Oct	16-Oct	28-Nov	30-Dec	27-Nov	30-Dec	18-Oct
2018/2019	28-Dec	23-Mar	2-Mar	24-Mar	23-Dec	27-Oct	5-Mar	25-Oct

3.6. Water Use

Water use data for the FR_POTWELLS, five PODs associated with minimum IFRs at FR_FRNTP (Measuring Point B), and two PODs not associated with minimum IFRs (Eagle Settling Pond and Eagle Pit 4), are summarized as total daily volume during each of the WCT life stage periods in Table 38. Water use data for the two PODs associated with minimum IFRs at FR_FRABCHF and two non-licensable sources (North Loop Settling Pond and Smith Ponds) located downstream of FR_FRNTP and upstream of FR_FRABCHF are summarized as total daily volume during each of the WCT life stage periods in Table 39. Data are summarized for 2015-2019 in various combinations to allow for different assumptions of hydraulic connectivity between the UFR and some of the water sources associated with FR_FRNTP (see Section 2.1.6 for rationale): Table 40 summarizes total water use from the FR_POTWELLS and the five PODs associated with minimum IFRs at FR_FRNTP without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water; Table 41 summarizes total water use with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water; Table 42 includes Shandley Pit stored water but not Eagle Pit 4 or Eagle Settling Pond water; and Table 43 summarizes total water use with Eagle Pit 4 and Eagle Settling Pond water, but without Shandley Pit stored water. Figure 35 to Figure 46 provide a graphical display of these data. The water use tallies that include Shandley Pit, Eagle Settling Pond, and Eagle Pit water, assume water is drawn directly from the Fording River, and thus do not accurately reflect the surface water reductions at these times since the stored water was accumulated from prior runoff from snowmelt and rainfall. Recycled water use from the seepage return wells are not included in the tallies, but data are summarized in Table 44.

Table 45 summarizes water use data for the two PODs with minimum IFRs linked to FR_FRABCHF (Measuring Point C) and non-licensable water from North Loop Settling Pond and Smith Ponds; the data are summarized as total daily volume of all water used during each of the WCT life stage periods from 2015-2019. Table 46 summarizes water use (expressed as total daily volume of all water used during each of the WCT life stage periods) for all PODs, including those without minimum IFRs (i.e., Eagle Pit 4 stored water and Eagle Settling Pond water), and non-licensable water, upstream of FR_FRABCHF. Total water use could not be expressed as the percent of total average observed streamflow from FR_FRABCHF for all periods or years, because the hydrometric station was not installed until October 2017 and there are data gaps during the spawning period for all years. Therefore, the data were not displayed graphically but are provided in Table 45.

We assumed that all recorded water use is consumptive and there are no (or minimal) returns to the Fording River. The following is an interannual comparison of water use for the WCT life stages.

- Total water use recorded for the FR_POTWELLS and PODs associated with FR_FRNTP (excluding Shandley Pit and Eagle 4 Pit stored water, and Eagle Settling Pond water) was greatest in 2016 for all WCT life stage periods except for over-wintering, which was greatest in 2015-2016, when compared to all years (see solid bars in Figure 35 – Figure 46 and Table 40).

- When Shandley Pit and Eagle 4 Pit stored water, and Eagle Settling Pond is included in the calculations with the FR_POTWELLS and PODs associated with FR_FRNTP, total water use was greatest in:
    - 2017 for summer rearing, over-wintering migration, and overwintering periods;
    - 2018 for the spawning and incubation periods; and
    - 2019 for the spawning migration period.
- Total water use recorded for the PODs associated with FR_FRABCHF was greatest in 2019 for the WCT spawning migration and spawning periods, greatest in 2015 for the incubation period, greatest in 2017 for the WCT summer rearing period, greatest in 2018 for the over-wintering migration period, and greatest in 2018-2019 for the over-wintering period (Table 45). The FR_FRABCHF gauge was installed in 2017 and therefore had only had three years of data.
- Total water use recorded for all PODs, including those without IFRs, and non-licensable water upstream of FR_FRABCHF, was greatest in 2017 for the WCT over-wintering migration period (Table 50).

Table 38. Total water use (m^3) for PODs and potable wells upstream of FR_FRNTP per WCT life stage. Totals include PODs without IFRs.

Licenced Water Source	Minimum Instream Flow Threshold (Y/N)	Year[1]	Westslope Cutthroat Trout Life Stages					
			Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
			April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
Kalmakoff Pond	Y	2015	-	-	-	-	-	-
		2016	35,972	59,761	72,383	18,942	6,003	-
		2017	-	47,473	47,473	-	-	-
		2018	-	-	-	-	-	-
		2019	-	-	-	-	-	-
I pit	Y	2015	104,659	113,381	143,906	34,886	-	126,463
		2016	223,706	82,553	91,330	9,803	-	117,372
		2017	130,824	92,594	94,647	2,071	-	-
		2018	-	-	-	-	-	-
		2019	-	-	-	-	-	-
Lake Mountain Pit	Y	2015	-	-	-	-	-	-
		2016	-	-	-	-	-	-
		2017	-	-	-	-	-	-
		2018	-	-	-	-	-	-
		2019	2,281	18,990	27,421	12,454	3,625	-
Liverpool Sediment Pond - Lee's Lake	Y	2015	49,300	179,800	316,100	226,200	130,500	2,900
		2016	48,076	120,039	243,717	207,258	124,497	5,284
		2017	-	-	-	-	-	-
		2018	-	-	-	-	-	-
		2019	-	-	-	-	-	-
FR_POTWELLS	N	2015	197,331	190,628	331,256	216,682	107,715	558,100
		2016	203,305	226,582	396,655	281,442	161,440	560,727
		2017	215,888	219,761	380,258	294,047	194,332	621,479
		2018	234,394	265,325	438,113	294,160	177,490	534,756
		2019	221,648	222,037	393,191	291,844	176,785	
Shandley Pit	Y	2015	190,785	54,510	54,510	-	63,765	266,835
		2016	70,420	179,569	654,848	547,026	65,928	140,635
		2017	23,468	114,661	617,906	955,266	624,872	486,538
		2018	398,971	686,173	1,164,574	702,008	417,717	163,013
		2019	475,248	408,232	510,611	130,408	36,601	
Eagle Pit 4	N	2015	0	0	0	0	0	0
		2016	0	0	0	0	0	0
		2017	21,107	113,509	238,640	166,914	39,058	0
		2018	56,167	52,813	184,416	131,603	0	0
		2019	13,067	109,989	134,488	44,183	16,777	-
Eagle Settling Pond	N	2015	43,871	45,463	76,653	44,372	21,601	102,156
		2016	31,472	41,717	58,344	22,671	15,337	113,934
		2017	28,621	19,769	30,476	26,573	22,163	87,219
		2018	45,516	49,372	50,742	3,028	1,255	88,199
		2019	47,214	48,075	81,720	57,624	34,256	-

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 39. **Total water use (m^3) for PODs and non-licensable water upstream of FR_FRABCHF and downstream of FR_FRNTP per WCT life stage.**

Licenced Water Source	Minimum Instream Flow Threshold (Y/N)	Year[1]	Westslope Cutthroat Trout Life Stages					
			Spawning	Spawning	Incubation	Summer	Over-wintering	Over-wintering
			April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
Kilmarnock Control Pond	Y	2015	289,993	335,781	656,300	484,402	248,304	102,667
		2016	241,466	206,285	263,577	161,900	121,031	22,508
		2017	-	98,820	609,338	760,654	324,113	28,590
		2018	-	-	-	-	-	-
		2019	-	-	-	-	-	-
Kilmarnock Phase 1 Secondary Pond	Y	2015	-	-	-	-	-	-
		2016	-	-	-	-	-	-
		2017	-	-	-	-	-	110,147
		2018	211,781	266,550	753,411	736,532	318,273	415,741
		2019	701,468	612,952	652,429	54,261	7,393	-
North Loop Settling Pond	N (non-licensable)	2015	13,110	25,454	45,774	28,439	11,140	16,723
		2016	45,688	24,530	51,349	38,351	24,579	30,719
		2017	39,840	69,602	79,579	15,172	7,024	22,969
		2018	18,192	18,490	32,506	23,261	13,420	142,953
		2019	23,320	53,660	73,473	21,077	0	-
Smith Ponds	N (non-licensable)	2015	0	35,632	130,861	111,146	45,175	31,485
		2016	0	0	216,000	216,000	0	-
		2017	-	-	-	-	-	-
		2018	-	-	-	-	-	-
		2019	-	-	-	-	-	-

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 40. **Total water use (m^3) upstream of FR_FRNTP per WCT life stage. Totals exclude Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water.**

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	351,291	483,808	791,262	477,768	238,215	687,463
2016	511,059	488,936	804,085	517,445	291,940	683,382
2017	346,712	359,828	522,378	296,118	194,332	621,479
2018	234,394	265,325	438,113	294,160	177,490	534,756
2019	223,930	241,027	420,613	304,298	180,409	

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 41. **Total water use (m^3) upstream of FR_FRNTP per WCT life stage. Totals include Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water.**

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	585,947	583,781	922,424	522,140	323,580	1,056,454
2016	612,951	710,221	1,517,276	1,087,142	373,205	937,951
2017	419,909	607,768	1,409,400	1,444,871	880,424	1,195,235
2018	735,048	1,053,683	1,837,845	1,130,799	596,461	785,968
2019	759,460	807,322	1,147,431	536,513	268,043	-

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 42. **Total water use (m^3) upstream of FR_FRNTP per WCT life stage. Totals include Shandley Pit stored water, and exclude Eagle Pit 4 and Eagle Settling Pond water.**

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	542,075	538,318	845,772	477,768	301,980	954,298
2016	581,479	668,505	1,458,933	1,064,471	357,868	824,017
2017	370,181	474,489	1,140,284	1,251,384	819,204	1,108,016
2018	633,365	951,498	1,602,687	996,168	595,206	697,769
2019	699,178	649,259	931,224	434,705	217,010	

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 43. Total water use (m^3) upstream of FR_FRNTP per WCT life stage. Totals include Eagle Pit 4 and Eagle Settling Pond water, and exclude Shandley Pit stored water.

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	395,162	529,271	867,914	522,140	259,815	789,619
2016	542,531	530,652	862,428	540,116	307,277	797,316
2017	396,441	493,106	791,494	489,605	255,552	708,698
2018	336,077	367,510	673,271	428,792	178,745	622,955
2019	284,211	399,090	636,820	406,105	231,442	-

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 44. Total recycled water use (m^3) from the seepage return wells per WCT life stage.

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	87,230	90,516	157,473	82,229	31,621	339,493
2016	121,438	120,651	187,381	102,470	49,586	173,860
2017	45,817	73,137	140,347	111,540	64,350	240,240
2018	87,230	88,660	155,870	111,540	64,350	240,240
2019	87,230	88,660	155,870	111,540	64,350	-

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 45. Total water use (m^3) upstream of FR_FRABCHF and downstream of FR_FRNTP per WCT life stage. Totals include non-licensable water.

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	303,103	396,867	832,935	623,987	304,618	150,875
2016	287,154	230,815	530,926	416,251	145,610	53,227
2017	39,840	168,422	688,917	775,826	331,137	161,707
2018	229,973	285,040	785,917	759,793	331,693	558,694
2019	724,789	666,613	725,902	75,339	7,393	0

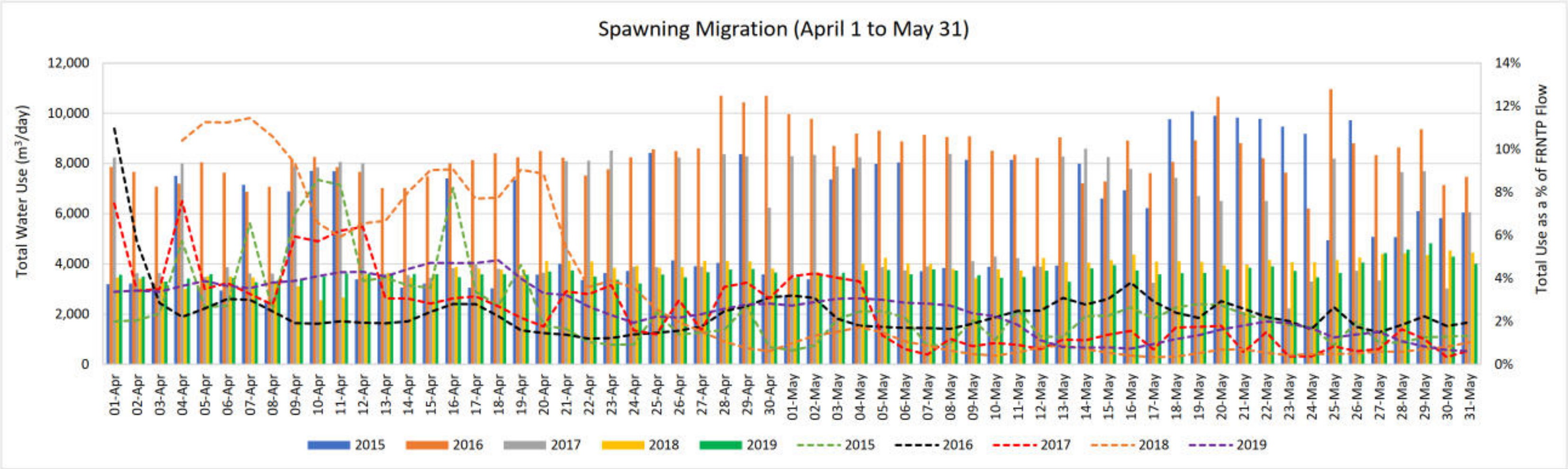
[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Table 46. Total water use (m^3) upstream of FR_FRABCHF per WCT life stage. Totals include Shandley Pit stored water, PODs without IFRs (Eagle Pit 4 stored water and Eagle Settling Pond), and non-licensable water.

Year[1]	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September	September 1 to October 15	October 15 to March 31
2015	889,049	980,648	1,755,359	1,146,127	628,199	1,207,329
2016	900,106	941,037	2,048,202	1,503,394	518,815	991,179
2017	459,750	776,190	2,098,317	2,220,697	1,211,561	1,356,942
2018	965,021	1,338,723	2,623,762	1,890,593	928,154	1,344,661
2019	1,484,248	1,473,935	1,873,333	611,851	275,436	

[1] For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter.

Figure 35. Total daily water withdrawal (m³/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (upper) and with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (lower) during the WCT spawning migration period (April 1 to May 31).



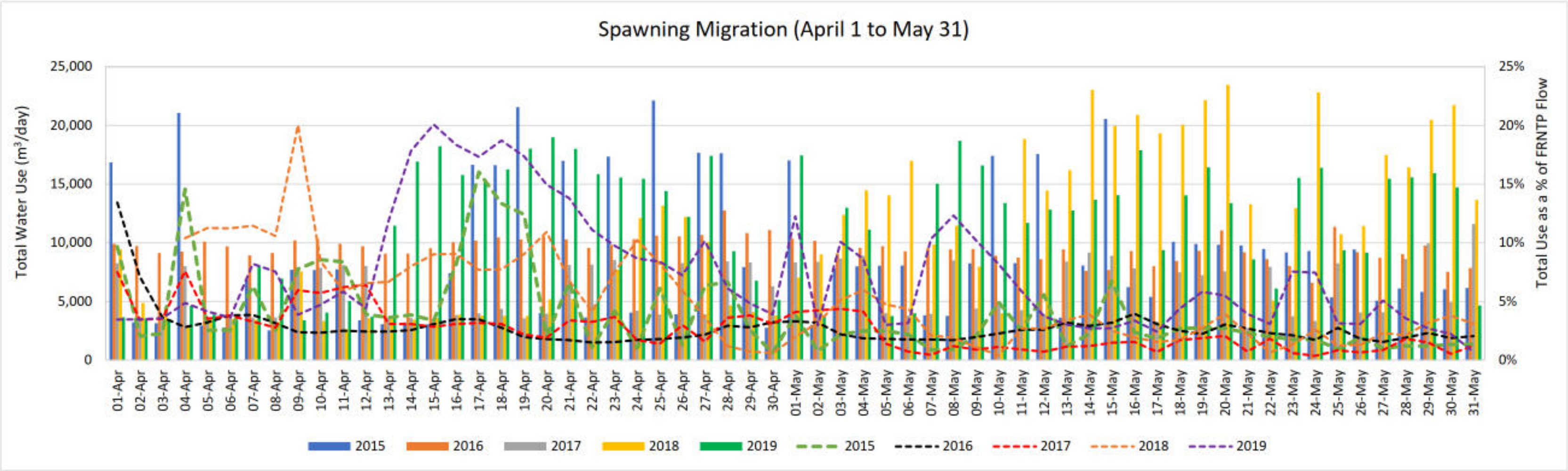
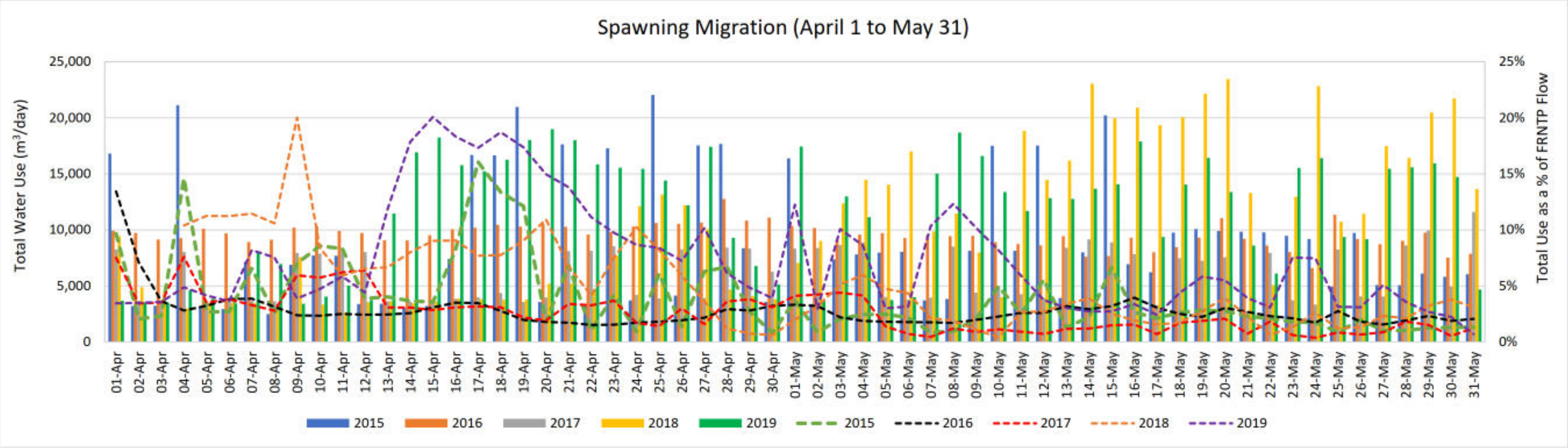


Figure 36. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) with Shandley Pit stored water, but without Eagle Pit 4 and Eagle Settling Pond water (upper), and with Eagle Pit 4 and Eagle Settling Pond water, but without Shandley Pit stored water (lower) during the WCT spawning migration period (April 1 to May 31).



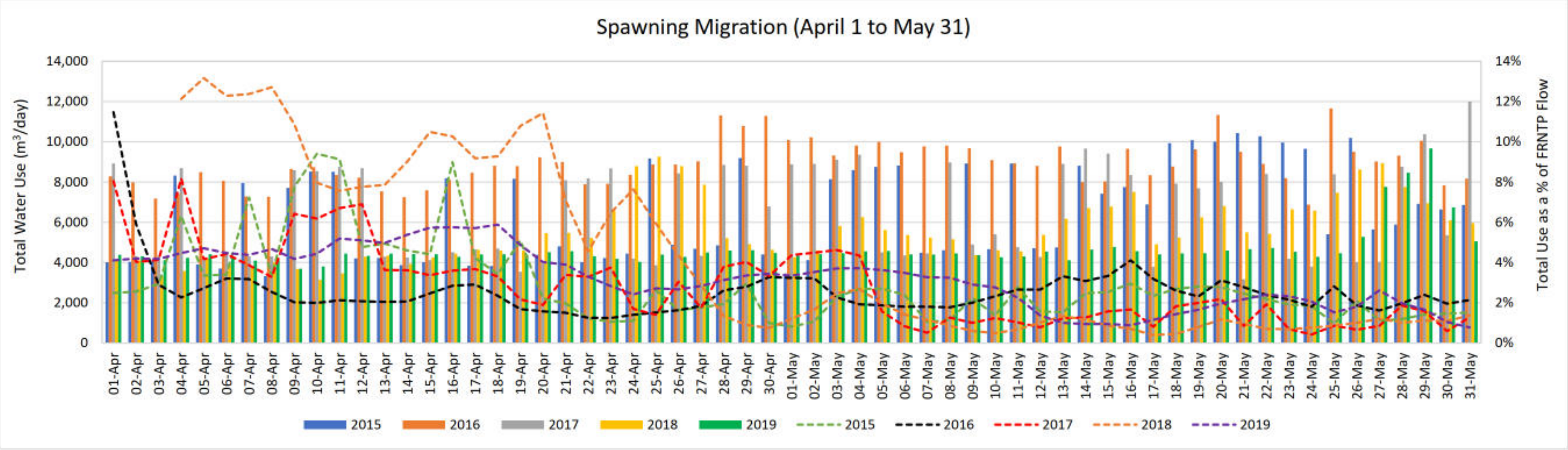
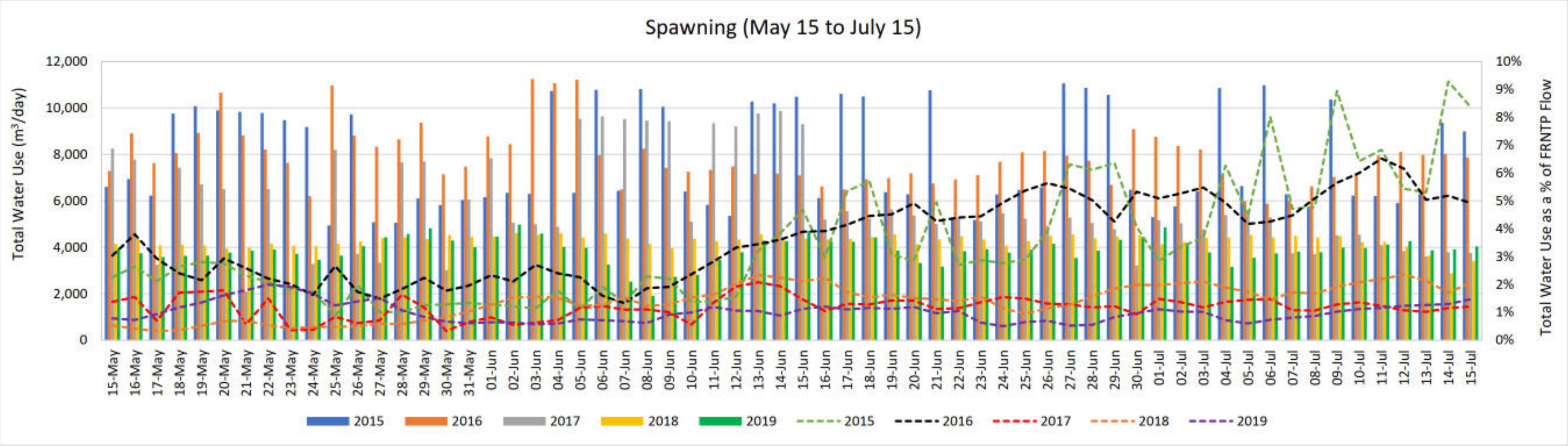


Figure 37. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (upper) and with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (lower) during the WCT spawning period (May 15 to July 15).



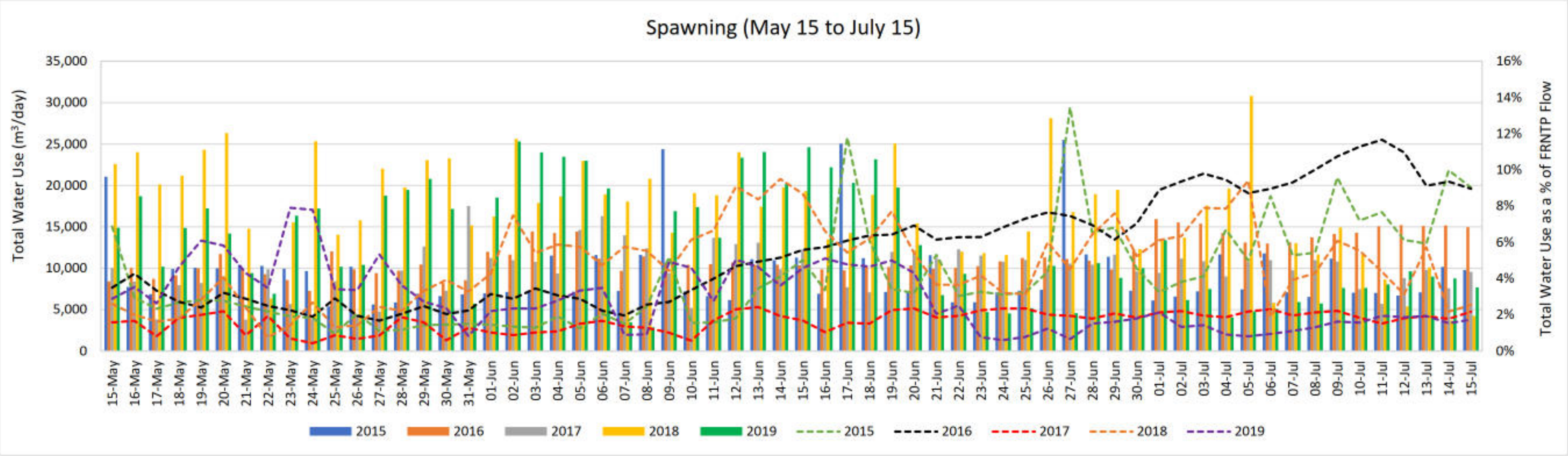
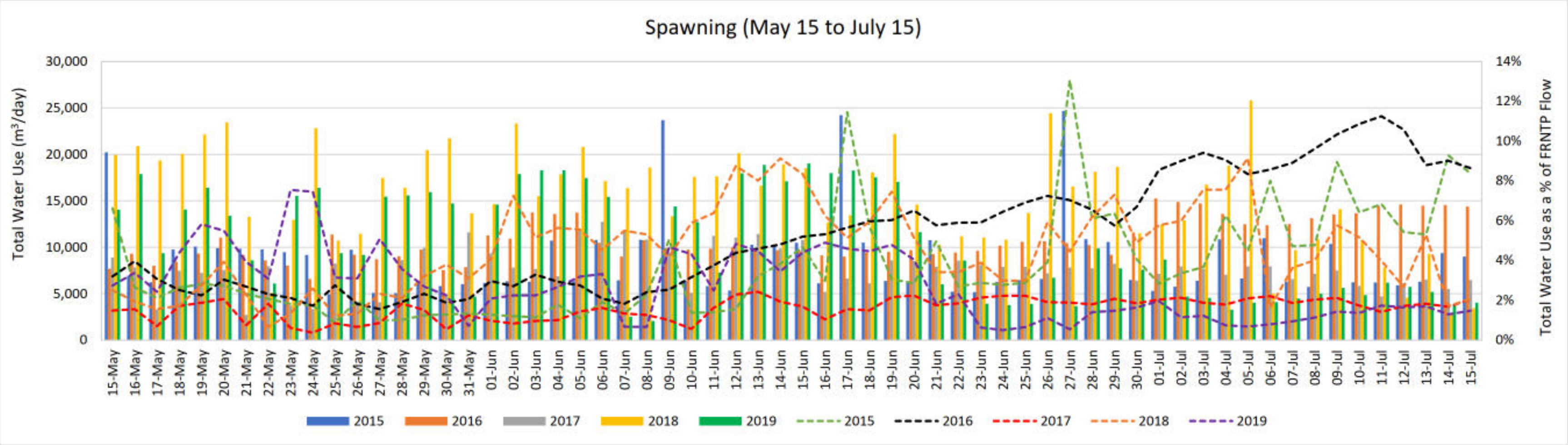


Figure 38. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) with Shandley Pit stored water, but without Eagle Pit 4 and Eagle Settling Pond water (upper) and with Eagle Pit 4 and Eagle Settling Pond water, but without Shandley Pit stored water (lower) during the WCT spawning period (May 15 to July 15).



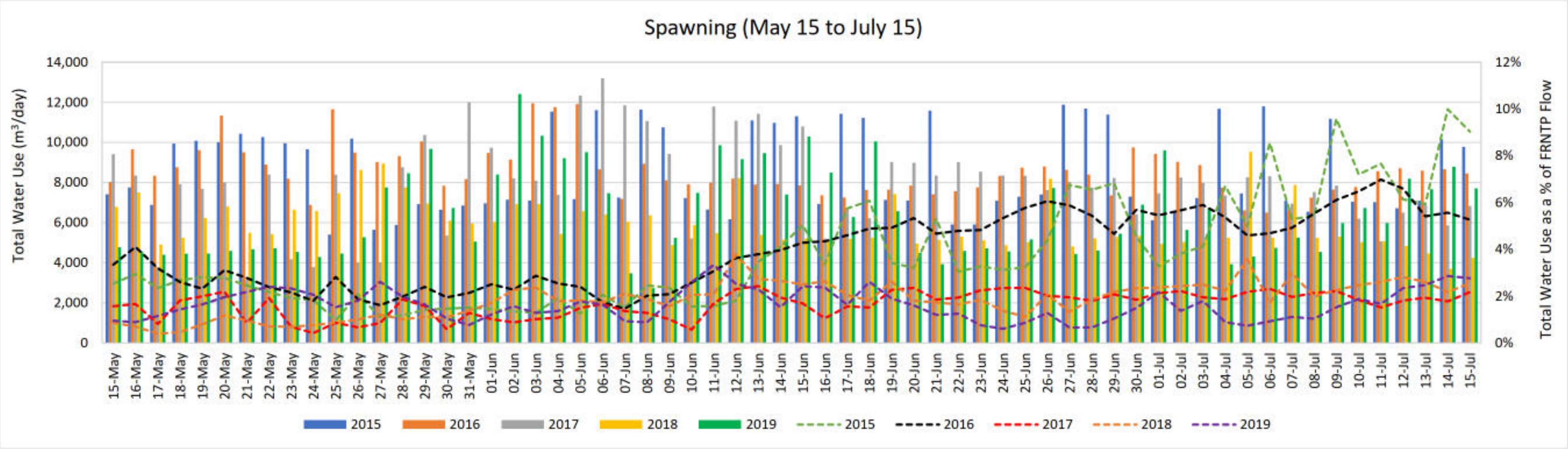


Figure 39. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (upper) and with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (lower) during the WCT incubation period (May 15 to August 31).

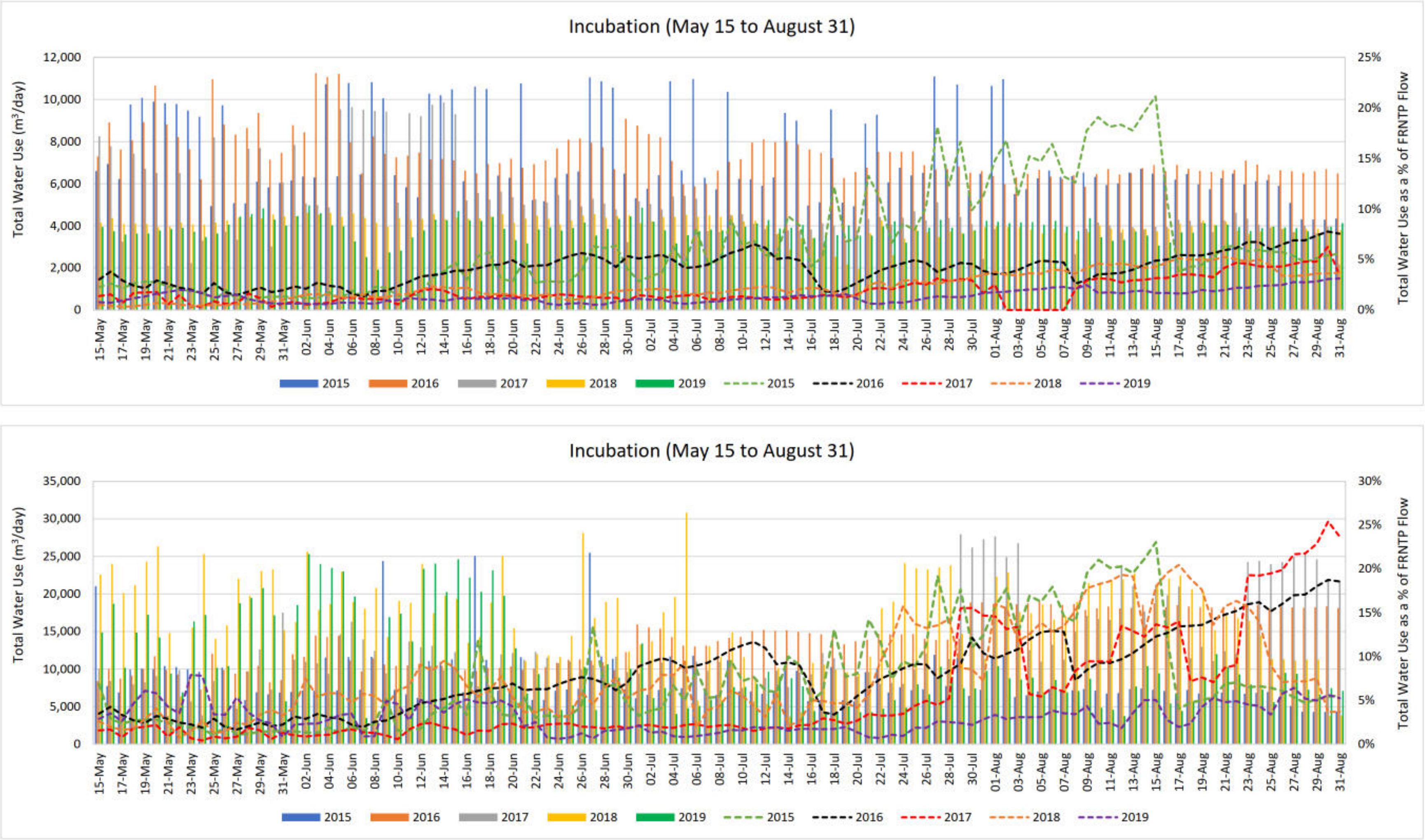
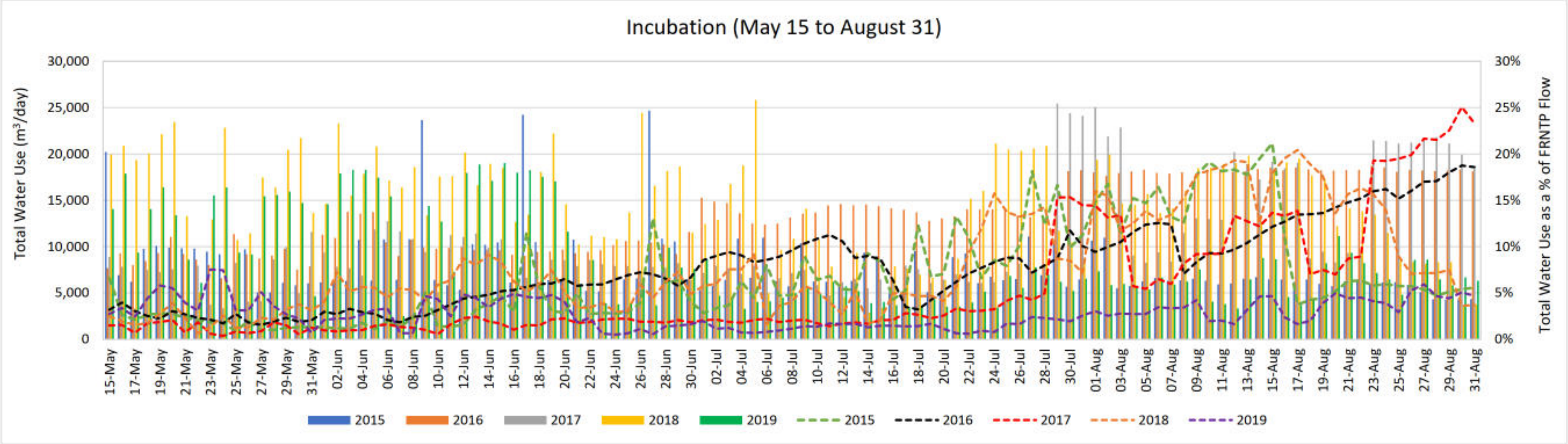


Figure 40. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) with Shandley Pit stored water, but without Eagle Pit 4 and Eagle Settling Pond water (upper) and with Eagle Pit 4 and Eagle Settling water, but without Shandley Pit stored water (lower) during the WCT incubation period (May 15 to August 31).



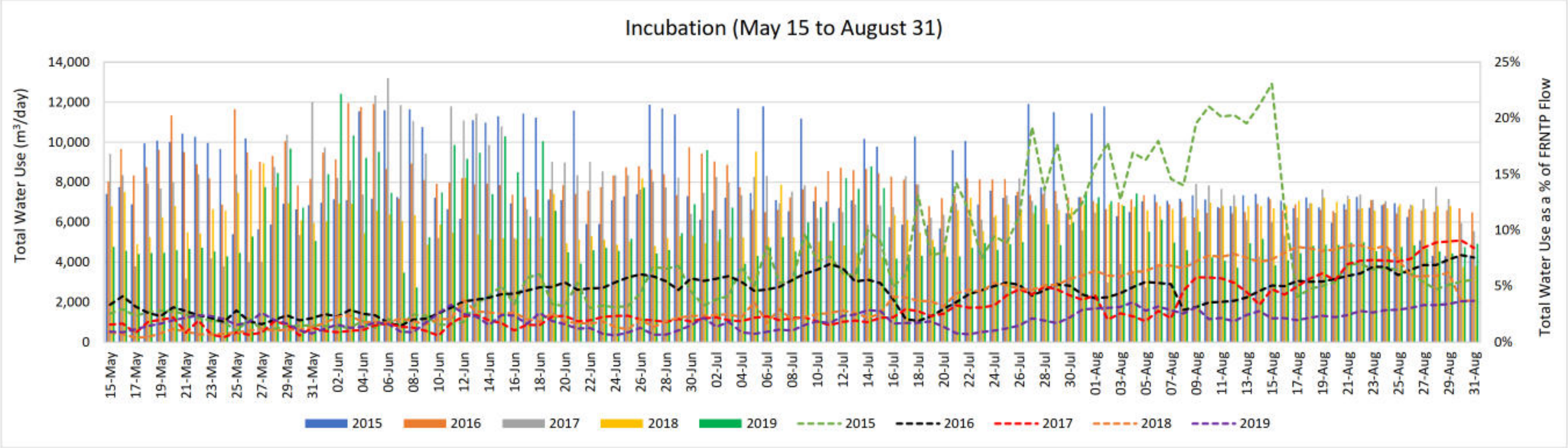


Figure 41. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (upper) and with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (lower) during the WCT summer rearing period (July 15 to September 30).

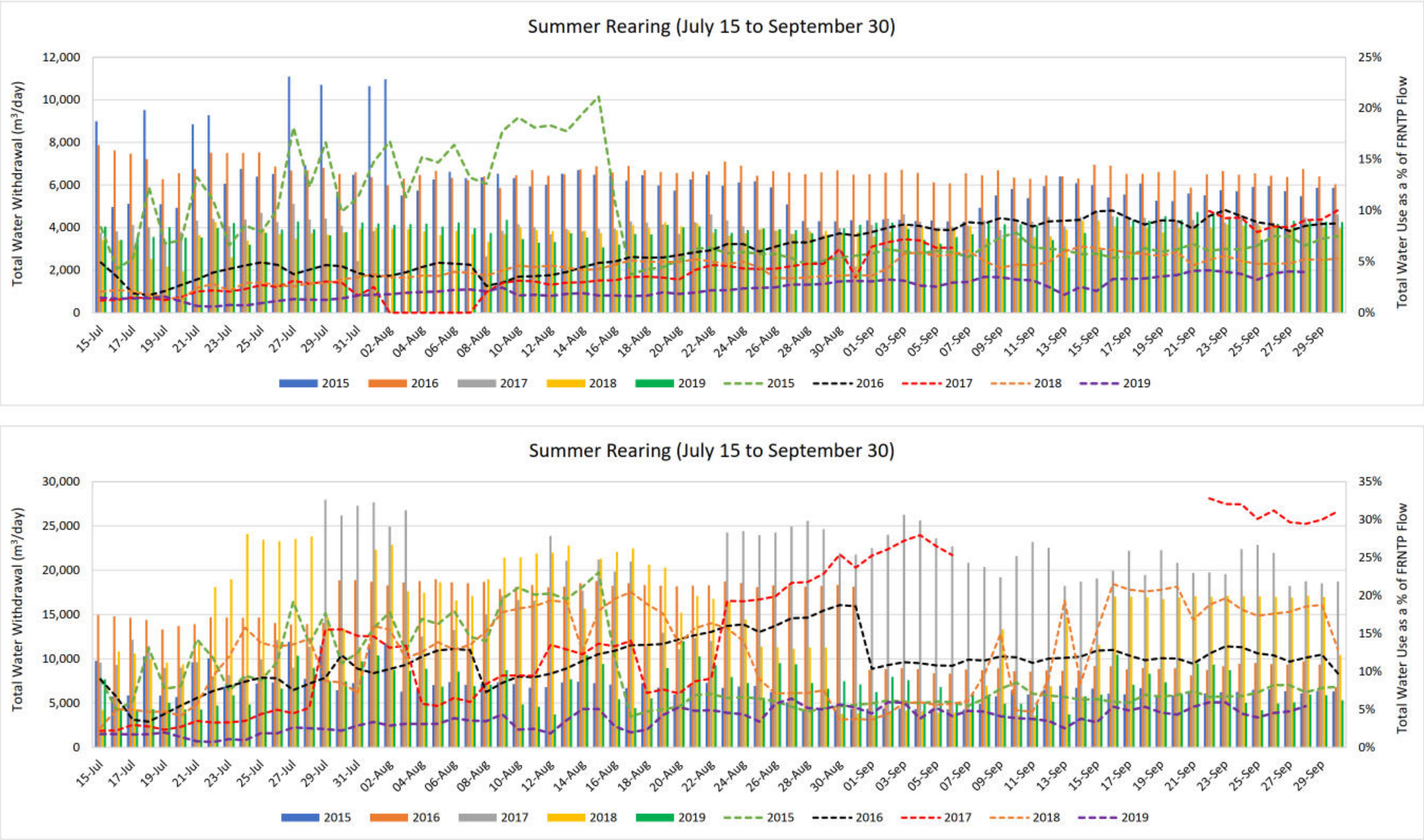


Figure 42. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) with Shandley Pit stored water, but without Eagle Pit 4 and Eagle Settling Pond water (upper) and with Eagle Pit 4 and Eagle Settling Pond water, but without Shandley Pit stored water (lower) during the WCT summer rearing period (July 15 to September 30).

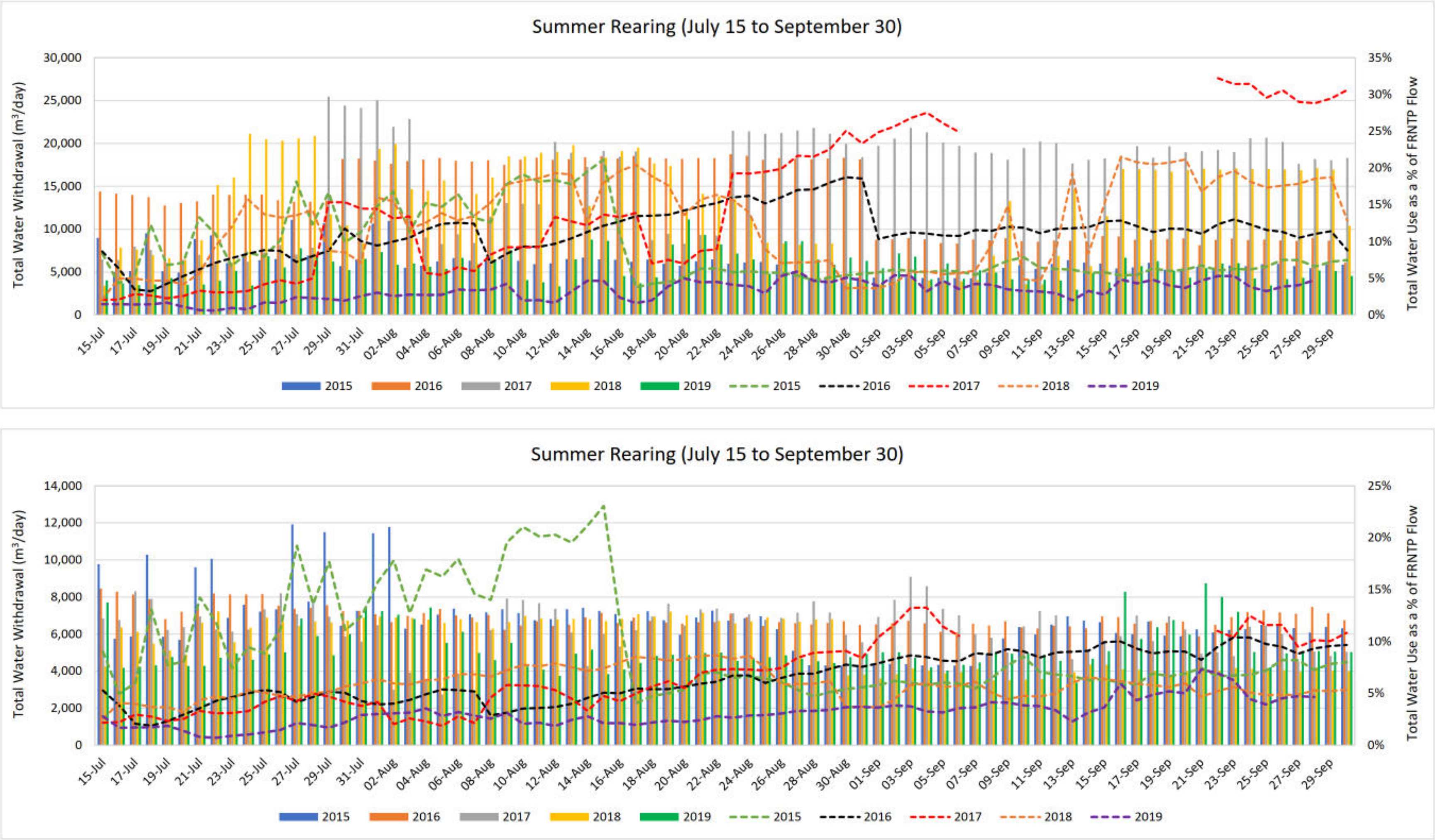
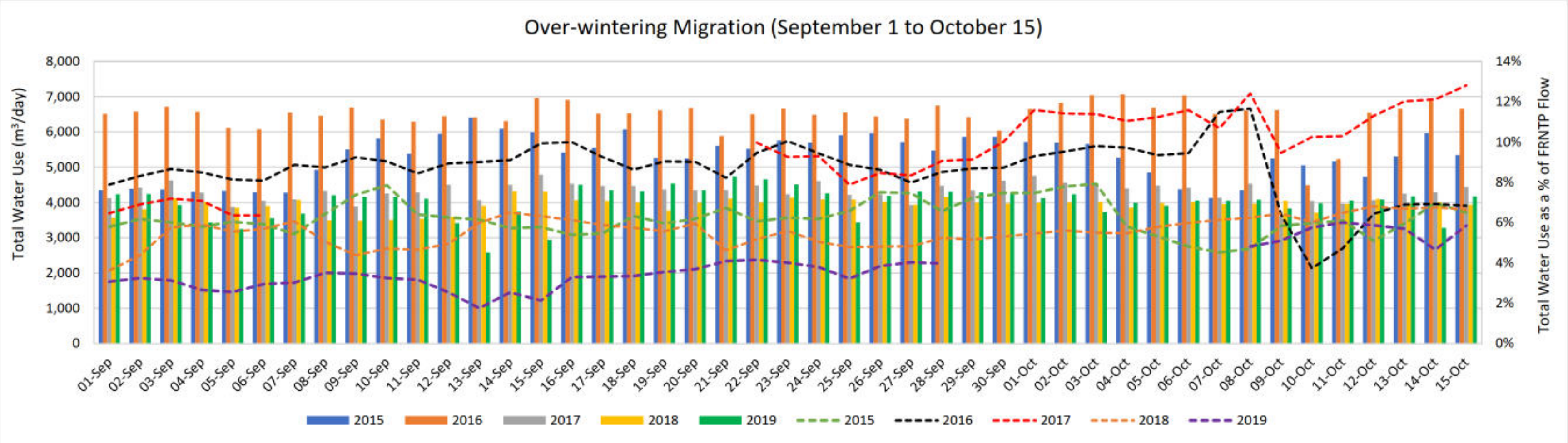


Figure 43. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (upper) and with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (lower) during the WCT over-wintering migration period (September 1 to October 15).



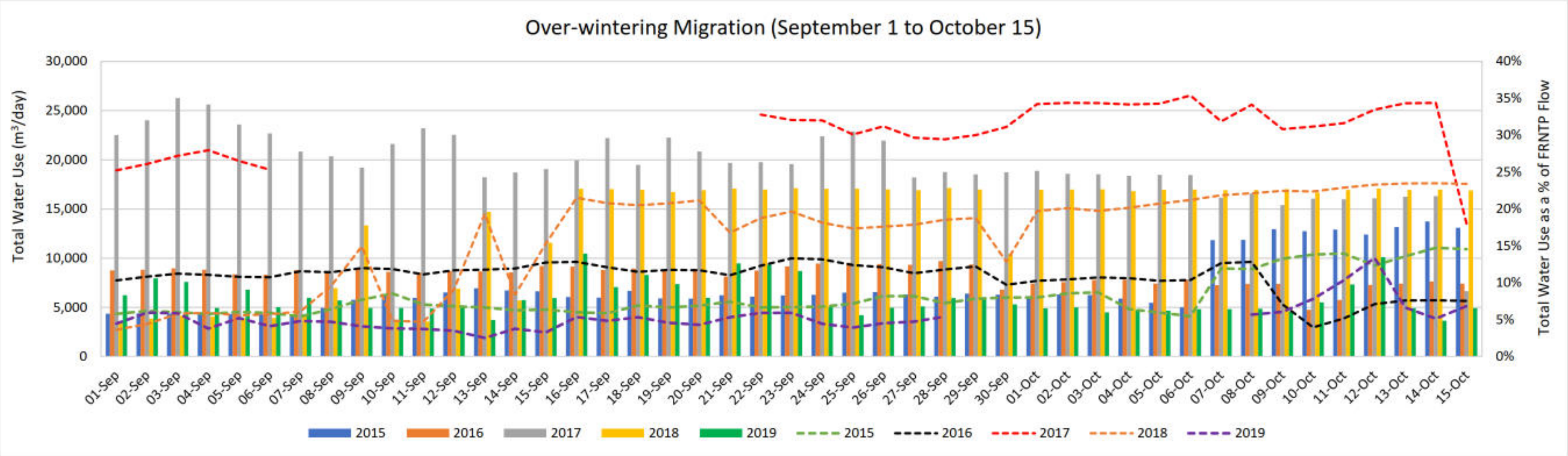


Figure 44. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) with Shandley Pit stored water, but without Eagle Pit 4 and Eagle Settling Pond water (upper) and with Eagle Pit 4 and Eagle Settling Pond water, but without Shandley Pit stored water (lower) during the WCT over-wintering migration period (September 1 to October 15).

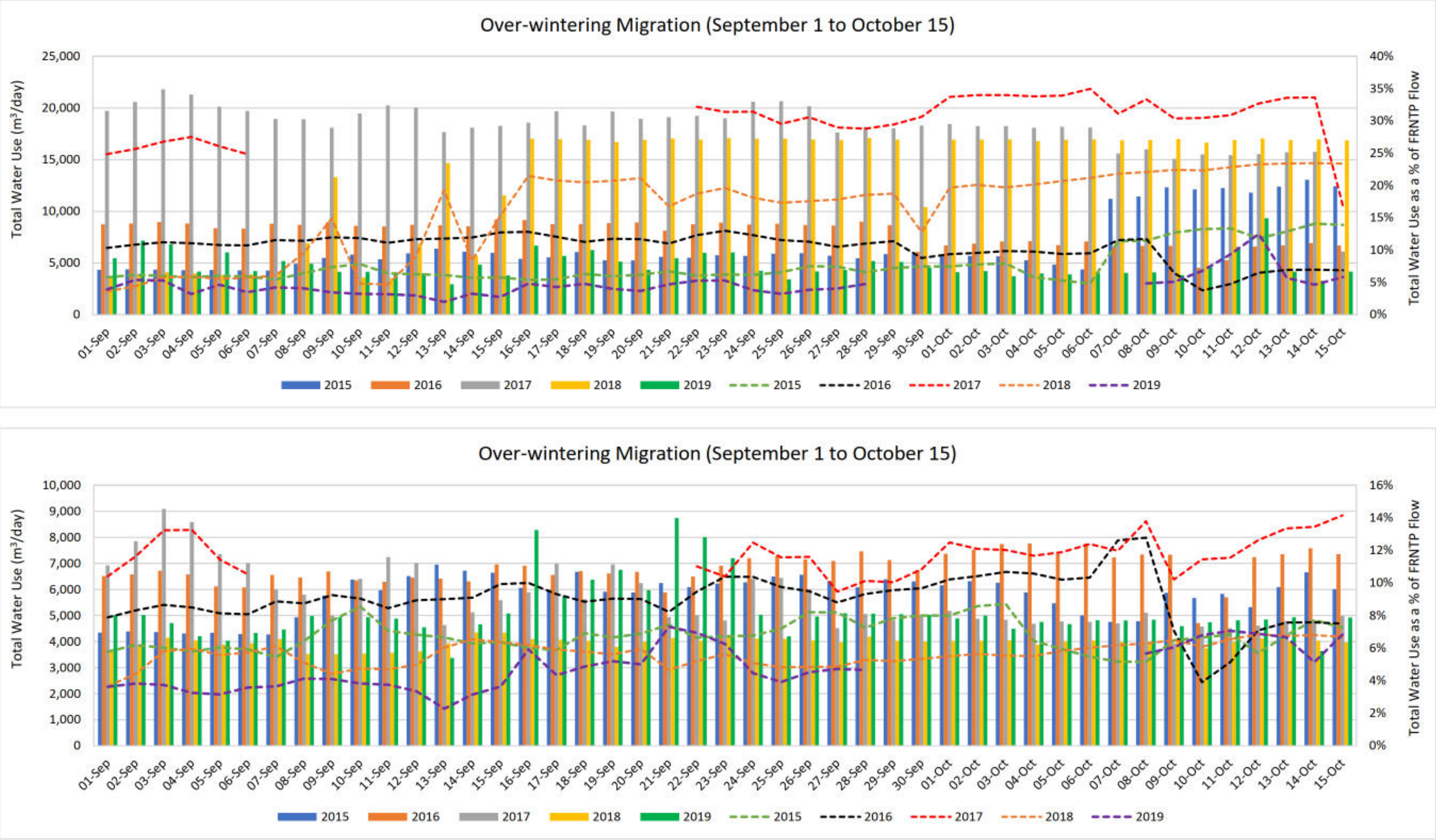


Figure 45. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (upper) and with Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (lower) during the WCT over-wintering migration period (September 1 to October 15).

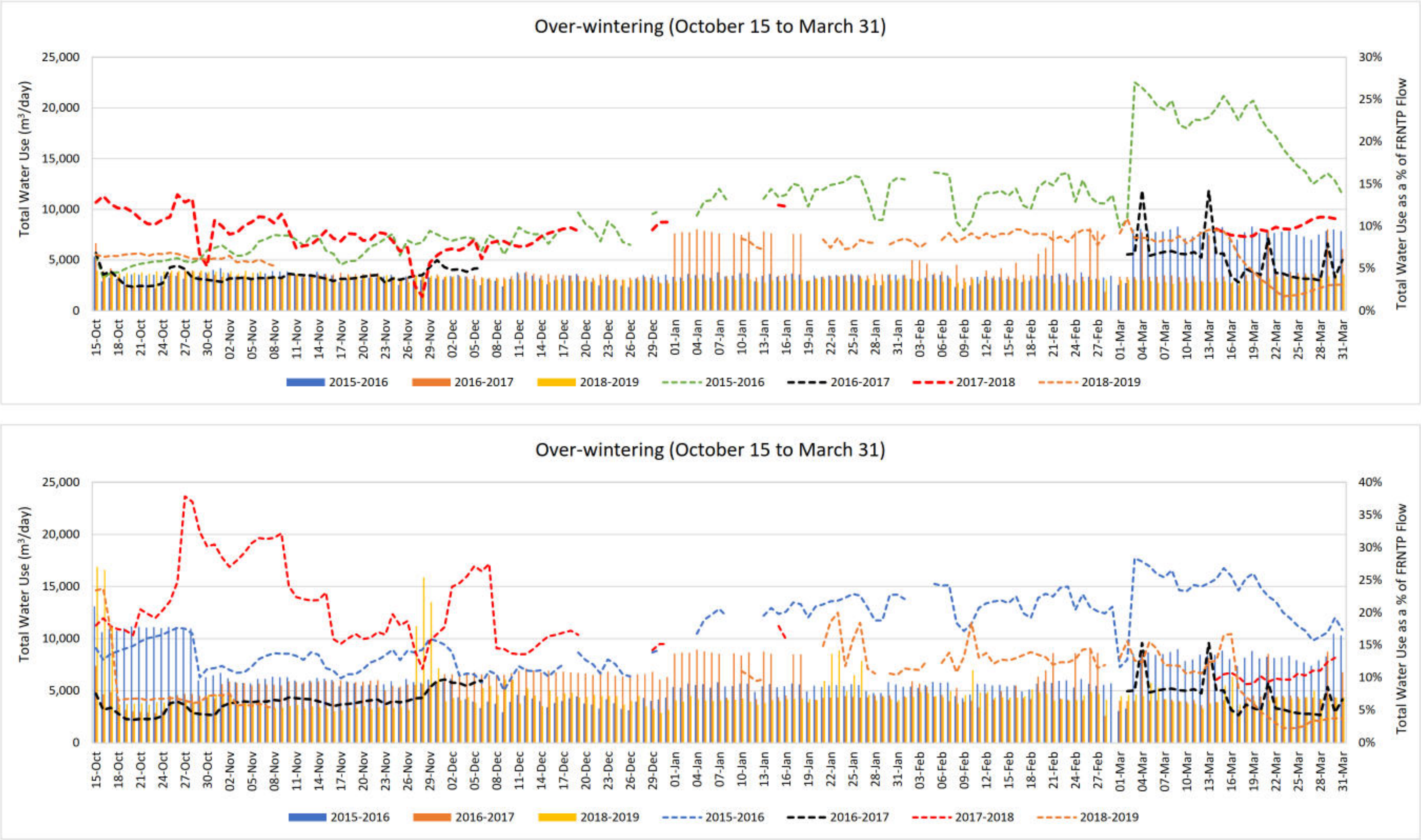
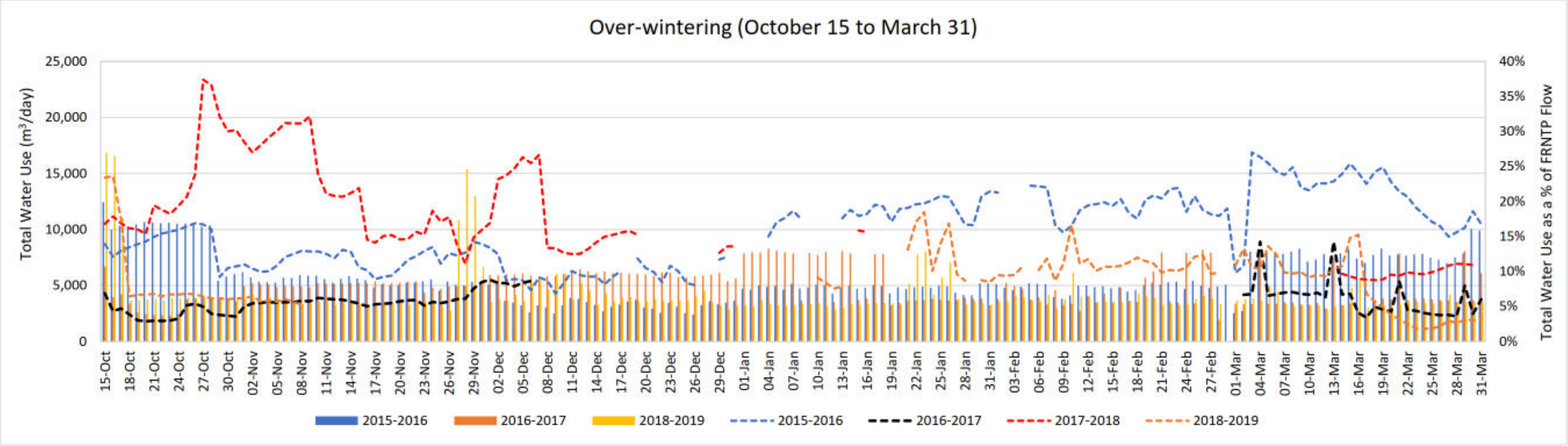
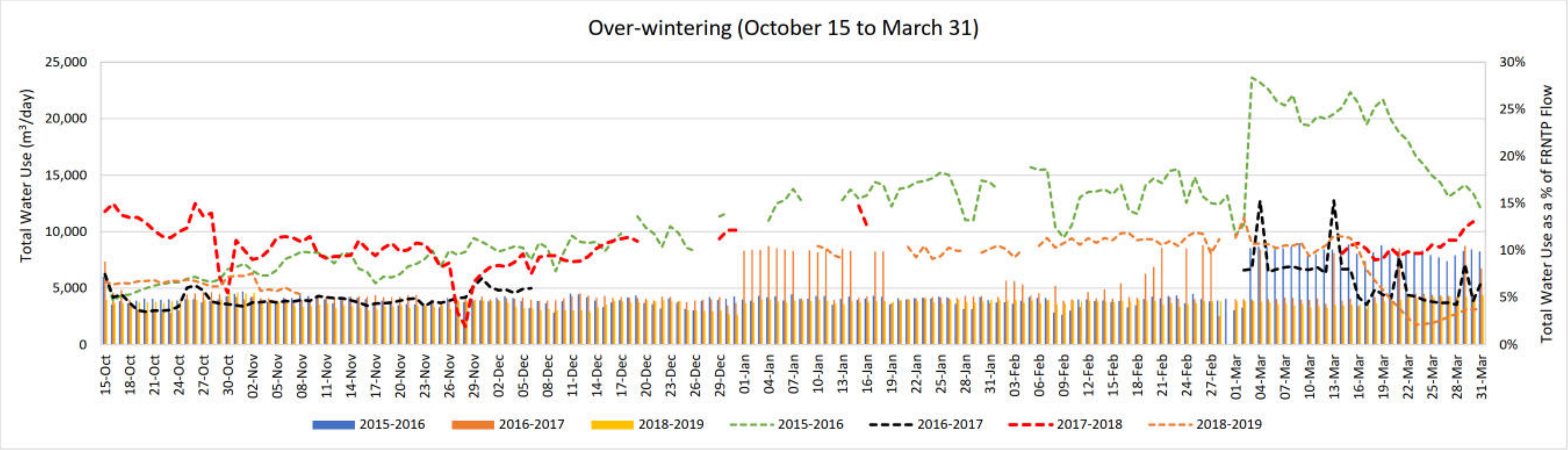


Figure 46. Total daily water withdrawal (m^3/day; solid bars) and total daily withdrawal as a % of observed flow at FR_FRNTP (dashed lines) with Shandley Pit stored water, but without Eagle Pit 4 and Eagle Settling Pond water (upper) and with Eagle Pit 4 and Eagle Settling Pond water, but without Shandley Pit stored water (lower) during the WCT over-wintering migration period (September 1 to October 15).





Water use expressed as % of total water available (computed as average observed daily flow plus water use) at FR_FRNTP was greatest during the WCT over-wintering migration period (September 1 to October 15) in 2017 and over-wintering (October 15 to March 31) period in 2017-2018, compared to other years excluding Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (Table 47), and including Shandely Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water (Table 48). However, both these periods were subject to gaps in the continuous and manual streamflow record and therefore the water use expressed as a % of water availability are estimates only. As noted in Section 2.1.6, the tallies of water use when expressed as % of surface flow are reasonable representations of water demand at those times, but provide only a coarse estimate of surface flow in the absence of water use. A detailed site-wide hydrology model would be required to provide more accurate predictions of surface flow in the absence of water use, water storage, water diversion or landscape change. Such a model was not available for the EoC analyses.

- Total water use (as a % of water available) during the over-wintering migration period was 13.1% (40.5% including Shandley Pit, Eagle Pit 4, Eagle Settling Pond water) in 2017, and was 13.8% (23.5% including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water) during the over-wintering period in 2017-2018.
- The highest % water use to river flow during the spawning migration period occurred in 2016 but was relatively low overall (2.1% of the available water at FR_FRNTP). Including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water, total water use during the spawning migration period occurred in 2019 and was 6.0% of the water available at FR_FRNTP.
- Water use during the spawning and incubation periods was highest in 2016 and 2015, respectively, compared to other years; but was less than 4% of the observed flow during these periods. Including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water, total water use was highest during the spawning and incubation periods in 2016 followed by 2018 but was less than 6.5% of the water available at FR_FRNTP.
- The highest total water withdrawal as a % of river flow during the summer rearing period occurred in 2015 (7.7%); including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water, total water use was highest in 2017 at 15.7%.
- Water use expressed as % of total water available at FR_FRNTP including Shandley Pit stored water, but excluding Eagle Pit 4 stored water and Eagle Settling Pond water, is summarized in Table 49. Table 50 provides a summary of water use expressed as a % of water available at FR_FRNTP including Eagle Pit 4 stored water and Eagle Settling Pond water, but without Shandley Pit stored. The results summarized in these two tables are not described herein.

Water use expressed as % of total water available at FR_FRABCHF for PODs associated with this compliance gauge and non-licensable water located downstream of FR_FRNTP and upstream of FR_FRABCHF, was greatest during the WCT spawning migration period (April 1 to May 31) in 2019 (5.2%), the summer rearing period (July 15-September 30) in 2018 (6.0%), and over-wintering migration period (September 1 to October 15) in 2017 (27.5%) and 2018 (7.1%), compared to other years on record (Table 51). Water use during other WCT periods was less than 5%. Due to the short record and gaps, no further comparisons were made.

Total water use of all PODs (including those without IFRs) and non-licensable water, are expressed as % of total water available at FR_FRABCHF in Table 52. Water use (expressed as total water available at FR_FRABCHF) was greatest during the WCT over-wintering migration period in 2017 (50.2%) and 2018 (12.1%), the over-wintering period in 2017-2018 (8.3%), and the summer rearing period in 2018 (8.7%). Water use during other WCT periods was less than 6.5% (Table 52). Due to the short streamflow record at FR_FRABCHF, no further comparisons were made.

Table 47. Total water withdrawal per WCT life stage period expressed as % of total water available (daily average observed flow plus total daily water use) at FR_FRNTP for the FR_POTWELLS and PODs associated with this compliance monitoring point. Totals exclude Shandley Pit and Eagle Pit stored water, and Eagle Settling Pond water.

Year	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	2.0%	2.6%	3.5%	7.7%	6.2%	12.0%
2016	2.1%	3.0%	3.4%	5.2%	8.4%	9.8%
2017	1.6%	1.1%	1.3%	3.7%	13.1%	13.8%
2018	1.0%	1.0%	1.4%	3.9%	5.5%	9.2%
2019	1.8%	0.9%	1.1%	2.0%	4.4%	

For the overwintering period, the year reflects the start of the period; e.g., 2017 is the 2017-2018 winter.
-' indicates too few continuous or manual streamflow and water use data available for sufficient characterization of the amount of water that would be available for fish if there were no water use.

Table 48. Total water withdrawal per WCT life stage period expressed as % of total water available (daily average observed flow plus total daily water use) at FR_FRNTP for the FR_POTWELLS and PODs associated with this compliance monitoring point. Totals include Shandley Pit and Eagle Pit stored water, and Eagle Settling Pond water.

Year	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	3.2%	3.1%	4.1%	8.4%	8.2%	17.4%
2016	2.5%	4.3%	6.2%	10.3%	10.5%	13.0%
2017	1.9%	1.8%	3.5%	15.7%	40.5%	23.5%
2018	3.1%	4.0%	5.7%	13.6%	16.4%	13.0%
2019	6.0%	3.0%	3.0%	3.5%	6.4%	

For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter. The over-wintering period is subject to gaps in the continuous and manual flow measurements; therefore, the % of water use to total available water are estimates. Similarly, the 2017 over-wintering migration period has a gap in the streamflow record of 14 days.

Table 49. Total water withdrawal per WCT life stage period expressed as % of total water available (daily average observed flow plus total daily water use) at FR_FRNTP for the FR_POTWELLS and PODs associated with this compliance monitoring point. Totals include Shandley Pit stored water but exclude Eagle Pit 4 and Eagle Settling Pond water.

Year	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	3.0%	2.8%	3.8%	7.7%	7.7%	16.0%
2016	2.4%	4.1%	5.9%	10.1%	10.1%	11.6%
2017	1.7%	1.4%	2.8%	13.9%	38.8%	22.2%
2018	2.6%	3.6%	5.0%	12.2%	16.4%	11.7%
2019	5.5%	2.4%	2.4%	2.8%	5.3%	

For the overwintering period, the year reflects the start of the period; e.g., 2015 is the 2015-2016 winter. The over-wintering period is subject to gaps in the continuous and manual flow measurements; therefore, the % of water use to total available water are estimates. Similarly, the 2017 over-wintering migration period has a gap in the streamflow record of 14 days.

Table 50. **Total water withdrawal per WCT life stage period expressed as % of total water available (daily average observed flow plus total daily water use) at FR_FRNTP for the FR_POTWELLS and PODs associated with this compliance monitoring point. Totals include Eagle Pit 4 and Eagle Settling Pond water, but exclude Shandley Pit stored water.**

Year	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	2.2%	2.8%	3.9%	8.4%	6.7%	13.6%
2016	2.2%	3.2%	3.6%	5.4%	8.8%	11.2%
2017	1.8%	1.5%	2.0%	5.9%	16.5%	15.4%
2018	1.4%	1.4%	2.2%	5.6%	5.5%	10.6%
2019	2.3%	1.5%	1.7%	2.7%	5.6%	

For the overwintering period, the year reflects the start of the period; e.g., 2017 is the 2017-2018 winter.
-' indicates too few continuous or manual streamflow and water use data available for sufficient characterization of the amount of water that would be available for fish if there were no water use.

Table 51. **Total water withdrawal per WCT life stage period expressed as % of total water available (daily average observed flow plus total daily water use) at FR_FRABCHF for those PODs and non-licensable water sources associated with this compliance monitoring point.**

Year	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	-	-	-	-	-	-
2016	-	-	-	-	-	-
2017	-	-	-	-	27.5%	1.2%
2018	0.6%	0.7%	1.5%	6.0%	7.1%	4.9%
2019	5.2%	2.3%	1.7%	0.4%	0.1%	

For the overwintering period, the year reflects the start of the period; e.g., 2017 is the 2017-2018 winter.
-' indicates too few continuous or manual streamflow and water use data available for sufficient characterization of the amount of water that would be available for fish if there were no water use.

Table 52. **Total water withdrawal per WCT life stage period expressed as % of total water available (daily average observed flow plus total daily water use) at FR_FRABCHF for all PODs and non-licensable water sources upstream of this gauge.**

Year	Westslope Cutthroat Trout Life Stages					
	Spawning Migration	Spawning	Incubation	Summer Rearing	Over-wintering Migration	Over-wintering
	April 1 to May 31	May 15 to July 15	May 15 to August 31	July 15 to September 30	September 1 to October 15	October 15 to March 31
2015	-	-	-	-	-	-
2016	-	-	-	-	-	-
2017	-	-	-	-	50.2%	8.3%
2018	1.8%	2.4%	3.4%	8.7%	12.1%	6.8%
2019	5.5%	2.7%	2.7%	3.0%	4.0%	-

For the overwintering period, the year reflects the start of the period; e.g., 2017 is the 2017-2018 winter.
-' indicates too few continuous or manual streamflow and water use data available for sufficient characterization of the amount of water that would be available for fish if there were no water use.

4. DISCUSSION

General trends in the climate and hydrology data are summarized below, followed by a high-level evaluation of potential ecological effects to WCT (Section 4.2). Detailed evaluations of effects will be addressed through consideration of other stressors (e.g., migration barriers, rearing habitat availability, interactions with acute and chronic stressors, etc.).

4.1. General Trends and Anomalies

- Air Temperature:
  - Four weather stations in the UFR watershed, FRO_TCR, FRO_A Spoil, FRO_CSP, and FRO_WWT recorded air temperature throughout the September 2017- September 2019 period with no data gaps. Data records at these stations started in October 2012, November 2014, October 2013, and December 2013, respectively, though there is a data gap at FRO_TCR in January 2013 and February 2014.
  - Long-term data in the watershed were provided by EC Cominco from 1970-2019, although gaps at this station in 2014, 2015, and 2019 were filled using data from FRO_WWT (located 2 km away) and other regional stations in earlier years.
  - Seasonal and annual trends in air temperature were similar between stations.

  - Annual average air temperatures were generally lower during the Decline Window compared to historical air temperatures. At FRO_TCR, annual average air temperatures were 1.4ºC colder during the Decline Window compared to 2013-2017 temperatures. Long-term records indicate average annual air temperatures in 2017 (1.98ºC) and 2018 (2.5ºC) were warmer than the historical average between 1970-2019 of 1.4ºC; however, 2019 was slightly colder (1.1ºC).
  - Monthly average air temperatures in February 2019 were the coldest temperatures of any February at stations with records dating back to 2001. Within the longer-term record at EC Cominco (dating back to 1970), February air temperatures in 1989 (-14.8ºC) were similar to 2019, but not colder than 2019 (-15.2ºC).
  - Daily average air temperatures declined more than 20ºC over two days at the start of February 2019, following a period of moderate January temperatures, and remained low throughout much of the month. The magnitude of this drop was the largest recorded between 2013-2019, with air temperatures immediately after the drop falling well below the 25th percentile at that time of year in the long-term (50-year) record at EC Cominco.
- Water Temperature:
  - Two of the three water temperature monitoring stations (FR_HC1 and FR_FRNTP) had data from 2015 to 2019, though there were some gaps in the data during winter months due to ice conditions. Records in earlier years were excluded from the summary due to large gaps in the data that could not be interpolated with manual measurements.
  - Overall, water temperatures at FR_HC1 and FR_FRNTP were cooler during the Decline Window (0.3 to 0.8ºC cooler).
  - Minimum annual water temperatures at FR_HC1 and FR_FRNTP typically occur in December. Unlike other years on record, minimum annual water temperatures occurred in February 2018 and 2019 at both stations. The frequency of mean daily water temperatures <1°C was also greater in 2018-2019 compared to other years on record (since 2015) at FR_HC1 and FR_FRNTP.
  - Mean monthly water temperatures at FR_FRNTP show that February and March 2019 were colder in 2019 than during the same months in previous years.
  - The mean monthly water temperature was -1.51°C in February 2019 at FR_FRNTP, a large decline from the mean January 2019 water temperature of 0.25°C.
  - Mean daily water temperatures were almost always below the optimal range for WCT (13ºC - 15ºC) at each of the three monitoring stations. Sub-daily water temperature records indicate that while mean daily water temperatures were typically lower than

the optimal range (13°C - 15°C) for WCT, diurnal fluctuation in water temperatures meant that during summer months water temperatures at FR_FRNTP were frequently within this range for a portion of each day; cumulatively, this amounted to a maximum of 12 days when water temperatures were at or above the optimum range.

  - There is a large variation in the number of degree-days across stations and between years and no notable difference in the number of degree-days during the Decline Window relative to historical data. However, the available data indicate that annual total degree-days between 2015 to 2019 at FR_HC1 were typically <800 (the threshold below which recruitment failure may occur (Coleman and Fausch 2007), while degree-days at FR_FRNTP varied from 800 to 1215.
  - Based on mean weekly maximum water temperature, site FR_HC1 had the highest proportion of days with water temperatures below the lower threshold of optimum water temperature for all life stages, whereas site FR_FRNTP had the highest proportion of days with water temperatures above the upper threshold of optimum water temperature for all life stages.

- Precipitation:
  - FRO_WWT and FRO_CSP weather stations recorded precipitation and rainfall from October 2013 to September 2019 with no data gaps.
  - Precipitation was variable across months, years, and sites, and missing and inconsistent data made it difficult to discern trends. No apparent trends were found in the timing of annual or monthly precipitation minima and maxima, as the highest and lowest total precipitation occurred in different years at each station. The lack of trends found in the data may be due differences in local conditions (elevation/orographic effects, ground cover), and/or sensors used to measure and record precipitation.
  - Precipitation during winter months at FR_TCR, FRO_A-Spoil, and FR_FRNTP was lower than at other stations in some years, with no precipitation in some months when precipitation was recorded at other sites. The lack of record in winter months likely reflects the inability of some gauges to accurately measure snowfall.
  - In general, 2018-2019 was drier than preceding years, including 2017-2018 and 2016-2017. Longer-term records from EC Sparwood (40 years) show that 2018-2019 was drier in November 2018 to June 2019 than the historical median.
  - There was no apparent trend in the timing of minimum monthly precipitation, which occurred in March (2019), April (2016), May (2015, 2017 and 2018), and July (2014) at FRO_CSP.
  - In 2018-2019; snowfall occurred earlier than normal, but the winter had less total snowfall compared to the historical record. Cumulative snowfall in early February 2019

was equal to approximately the 25th percentile of the long-term record at EC Sparwood (1980-2019).

- Snow Depths:
    - FRO_TCR, FRO_BRNSSLP, and FRO_WWT were the most reliable stations for snow data, with few data gaps and records extending from winter 2013-2014 to 2018-2019.
    - The timing of maximum snow depth across all sites generally occurred one to two months later in February or March during the winters of 2016-2017, 2017-2018, and 2018-2019, compared to previous winters, when it occurred most frequently in January.
    - Snow water equivalent (SWE) measured at Morrissey Ridge snow pillow indicate snowpack levels in 2018-2019 SWE were below the 25th percentile of the long-term record from mid-January 2019 onward. The 2019 peak-SWE (487 mm) was the lowest on record since 1984, apart from in 2001 when it was the same.
- Streamflow:
    - Flow records from two of the three hydrometric stations (FR_HC1 and FR_FRNTP) were provided for 2010 onwards but were more reasonably complete from 2014 onwards, with the exception of data gaps during winter months due to ice. Manual measurements were relied on during these ice-affected periods. Data from the WSC Fording River at the Mouth gauge and WSC Line Creek at the Mouth were also analyzed to provide historical context.
    - Average annual flow was greatest at FR_HC1 in 2018-2019 and in 2016-2017 at FR_FRNTP. Lowest average annual streamflow occurred at both gauges in 2014-2015.
    - For records since 2010, peak flow was highest in 2011-2012 at both FR_HC1 and FR_FRNTP (though flows were estimated to be higher during the flood event in June 2013 that damaged the gauges), whereas the lowest flows occurred in 2012-2013 and 2013-2014 for each station, respectively.
    - Peak flow related to spring snowmelt occurred earlier in 2016 and 2018 than in other years, though there were substantially higher flows in 2018 than in 2016.
    - Mean flow was lower in the spring of 2019, peaked later, and was of a lower magnitude than previous years (2017 and 2018), though summer flows were highest in 2019 (particularly at FR_FRNTP) compared to previous years.

  - At the WSC Fording River gauge, mean streamflow was lowest during all WCT life stage periods in 2001. The timing of maximum mean flow occurred prior to the Decline Window in all periods.
  - During the Decline Window the highest mean monthly flow in each year occurred in May 2018 and in June 2019 at both FR_HC1 and FR_FRNTP, when streamflow as a percentage of mean annual discharge (% MAD) exceeded 400% in 2018 and was over 300% in 2019.
  - A review of the 50-year record of streamflow at the WSC Fording River at the Mouth station (08NK018) shows that the timing of maximum mean flow varied for each of the WCT periods but highest flows for all periods occurred prior to the Decline Window.
  - The lowest flows at FR_HC1 occurred in March of 2016 (20% of MAD) and December and February 2018 (15% and 17% MAD, respectively). At FR_FRNTP, mean flows in February 2019 (20 % MAD) were the lowest of any month from September 2016 to September 2019. Manual streamflow measurements made in January, February and December 2018 were used to estimate mean flows in these months. These measurements indicate that streamflow during January and February 2018 may have been similar to flows measured in February 2019.
  - Mean daily streamflow at the WSC Fording River at the Mouth and Line Creek at the Mouth gauges were generally lower than the historical mean in the summer months of 2019, and the late summer, and winter months of 2017, 2018 and 2019; though there were other years with lower streamflow during these months.
- Water Use:
  - Total daily water uses recorded in the UFR since January 1, 2015 were provided by Teck. We provide tallies of all water uses, and tallies of water use in relation to surface flow in the UFR. The tallies of water use when expressed as % of surface flow are reasonable representations of water demand at those times, but provide only a coarse estimate of surface flow in the absence of water use. A detailed site-wide hydrology model would be required to provide more accurate predictions of surface flow in the absence of water use, water storage, water diversion or landscape change. Such a model was not available for the EoC analyses.
  - Our analysis assumed that all recorded water use is consumptive and there are no (or minimal) returns to the Fording River. We acknowledge that there are four PODs (189633, 189638, 189640 and 189642) that were excluded from EFN considerations in the water licences. No water use occurred during the Decline Window at POD 189640 (Turnbull Pit) or 189642 (Henretta Pit). Water use from PODs 189633 and 189638 (Eagle Settling Pond and Eagle Pit 4, respectively) were summarized along

    with 189629 (Shandley Pit) and two non-licensable locations (North Loop Settling Pond and Smith Ponds).

  - Total water use recorded for FR_POTWELLS and PODs associated with FR_FRNTP (excluding Shandley Pit and Eagle Pit stored water, and Eagle Settling Pond water) was greatest in 2016 for all WCT life stage periods except for the over-wintering period, which was greatest in 2015-2016, compared to other years on record. When Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water is included in the calculations, total water use was greatest in:
    - 2017 for the summer rearing, over-wintering migration, and over-wintering,
    - 2018 for the for spawning and incubation, and
    - 2019 for the spawning migration period.
  - SNC-Lavalin (2021) considered water in Shandley Pit to have a low rate of discharge to the Fording River, long travel time, and small volume compared to Fording River flow. Similarly, Eagle Settling Pond and Eagle Pit 4 were deemed to have minimal hydraulic connection with the Fording River, and consumptive water use was found to be a small portion (<0.5%) of Fording River flow (SNC-Lavalin 2021).
  - Total water use recorded for PODs and non-licensable locations (North Loop Settling Pond and Smith Ponds) associated with FR_FRABCHF was greatest in the 2019 for the WCT spawning migration and spawning periods, greatest in 2015 for the incubation period, greatest in 2017 for the WCT summer rearing period, greatest in 2018 for the over-wintering migration period, and greatest in 2018-2019 for the over-wintering period, compared to other years. The FR_FRABCHF gauge was installed in 2017 and therefore had only had three years of data.
  - Water use (expressed as a % of total water available at FR_FRNTP) was highest during the WCT overwintering migration period (September 1 to October 15) in 2017 and the overwintering period (October 15 to March 31) in 2017-2018 (with and without Shandley Pit and Eagle Pit 4 stored water, and Eagle Settling Pond water). However, both these periods had gaps in the continuous and manual streamflow record and therefore, water use when expressed as % of total water available are estimates only.
  - Among WCT life stage periods, water use expressed as % of total water available at FR_FRABCHF was greatest during the WCT spawning migration period (April 1 to May 31) in 2019, greatest during the summer rearing period (July 15-September 30) in 2018, and greatest during the over-wintering migration period (September 1 to October 15) in 2017. Due to the short record and gaps, no further summaries were made for FR_FRABCHF in other years.

  - Total water use recorded for all PODs (including those without IFRs) and non-licensable water upstream of FR_FRABCHF, was greatest during the WCT over-wintering migration period (September 1 to October 15) in 2017 and 2018.

4.2. Trends and Anomalies by WCT Life Stage Periods

- Spawning Migration Period:
  - During the Decline Window, FR_FRNTP had a lower proportion of days (0-16% of the time) with water temperatures below the lower threshold of optimum water temperature for spawning migration than were observed in 2011-2016 (0-31.3% of the time). FR_HC1 had the highest proportion of days with water temperatures below the lower threshold of optimum water temperature for spawning migration in 2012 (100% of the time); during the Decline Window, water temperatures were below the lower threshold for spawning migration 51-59% of the time.
  - Mean flow was less during the 2019 spawning migration period than in previous years, and was highest in 2018; however, data for these periods in each year were affected by gaps, so there is some uncertainty in these results. Among years with complete data, the lowest flows at FR_HC1 during spawning migration occurred in 2010 (1.01 m^3/s), which is similar to the value calculated from incomplete data in 2019 (0.95 m^3/s). Incomplete data at FR_FRNTP also indicate flows during spawning migration were less in 2019 (2.25 m^3/s) than other years including 2002 (2.62 m^3/s), which had the lowest mean streamflow during spawning of any year with complete data coverage. The magnitude and duration of maximum flow was greater in 2017 and 2018 compared to other years.
  - The magnitude and duration of high flow at FR_HC1 was greater in 2013 compared to other years. At FR_FRNTP, flows were higher for a longer duration in 1998. Minimum 30-day flow at FR_HC1 during this period was lowest in 2000. At FR_FRNTP, the magnitude and duration of minimum flow was lowest in 2003 (30-day). This summary excludes flows in 2017, 2018, and 2019 due to an incomplete data record during this period. A review of the longer WSC station record showed that maximum 30-day flow was highest in 1981, 1991, and 2018 during the spawning migration, and minimum 30-day flow occurred in 2016.
  - The highest water use as % of total water available at FR_FRNTP during the spawning migration period occurred in 2016 (excluding use of Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water) or 2019 (including Shandley Pit, Eagle Pit 4, Eagle Settling Pond water), but in both cases had relatively low (2.1% and 6.0%, respectively) water use.

- Spawning Period:
    - In 2019, water temperature at FR_FRNTP was below the lower threshold of optimum water temperature for spawning (12.9% of the time); based on the available data, optimum water temperature for spawning was exceeded for a longer period in 2011 (31.3% of the time).
    - Streamflow was highest during the spawning period in 2005 at FR_HC1 and 2012 at FR_FRNTP. Lowest average streamflow during this period occurred in 2008 at FR_HC1 and 2016 at FR_FRNTP.
    - The magnitude and duration of high flow at FR-HC1 was greater in 2002 (7-day) and 2017 (30-day) in the spawning period compared to other years. At FR_FRNTP, flows were higher for a longer duration during this period in 2002, 2003 and 2012. The longer-term record at the WSC station showed maximum 30-day flows were for this period in 1972.
    - Minimum 30-day flows occurred in 2005 at FR_HC1, and in 2012 at FR_FRNTP. The longer-term record at the WSC station showed minimum 30-day flows occurred in 1972 and 2012 during the spawning period.
    - Water use as % of total water available was highest at FR_FRNTP during the spawning period occurred in 2016 (including and excluding Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water) compared to other years, and in both cases was relatively low (less than 5%).
- Incubation Period:
    - The Proportion of days above the upper threshold of optimum water temperature for incubation was highest in 2014 and 2017 (57.5% and 63%, respectively), and lowest in 2019 (7.4% of the time) at FR_FRNTP.
    - The highest proportion of days below the optimum water temperature threshold for incubation was highest in 2011 (12.7% of the time) at FR_FRNTP across years.
    - Streamflow was highest during the incubation period in 2005 at FR_HC1 and in 2012 at FRNTP, and lowest in 2008 at FR_HC1 and 2016 at FR_FRNTP.
    - During the incubation period, the magnitude and duration of high flow at FR_HC1 was greatest in 2017 (30-day). At FR_FRNTP high flow occurred longer in 2002, 2003, and 2012. During this period, minimum 30-day flows occurred in 2005 and 2009 at FR_HC1, and in 2010 at FR_FRNTP. The longer-term WSC station record showed 30-day flows were highest in 1972. Minimum 30-day flows occurred in 1976 and 1993 during the incubation period.

  - Water use expressed as % of total water available at FR_FRNTP during the incubation period was highest in 2015 (excluding Shandley Pit, Eagle Pit 4, Eagle Settling Pond water) or 2016 (including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water), compared to other years but was less than 7.0% of the flow during this period (with and without Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water).

- Summer Rearing Period:
  - The lower threshold of optimum water temperature for rearing (7°C) was exceeded at FR_HC1 in 2012, 2018 and 2019 3.8-7.7% of the time, and 2.6% of the time in 2019 at FR_FRABCHF.
  - Mean flow during the summer rearing period was highest in 2009 at FR_HC1, and in 2012 at FR_FRNTP; mean flow during this period was lowest in 2017 at FR_HC1 and in 2001 at FR_FRNTP.
  - Maximum flows for all durations (1-day, 3-day, 7-day, and 30-day) during the summer rearing period occurred in 2009 at FR_HC1, and in 2012 and 2019 at FR_FRNTP (Table 28 and Table 29.) Minimum flows during this period occurred in 2004 at FR_HC1 and in 2019 at FR_FRNTP. The longer-term record at the WSC station showed maximum 30-day summer rearing flows occurred in 1976, and minimum 30-day flows occurred in 1993 (Table 30).
  - Water use expressed as the % of total water available at FR_FRNTP was greatest (7.7%) during the WCT summer rearing period (July 15-September 30) in 2015, compared to other years. When water use from Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water is included in the calculation, total water use was greatest (15.7%) in 2017.

- Over-wintering Migration Period (September 1 to October 15):
  - Mean flow during the overwintering (fall) migration period was lowest in 2017 at both stations, and highest in 2014 at FR_HC1 and in 2019 at FR_FRNTP. Note there were several years with less than full data coverage for this period, which may influence the results.
  - During the over-wintering migration period, maximum flow for all durations occurred in 2014 at FR_HC1. At FR_FRNTP, 7-day maximum flow occurred in 2014 and 30-day maximum flow occurred in 2017 and 2018. The minimum 7-day flow during the over-wintering migration period occurred in 2014 at FR_HC1, whereas the minimum 30-day flow occurred in both 1999 and 2019. At FR_FRNTP, minimum 7-day flow during the over-wintering migration period occurred in 2017 and 30-day minimum flow occurred in 2014.
  - Water use expressed as a % of total water available was greatest during the WCT over-wintering migration period in 2017, compared to other years (13.1% of the

    streamflow at FR_FRNTP excluding Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water and 40.5% including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water).

- Over-wintering Period
    - Mean flow during the WCT over-wintering period was lowest in 2016-2017 at FR_HC1 and in 2015-2016 during the Decline Window) at FR_FRNTP. Considering the years with the most complete data for the overwintering period, mean flow during this period was highest in the winter of 2014-2015 at both FR_HC1 and FR_FRNTP. Note there were a number of years with less than full data coverage for this period, which may bias the results.
    - Over-wintering high flows were greatest for all durations in the winter of 2016-2017 at both FR_HC1 and FR_FRNTP. Minimum flows were lower for a longer duration in winter of 2018-2019 at FR_HC1 and FR_FRNTP. At the WSC station, over-wintering flows were highest in the winter of 1999-2000 (for 1-day, 3-day and 7-day flows) and in 2005-2006 (for 30-day flows). Minimum 30-day flows for the same period occurred in the 2005-2006 winter.
    - The highest total water use as a % of total water available at FR_FRNTP during the over-wintering period occurred in 2017-2018, compared to other years (13.8% excluding Shandley Pit, Eagle Pit 4, and Eagle Settling Pond water and 23.5% including Shandley Pit, Eagle Pit 4, and Eagle Settling Pond stored water).

5. CONCLUSION

The primary objective of this report is to review and compile available information to evaluate if, and to what extent, climatic factors, water temperature, streamflow, and water use may have influenced the stressors investigated for the Evaluation of Cause. Data from nine weather stations, three water temperature stations, four hydrometric stations, six potable wells (FR_POTWELLS), eight PODs (across nine water use locations), and two non-licensable stored water locations were reviewed to identify trends and anomalies in the Decline Window relative to historical data. Analysis of daily climate data involved computing summary statistics for each station, for each month and year. Ecologically relevant statistics were used to describe trends and anomalies in daily water temperature, streamflow, and water use data for each WCT life stage period. Results from the climate and hydrology analyses were used to flag events that may have contributed to the observed decline in WCT abundance.

Requisite conditions (Intensity, Location, and Timing) for climate effects to cause the WCT population decline were not evaluated; however, some anomalies were identified. Climate, water temperature, hydrology, and water use were determined to be similar between the Decline Window and the historical period, with the exception of air temperatures in February 2019 and water temperatures during the spawning migration period during the Decline Window. It is unlikely that air temperature or water temperature during these periods were the single or primary cause for the observed decline in WCT, though they may have interacted with other stressors to factor in the observed decline and are identified as anomalies for consideration within other SME stressor reports during analysis of other stressor pathways.

Anomalous air temperatures, water temperatures, and snow cover occurred during portions of the winter of 2019. These conditions may have interacted with other stressors identified in the Evaluation of Cause; particularly, over-wintering ice conditions during the anomalous winter months of January through early March 2019. Results reported here were then considered by other SMEs when conducting their analyses and by the EoC Team when integrating information across multiple stressors (EoC Team (2021).

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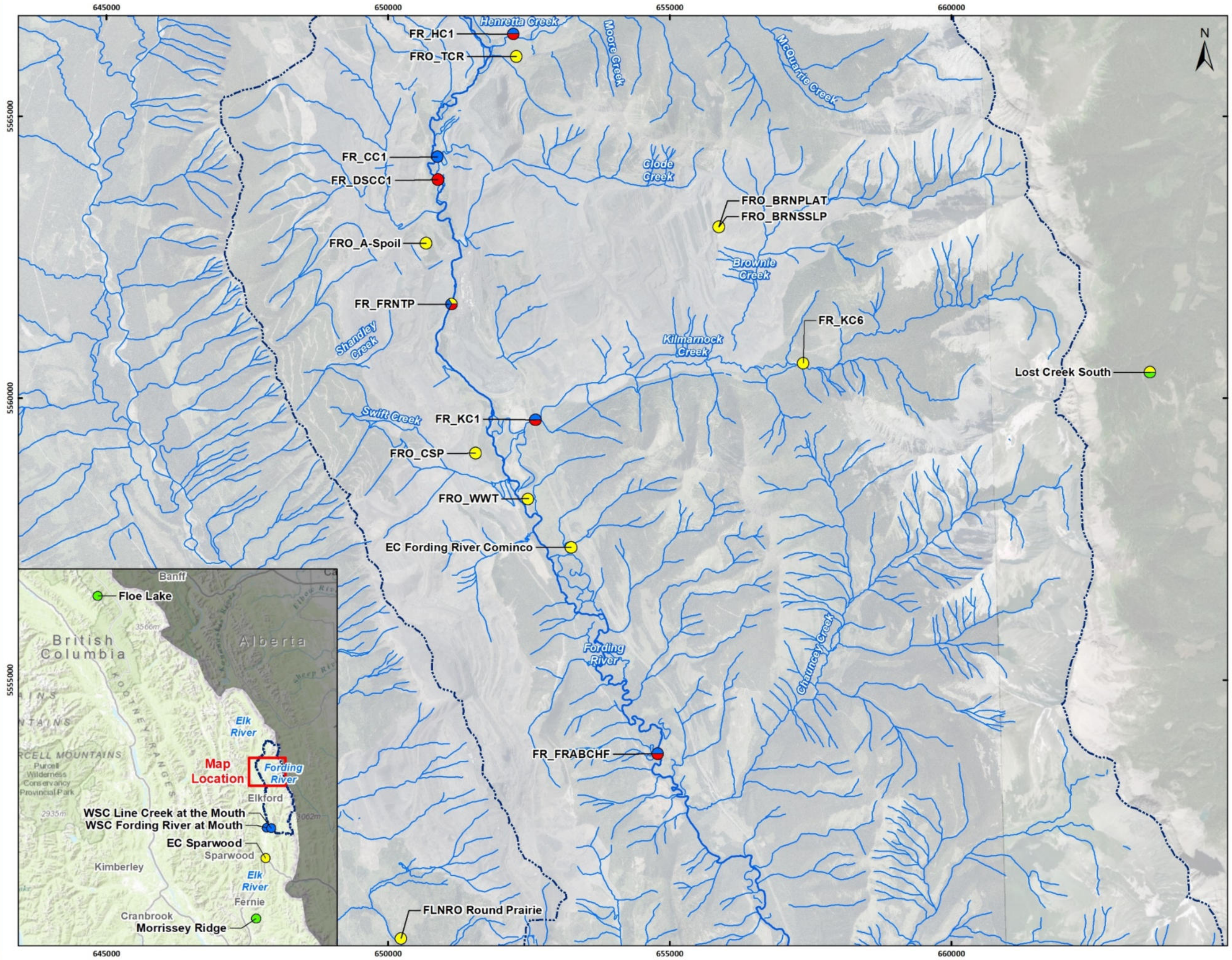
PROJECT MAPS

TECK COAL LTD.

Climate, Water Temperature and Hydrometric Monitoring Stations



Legend

Monitoring Station

- 🟡 Climate Station
- 🔵 Hydrometric Station
- 🔴 Water Temperature Station
- 🟢 Snow Pillow Station
- ⬚ Fording River Watershed

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

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Scale: 1:65,000

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Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 1

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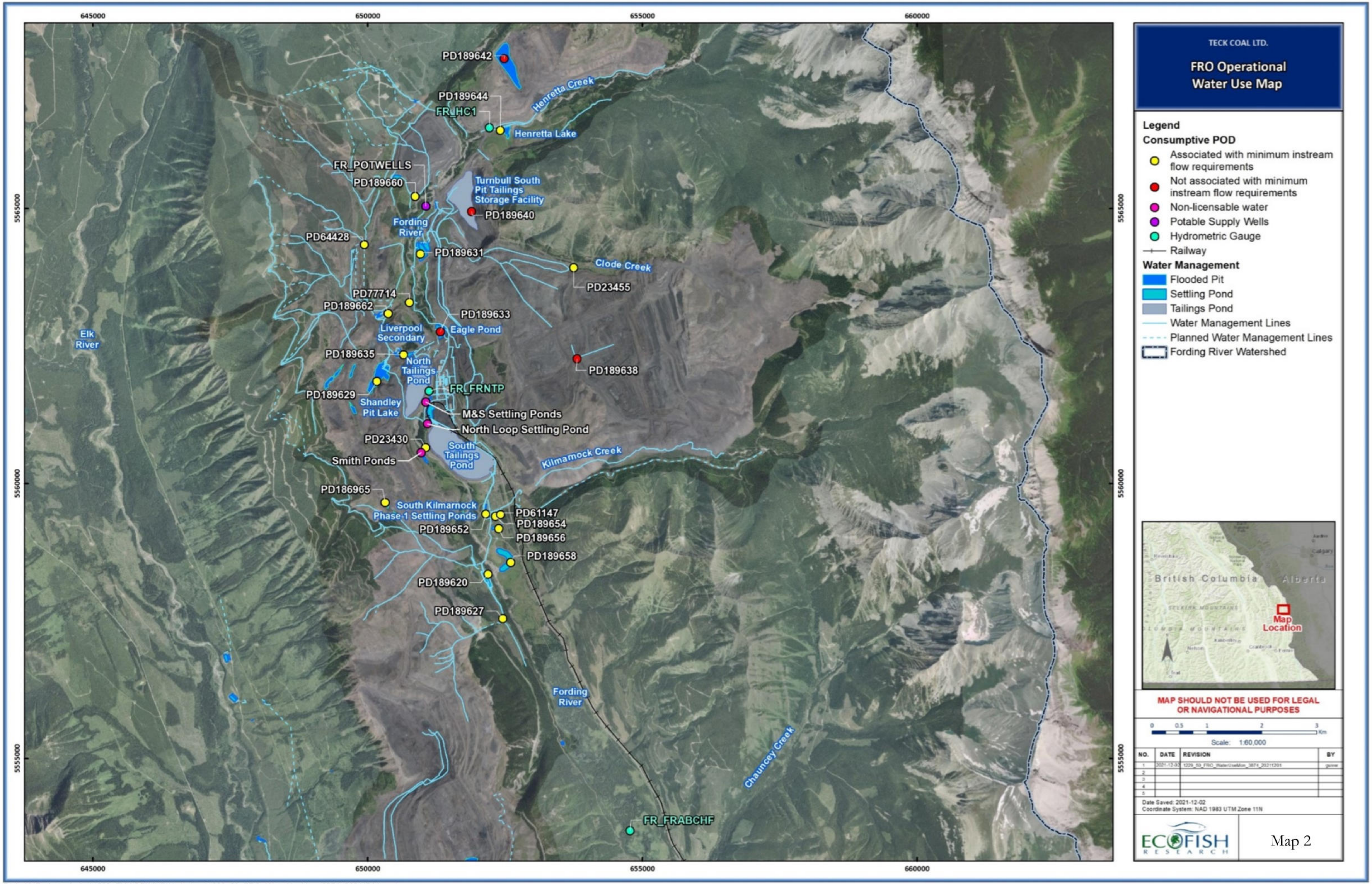

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